GOVERNMENT OF WESTERN AUSTRALIA

# Browse LNG Precinct


# Browse Liquefied Natural Gas Precinct

## Strategic Assessment Report

(draft for public comment)

December 2010

## PART 3

## Environmental Assessment – Marine Impacts

# Browse LNG Precinct

## Strategic Assessment Report – Structure Display

The State of Western Australia, through the Minister for State Development, has developed the Browse LNG Precinct Strategic Assessment Report (SAR) to enable consideration of a proposed common user liquefied natural gas (LNG) Precinct to process natural gas from the Browse Basin gas fields, at a location near James Price Point, approximately 60 kilometres north of Broome. This SAR is presented in six parts as shown in the following diagram. You are invited to make a submission by visiting the Environmental Protection Authority website at http://public-consult.epa.wa.gov.au/portal. Appendices are also available at http://www.dsd.wa.gov.au/browseLNG.

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| Acronym | Definition |
|---|---|
| ABS | Australian Bureau of Statistics |
| ACMC | Aboriginal Cultural Materials Committee |
| AGRU | Acid Gas Removal Unit |
| AGT | Aero Derivative Gas Turbines |
| AH Act | *Aboriginal Heritage Act 1972(WA)* |
| AHC | Aboriginal Heritage Commission |
| AHD | Australian Height Datum |
| AIHW | Australian Institute of Health and Welfare |
| AIMS | Australian Institute of Marine Science |
| aMDEA | activated methyl-di-ethanol amine |
| AMSA | Australian Maritime Safety Authority |
| ANZECC | Australian and New Zealand Environment Conservation Council |
| AQIS | Australian Quarantine Inspection Service |
| ARI | Average Recurrence Interval |
| ARMCANZ | Agriculture and Resource Management Council of Australia and New Zealand |
| ARR | Australian Rainfall and Runoff |
| ARRP Act | *Agriculture and Related Resources Protection Act 1976* |
| ASIA | Aboriginal Social Impact Assessment |
| ASS | Acid Sulphate Soils |
| ATSIHP Act | *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* |
| AWAC | Acoustic Doppler Wave and Current Profiler |
| BLNG | Browse Liquefied Natural Gas |
| BLNG Precinct | Browse Liquefied Natural Gas Precinct |
| BoM | Bureau of Meteorology |
| BPA | Broome Port Authority |
| BPEMP | BLNG Precinct Environmental Management Plan |
| BPMF | Broome Prawn Managed Fishery |
| BPP | Benthic Primary Producer |
| BPPH | Benthic Primary Producer Habitat |
| Bq $kg^{-1}$ | Becquerels per kilogram |
| BRAC | Broome Recreation and Aquatic Centre |
| BRAMS | Broome Regional Aboriginal Medical Service |
| BRUVS | Baited Remote Underwater Video Surveys |
| BTEX | benzene, toluene, ethybenzene and xylene |
| °C | degrees celsius, degrees centigrade |
| $CaCO_3$ | Calcium Carbonate |
| CAEPR | Centre for Aboriginal Economic Policy Research |
| CALM | Department of Conservation and Land Management , now DEC |
| CAMBA | China-Australia Migratory Bird Agreement |
| Category A | These are the core elements of the BLNG Precinct, including associated infrastructure, necessary to process and export hydrocarbons. |
| Category B | These are indirect activities and actions as a result of the BLNG Precinct that are considered in the impact assessment but do not form part of the approvals process. |

| Acronym | Definition |
|---|---|
| Category C | Related projects that are outside the scope of the Strategic Assessment but form part of the cumulative impact assessment. |
| CCIMP | Committee for Introduced Marine Pest Emergencies |
| CEMP | Construction Environment Management Plan |
| CDEP | Community Development Employment Projects |
| CEO | Chief Executive Officer |
| $CH_4$ | Methane |
| CHMP | Cultural Heritage Management Plan |
| CITES | Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| $CO_2$ -e | Carbon Dioxide Equivalents |
| CPI | Consumer Price Index |
| CPRS | Carbon Pollution Reduction Scheme |
| CSD | Cutter Suction Dredger |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CTM | Chemical Transport Model |
| CWR | Centre for Whale Research |
| Cwth | Commonwealth |
| DAFF | Department of Agriculture, Fisheries and Forestry |
| DAFWA | Department of Agriculture and Food Western Australia |
| dB | decibels |
| dB(A) | A-weighted decibels |
| DCCEE | Department of Climate Change and Energy Efficiency |
| DDSDMP | Dredging and Dredge Spoil Disposal Management Plan |
| DEC | Department of Environment and Conservation |
| DEEWR | Commonwealth Department of Education, Employment and Workplace Relations |
| DEWHA | Commonwealth Department for the Environment, Water, Heritage and the Arts, now SEWPAC |
| DIA | Department of Indigenous Affairs |
| DLGRD | Department of Local Government and Regional Development |
| DLNG | Darwin Liquefied Natural Gas |
| DMAG | Dredging Management Advisory Group |
| DMP | Department of Mines and Petroleum |
| DoF | Department of Fisheries |
| DoIR | Department of Industry and Resources |
| DoLA | Depart of Land Administration |
| DoP | Department of Planning |
| DoT | Department of Transport |
| DoW | Department of Water |
| DPI | Department for Planning and Infrastructure |
| DRDL | Department of Regional Development and Lands |
| DRET | Commonwealth Department of Resources, Energy and Tourism |
| DRF | Declared Rare Flora |
| DSD | Department of State Development |
| DSDG | Dredge Spoil Disposal Ground |

| Acronym | Definition |
|---|---|
| DSDMP | Dredging and Dredge Spoil Disposal Management Plan |
| EAG3 | Environmental Assessment Guideline 3 |
| ECHT | Environment and Cultural Heritage Team |
| EIA | Environmental Impact Assessment |
| EMP | Environment Management Plan |
| EP Act | *Environmental Protection Act 1986* |
| EPA | Environmental Protection Authority |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* |
| eq. | Acid Equivalents |
| EVT | Evergreen Vine Thickets |
| FEED | Front End Engineering Design |
| FESA | Fire and Emergency Services Authority of Western Australia |
| FID | Final Investment Decision |
| FIFO | Fly in/Fly out |
| FIS | Fishing Industry Impact Study |
| FLNG | Floating LNG |
| FM Act | *Fish Resources Management Act 1994* |
| Foundation Proponent | Woodside is a potential Foundation Proponent |
| FRMR | Fisheries Resource Management Regulations 1995 |
| FRP | Filterable reactive phosphorus |
| GBRMPA | Great Barrier Reef Marine Park Authority |
| GBS | Gravity Based Structure |
| GCA | Gaffney Cline and Associates |
| GDEs | Groundwater Dependant Ecosystems |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| G | grams |
| GJ | gigajoule |
| GL | gigalitre |
| GL/yr | gigalitres per year |
| GGAP | Greenhouse Gas Abatement Plan |
| GROH | Government Regional Officer Housing |
| GRP | Gross Regional Product |
| GSP | Gross State Product |
| GST | Goods and Services Tax |
| GWP | Global Warming Potential |
| $H_2S$ | hydrogen sulphide |
| ha | hectare |
| HAT | Highest astronomical tide |
| HCWA | Heritage Council of Western Australia |
| HDD | Horizontal Directional Drilling |
| HFCs | Hydroflurocarbons |
| HIA | Heritage Impact Assessment |
| $HNO_3$ | Nitric Acid |

| Acronym | Definition |
|---|---|
| HoA | Heads of Agreement |
| HONO | Nitrous Acid |
| HPA | Heritage Protection Agreement |
| hr | hour |
| HSE | Health, Safety and Environment |
| HYPE | Helping Young People Engage |
| IBRA | Interim Biogeographic Regionalisation of Australia |
| ICC | Indigenous Coordination Centres |
| IFPIC | Indigenous Free Prior Informed Consent |
| IGCC | Integrated Gasification Combined Cycle |
| ILUA | Indigenous Land Use Agreement |
| IMO | International Maritime Organisation |
| IMS | Invasive Marine Species |
| IMSMP | Invasive Marine Species Management Plan |
| IP | Important Population |
| IPCC | Intergovernmental Panel on Climate Change |
| IS | Integrated System |
| ISQG | Interim Sediment Quality Guidelines |
| ITF | Indonesian Throughflow |
| IUCN | International Union for Conservation of Nature |
| JAMBA | Japan-Australia Migratory Bird Agreement |
| JPP | James Price Point |
| KAMSC | Kimberley Aboriginal Medical Services Council |
| KAC | Kimberley Aquaculture Corporation |
| KACS | Kimberley Aged and Community Services |
| KDC | Kimberley Development Commission |
| KES | Kullari Employment Services |
| kg | kilogram |
| $kgCO_2$-e | kilogram of Carbon Dioxide Equivalents |
| $kmh^{-1}$, km/h | kilometres per hour |
| kHz | kilohertz |
| KLC | Kimberley Land Council |
| km | kilometre |
| $km^2$ | square kilometre |
| kn | knot |
| KPP | Kadar Pearson and Partners |
| kt | kilotonne |
| LAU | Local Assessment Unit |
| LCUs | Landscape Character Units |
| LGA | Local Government Area |
| LIA | Light Industrial Area |
| LiDAR | Light Detection and Ranging |
| LIGT | Large Industrial Gas Turbines |
| LNG | Liquefied Natural Gas |
| LNG Hub | Alternative wording for BLNG Precinct |

| Acronym | Definition |
|---|---|
| LoR | Limit of Reporting |
| LPG | Liquefied Petroleum Gas |
| LPS | Local Planning Strategy |
| LSR | Light Sensitive Receptors |
| LVIA | Landscape and Visual Impact Assessment |
| $\mu g/m^3$ | microgram per cubic metre |
| $\mu g\ g^{-1}$, $\mu g/g$ | microgram per gram |
| $\mu g\ L^{-1}$, $\mu g/L$ | microgram per litre |
| µm | micrometre |
| $\mu g\ m^{-3}$, $\mu g/m^3$ | microgram per metre cubed |
| µMol | micromole |
| m | metre |
| $m^2$ | square metre |
| $m^3$ | cubic metre |
| $m^3/hr$ | cubic metre per hour |
| m/s | metres per second |
| Ma | Mega annum (million years) |
| mAHD | Metres Australian Height Datum |
| MDS | Multi Dimensional Scaling |
| MEG | Mono-ethylene glycol |
| MF | Marine Facility |
| $mg\ L^{-1}$, mg/L | milligram per litre |
| MIGT | Medium Industrial Gas Turbines |
| ML | megalitre |
| mm | millimetre |
| MMbtu | Millions of British Thermal Units |
| MNES | Matters of National Environmental Significance |
| MODIS | Moderate Resolution Imaging Spectroradiometer |
| MOF | Materials Offloading Facility |
| mol% | Mole percentage |
| MPA | Marine Protected Areas |
| MPB | Microphytobenthos |
| $ms^{-1}$, m/s | metre per second |
| MSL | Metres below sea level |
| Mt | megatonne (million tonne) |
| Mtpa | million tonnes per annum |
| MVT | Monsoon Vine Thicket |
| MWDMP | Marine Wastewater Discharge Management Plan |
| MWh | megawatt hour |
| NAGD | National Assessment Guidelines for Dredging |
| NDT | Northern Development Taskforce |
| NE | North-east |
| NEPC | National Environment Protection Council |
| NEPM | National Environment Protection Measure |
| NES | National Environmental Significance (i.e. matters of NES) |

| Acronym | Definition |
|---|---|
| NGA | National Greenhouse Accounts |
| NGCC | Natural Gas Combined Cycle |
| NGER Act | *National Greenhouse and Energy Reporting Act 2007* |
| $NH_3$ | Ammonia |
| $NH_4$ | Ammonium |
| NILF | not in labour force |
| Nm | nautical mile |
| NNTT | National Native Title Tribunal |
| NNW | north-north-west |
| $NO_2$ | nitrogen dioxide |
| $NO_X$ | oxides of Nitrogen (NO and $NO_2$) |
| NPI | National Pollutant Inventory |
| NRIF | *National Recreational and Indigenous Fishing Survey* |
| NRM | Natural Resource Management |
| NSW | New South Wales |
| NT | Northern Territory |
| NTA | *Native Title Act 1993* |
| NTU | Nephelometric Turbidity Units |
| NWMR | Northwest Marine Region |
| NWQMS | National Water Quality Management Strategy |
| $O_3$ | Ozone |
| OSCP | Oil Spill Contingency Plan |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PAR | Photosynthetically Available Radiation |
| PASS | Potential Acid Sulphate Soils |
| PBC | Prescribed Body Corporate |
| PCG | Precinct Control Group |
| PECs | Priority Ecological Communities |
| Plan | The formal Plan for the BLNG Precinct under Commonwealth legislation (see also Precinct Plan) |
| PM | particulate matter |
| PF | Port Facility |
| PFCEMP | Port Facilities Construction Environmental Management Plan |
| PFCs | Perfluorocarbons |
| ppb | Parts per billion |
| Ppt | parts per thousand |
| Precinct Plan | The formal Plan for the BLNG Precinct under Commonwealth legislation (see also Plan) |
| proponent | Commercial proponents will undertake projects within the Precinct. |
| Proponent | The Proponent for the Precinct is the Minister for State Development |
| PRRT | Petroleum Rent Resource Tax |
| PSD | Particle size distribution |
| PTS | Permanent Threshold Shift |
| QA/QC | Quality Assurance/ Quality Control |
| QMP | Quarantine Management Plan |
| QLD | Queensland |

| Acronym | Definition |
|---|---|
| RBA | Reserve Bank of Australia |
| RBWG | Roebuck Bay Working Group |
| RIWI Act | *Rights in Water and Irrigation Act 1914* |
| RMS | Root Mean Square |
| RNE | Register of National Estate |
| RO | Reverse Osmosis |
| ROKAMBA | Republic of Korea-Australia Migratory Bird Agreement |
| RORO | Roll on Roll off |
| RoW | Right of Way |
| RTO | Registered Training Organisation |
| SA | Strategic Assessment |
| SAA | Strategic Assessment Agreement |
| SAP | Sediment Sampling and Analysis Plan |
| SAR | Strategic Assessment Report |
| SE | south-east |
| SEL | Sound Pressure Level |
| SEP | State Environmental Policy |
| SEWPAC | Commonwealth Department of Sustainability, Environment, Water, Population and Community |
| $SF_6$ | Sulphur Hexafluoride |
| SIA | Social Impact Assessment |
| $SO_x$ | oxides of sulphur |
| $SO_2$ | sulphur dioxide |
| SOPEP | Shipboard Oil Pollution Emergency Plan |
| SoSA | Scope of the Strategic Assessment |
| SPL | Sound Pressure Level |
| SPMT | Self Propelled Module Trailers |
| SPRAT | Species Profile and Threats Database |
| SRE | Short Range Endemic |
| SRG | Stakeholder Reference Group |
| SSIMP | Strategic Social Impact Management Plan |
| STI | Sexually Transmitted Infection |
| SWIS | South West Interconnected System |
| TAFE | Technical and Further Education |
| TAPM | The Air Pollution Model |
| TBT | Tributyltin |
| tcf | trillion cubic feet |
| TCU | Thermal Combustion Units |
| TDS | Total Dissolved Solids |
| TEC | Threatened Ecological Community |
| TIA | Tourism Impact Assessment |
| TJ | terajoules |
| TM | Thematic Mapper |
| TN | Total Nitrogen |
| TOC | Total Organic Carbon |
| TONC | Traditional Owner Negotiating Committee |

| Acronym | Definition |
|---|---|
| ToR | Terms of Reference |
| TOTF | Traditional Owner Taskforce |
| TP | Total Phosphorous |
| tpa | tonne per annum |
| TPH | Total Petroleum Hydrocarbons |
| TSHD | Trailer Suction Hopper Dredger |
| TSS | Total Suspended Solids |
| TTS | Temporary Threshold Shift |
| UNDRIP | United Nations Declaration of Rights of Indigenous People |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UV | Ultraviolet |
| VET | Vocational Education and Training |
| VMP | Vessel Management Plan |
| VOC | Volatile Organic Compounds |
| VSR | Visually Sensitive Receptors |
| WA | Western Australia |
| WACHS | Western Australian Country Health Service |
| WALFA | West Arnhem Land Fire Abatement |
| WAM | Western Australian Museum |
| WAPC | Western Australian Planning Commission |
| WC Act | *Wildlife Conservation Act 1950* |
| WEED | Weed Education Eradication Delivery |
| WHO | World Health Organisation |
| WNW | west-north-west |
| WONS | Weed of National Significance |
| Woodside | Woodside Energy Limited |
| WRC | Water and Rivers Commission, now Department of Water (DoW) |
| WSW | west-south-west |
| WWF | World Wildlife Fund |
| WWTP | Waste Water Treatment Plant |

# 1. Environmental Overview

The State of Western Australia (**WA**), through the Minister for State Development (the **Proponent**), proposes to develop an onshore, common-user Liquefied Natural Gas (**LNG**) precinct to process natural gas from Browse Basin gas fields off the west Kimberley coast. The Department of State Development (**DSD**) has been charged with advancing this proposal under direction of the Proponent.

The Browse Liquefied Natural Gas Precinct (**BLNG Precinct** or **Precinct**) would consist of LNG processing facilities and associated infrastructure, and would be located in the vicinity of James Price Point, approximately 60 kilometres (**km**) north of Broome, on the west Kimberley coast of Western Australia. The BLNG Precinct would provide a location for processing gas and associated products from the Browse Basin with an LNG production capacity of up to 50 million tonnes per annum (**Mtpa**). If it were to occur, full development of the Precinct would most likely be phased in as demand for additional processing capacity arises. The Precinct would accommodate a minimum of two proponents at one location and enable sharing of common-user facilities such as the port, roads, infrastructure corridors and workers' accommodation. A **Precinct Plan** has been developed to meet the requirements of the State and Commonwealth Governments.

Woodside Energy Limited (**Woodside**), on behalf of the Browse LNG Development Joint Venture participants, was appointed as a potential Foundation Proponent for the Precinct under the Preliminary Development Agreement signed in October 2009. This Agreement established Woodside as a partner with the State Government in bringing the project to completion.

A detailed and comprehensive assessment has considered the environmental, social, economic, heritage and strategic implications of the Precinct should it reach its full capacity. The assessment process has involved desktop studies, field surveys, modelling, data analysis, impact assessment and stakeholder consultation, the results of which are documented in the BLNG Precinct Strategic Assessment Report (**SAR**).

The purpose of this Strategic Assessment Report is to meet the requirements of the State and Commonwealth governments in accordance with the Terms of Reference. The Strategic Assessment includes a high level impact assessment (including social factors), a description of the strategic proposal, identifying 'future proposals' (to be approved under the *Environmental Protection Act 1986* (the **EP Act**)) and the Precinct Plan (to be endorsed under the *Environment Protection and Biodiversity Conservation Act 1999* (the **EPBC Act**)), and includes the Proponent's proposed draft conditions that may be applied to future proposals. The document includes a summary of existing information, identifying main impact areas and sets out the proposed management arrangements, mitigation and safeguards to ensure impacts are managed.

The SAR is presented in six parts:

Part 1: Executive Summary

Part 2: Strategic Assessment Process including Site Selection, Facilities Description and Consultation Process

Part 3: Environmental Assessment – Marine Impacts

Part 4: Environmental Assessment – Terrestrial Impacts

Part 5: Social Assessment

Part 6: Commonwealth Matters including Precinct Plan, Management Arrangements and Matters of National Environmental and Social Significance

This document (**Part 3**) of the Strategic Assessment Report provides an overview of the existing marine environment, and assessment of potential impacts and proposed mitigative measures.

Although the SAR is formatted into 6 parts it is important to note that they are not standalone parts and in particular key sections in **Part 2** will help inform an understanding of this Part. Information in **Part 2** of relevance to this Part includes the site selection process, the description of facilities and activities, indirect activities and related projects and the impact assessment methodology.

The proposed BLNG Precinct is situated within the Kimberley Region, however from a marine bioregional perspective it is more accurately defined as being in the Canning Marine Bioregion. The area is associated with a diverse range of fauna and flora including migrating birds, turtles, dugongs, whales and dolphins. The Canning Marine Bioregion supports feeding, breeding, and resting habitat for many plants and animals which contribute to the biodiversity of the bioregion. The Kimberley region also supports an active population of people with a diversity of backgrounds, experiences, and interests with many utilising the marine resources of the bioregion. These are discussed further in **Part 5** (Social Impact Assessment).

The following section (**Section 1**) provides a description of the existing physical and ecological marine environment of the Canning Marine Bioregion and more localised James Price Point coastal area. The description has been compiled from a composite of desktop studies, physical and ecological baseline surveys and investigations undertaken to support the site selection and Strategic Assessment processes. The section is structured to provide information relevant from the Kimberley region, as well as that from the Dampier Peninsula and James Price Point coastal area. It provides an understanding of the key regional marine environmental values that may be affected by the proposed BLNG Precinct development and to place the James Price Point coastal area into context.

Subsequent sections (**Part 3**, **Section 2**) discuss the impacts and mitigation measures for the key marine environmental values discussed earlier and provide summary tables of the assessment of impacts and mitigation measures proposed to ensure these impacts are minimised to the extent possible. For convenience, the following provides a cross-reference to the summary tables provided for each marine environmental factor:

| | |
|---|---|
| Tidal Regimes, Wave Climate, Currents and Hydrodynamics | **Table 2.1–4** |
| Marine Sediment Quality | **Table 2.2–6** |
| Marine Water Quality | **Table 2.3–5** |
| Benthos including Benthic Primary Producers | **Table 2.4–7** |
| Fish | **Table 2.5–4** |
| Marine Mammals | **Table 2.6–11** |
| Marine Reptiles | **Table 2.7–6** |
| Marine Ecosystem Integrity | **Table 2.8–5** |

In most instances the significance of residual impact following the implementation of mitigation measures was assessed to be low or very low. One exception to this was related to impacts on Marine Water Quality where the site disturbance and excavation for the port development is unable to be avoided and the impact was assessed as high. To the extent possible this impact was minimised by the selection of the location to the south of James Price Point which reduced dredge volumes. Further detailed work is required through the development of a Dredging and Dredge Spoil Disposal Management Plan, to demonstrate best practice management techniques and technologies which would be applied to minimise potential dredging impacts.

One other instance where residual impacts were not assessed as low or very low related to the impact of site disturbance and excavation activities would have on benthos and in particular on seagrass, algae and filter feeders. This was assessed as medium significance. Although this unavoidable impact was considered to be very localised and would not impact on significant areas of high value benthos due to avoidance of such areas during site selection, it was assessed as being of medium significance because it would be long term. To manage this impact, the Dredging and Dredge Spoil Disposal Management Plan noted above would also need to demonstrate that impacts to benthos will be minimised.

The only other instance where residual impacts were not assessed as low or very low was the potential impact of marine discharges on Marine Ecosystem Integrity which was assessed as medium. It was considered that while routine discharges were unlikely to have a significant impact following mitigation measures there was potential for significant impacts in the unlikely event of a major hydrocarbon spill. It is proposed that such impacts would be reduced through the implementation of an Emergency Response Plan including spill contingency procedures and coordination of proponents in the event of emergency response procedures.

Overall the assessment of the impacts on the marine environment demonstrates that the site selection process undertaken by the Northern Development Taskforce succeeded in ensuring that most areas of environmental significance or sensitivity were avoided. It also supports the S16(e) advice of the EPA that environmental risks and impacts were likely to be manageable (EPA, 2008). For example in relation to the potential impacts on marine mammals such as whales and dugongs, and marine turtles it was found that the site selection had avoided the whale aggregation

and calving areas towards the northern end of the Dampier Peninsula, as well as turtle nesting areas on the Lacepede Islands. Impacts on significant seagrass areas in Roebuck Bay and Beagle Bay used by dugong had also been avoided.

## 1.1. Existing Marine Environment

### 1.1.1. Environmental Context

The regional geology and the varying environmental conditions along the Kimberley Region coastline result in a diverse range of coastal features and ecological habitats. Such features include sandy beaches, coastal cliffs and headlands, estuarine inlets, intertidal mudflats and mangrove forests, as well as numerous offshore island archipelagos.

The Kimberley region is characterised by a tropical monsoonal climate with two distinct seasons; wet (October–April) and dry (April–October). During the wet season, winds from the Indian Ocean and southern Asian waters prevail, resulting in monsoonal troughs and cyclones. During the dry season, a predominantly south easterly airflow from the continent's interior brings warm, dry air.

The Northwest Marine Region (**NWMR**) which extends from Kalbarri to the border between Western Australia and the Northern Territory is a broad grouping characterised by similar biogeographical features (DEWHA, 2009a) (**Figure 1-1**). The North West Marine Region is characterised by relatively shallow offshore waters, the majority less than 500m deep. The marine environment is essentially tropical, characterised by nutrient poor water. Consequently, the NWMR is considered to have a lower level of primary productivity compared to other regions in Australia. However, there are periodic surges in primary productivity within the region, which are thought to be associated with regional hydrodynamic processes, such as surface currents and nutrient rich upwellings (DEWHA, 2008a).

The Canning Marine Bioregion is a sub-region of the North West Marine Bioregion, extending from the southern boundary at Cape Missiessy (Eighty Mile Beach) (approximately 197km south of James Price Point) to the western edge of Cape Leveque (approximately 150km north of James Price Point). This region includes a vast abyssal seafloor and a broad continental shelf with atolls and islands. James Price Point is located on the coast within the Canning Marine Bioregion and represents a low energy environment, receiving occasional storm surges from cyclonic weather events. Rocky shores, offshore reef systems, sandy beaches, sand flats, seagrass, tracts of mangroves and mud flats form part of this Bioregion (**Figure 1-2**).

Hydrodynamic processes represent a major ecological factor in such marine ecosystems. Such processes affect the transport and distribution of sediments and nutrients, which in turn influences water quality parameters such as turbidity and light penetration (DEWHA, 2009a). The availability of nutrients and adequate light penetration significantly affects the ability of primary producers to photosynthesise, which in turn affects the role they play in an ecosystem's function in terms of trophic structure. The marine environment in the region is strongly influenced by the macro-tidal regime, with the tidal flux resulting in a high variability in background turbidity within nearshore waters. This process contributes to a dynamic coastal sediment transport regime regionally.

The dominant nearshore benthic communities are filter feeding bi-valves and vegetative primary producers (i.e. macroalgae and seagrass; refer to **Section 1.4.2** for further information). The area does contain coral communities, although at a regional scale, they are not considered comparable in size or diversity to those communities well documented in clear oceanic waters at Scott and Ningaloo reefs (Miller *et al*., 2008). Available survey data indicates that although there are some areas of patchy and sparse coral communities, there are no areas of significant coral cover, or typical reef structures surrounding James Price Point (SKM, 2010a; **Appendix C-5**). The James Price Point intertidal zone is considered not suitable for the development of highly diverse or complex coral communities, due to the area being dominated by flat, sandy sections with relatively sparse, intermittent habitat of rocky substratum and reef platform which is exposed at low tide (SKM, 2010b; **Appendix C-3**).

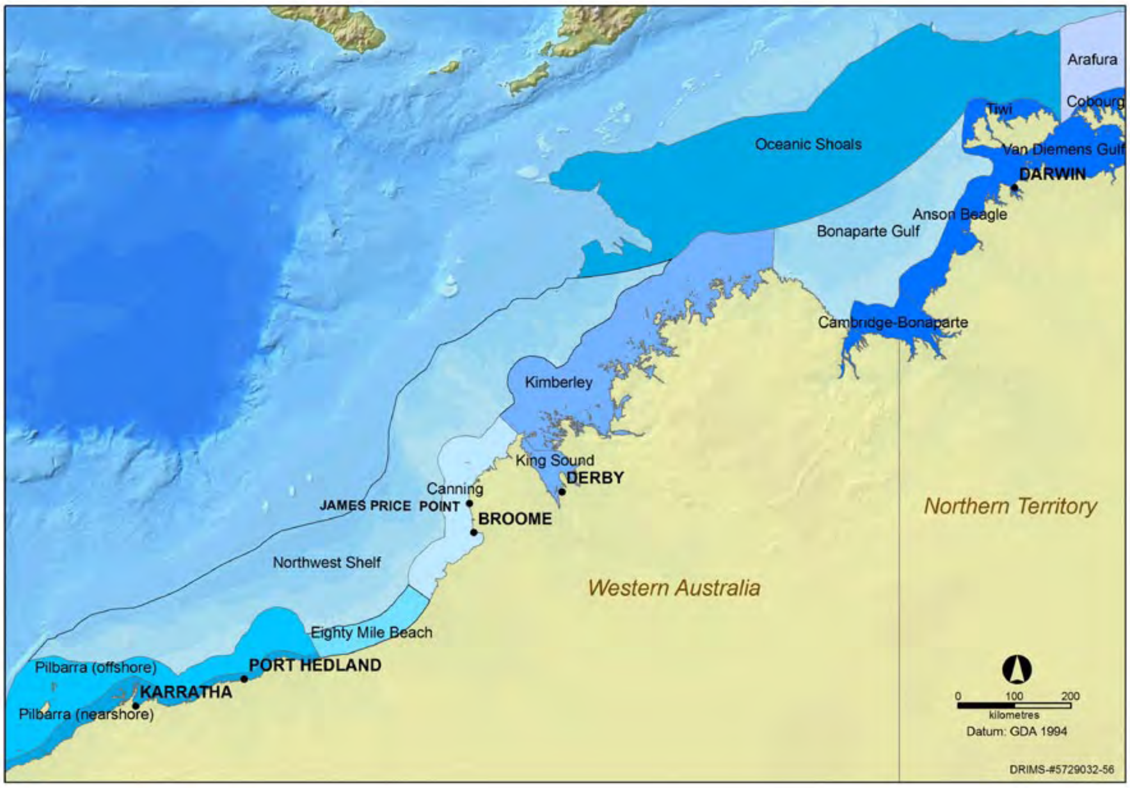
Seagrass beds are found throughout the NWMR, with extensive and diverse intertidal seagrass meadows predominantly found within the southern Kimberley (Cape Leveque to Montgomery Reef) (Walker, 1995). Seasonally abundant subtidal seagrass communities are patchily distributed across large areas along the Dampier Peninsula, including James Price Point (SKM, 2010a; **Appendix C-5**). The area between Quondong and Coulomb Points have been shown to support extensive, although sparse, seagrass beds consisting of *Halophila* sp. in waters approximately 10m deep (Fry *et al*., 2008; **Appendix C-4**). Nearshore benthic habitat surveys and mapping of James Price Point found that seagrass distribution was mainly sparse and patchily distributed across the study area, with *Halophila* sp. the dominant species identified (Fry *et al*., 2008; **Appendix C-4** and SKM, 2010a; **Appendix C-5**).

The North-west Marine Region provides significant habitat for a large diversity of fish, reptile and marine mammal species including the seasonal presence of humpback whales (*Megaptera novaeangliae*). The humpback whales are known to utilise the inshore waters of the Kimberley region, moving between feeding grounds in the Antarctic to breeding grounds in the Kimberley region (Jenner *et al.,* 2001). The exact timing of the migration period can vary from year to year; however, the northern humpback whale migration occurs generally from June to early September, with the peak of the northward migration occurring over a three week period in August (RPS, 2010a; **Appendix C-8**). The southern migration peaks for cows with calves generally in mid September (RPS, 2010a; **Appendix C-8**). Humpback whales pass by offshore areas adjacent to James Price Point coastal area, however they do not use the area specifically for feeding, calving, socialising or resting. Breeding and calving largely takes place in the Kimberley north of the Dampier Peninsula. The inshore waters around Camden Sound are internationally significant calving grounds which are typically used between June and mid November each year (Jenner *et al.,* 2001 and RPS, 2010a; **Appendix C-8**).

Regionally significant marine turtle nesting beaches are known to occur in the North West Marine Bioregion, including the Lacepede Islands (located approximately 65km north of James Price Point). These islands have been recognised as a key breeding area for green turtles (*Chelonia mydas*) (DEWHA, 2009a). Recent surveys indicate that marine turtle nesting along the Dampier Peninsula coastline itself is sporadic and of low intensity (RPS, 2010b; **Appendix C-2** and Biota, 2009a).

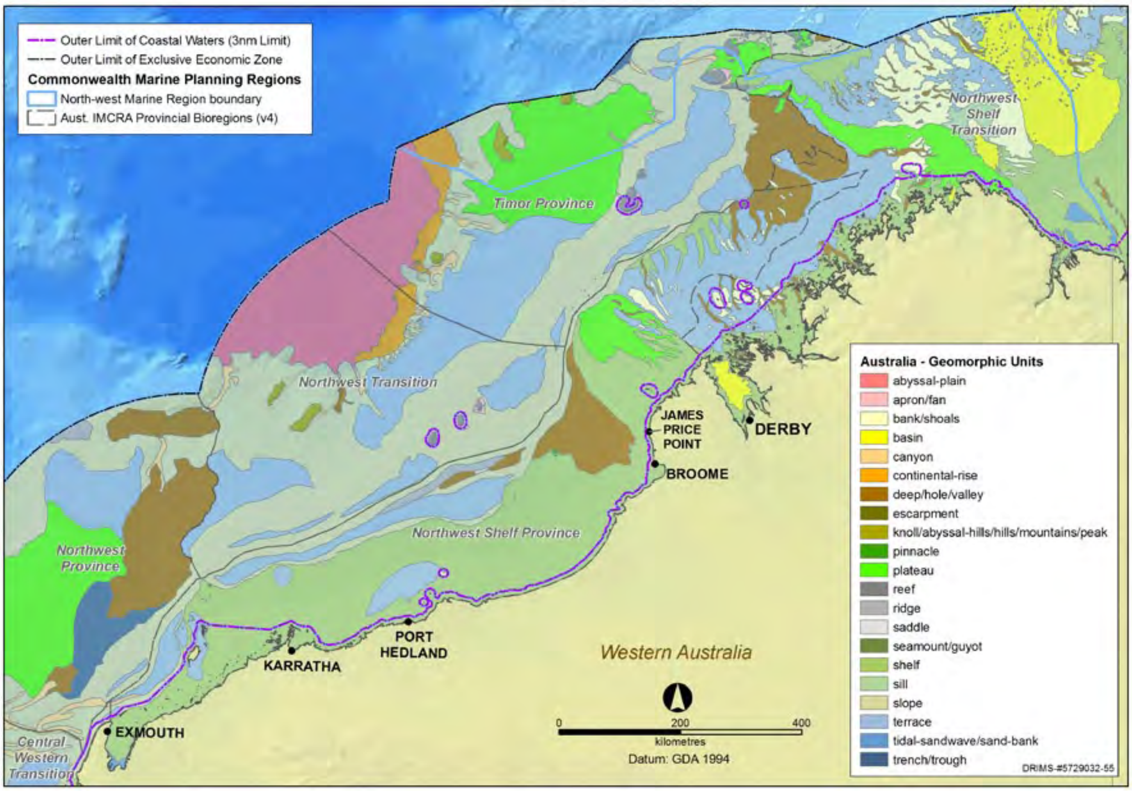
Similarly, dugongs (*Dugong dugon*) are known to occur throughout the North West Marine Region (Prince, 1984; Hodgson, 2007; Holley & Prince, 2008 and RPS, 2010c; **Appendix C-9**). The largest global population of these marine mammals, with an estimated population of 10,000 individuals, occurs in Shark Bay situated approximately 1250km south of the Dampier Peninsula (Hodgson, 2007). In comparison, surveys along the Dampier Peninsula between Cape Leveque and Cape Bossut estimated a population of between 930 to 1,700 individuals (RPS, 2010c; **Appendix C-9**). Results from these surveys and other research (Prince, 1986) indicates that the number of dugongs in the Dampier Peninsula vary throughout the year, suggesting that the area supports a more transient population than the essentially resident population evident at places such as Shark Bay. Anecdotal information shared by the Traditional Owners of the Dampier Peninsula supports this assertion. Surveys undertaken in 2008 (SKM, 2009c) and 2009 (RPS, 2010c; **Appendix C-9**) identified the areas inshore of the Lacepede Islands, Carnot Bay and Roebuck Bay, as important feeding areas for dugongs. Survey results also identified James Price Point coastal area did not appear to have any particular significance for the distribution, density or abundance of dugongs (calves and adults) (RPS, 2010c; **Appendix C-9**)

The Commonwealth waters adjacent to Quondong Point have been identified by the Department of Sustainability, Environment, Water, Population and Community (**SEWPAC**) (formerly known as DEWHA) as one of the 14 key ecological features of the NWMR (DEWHA, 2009a). These waters are considered to be an area that possibly supports enhanced biological productivity, which may support larger numbers of baitfish that in turn, may attract aggregations of seabirds and other marine life such as large predatory fish.




Source: DEWHA, 2009a.

- **Figure 1-1 Marine Subregions of North-West Marine Region.**




Source: DEWHA, 2009a.

- **Figure 1-2 Significant Features of the North-West Australian Coastal Zone.**

## 1.2. Studies and Surveys

The Northern Development Taskforce (**NDT**) (NDT, 2008a; **Appendix B-2**) undertook a number of surveys to support the site selection process for the proposed LNG Precinct. Reports and data on the marine environment of the Kimberley coast, including the recent Department of the Environment and Conservation (**DEC**) (DEC, 2009a) report, *A synthesis of scientific knowledge to support conservation management in the Kimberley region of Western Australia*, provide supporting information on the existing environment within the region.

As part of the scoping phase for the Precinct Strategic Assessment process, a range of additional studies were identified to support the environmental assessment. The following key marine studies, provided as appendices, have been undertaken to inform the impact assessment process and support decision-making*:*

- Browse LNG Development Migratory Bird Study, James Price Point. (Galaxia, 2010; **Appendix C-1**).
- Woodside Browse Turtle Technical Report, Ecology of Marine Turtles of the Dampier Peninsula and the Lacepede Island Group 2009-2010 (RPS, 2010b; **Appendix C-2**).
- James Price Point Intertidal Survey, Browse LNG Development. (SKM, 2010b; **Appendix C-3**).
- Benthic Habitat Surveys of Potential LNG Hub Locations in the Kimberley Region. (Fry *et al*., 2008; **Appendix C-4**) and Nearshore Benthic Habitat Modelling and Mapping, James Price Point (SKM, 2010a; **Appendix C-5**).
- Surveys of Fish-Habitat Associations in the Region Offshore from James Price Point using Baited Remote Underwater Video Stations (**BRUVS**) (Cappo *et al.,* 2010b; **Appendix C-6**).
- Endangered Sawfish and River Sharks in Western Australia. (Morgan *et al.,* 2009; **Appendix C-7**).
- Marine Megafauna surveys, including: Humpback Whale Survey Report, Browse (RPS, 2010a; **Appendix C-8**); Nearshore Regional Survey Dugong Report, Browse (RPS, 2010c; **Appendix C-9**); Marine Megafauna Report Browse MMFS 2009 (RPS, 2010d; **Appendix C-10**); Browse LNG Development Humpback Whale Distribution and Abundance in the Nearshore SW Kimberley During Winter 2008 Using Aerial Surveys (Jenner and Jenner, 2009; **Appendix C-11**).
- Downstream Browse Underwater Noise Assessment (SVT, 2010; **Appendix C-12**).
- BLNG Precinct Dredging and Spoil Disposal Assessment (DSD, 2010d; **Appendix C-13**).

The outcomes of these studies, in combination with a large number of engineering studies undertaken as part of the study program, provides supporting information at a local and regional scale.

## 1.3. Physical Marine Environment

### 1.3.1. Coastal Geomorphology

#### Regional Environment

The Kimberley region is generally described as a dissected plateau. Within the region there are two distinct types of coastal geomorphology, the flat-bedded Speewah and the Kimberley Group sandstones and siltstones, which both tend to erode as breakaway cliffs with a sloping mass of boulders at the base of the cliffs. In most areas these geological features form the shoreline with the exception of narrow areas of Holocene sands in more open bays and alluvial mud flats in the sheltered bays and gulfs (IMCRA, 2006). Nearshore islands are of either sandstone/siltstone or Carson Volcanics and their structure and appearance varies accordingly.

An overview of general characteristics of regional coastlines of the west Kimberley is shown in **Table 1-1**.

- **Table 1-1 Overview of General Physiographic Characteristics of the West Kimberley and Dampier Peninsula.**

| Sites | General Physical Characteristics | Locality in Context with James Price Point |
|---|---|---|
| Anjo Peninsula | Relatively protected peninsula, several islands offshore. Sandy bays, rocky shores, coral reefs, mangrove forests. Tidal currents may be significant. South east side relatively sheltered. West side more exposed with significant fringing coral reefs. | Approximately 600km north east of James Price Point. |
| Cape Voltaire | Relatively exposed peninsula. Islands mainly occur off the northern coast. Sandy bays, rocky shores, coral reefs, mangrove forests. Tidal currents and turbidity may be significant. Some deeply incised bays and estuaries. | Approximately 500km north east of James Price Point. |
| Maret Islands | Mid-shelf Island group with well-developed fringing coral reefs; relatively low tidal currents and turbidity; high geomorphological complexity; exposure to swell waves ranges from high to low. | Approximately 500km north east of James Price Point. |
| Wilson Point | Relatively protected embayment with several islands to the west; relatively low tidal currents and turbidity. Exposure to wave energy is mod/high on seaward side. | Approximately 350km north east of James Price Point. |
| Koolan Island | Protected islands; relatively high tidal currents and moderate turbidity. Exposure to wave energy is low on south-western, and mod/high on north eastern shore. | Approximately 250km north east of James Price Point. |
| Packer Island | Barrier Island linked to the mainland, protecting embayments to the north and south. West side exposed to high wave energy. East side sheltered/lagoonal. Coarse sediments offshore, slightly finer inside Island and in tidal creeks. | Approximately 200km north east of James Price Point. |
| Perpendicular / North Head | Rocky headland at entrance to sheltered V-shaped Pender Bay. Coarse sediments offshore, moderate tidal currents and low turbidity. Exposure to wave energy is high on western shore and low in southern Pender Bay. | Approximately 150km north east of James Price Point. |
| Coulomb Point | Sandy point on west facing sandy coast. Coarse sediments offshore, rocky reefs inshore, moderate tidal currents and low turbidity offshore, moderate inshore on spring tides. Exposure to wave energy is high. | Approximately 12km north of James Price Point. |
| James Price Point | Small rocky headland on west facing sandy coast. Coarse sediments offshore, rocky reefs inshore, moderate tidal currents and low turbidity offshore, moderate inshore on spring tides. Exposure to wave energy is high | N/A |
| Quondong Point | Small rocky headland on west facing sandy coast. Coarse sediments offshore, rocky reefs inshore, moderate tidal currents and low turbidity offshore, moderate inshore on spring tides. Exposure to wave energy is high | Approximately 10km south of James Price Point. |
| Gourdon Bay | Rocky headland on southern end of sandy bay exposed to the north-west. West-facing coastline to the south of the headland is exposed to wave energy from south/west. | Approximately 100km south west of James Price Point. |

Source: DEC, 2009a.

Circulation and mixing of the marine waters in the region is strongly influenced by the large tidal regime (DEWHA, 2009a). Nearshore waters appear to be well mixed and regularly (twice daily) 'flushed' by strong currents generated through the high tidal range. Seasonal cyclones, strong tidal influences and internal waves create shear stresses strong enough to re-suspend sediment in depths shallower than approximately 170m (Brewer *et al,.* 2007).

**Dampier Peninsula**

In a more local context, the Dampier Peninsula's northern and western margins receive occasional storm surges from cyclonic weather events. The Peninsula's west coast receives refracted westerly swells for the majority of the year, with the swells from the north and north-west affecting the western and northern facing shores predominantly during the summer months. It is during these months that weather events from cyclones often batter the region, resulting in very rough seas and large swells which often causes extensive coastal erosion. These events are the predominant factor in

influencing the Dampier Peninsula's coastal morphology. Much of the Dampier Peninsula is composed of red Pindan soil of wind-blown origin formed during the Quaternary period. Cliff landforms have formed in areas where the red Pindan plain soils abut the coastline. These features are formed from the undercutting and subsequent slumping of the soil at the high tide mark (Kenneally *et al,.* 1996). Wide intertidal sand flats are a common feature in the Dampier Peninsula. During low spring tides, these intertidal areas can be more than one km in width. Sediments composing the flats range from silty sands to coarse rubble.

The coastal sediments of the Dampier Peninsula include quartz beach sands, shell ridges, mudflats, limestone platforms and sand dunes. White Holocene sand dunes run parallel to the coast often forming long, expansive features. The sand dunes at Cable Beach, Broome are a good example of these features. Older, less exposed dunes of Pleistocene origin also occur on the Dampier Peninsula. These older dunes are typically pink in colour and more stable, examples of which can be found fringing Roebuck Bay (Kenneally *et al,.* 1996), approximately 60km south of James Price Point.

The prominent large scale coastal features include riverine channels, shallow embayments, rocky headlands and sandy beaches. The intertidal zone of this shoreline varies in width across the Peninsula. In general, the widest intertidal zones are found in bays, which are typically fully exposed at the lowest astronomical tide revealing rocky reef platforms, quartz beach sands and shell.

**James Price Point Coastal Area**

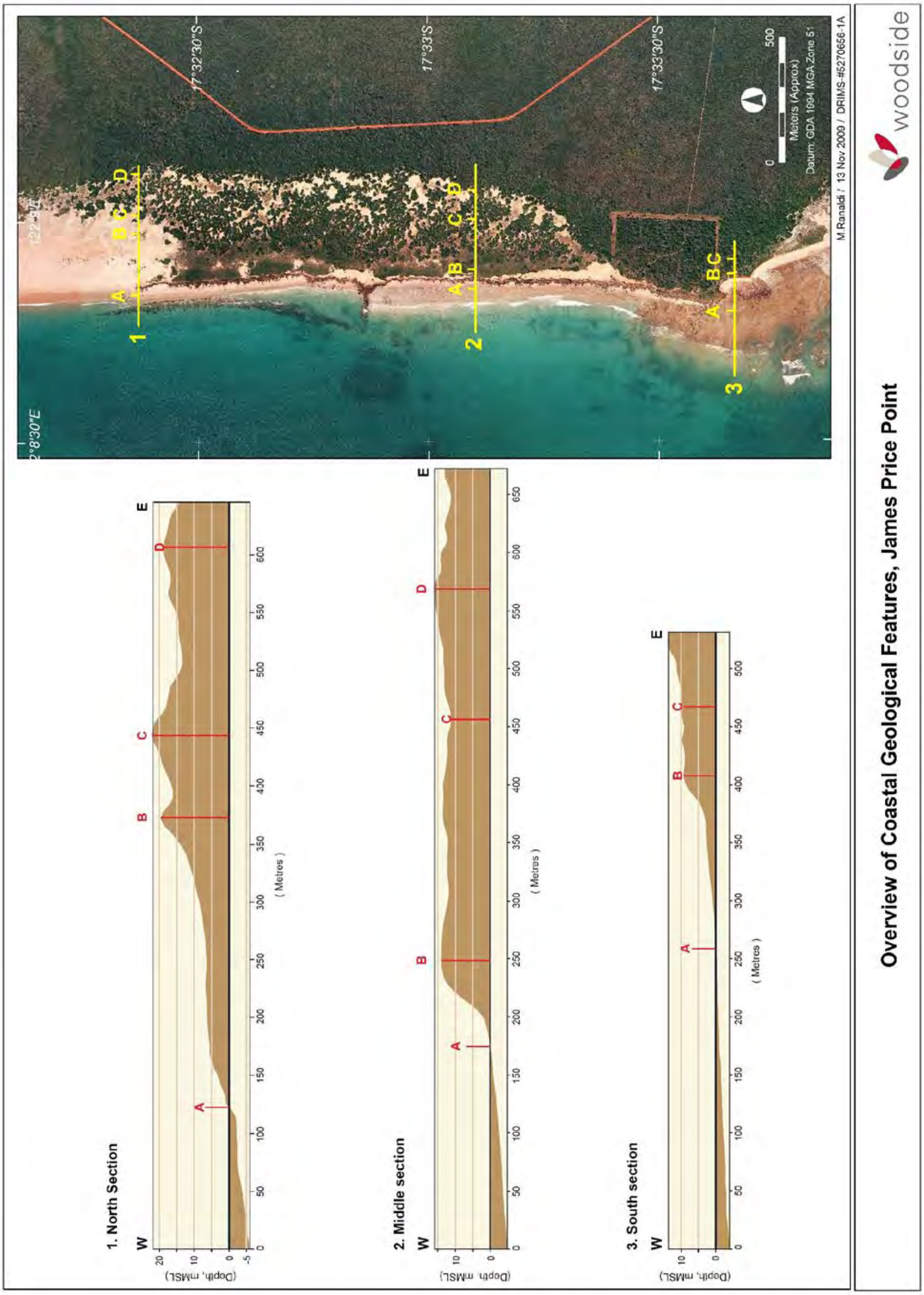
Typical of the local environment, the James Price Point coastal area is characterised by narrow beaches with an intermittent rocky shoreline and platforms of lithified coastal sediments, which adjoin stretches of low lying cliffs and sand dunes to the landward side (**Figure 1-3**). Four small headlands, less than 0.5km in length, outcrop between Coulomb Point and Quondong Point. Other outcrops occur as linear, shore-parallel rock platforms underlying sandy beaches.

- **Figure 1-3 Typical Coastal Geological Features in the Vicinity of James Price Point.**

Storm surge associated with occasional severe meteorological conditions interact with the geology to affect shoreline development and stability in nearby embayments. The upper sandy intertidal zone and dune systems are comprised of aeolian quartz and carbonate sands. Coastal dunes are located at Quondong Point, close to James Price Point and in the embayment immediately south of Coulomb Point. Storm surge and onshore winds associated with tropical cyclones and seasonal monsoonal activity contribute to the formation of these dune storm ridges. **Figure 1-4** provides a schematic representation of the typical coastal cross section found immediately south of James Price Point area. **Figure 1-6** provides a conceptual diagram of the geological cross section from James Price Point.

The coastline at James Price Point runs roughly north/south with nearshore seabed contours (down to approximately -20m Chart Datum) running parallel to the shoreline. Further offshore the contours are orientated roughly north-east to south-west. The nearshore seabed slopes at approximately 1:300 gradient for a distance of 1.5km where it then flattens to approximately 1:900 gradient. Parallel contours in the nearshore zone bathymetry indicate that cross-shore water movement is likely to dominate sediment transport rather than longshore movement.

The marine water and sediment quality in the vicinity of the James Price Point and the wider Kimberley region is considered to have little or no anthropogenic contamination as a result of the lack of industry and lack of large population centres in the area.




- **Figure 1-4 Overview of Typical Coastal Geological Features Present Throughout the Coastal Zone South of James Price Point at Quondong Point.**

- **Table 1-2 Shoreline Geomorphology from Coulomb Point to Quondong Point Including James Price Point.**

| Landform Component | Extent and Condition | Key Processes |
|---|---|---|
| **Rocky Coast:** Outcrops and reefs forming local rocky headlands | Four small headlands, less than 0.5km outcrop from Coulomb Point to Quondong Point. Other outcrops occur as linear, shore-parallel rock platforms underlying sandy beaches. | Storm surge associated with fluctuations in sea level, and extreme meteorological conditions interact with the geology to affect shoreline development and stability in nearby embayments. |
| **Sandy Coast:** Dunes | Coastal dunes are located at Quondong Point, close to James Price Point and in the embayment immediately south of Coulomb Point | Storm surge, onshore winds associated with tropical cyclones and monsoonal activity contribute to the formation of composite storm bars and dune formations. |
| **Hinterland:** Pindan Cliffs | In the 10km north of James Point the Pindan soils have been eroded by coastal processes and terrestrial run off. | Sea level fluctuations associated with extreme meteorological events bring coastal processes to the base of the Pindan. Cliffs formed by ocean processes are then degraded by slumping and gullying. |

Source: NDT, 2008b; **Appendix B-3**, derived from Eliot and Eliot, 2008.

The coastline due north and south of James Price Point consists of two beaches. Both beaches at James Price Point are categorised as rock/reef fronted and fronted by intertidal rock flats. This beach type is mainly dependent on local geology rather than wave or tide processes for its formation. Beaches fronted by intertidal rock flats usually consist of steep high tide beach with rocks extending seaward from the base of the beach (Short, 2006). The beach south of James Price Point reaches 1.8km south and is a crenulated high tide sand beach. The beach is backed by sand-draped 10 to 20m high red bluffs and fronted by rock flats that widen from 300 to 500m.

### 1.3.2. Subtidal Geomorphology and Bathymetry

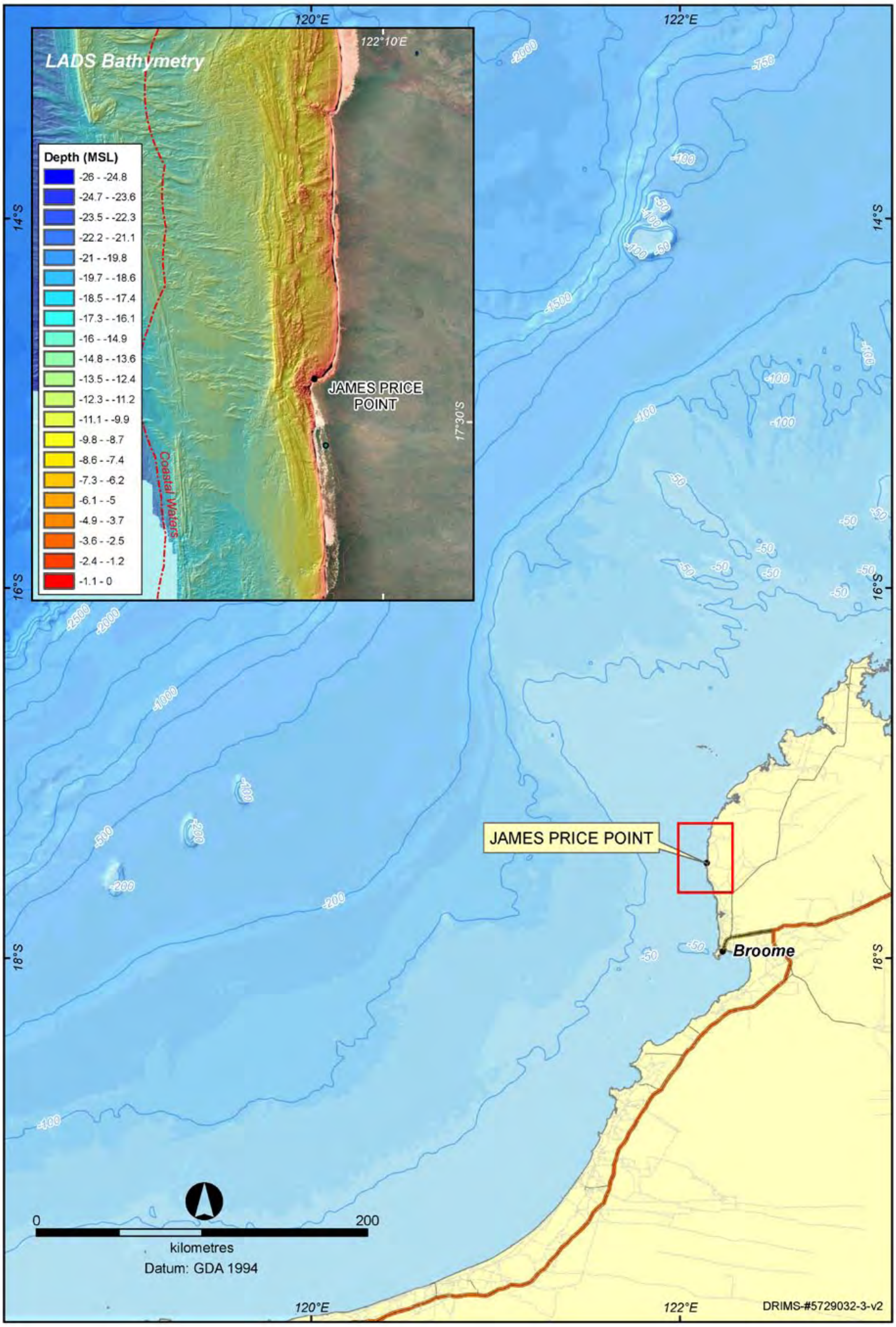
#### Regional Environment

The North West Shelf Province (**Figure 1-1**), a subregion of the NWMR is located primarily on the continental shelf between North West Cape and Cape Bougainville, offshore of James Price Point in the Canning Marine Bioregion. It encompasses much of the area more commonly known as the North West Shelf (DEWHA, 2009a). This area encompasses more than 60% of the continental shelf within the NWMR and is characterised by distinct seabed features such as shoals and valleys. Natural sedimentation within this subregion occurs on a north-south gradient, with subtidal sediment characteristics south of Broome being relatively homogenous and dominated by sand and a small amount of gravel. In comparison, north of Broome (including along Dampier Peninsula), sediment types are spatially variable (Baker *et al,.* 2008). The Leveque Rise is a large shelf plateau within the NWMR containing several terraces and steps which extend into adjacent bioregions reflecting ancient coastlines. The most prominent of these ancient coastlines occurs on the 125km depth contour. This feature is recognised as an important migratory pathway for cetaceans and other pelagic species (DEWHA, 2008a).

#### Dampier Peninsula

The Lacepede Islands (approximately 50km to the west of Beagle Bay and 65km north of James Price Point) are low lying sandy cays and are the only offshore islands along the Dampier Peninsula (CALM, 1994). The continental shelf extends approximately 200km offshore, gently sloping to the abyssal plain and marked with the occasional tidal scour channels (CALM, 1994). The near shore bathymetry is more complex and shallow than that offshore. **Figure 1-5** illustrates the nearshore bathymetry of the Dampier Peninsula between Gourdon Bay and Cape Leveque.

Sediment characteristics, including particle size distribution, were investigated by Gardline Marine Sciences (2009) at both inshore and offshore locations off the Kimberley coast between June and July 2009. It was found that sediments were highly variable between stations and zones, ranging from silt and clay to coarse sand and gravel.

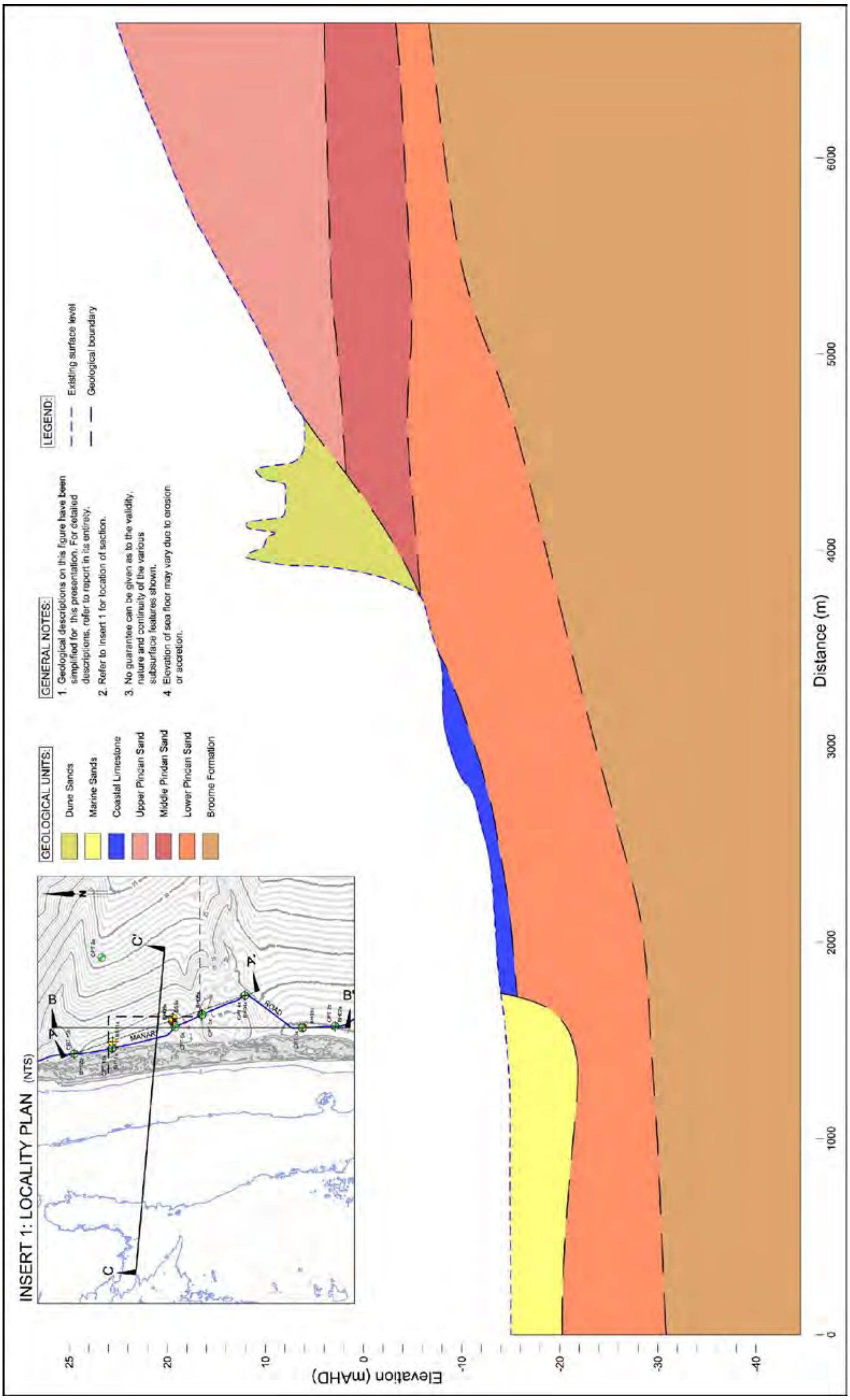



- **Figure 1-5 Regional Bathymetry of the Canning Marine Bioregion.**

**James Price Point Coastal Area**

The BLNG Precinct sits within the Canning Basin which is largely onshore with the coastal regions of the basin bounded by the geological features of the Pilbara Block to the south and the Kimberley Block to the north. The basin contains two major north westerly-trending troughs separated by a mid-basin arch and marginal shelves. These major troughs are subdivided into sub troughs and basins. The northern trough contains the Gregory Sub-basin and the Fitzroy Trough. These are estimated to contain up to 15km of predominantly Paleozoic rocks (540 – 210 million years ago). The southern trough is comprised of the Kidson and Willara sub-basins, in which there are thinner sedimentary layers. The mid basin arch, separating the two major troughs, is divided into the Broome and Crossland platforms.

The coastline in the James Price Point coastal area runs roughly north to south with the nearshore seabed contours running parallel to the shoreline (**Figure 1-8**). Further offshore, the contours are orientated north-east to south-west. The nearshore seabed gradient is approximately 1:300 for a distance of 1.5km where it flattens to a gradient of approximately 1:900. Parallel contours in the nearshore zone suggest that cross-shore sediment movement may be more dominant than longshore movement. James Price Point coastal area sediments were characterised primarily as sandy (Fry *et al.,* 2008; **Appendix C-4**). In the centre and north of the James Price Point coastal area, the substratum is typically low relief reef while west of these areas, further offshore, the substratum is dominated by soft sediments. Subtidal seabed features of the nearshore coastal area are shown in **Figure 1-9**.




Source: Worley Parsons, 2010; **Appendix B-8**.

- **Figure 1-6 Conceptual Diagram of a Geological Cross Section from James Price Point Coastal Area Interpreted from Geotechnical Borehole Data (not to scale).**

The area around Coulomb Point, approximately 12km north of James Price Point consists primarily of fine sand substrate (70% sand coverage). Deeper water (greater than 5 metres) between Quondong Point and James Price Point has predominantly flat silt sand substrate. From James Price Point north to Coulomb Point, the seabed is comprised of mostly sand (55% coverage) and extensive areas of subsea sand dunes (Fry *et al.,* 2008; **Appendix C-4**).

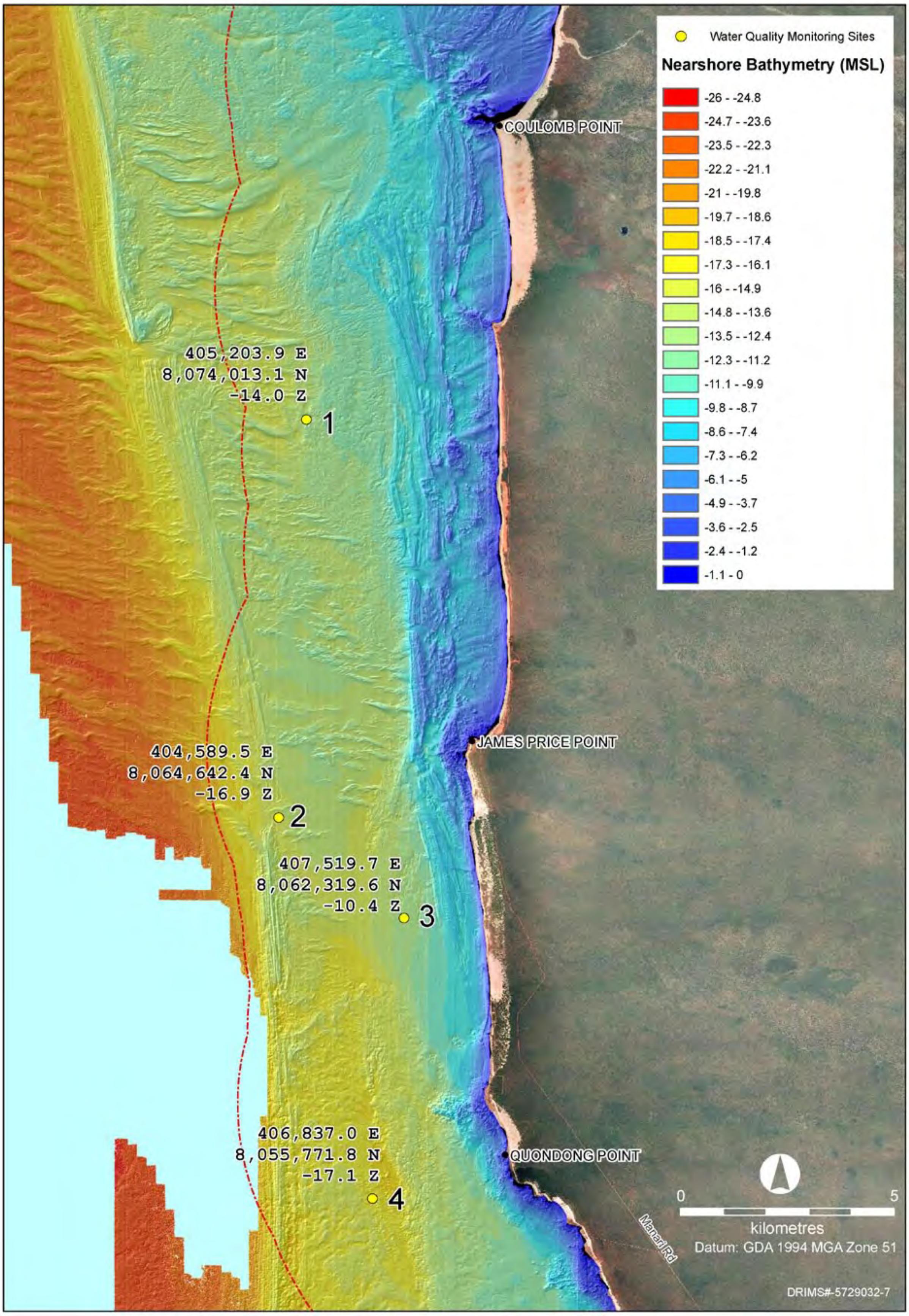
Relatively large patches of low relief reef structure are present in this northern area. Fry *et al.* (2008) (**Appendix C-4**) described one site in the northern area between James Price Point and Coulomb Point as having a significant coverage of high relief reef structure and rocky substrate. Limited tracts of low relief reef are present in shallow waters from Quondong Point to James Price Point.

Preliminary nearshore geotechnical investigations have been undertaken in order to provide information to both engineering and environmental aspects of the BLNG Precinct including environmental assessment and dredging works (Aurecon, 2010). As part of these investigations, three boreholes were bored to completion approximately 20 – 22.5m below the sea bed. A fourth borehole was terminated at a depth of approximately 7m below the sea bed. Preliminary interpretation of the results indicated the dominant material encountered on site was fine and sometimes silty red brown sand. These reworked sands were generally overlaid by either a hard 1m thick layer of calcarenite or a marine deposit of fine grained carbonate sand. Generally, the marine sediment was a loose surficial deposit of very fine to fine grained carbonate sand, silt, shell fragments and various other organic matter. It is predominantly grey to light grey in colour and quite uniform in consistency throughout the deposit. The marine sediment ranged between 0.25m to 7.25m in thickness in the completed boreholes. Nearshore boreholes (BH2 and BH6) comprised a thin layer (between 0.25m and 0.55m), while there was a noticeable increase in the thickness of the deposit in BH1 and BH3 (4.85m and 7.25m respectively) which were located in deeper water further offshore (Aurecon, 2010). Weathered rock encountered at the base of each of the completed boreholes was estimated to be very low strength sandstone, using field assessment techniques such as observed friability and scratch tests. Data for each borehole is presented in **Table 1-3** and a graphical representation of the sediment profile is presented in **Figure 1-6**.

- **Table 1-3 Geotechnical Data from Four Boreholes at James Price Point.**

| Borehole ID | Seabed level | Marine Sediment (Carbonate Sand) | | Calcarenite | | Reworked Sand | | Bed Rock | End of hole depth (MSL) |
|---|---|---|---|---|---|---|---|---|---|
| | | Top of Layer (MSL) | Layer Thickness | Top of Layer (MSL) | Layer thickness | Top of Layer (MSL) | Layer thickness | Top of Layer (MSL) | |
| BH1 | -14.92 | -14.92 | 4.85 | -- | -- | -- | -- | -- | -22.42 |
| BH2 | -13.23 | -13.23 | 0.25 | -13.48 | 1.05 | -14.53 | 14.65 | -29.18 | -34.23 |
| BH3 | -14.71 | -14.71 | 7.25 | -- | -- | -21.96 | 7.1 | -29.06 | -37.21 |
| BH6 | -12.98 | -12.98 | 0.55 | -13.53 | 1.1 | -14.63 | 16.6 | -31.23 | -32.98 |

Sediment deposition rates calculated from material collected from four sediment traps deployed as part of the nearshore water quality monitoring study (period 2–22 November 2009) were highest at Site 3, which had a deposition rate of 874g/m$^2$/day (SKM, 2010c) (**Figure 1-7**). The lowest deposition rate, 165g/m$^2$/day was at Site 4, 5-fold lower than at Site 3 (**Table 1-4**). Sediment deposition rates could not be calculated for later periods due to damage to the sediment traps and/or traps overflowing with particulate material, precluding accurate measurements. New sediment traps were designed and deployed in February 2010.




- **Figure 1-7 Nearshore Marine Water Quality Locations November 2009 - February 2010.**

- **Table 1-4 Total Deposition Mass and Rate Calculated from Sediment Traps between 2–22 November 2009.**

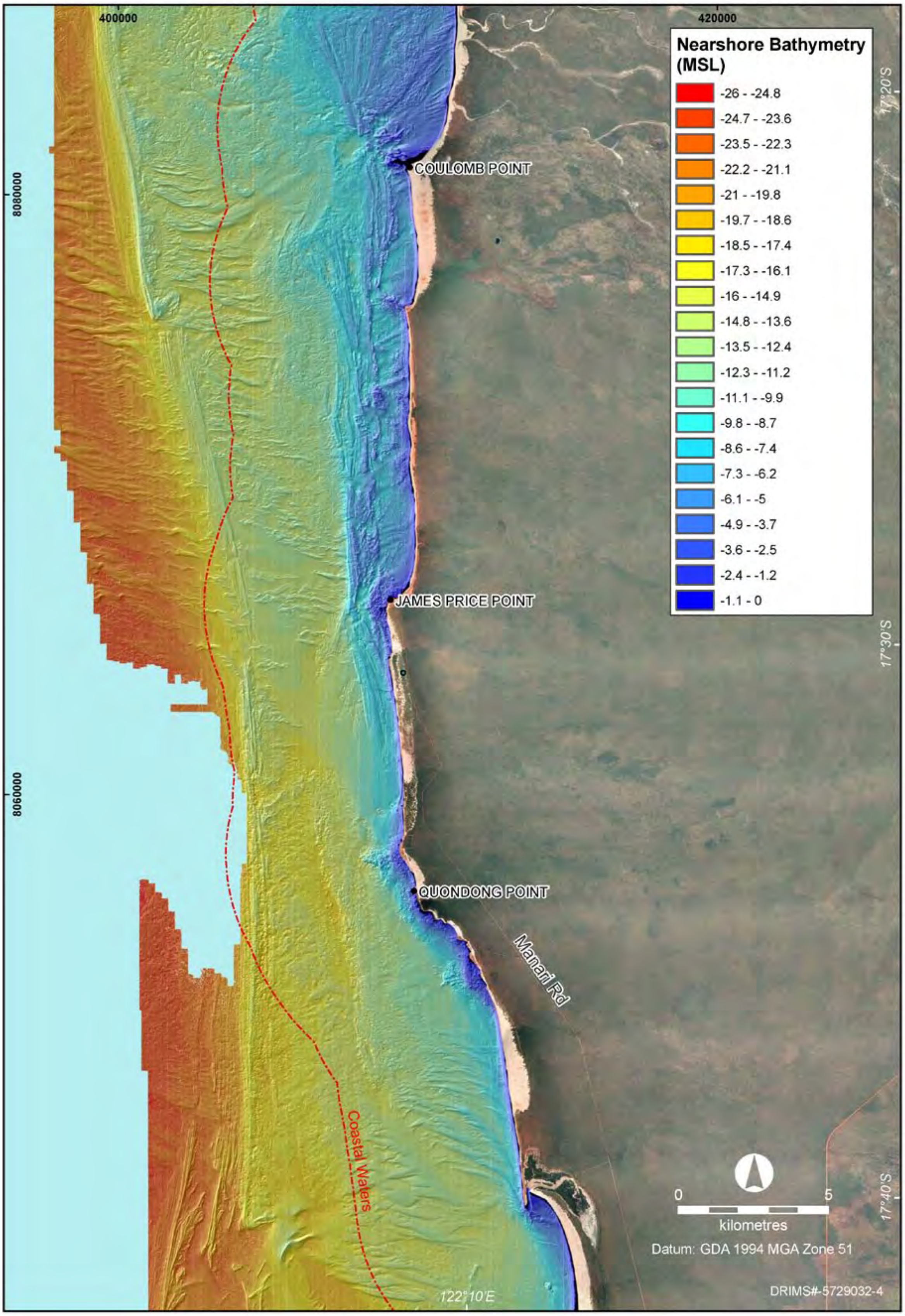
| Location | Total Mass (g wet) | Moisture Content (%w/w) | Total Mass (g dry) | Deposition Rate (g dry / $m^2$ /day) |
|---|---|---|---|---|
| **Site 1** | 347.4 | 59 | 142.4 | 424.2 |
| **Site 2** | 421.1 | 46 | 227.4 | 677.4 |
| **Site 3** | 458.4 | 36 | 293.4 | 873.9 |
| **Site 4** | 324.9 | 83 | 55.2 | 164.5 |

The particle size of deposited material at all sites in November 2009 was dominated by the 0.063–2.0mm (sand) fraction. This changed during the January–February 2010 period, when the silt and clay fraction comprised a much larger and in some cases dominant proportion of the sediment collected. This likely due to the high turbidity during January–February 2010, potentially derived from re-suspension of fines, compared to November 2009.

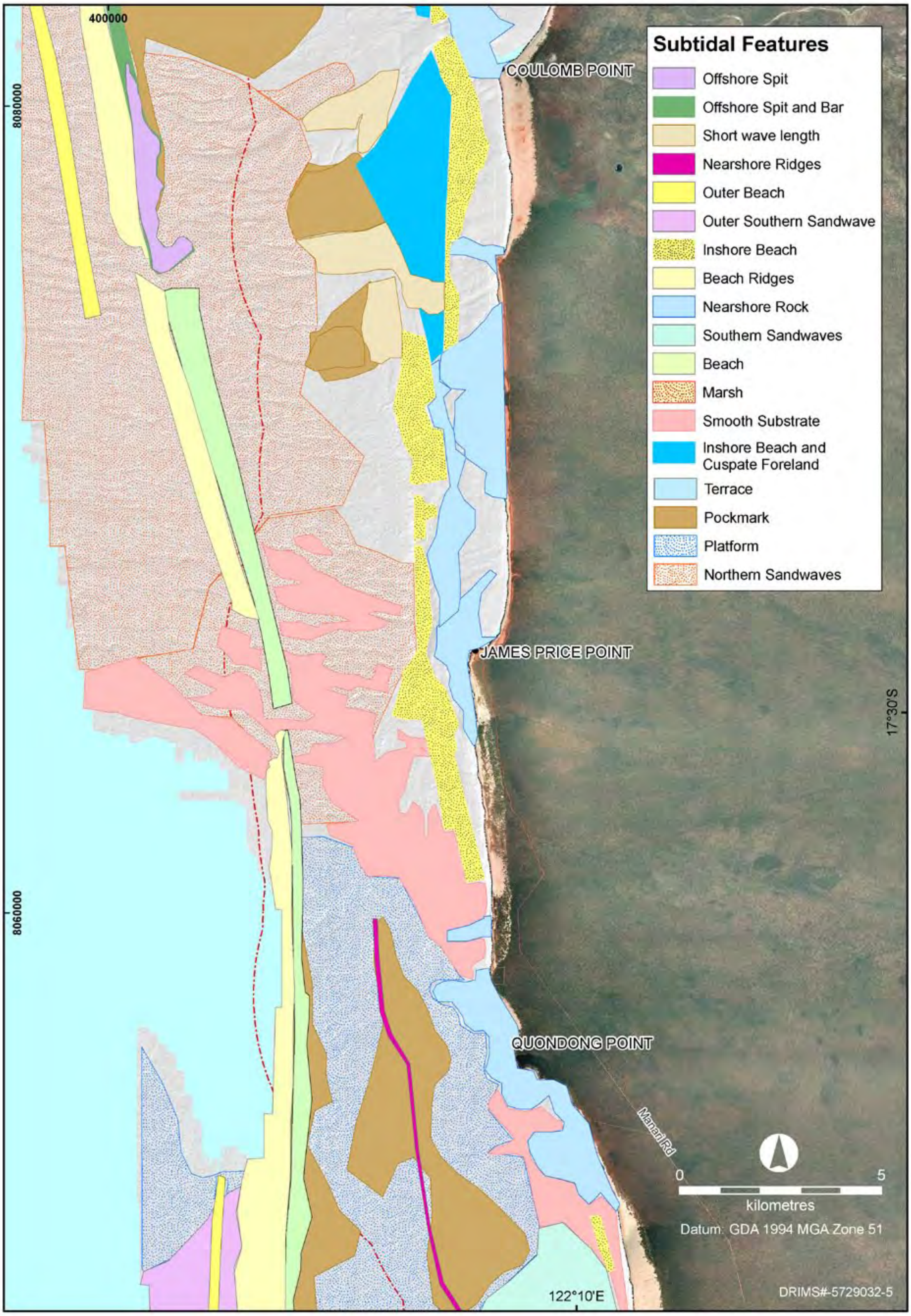
- **Table 1-5 Particle Size Analysis of Sediment Trapped.**

| Location | Percent Silt and Clay <0.063mm (%) | Percent Sand 0.063 - 2.0mm (%) | Percent Gravel >2.0mm (%) |
|---|---|---|---|
| **2 November 2009 – 22 November 2009** | | | |
| **Site 1** | 7.9 | 81.9 | 10.2 |
| **Site 2** | 8.4 | 91.3 | 0.3 |
| **Site 3** | 9.4 | 90.6 | 0 |
| **Site 4** | 19.9 | 80.0 | 0 |
| **22 November 2009 – 20 January 2010** | | | |
| **Site 1** | 16.1 | 80.5 | 3.4 |
| **Site 2** | - | - | - |
| **Site 3** | - | - | - |
| **Site 4** | - | - | - |
| **20 January 2010 – 25 February 2010** | | | |
| **Site 1** | 44.6 | 55.4 | 0 |
| **Site 2** | 63.1 | 36.9 | 0 |
| **Site 3** | 57.3 | 42.7 | 0 |
| **Site 4** | - | - | - |

Note: - RL denotes reporting limit.




▪ **Figure 1-8 Local Nearshore Bathymetry, Metres Below Sea Level (MSL), in the Vicinity of the James Price Point Area.**




- **Figure 1-9 Subtidal Seabed Features of the James Price Point Coastal Area.**

### 1.3.3. Sediment Quality

**Regional Environment and Dampier Peninsula**

The particle size distribution of marine sediments in the Kimberley region vary from clay and silt to coarse sand and gravel (Gardline Marine Sciences, 2009). In an environmental baseline study undertaken in June/July 2009, the offshore sediments appeared to become finer to the north of the survey area in deeper waters (Calliance and Torosa Fields), with coarser sediments recorded closer to shore between James Price Point to the Shelf Based Facility adjacent to the continental slope (**Figure 1-10**). Sediment fines have a particle size less than 63 micro metres (**µm**) in diameter. The Kimberley shelf sub-region in the NWMR also contains the highest concentration of silicate of any sub region (Brewer *et al.,* 2007). The high silicate concentrations tend to reflect localised terrestrial inputs in tropical waters (Hayes *et al.,* 2005) and lend weight to the influence of seasonal river inputs into the ecological and trophic dynamics of this sub-region.

Metal concentrations within sediments sampled at the Dampier Peninsula during the Gardline environmental baseline study were compared to the Interim Sediment Quality Guidelines (**ISQG**) (ANZECC/ARMCANZ, 2000). While the intent was not to prompt a management action or indicate contamination of marine sediments in the vicinity of the James Price Point coastal area, the comparison allows for benchmarking of native marine sediments quality against a national standard prior to construction and commissioning.

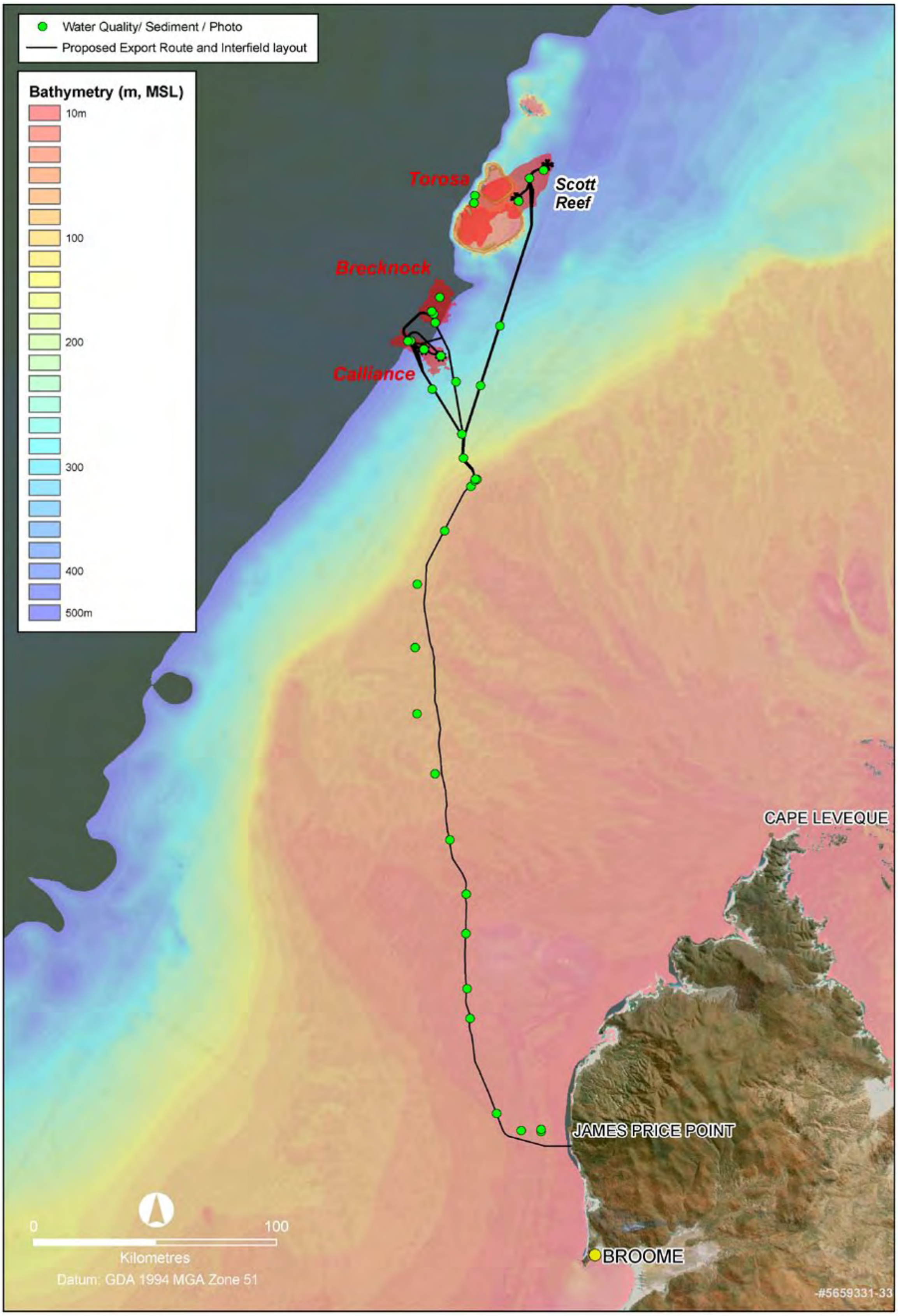
The baseline survey also investigated the nutrient, organic and metal sediment concentrations off the Kimberley coast (**Figure 1-10**). Total Nitrogen **(TN)** concentrations within sediments varied considerably across the survey area (40µg/g to 1900µg/g) with a mean of 520µg/g. There was less variation in total phosphorus **(TP)** with a mean of 584µg/g. The nitrite plus nitrate concentrations varied between less than 0.100µg/g to 0.617µg/g with no obvious correlation to depth or sediment particle size. The total organic carbon (**TOC**) amount recorded at all sites was below 0.91%. Concentrations of tributyltin **(TBT)** were below the levels of detection so less than the ISQG. Similarly, total petroleum hydrocarbon concentrations were below the limits of detection, thus not indicative of anthropogenic contamination (Gardline Marine Sciences, 2009).

**James Price Point Coastal Area**

A baseline survey undertaken by Gardline Marine Sciences sampled two sites within the vicinity of the James Price Point coastal area (Gardline Marine Sciences, 2009) along the proposed pipeline route. Additionally, sediment sampling was undertaken during the nearshore geophysical survey. These data have been used to characterise the sediment quality within the nearshore James Price Point coastal area, prior to a more robust sediment sampling and analysis plan (**SAP**) being undertaken during the further approvals process. A **SAP** has not been undertaken for the BLNG Precinct development to date, given the strategic nature of the assessment process.

The sediments at these sites were found to have low fines content (14.18% and 10.4%) with the majority of sediment characterised as sand (83.82% and 85.20%). At these sites, sediment organic and nutrient measurements were also undertaken. Total nitrogen concentrations at these sites were 340 µg/g and 440µg/g, while nitrate plus nitrite concentrations were 332µg/g and less than 0.100µg/g. Total phosphorus concentrations recorded were 1390µg/g and 1400µg/g, which were substantially greater than recorded elsewhere in the study area. Total organic carbon concentrations were 0.19% and 0.17%, which is indicative of the coarse sandy nature of surface sediments, while, TBT concentrations were less than the reporting limit of 0.5 micrograms of tin per kilogram (0.5µg Sn $kg^{-1}$) and below the ISQG trigger value. All metal concentrations recorded at the two sites were below the ISQG. Radionuclide concentrations were below the means of 16.3Bq/kg and 6.7Bq/$kg^{1}$ for radium 226 and radium 228, respectively.

During the nearshore geophysical survey (November 2009) thirty-one seabed sediment samples were recovered within the James Price Point coastal area using a Van Veen grab sampler. Of these samples, twenty were sent to an accredited laboratory for analysis. A broad suite of parameters were tested for, including; moisture content, total organic carbon, total petroleum hydrocarbons, trace metals, poly-aromatic hydrocarbons, organo-chlorine pesticides, organo-phosphate pesticides, polychlorinated biphenyls and organotins. All parameters except trace metals (nickel and mercury - in offshore locations in the vicinity of Scott Reef) were below laboratory detection limits, indicating high sediment quality with no contamination. Trace metals often naturally occur within seabed sediments. Considering the lack of historical anthropogenic development or activity within the area, the trace metals detected within all the twenty samples are determined to be natural and not the result of contamination (Gardline Marine Sciences, 2009).




Source: Gardline Marine Sciences, 2009.

- **Figure 1-10 Location of Sediment Sampling Sites within the Offshore Calliance and Torosa Fields Along the Hydrocarbon Feedstock Pipeline Route and James Price Point Coastal Area.**

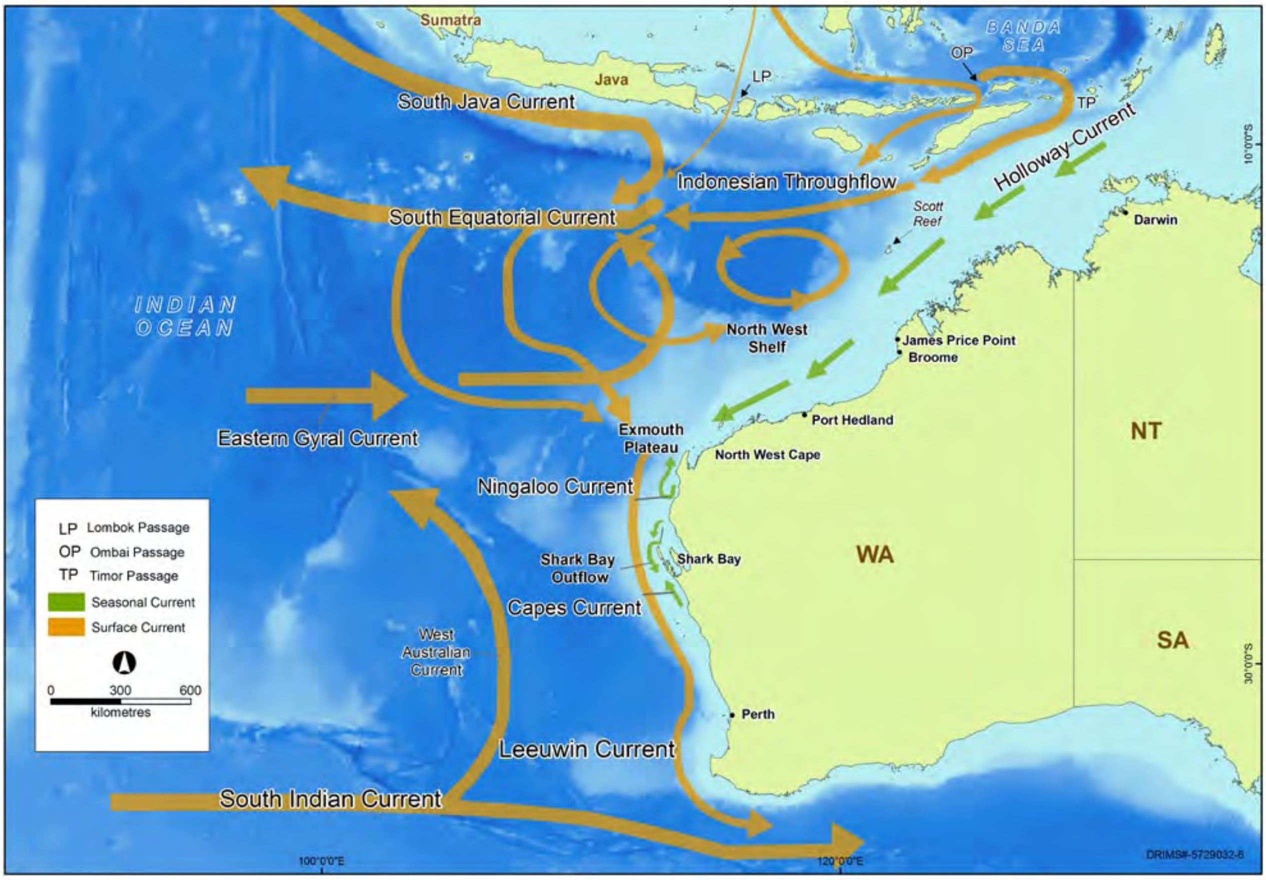
### 1.3.4. Oceanography and Coastal Processes

**Regional Environment**

The oceanography of the Kimberley region is strongly influenced by the Indonesian Throughflow (**ITF**) current (**Figure 1-11**). The ITF comprises a complex system of currents, linking the Pacific and Indian Oceans via the Indonesian Archipelago. The strength of the ITF fluctuates seasonally, reaching maximum strength during the south-east monsoon (May to September), and weakening during the north-west monsoon (November to March) (Tomczak and Godfrey, 1994). The Kimberley region is also influenced by the Holloway current, which during March-April moves southward along the shelf, bringing water from the Banda and Arafura seas (DEWHA, 2008a) (**Figure 1-11**).

Variations in oceanographic conditions result from seasonal monsoonal conditions and the long-term El Ninõ Southern Oscillation with varying implications for primary productivity in the Kimberley region. During El Ninõ events when the ITF is weaker, there is a rising of the thermocline into shallower water and an increase in upwelling strength leading to enhanced phytoplankton production (Susanto *et al.,* 2001). During La Niña events the ITF strengthens, deepening the thermocline and reducing upwelling strength (Susanto *et al.,* 2001), thereby reducing phytoplankton production. This pattern has also been observed in the Kimberley area, where higher levels of sea surface chlorophyll were reported during winter months when the ITF is strong and sea surface temperatures are relatively low (Mustoe and Edmunds, 2008).

The upper euphotic zone in tropical waters is generally nutrient poor, with the majority of nutrients occurring in the cooler, deeper waters. Upwelling provides an important mechanism for bringing these nutrient-enriched waters to the surface where there is sufficient light for photosynthesis. The increase in nutrient load from deeper waters to the well-lit surface waters results in a proliferation of phytoplankton, boosting primary productivity.




Source: DEWHA, 2008a.

- **Figure 1-11 Location of the Indonesian Throughflow and Holloway Currents.**

Key drivers for coastal processes in the Kimberley region are tides and rainfall (Mustoe and Edmunds, 2008), which contribute to productivity through catchment runoff, sediment transportation and tidal mixing. A study by Cresswell and Badcock (2000) indicated that tidal mixing plays an important role in nutrient enrichment of nearshore waters, reef and islands through mixing of the thermocline. This process transports cooler nutrient rich waters to the surface where photosynthesis occurs, and therefore is likely to be an important mechanism for supporting the area's marine ecosystem.

Ocean circulation within the region is not well-defined and the extent and frequency of nutrient upwelling onto the continental shelf is poorly understood (Wood and Mills, 2008). These authors advise that drifter trajectories and model experiments have been used to investigate water circulation and connectivity within and between outer-shelf atolls, but cross-shelf and near-shore circulation and connectivity requires investigation

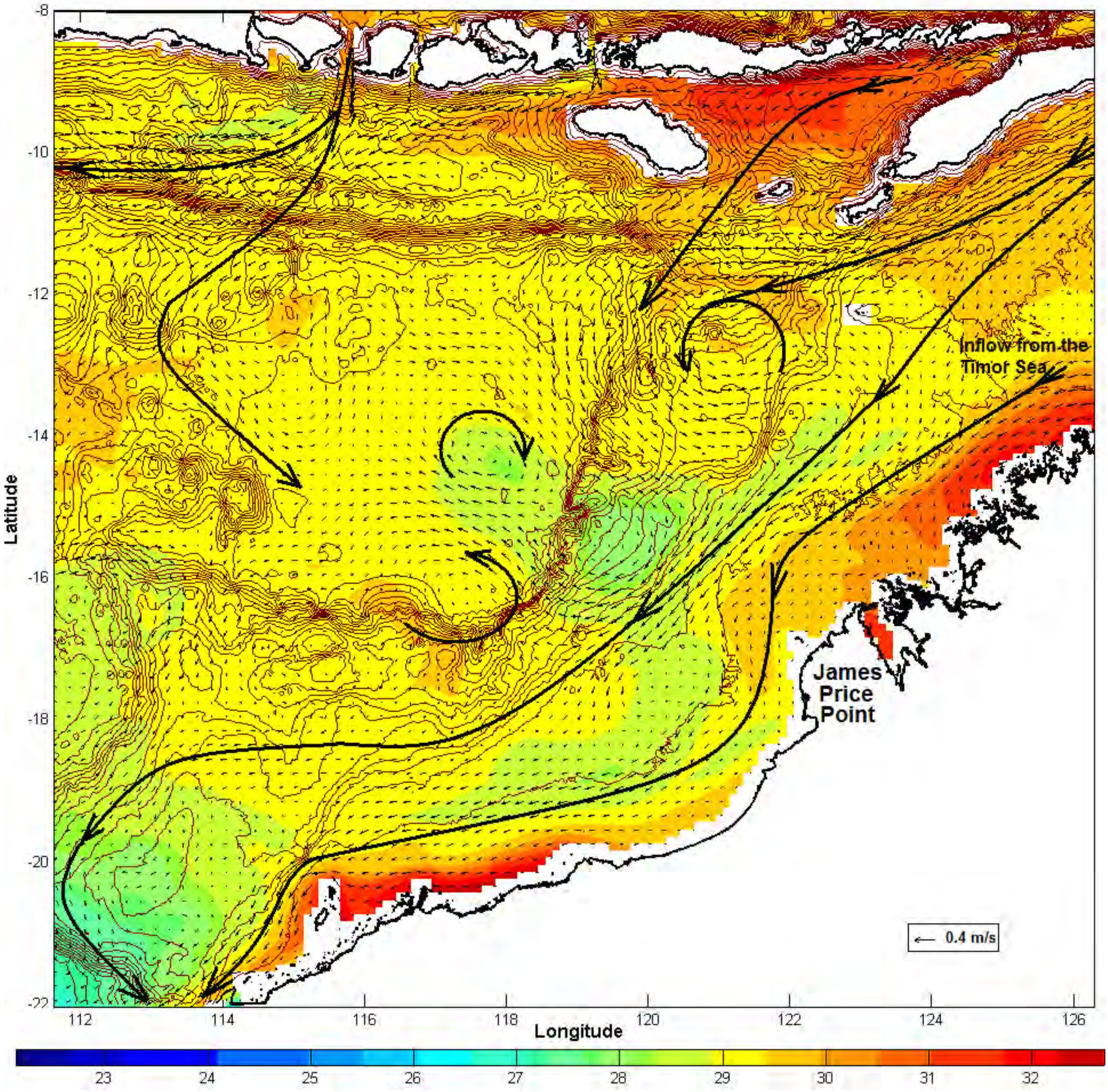
The Kimberley region has a tidal range of up to 10m, representing one of the largest tidal ranges in the world (Mustoe and Edmunds, 2008), with strong tidal currents reaching up to 4 knots (Anon, 1972). This strong tidal regime and high summer monsoonal rainfall result in naturally turbid coastal waters.

Sediments are transported by the currents and form subtidal features such as channels, harder sand banks and soft muddy areas. Currents also scour sediments from reef structures and supply food to filter-feeding fauna (Mustoe and Edmunds, 2008).

**Dampier Peninsula and James Price Point Coastal Area**

The influence of regional scale oceanographic currents on local coastal processes is relatively limited (DHI, 2010b). Such currents are driven by the setup of horizontal density gradients that can advect coherent fluid masses large distances (**Figure 1-12**). Evident in the figure is the existence of a weak alongshore current (<0.1m/s) flowing in a southerly direction past the James Price Point coastal area. The dominant forcing mechanism is the pooling of warm low salinity Pacific Ocean waters off the Kimberley coast through the Indonesian Archipelago (Indonesian Throughflow). The strength of the ITF fluctuates seasonally, reaching a maximum during the south-east monsoon, and weakening during the north-west monsoon (Tomczak and Godfrey, 1994).

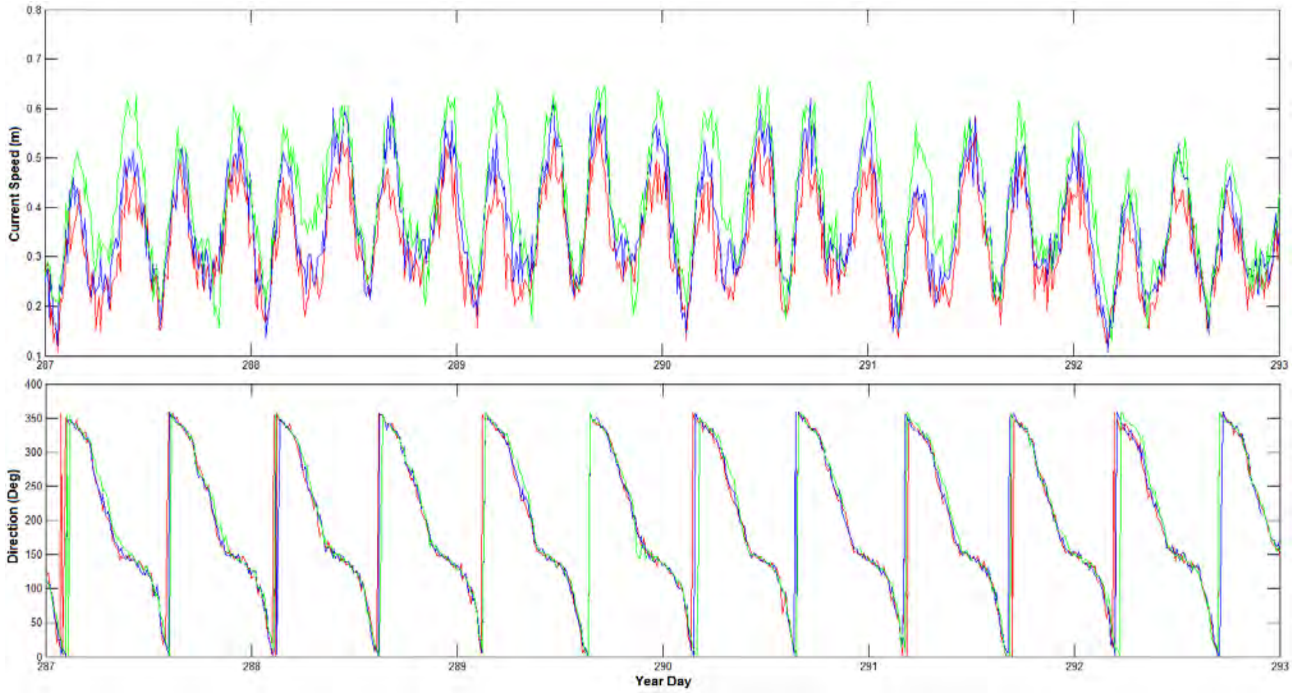
A review of the mean non-tidal circulation dynamics of five years of current and temperature measurements collected through the water column at North Rankin Platform A demonstrated not only a possible regional seasonal variability, but also an inter-annual variability, possibly linked to the ENSO cycle. The hydrodynamic modelling study undertaken by DHI (DHI, 2010c) examined the summer and winter circulation dynamics off Australia's north west coastline for 2006 and showed that a weak alongshore drift existed all year round, varying in magnitude from between ~0.07m/s during the summer months to ~0.12m/s during the winter period. This result, although for a different year, corresponds well with the low frequency response recorded by the Acoustic Doppler Wave and Current Profiler (**AWAC**) instruments located offshore Gourdon Bay and Pender Bay.




Source: Meuleners *et al*., 2009.

- **Figure 1-12 Summer Signature of Non-tidally Driven Mean Flow Characteristics off the North West Coast.**

Note: Sea temperature scale (°C) is displayed at the bottom of the figure.

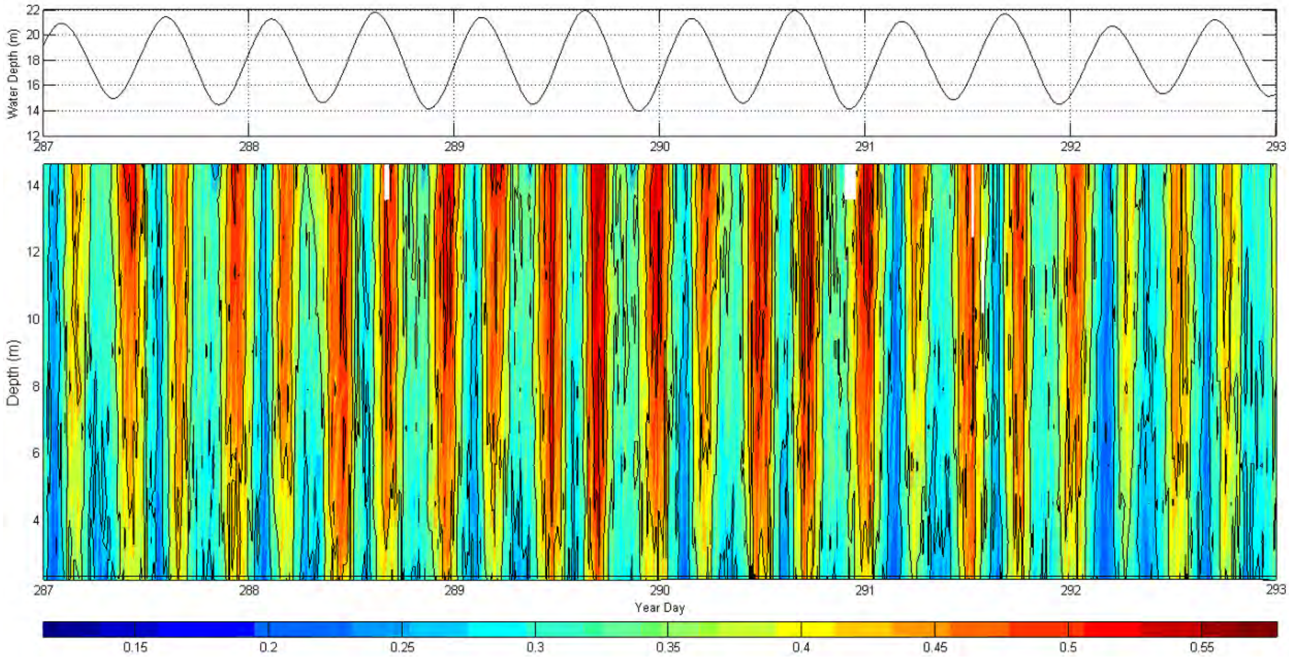



Source: DHI, 2010b.

- **Figure 1-13 Depth-specific Current Speed at James Price Point Extracted at 3.3m ASB (Red Profile), 6.7m ASB (Blue Profile) and 14.6m ASB (Green Profile).**

Note: Corresponding current directions are shown in the bottom image.

The combination of strong tide, undulating topography and year round strong solar heating generates a water column that is vertically well mixed with strong topographical forcing (**Figure 1-13**). This regime suggests that the undulating topography induces a flow field that has a strong 3D structure, and that the uniformity of the current direction (alongshore) over the water depth, (**Figure 1-14**), implies that the flow field is purely barotropic. Depth average tidal velocity components are of similar magnitude indicating a near circular anticlockwise flow pattern. The depth-averaged current speed during the peak of the spring tide ranges from 0.3m/s to 0.6m/s, with a corresponding maximum tidal excursion of approximately two km. Tidal ellipse parameters show a preferentially-orientated alongshore north/south flow, induced by tides of 0.1m/s. This flow oscillates in a north-north west (**NNW**) direction over the tidal cycle, and may play a minor role in the sediment transport process.




Source: DHI, 2010b.

- **Figure 1-14 Sea-surface Height with the Peak of the Spring Tide Reaching a Magnitude of Approximately 4m Around MSL.**

Note: The bottom image is water column current speed (m/s) over the depth range of available data.

Tides near the James Price Point coastal area are semi-diurnal (two highs and two lows each day), with tidal sea-surface height variability in excess of plus or minus (±) 4m. The tidal range at James Price Point is about 7.8m. Tide levels at the BLNG Precinct location are detailed below in **Table 1-6**:

- **Table 1-6 Tide Levels for James Price Point.**

| **James Price Point Tide Levels (m LAT)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| HAT(1) | MHWS(1) | MHWN(1) | MSL(1) | MLWN(1) | MLWS(1) | LAT(1) | AHD(2) |
| 7.8 | 7.3 | 4.6 | 4 | 3.5 | 0.8 | 0 | 4 |

Notes: 1) Tide levels determined from National Tide Tables 2010. HAT – Highest Astronomical Tide; MHWS – Mean High Water Spring; MHWN – Mean High Water Neap; MSL – Mean Sea Level; MLWN – Mean Low Water Neap; MLWS – Mean Low Water Spring; LAT – Lowest Astronomical Tide

2) Australian Height Datum (AHD) values determined from DPI submergence curves.

Tidal forcing is likely to dominate the current regime for the region of interest. Typically, the tidal current regime will display four direction reversals each day, in response to the semidiurnal tides of the region. Typical speeds are likely to be between 0.1-0.65m/s. Tidal ellipses are aligned in an alongshore direction.

While waves are important for turbulent mixing processes, they do not seem to contribute significantly to net horizontal movement of fluid particles (rather causing fluid particles to undergo a closed orbital trajectory) leaving winds and tidally induced currents as the contributors to the advection of ocean water in the vicinity of the James Price Point region.

Nevertheless, the wave climate for the exposed coastal area from Broome to Derby is likely to comprise contributions from the following:

- Indian Ocean swell – this is a perennial feature of exposed waters and this swell arrives at the outer edge of the continental shelf from the west before refracting during propagation across the shelf to become more perpendicular with the local bathymetric contours. Periods in the order of 12 to 18 seconds are likely with the largest heights generally occurring in winter;

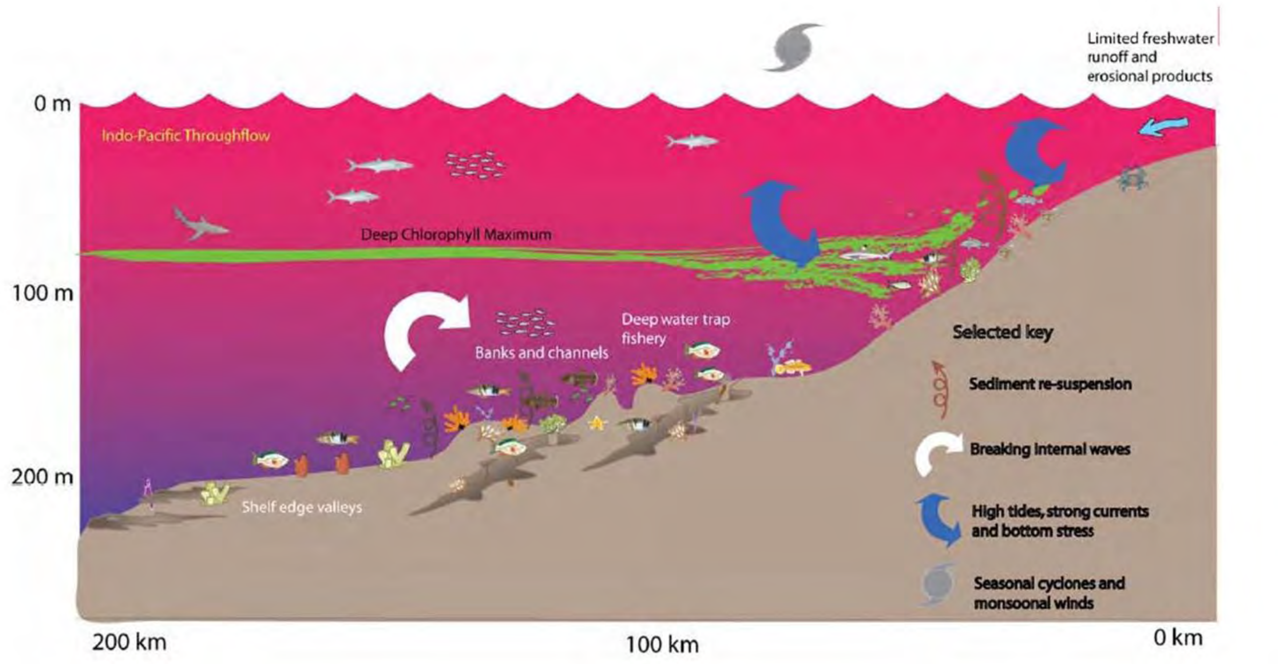
- winter easterly swell - the winter easterlies may generate a SE-NE swell with a period between 6 to 10 seconds where sufficient fetch is available (greater than 200km offshore);
- westerly monsoonal swell – the summer westerly monsoon may generate a W-NW swell between 6 to 10 second periods where sufficient fetch is available (greater than 200km offshore);
- tropical cyclone swell – tropical cyclones may generate swell with periods between 6 to 18 seconds from any direction with heights potentially greater than 10 metres; and
- Local bathymetric effects such as refraction, diffraction, shoaling and bottom friction will influence the local wave climate. Non-cyclonic monsoonal storms are likely to control the shorter return period extreme wave conditions near the coast, whilst tropical cyclones are likely to control longer return period extreme wave conditions.

### 1.3.5. Water Quality – Nutrients

In the nearshore environment of James Price Point, ambient water quality condition is dominated by the effect of daily (flood and ebb) and monthly (spring and neap) tidal fluctuations. Very large tidal prisms re-suspend naturally occurring surficial seafloor deposits mobilising suspended sediments that re-deposit elsewhere leading to a level of flux. This process is accentuated during and after extreme weather events. Cyclones in the direct vicinity of the Dampier Peninsula occur at an average rate of about one every four years. Their destructive wave energies and storm surge effects usually disturb and damage flora and fauna, particularly adjacent to the shoreline and in the near coastal zone. Tidal and wind driven process interact with further regional processes to a lesser extent by weak alongshore currents, mixing and upwelling from further offshore.

**Regional Environment**

The continental shelf waters in the Kimberley region receive an influx of nutrients from coastal runoff and from outer-shelf mixing that is influenced by swell and seabed re-suspension (**Figure 1-15**). Annual mean nitrate concentrations measured at the surface and at a depth of 150 metres were 0.21 micromoles (μM) and 16.06μM, respectively. The mean phosphate concentration measured at the surface and at 150 metres were 0.19μM and 1.15μM respectively (Brewer *et al.,* 2007).




Source: Brewer *et al.,* 2007.

- **Figure 1-15 Marine Habitat Diagram of the Kimberley Shelf Sub-region Showing Selected Important Drivers and Features.**

**Browse Basin to Dampier Peninsula**

Detailed nutrient data was also collected for the offshore Calliance and Torosa field stations, along a possible feedstock pipeline route to the James Price Point coastal area (Gardline Marine Sciences, 2009). Results from this survey found that mean water total nitrogen (**TN**) concentrations were 1,000µg/L, 3,000µg/L and 1,100µg/L for the surface, mid-water column and seabed respectively, with higher concentrations generally measured from offshore field stations. Total phosphorus (**TP**) concentrations were largely below the Limit of Reporting (**LoR**) and elevated TP concentrations were generally less than or equal to 240µg/L. Similarly, orthophosphate concentrations were generally below the LoR and all results were less than or equal to 50µg/L. Mean nitrates (**$NO_x$**) concentrations were 30µg/L, 110µg/L and 170µg/L for surface, mid water and seabed respectively.

The Australian and New Zealand Environment and Conservation Council (**ANZECC**) and Agriculture and Resource Management Council of Australia and New Zealand (**ARMCANZ**) Water Quality Guidelines were been prepared as part of Australia's National Water Quality Management Strategy (**NWQMS**) to sustain environmental values related to water quality in Australia's natural and semi natural waterbodies. One of the tools the ANZECC/ARMCANZ Water Quality Guidelines (ANZECC/ARMCANZ, 2000) provides in setting and assessing water quality objectives for water bodies in Australia are the guideline trigger values. Guideline trigger values are numerical values assigned to various water quality parameters which may cause environmental stress should the level of those parameters differ greatly from values typically experienced within that environment.

Guideline trigger values are not designed to be interpreted as threshold values, which when exceeded automatically indicate an environmental problem. Rather, trigger values indicate the level of a contaminant within a given ecosystem, below which there is only a low risk of adverse ecological effect and should be viewed as providing an initial appraisal of the quality of a water body and the potential for the presence of an environmental issue. Interpretation of the trigger values must be undertaken with an appropriate level of professional judgement as to appropriate management or monitoring of the potential issue. Default ANZECC/ARMCANZ (2000) guideline trigger values are presented for nutrients in Australian tropical marine waters are presented in **Table 1-7**.

- **Table 1-7 Summary of ANZECC/ARMCANZ (2000) Default Nutrient Guideline Trigger Values for Australian Tropical Marine Waters where a Range has been Specified. Higher Values are Typical of Turbid Macrotidal Systems of the NWMR.**

| Nutrient parameter | Units | Default ANZECC/ARMCANZ (2000) trigger values | |
|---|---|---|---|
| | | Inshore | Offshore |
| Chlorophyll-a | µg/L | 0.7 - 1.4 | 0.5 - 0.9 |
| Total phosphorus | µg P/L | 15 | 10 |
| Filtered reactive phosphorus | µg P/L | 5 | 2 – 5 |
| Total nitrogen | µg N/L | 100 | 100 |
| Nitrate and nitrite ($NO_X$) | µg N/L | 2 - 8 | 1 – 4 |
| Ammonium | µg N/L | 1 - 10 | 1 – 6 |

It should be noted that the respective ANZECC/ARMCANZ (2000) guidance level for TP was exceeded at seven sites, for orthophosphate at 14 sites, for ammonia at ten sites, for nitrate / nitrite all sites and for TN almost all sites. These results suggest that background levels in the survey area were higher than expected and that ANZECC/ARMCANZ (2000) may be unsuitable for setting baseline conditions and trigger values (Gardline Marine Sciences, 2009). Nutrients inputs, along with year-round high irradiance, and seasonal mixing provides the ingredients for a phytoplankton-based system in a large part of this sub-region. These conditions support chlorophyll maxima at about 70m depth where more nutrient rich waters are sporadically mixed with the surface layer. The annual mean chlorophyll-*a* levels were 0.3µg/L/$m^3$ and similar for monthly measurements (Brewer *et al.,* 2007). However, results from water samples taken in June/July 2009 recorded concentrations of chlorophyll-*a* were below the LoR (0.0009mg/L) at all sites (Gardline Marine Sciences, 2009).

### James Price Point Coastal Area

Nutrient data was collected in the James Price Point coastal area between 2 and 21 November 2009, 20 January 2010 and 25 February 2010 respectively from surface and seabed samples during the course of water quality monitoring (SKM, 2010c). Data was analysed and compared to ANZECC/ARMCANZ (2000) guidelines for tropical marine waters.

All water samples collected at the surface and seabed during the survey had ammonia and total nitrogen concentrations above the ANZECC/ARMCANZ (2000) trigger values for tropical waters, with concentrations of dissolved phosphorus (also referred to as filterable reactive phosphorus, **FRP**) below laboratory reporting limits. Oxides of nitrogen (**$NO_x$-N**) were undetectable except during the last survey, when concentrations from surface waters at all sites exceeded the ANZECC/ARMCANZ (2000) trigger values for tropical waters. Results showed equal concentrations of total Kjeldahl nitrogen and total nitrogen, indicating that the bulk of the nitrogen was in the form of organic nitrogen and ammonia. Organic nitrogen can be mineralised into ammonia under natural conditions, which may explain the presence of ammonia in the analysed water samples. It is noted that laboratory reporting limits were in some cases above the ANZECC/ARMCANZ (2000) trigger value, which requires modifications in analytical specifications for future sampling events. Due to remote area sampling constraints, ammonia-N values during the warmer months may have been influenced by mineralisation of organic nitrogen during transport of the samples. Preliminary results from recent sampling during a cooler period (May 2010) have defined ammonia-N levels to be between 10 and 50µg/L for both surface and bottom samples.

A few instances of total phosphorus exceeding ANZECC/ARMCANZ (2000) trigger values for tropical waters occurred at Site 1 in 2010 in both surface and bottom waters. These exceedances probably reflect phosphorus bound to suspended particulate material, which appears to be elevated during this period. Data for Site 3 in the James Price Point coastal area is presented in **Table 1-8**.

- **Table 1-8 Mean Concentrations (± Standard Error) of Total and Dissolved Nutrients in Surface and Bottom Waters for Site 3 at James Price Point, from November 2009 to February 2010.**

| Nutrients | | | | 2-Nov-09 | | | | 21-Nov-09 | | | | 20-Jan-10 | | | | 25-Feb-10 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | RL | ANZECC / AEMCANZ (2000) TV | Surface | | Bottom | | Surface | | Bottom | | Surface | | Bottom | | Surface | | Bottom | |
| | | | | Mean | ±SE | Mean | ±SE | Mean | ±SE | Mean | ±SE | Mean | ±SE | Mean | ±SE | Mean | ±SE | Mean | ±SE |
| Ammonia-N [1] | µg/L | 200 | 6 | 430 | 30 | 470 | 70 | 470 | 30 | 430 | 30 | 400 | 0 | 470 | 70 | 230 | 30 | 170 | 30 |
| $NO_x$-N | µg/L | 10 | 4 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | 20 | 0 | <10 | 0 |
| Total Kjeldahl nitrogen | µg/L | 200 | - | 700 | 170 | 1270 | 230 | 1470 | 370 | 1370 | 90 | 1570 | 330 | 2200 | 570 | 2200 | 650 | 970 | 90 |
| Total nitrogen | µg/L | 200 | 100 | 700 | 170 | 1270 | 230 | 1470 | 370 | 1370 | 90 | 1570 | 330 | 2200 | 570 | 2200 | 650 | 970 | 90 |
| Filterable reactive phosphorus | µg/L | 10 | 5 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Total phosphorus | µg/L | 10 | 10 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | 10 | 10 | <10 | 0 | <10 | 0 |

Note: RL denotes Reporting Limit; ANZECC/ARMCANZ (2000) TV is reference to the Australian and New Zealand Water Quality Guidelines Trigger Values for physical and chemical stressors for offshore waters in turbid macrotidal systems such as the NWMR. Note [1]: Ammonia-N values may have been influenced by mineralisation of organic nitrogen during transport, due to remoteness of sampling site.

### 1.3.6. Water Quality - Trace Metals and Organics

**Regional Environment and Dampier Peninsula**

The regional marine waters of the NWMR are comparatively free from anthropogenic inputs. Water quality data for deep, offshore waters (approximately 400m) indicate an undisturbed marine environment (URS, 2007).

A baseline survey undertaken by Gardline Marine Sciences (2009) found that with the exception of arsenic, copper, nickel and zinc, concentrations for other metals were below the limit of reporting in almost all water samples. The Gardline Marine Sciences (2009) study show that results from two sites in the vicinity of the James Price Point coastal area indicated that copper (mean = 13μg/L) and zinc (mean = 57μg/L) concentrations were above their respective ANZECC/ARMCANZ (2000) trigger levels (copper = 1.3μg/L; zinc = 15μg/L). As part of the nearshore water quality sampling undertaken during November 2009 to February 2010 (SKM, 2010c), results indicated that total copper (mean = 8.5μg/L) and total zinc (mean = 18.2μg/L) concentrations were above their respective ANZECC/ARMCANZ trigger values. ANZECC/ARMCANZ (2000) guidelines for trace metals and organics are presented in **Table 1-9**. The preliminary analysis of seawater samples collected from the James Price Point coastal area between 2- 21 November 2009 showed that the majority of parameters (such as elements, metals and nutrients) were below their respective limit of reporting and/or typical of nearshore concentrations.

Trace metal and organic contaminant recorded were considered naturally occurring based on the absence of any industrial developments, major population centres and agriculture lands in the vicinity of James Price Point coastal area. Therefore, the baseline data of the metals and organics in the coastal waters surrounding James Price Point will be used as a benchmark to evaluate the effects of future developments on the water and sediment quality.

- **Table 1-9 Summary of ANZECC/ARMCANZ (2000) Default Guideline Trigger Values for Trace Metals and Select Aromatic Hydrocarbons for 95% and 99% Species Protection in Marine Waters.**

| Parameter | Units | 95% SP Default ANZECC/ARMCANZ (2000) trigger value | 99% SP Default ANZECC/ARMCANZ (2000) trigger value |
|---|---|---|---|
| Cadmium | μg/L | 5.5 | 0.7 |
| Chromium (**III**) | μg/L | 27.4 | 7.7 |
| Chromium (**VI**) | μg/L | 4.4 | 0.14 |
| Cobalt | μg/L | 1 | 0.005 |
| Copper | μg/L | 1.3 | 0.3 |
| Lead | μg/L | 4.4 | 2.2 |
| Mercury | μg/L | 0.4 | 0.1 |
| Nickel | μg/L | 70 | 7 |
| Silver | μg/L | 1.4 | 0.8 |
| Tributyltin (**TBT**) | μg/L of tin | 0.006 | 0.0004 |
| Vanadium | μg/L | 100 | 50 |
| Zinc | μg/L | 15 | 7 |
| **Aromatic hydrocarbons** | | | |
| Benzene | μg/L | 700 | 500 |
| Naphthalene | μg/L | 70 | 50 |
| 1, 2, 4-trichlorobenzene | μg/L | 80 | 20 |

**James Price Point Coastal Area**

As part of the nearshore water quality sampling undertaken during November 2009 to February 2010 (SKM, 2010c), trace metals were sampled near the seabed and at the surface in samples collected at sites indicated previously and these were compared to ANZECC/ARMCANZ (2000) guidelines for marine waters.

Detectable levels of aluminium, arsenic, beryllium, boron, chromium, cobalt, copper, lead, mercury and zinc were found in water samples throughout the study period for water quality sampling. Of the metals detected, total copper, cobalt, mercury and zinc concentrations were found to exceed ANZECC/ARMCANZ (2000) trigger values on multiple occasions. For dissolved metals, measured as the concentration in filtered samples, copper, cobalt and zinc were reported at concentrations that exceeded ANZECC/ARMCANZ (2000) trigger values. However, the dissolved concentrations of these metals were inconsistent across survey times, depths and/or locations. These findings are in contrast to those of Wenziker *et al.* (2008) on the North West Shelf (adjacent to Port Hedland), which typically found very low concentrations of metals.

Dissolved metal concentrations are considered to be a better indicator of bioavailable metal concentrations than total metal concentrations and hence trigger values are more relevant for dissolved metals (ANZECC/ARMCANZ, 2000). Total metal analyses measure metals that are normally unavailable for biological uptake as they are bound up in the mineral matrix, and hence they are significantly influenced by the particulate load in the water column. This indicates that some metals are largely not bioavailable (e.g. aluminium) whereas others are (e.g. copper and zinc). Metal concentrations at Site 3 (in the James Price Point coastal area) are presented in **Table 1-10**.

Quality Assurance/Quality Control (**QA/QC**) review of results indicated sample contamination during sampling and transport, though introduction of copper, boron and zinc was observed (**Table 1-10**). Trip blanks (unopened bottles of deionised water prepared by the laboratory) had similar levels of each contaminant as the field blank (deionised water prepared by the laboratory but sampled in the field as per actual sampling), indicating that the introduction of copper, boron and zinc occurred in transit or during analysis. Subtracting the blank concentrations from actual sample results does lower concentrations of some sites, but does not reduce all concentrations below ANZECC/ARMCANZ 2000 trigger values, particularly for copper.

- **Table 1-10 Mean Concentrations (± Standard Error) of Total and Dissolved Metals in Surface and Bottom Waters from Site 3 from November 2009 to February 2010.**

| Metals | | | | 2-Nov-09 | | | | 21-Nov-09 | | | | 20-Jan-10 | | | | 25-Feb-10 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | RL | ANZECC/ ARMCANZ (2000) TV | Surface | | Bottom | | Surface | | Bottom | | Surface | | Bottom | | Surface | | Bottom | |
| **Total Metals** | | | | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** |
| Aluminium | µg/L | 10 | ID | 13 | 3 | 43 | 23 | 8 | 2 | 17 | 3 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Arsenic | µg/L | 1 | ID | 3.7 | 0.3 | 3.7 | 0.3 | 2 | 0 | 1.3 | 0.3 | 2 | 0 | 1.7 | 0.3 | 1.5 | 0.5 | 2 | 0 |
| Barium | µg/L | 10 | - | <10 | 0 | <10 | 0 | 20 | 0 | 20 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Beryllium | µg/L | 10 | ID | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Boron | µg/L | 100 | ID | 5200 | 60 | 5070 | 130 | 5270 | 30 | 5370 | 30 | 4370 | 30 | 4330 | 70 | 4330 | 70 | 4500 | 60 |
| Cadmium | µg/L | 0.4 | 5.5 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 |
| Chromium | µg/L | 1 | 4.4 | 1.3 | 0.3 | 1.7 | 0.3 | 2 | 0 | 1.7 | 0.3 | 1.3 | 0.3 | 1.7 | 0.3 | 2 | 0.6 | 1.7 | 0.3 |
| Cobalt | µg/L | 10 | 1 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | 1.7 | 0.3 | 1.7 | 0.3 | <10 | 0 | <10 | 0 |
| Copper [1] | µg/L | 1 | 1.3 | 7 | 0 | 8.3 | 1.2 | 5 | 0.6 | 6.3 | 0.9 | 7 | 0 | 9 | 1 | <1 | 0 | <1 | 0 |
| Iron | µg/L | 10 | ID | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | 70 | 6 | 83 | 7 |
| Lead | µg/L | 1 | 4.4 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 |
| Manganese | µg/L | 10 | ID | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Mercury | µg/L | 0.1 | 0.4 | <0.1 | 0 | <0.1 | 0 | <0.1 | 0 | <0.1 | 0 | <0.1 | 0 | 0.5 | 0.1 | <0.1 | 0 | <0.1 | 0 |
| Nickel | µg/L | 1 | 70 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 |
| Silver | µg/L | 10 | 1.4 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Zinc | µg/L | 5 | 15 | 16.3 | 0.7 | 16.7 | 0.3 | 9.7 | 3.3 | 10.3 | 3.8 | 13.7 | 0.9 | 10.7 | 0.7 | 36.3 | 4.4 | 32 | 4.6 |
| **Dissolved Metals** | | | | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** | **Mean** | **±SE** |
| Aluminium | µg/L | 10 | ID | 10 | 0 | 10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | 10 | 0 | 10 | 0 |
| Arsenic | µg/L | 1 | ID | 2 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | <1 | 0 | 1 | 0 | <1 | 0 | 2 | 0 |
| Barium | µg/L | 10 | - | <10 | 0 | <10 | 0 | 10 | 0 | 10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Beryllium | µg/L | 10 | ID | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Boron | µg/L | 100 | ID | 5200 | 60 | 5070 | 130 | 5170 | 70 | 5170 | 30 | 4070 | 90 | 4200 | 0 | 4300 | 60 | 4370 | 90 |
| Cadmium | µg/L | 0.4 | 5.5 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 | <0.4 | 0 |

| Metals | | | | 2-Nov-09 | | | | 21-Nov-09 | | | | 20-Jan-10 | | | | 25-Feb-10 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | RL | ANZECC/ ARMCANZ (2000) TV | Surface | | Bottom | | Surface | | Bottom | | Surface | | Bottom | | Surface | | Bottom | |
| Chromium | µg/L | 1 | 4.4 | 3.7 | 1.3 | 1 | 0 | 1.7 | 0.3 | 1 | 0 | 1.3 | 0.3 | <1 | 0 | 0.8 | 0.2 | 1.7 | 0.3 |
| Cobalt | µg/L | 10 | 1 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Copper [1] | µg/L | 1 | 1.3 | 6.7 | 0.3 | 6.3 | 0.3 | 4.3 | 1.2 | 5.7 | 0.3 | 7 | 0 | 7.7 | 0.3 | <1 | 0 | <1 | 0 |
| Iron | µg/L | 10 | ID | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | 63 | 3 | 60 | 6 |
| Lead | µg/L | 1 | 4.4 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 |
| Manganese | µg/L | 10 | ID | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Mercury | µg/L | 0.1 | 0.4 | <0.1 | 0 | <0.1 | 0 | <0.1 | 0 | 0.1 | 0 | <0.1 | 0 | 0.2 | 0.1 | <0.1 | 0 | <0.1 | 0 |
| Nickel | µg/L | 1 | 70 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 | <1 | 0 |
| Silver | µg/L | 10 | 1.4 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 | <10 | 0 |
| Zinc | µg/L | 5 | 15 | 16 | 0.6 | 16.3 | 0.3 | 7.3 | 1.2 | 10 | 3.5 | 10.7 | 1.3 | 10.7 | 0.7 | 36 | 4.5 | 32 | 4.6 |

Note: RL denotes Reporting Limit; ANZECC/ARMCANZ (2000) TV is reference to the Australian and New Zealand Water Quality Guidelines Trigger Values for toxicants at a level of protection of 95% of species; Grey shading indicates exceedance of ANZECC/ARMCANZ (2000) trigger value. Note [1] QA/QC samples identified contamination of samples.

### 1.3.7. Water Quality - Turbidity and Total Suspended Solids

Turbidity is a measure of the amount of light scattered through the water column by suspended particles including sediment (Stoddart and Anstee, 2004). It is an important parameter as it is a measure of light attenuation as light passes through the water column. Turbidity is typically measured in Nephelometric Turbidity Units (**NTU**) and is determined by the shape, size and refractive index of the particulate material. While turbidity is a good indication of water clarity, it does not provide quantitative information about the type, concentration or specific gravity of the suspended particles. In contrast, total suspended solids (**TSS**) is a measure of the actual mass of suspended solids in the water column. Both are considered important predictors of the amount of light available for photosynthetic activity for corals, seagrasses and other benthic primary producers (**BPP**) due to the light attenuating properties of particles in water. ANZECC/ARMCANZ (2000) guidelines specify a range of 1 to 20NTU as trigger values for turbidity, with higher values typical of inshore and estuarine waters while lower values are associated with offshore coral dominated habitats. ANZECC/ARMCANZ (2000) does not specify default trigger values for TSS.

#### Regional Environment

Naturally occurring suspended sediments can result from the re-suspension and transport of unconsolidated sediments from wind, wave, tides, current action and episodic weather events (Larcombe *et al.,*1995). The duration that suspended material can reside within the water column is strongly influenced by local weather conditions, bathymetry and sediment size. In the NWMR, regional oceanography is characterised by large tidal ranges (up to 10m) and associated high velocity tidal currents (2 to 3kn), which re-suspend sediments in shallow water and distribute finer materials.

#### James Price Point Coastal Area

As with temperature and conductivity, turbidity in the nearshore zone was undertaken using a combination of discrete profiling through the water column and fixed loggers deployed *in situ* between November 2009 and September 2010.

A continuous water quality monitoring program was initiated in November 2009 at four sites within the nearshore JPP coastal area. Data recorded during the program is presented in **Figure 1-16** to **Figure 1-21**. Mean depths at which loggers were deployed were approximately 13m at Site 1, 15m at Site 2, 13m at Site 3 and 16m at Site 4 (**Figure 1-7**). The varied depths largely dictated the level of photosynthetically available radiation **(PAR)** reaching the benthos, with more than a 50% reduction in maximum irradiance observed at Site 4 compared to Site 1. General characteristics observed included semi-diurnal tidal fluctuations in depth and the expected day/night cycle in PAR. Longer-term changes included transitions between spring and neap tides that also affected irradiance to the benthos (i.e. increased light availability during neap tidal stages).

The preliminary data indicates that highly variable levels of turbidity occur within the nearshore JPP coastal area, associated with the macro-tidal regime and meteorological perturbations (**Figure 1-17** to **Figure 1-21**). Similarly, high levels of sediment re-suspension and deposition were recorded within the nearshore environment. Turbidity at the beginning of deployment was relatively stable at Sites 1 and 4. However, it was variable at Sites 2 and 3, which are directly offshore of JPP. The median TSS level (November 2009 – September 2010 data, average of all sites) was determined to be 2.8mg/L, with a summer median of 7.5mg/L and a winter median of 2.3mg/L. The 95$^{th}$ percentile TSS level (November 2009 – September 2010 data, average of all sites) was 28.6mg/L, with a summer and winter 95$^{th}$ percentile level of 34.3mg/L and 9.8mg/L respectively.

Turbidity levels dramatically increased 10-fold and clearly above the 25NTU limit of the turbidity sensors from the middle of November 2009 for the reminder of the survey (**Figure 1-21**). Strong diurnal variation in turbidity remained evident during this period, indicating this was not a sensor technical issue. This variability probably results from a combination of tidal regimes and/or meteorological conditions. It should be noted that the water column profiling for turbidity indicates that the elevated turbidity is restricted to the bottom layers of the water column **Figure 1-16**, which is consistent with re-suspension being a major source of the observed turbidity.

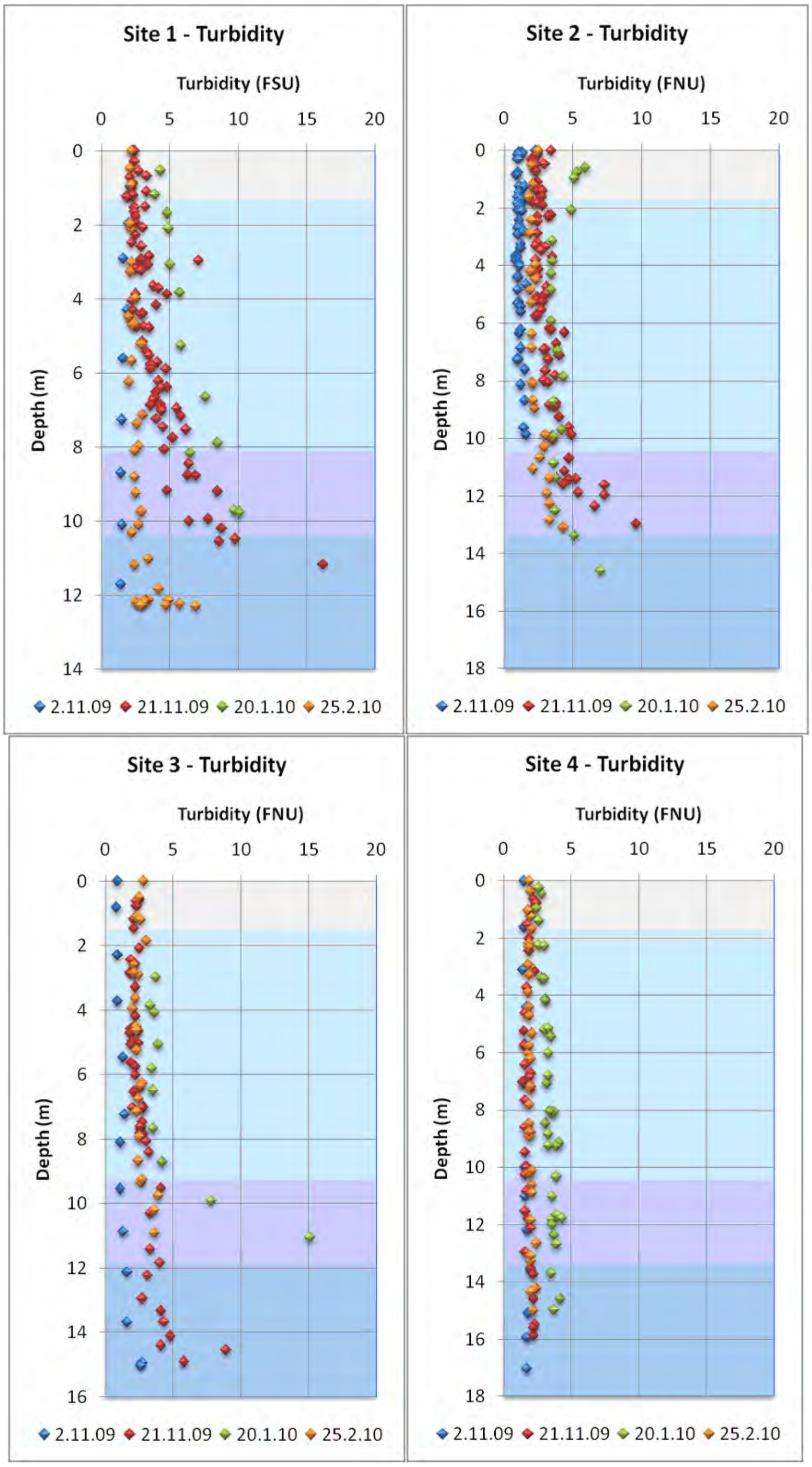
The effect of elevated turbidity in the water column was a dramatic decrease in PAR reaching the benthos, with PAR reduced by as much as 200-fold during peak turbidity conditions compared to low turbidity conditions. Following the onset of Tropical Cyclone Laurence in the Kimberley region (19 December 2009), which produced wind gusts over 75km/h (BoM – Broome Airport) and dense cloud cover, PAR readings on the seafloor were 0µmol photons/m$^2$/s for up to 7 days at Sites 2 (**Figure 1-18**) and 4 (**Figure 1-20**).

Chlorophyll-a as determined from fluorescence, which is a measure of phytoplankton abundance, followed a similar trend to turbidity, which was not expected due to the high light requirements of phytoplankton and subsequent inverse relationship typically observed (i.e. high turbidity results in low phytoplankton), although high phytoplankton concentrations can themselves reduce ambient light levels. The low chlorophyll-a concentrations in water samples collected at both surface and depth, during initial sampling surveys, combined with similar trends in turbidity suggest this source of fluorescence is potentially derived from benthic microalgae resuspended off the seafloor through the same physical actions resuspending sediments. Elevated chlorophyll-a concentrations were identified in bottom later sample collected on 20 January 2010 (**Table 1-11**).

*In situ* water column profiling indicates that the elevated turbidity is restricted to the bottom layers of the water column, which is consistent with high levels of tidally driven re-suspension being a major source of the observed turbidity. Similarly, PAR readings reduced by as much as 200-fold during peak turbidity conditions compared to 'normal' ambient turbidity conditions.

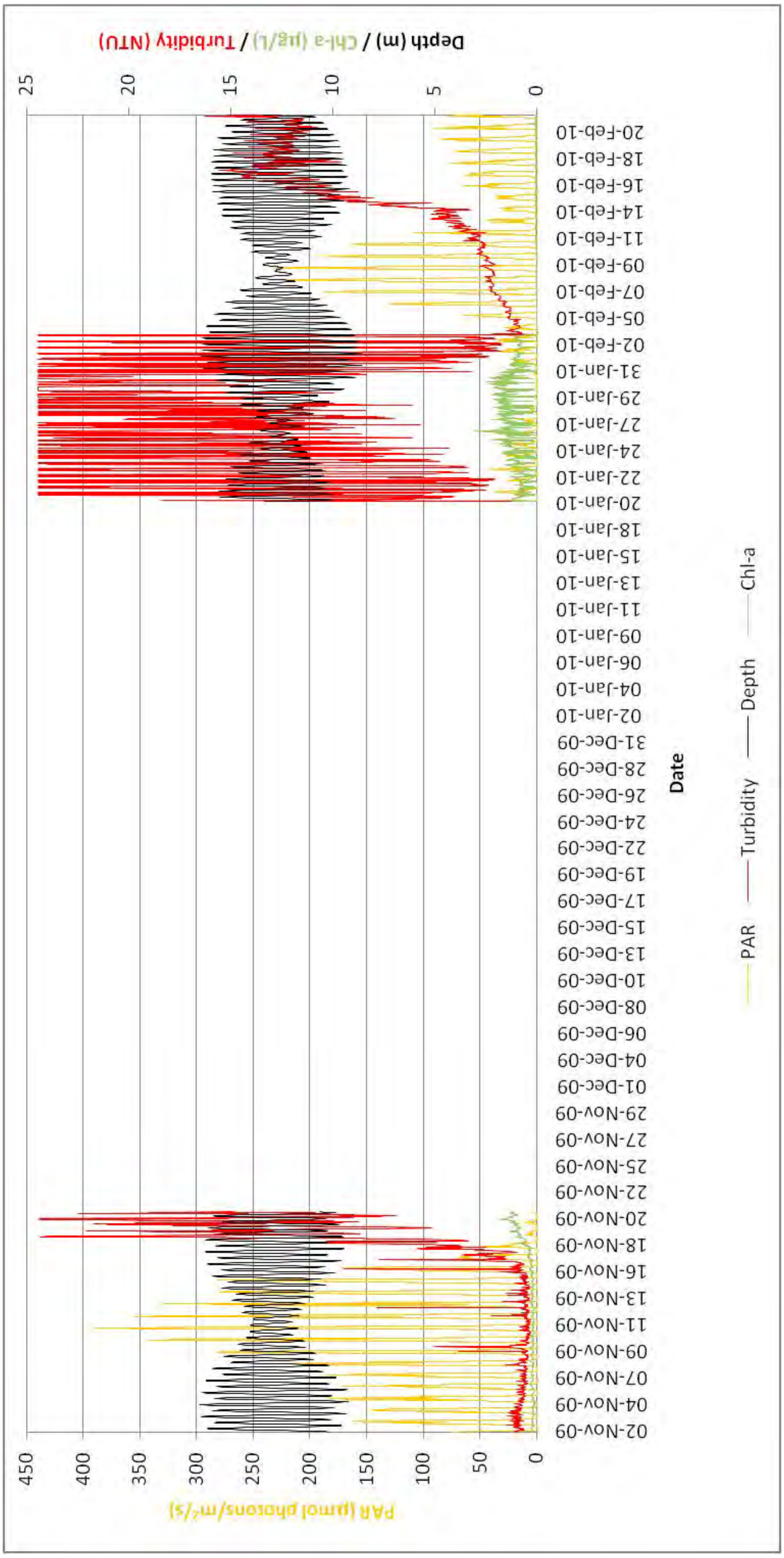
- **Table 1-11 Mean Concentrations of Chlorophyll-a in Surface and Bottom Waters from each Site at Differing Dates. All Triplicates were Below Laboratory Reporting Limits.**

| Chlorophyll-a | | | | Surface Samples | | | | Bottom Samples | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Site | | | | Site | | | |
| | Units | RL | ANZECC / ARMCANZ 2000 TV | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 2 November 2009 | µg/L | 0.5 | 0.9 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| 22 November 2009 | µg/L | 1.0 | 0.9 | 0.7 | <1.0 | <1.0 | <1.0 | <1.0 | 0.7 | 1.0 | <1.0 |
| 20 January 2010 | µg/L | 1.0 | 0.9 | 2.3 | 1.3 | 4.7 | 5.8 | 5.2 | 2.5 | 3.8 | 1.0 |
| 25 February 2010 | µg/L | 1.0 | 0.9 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |



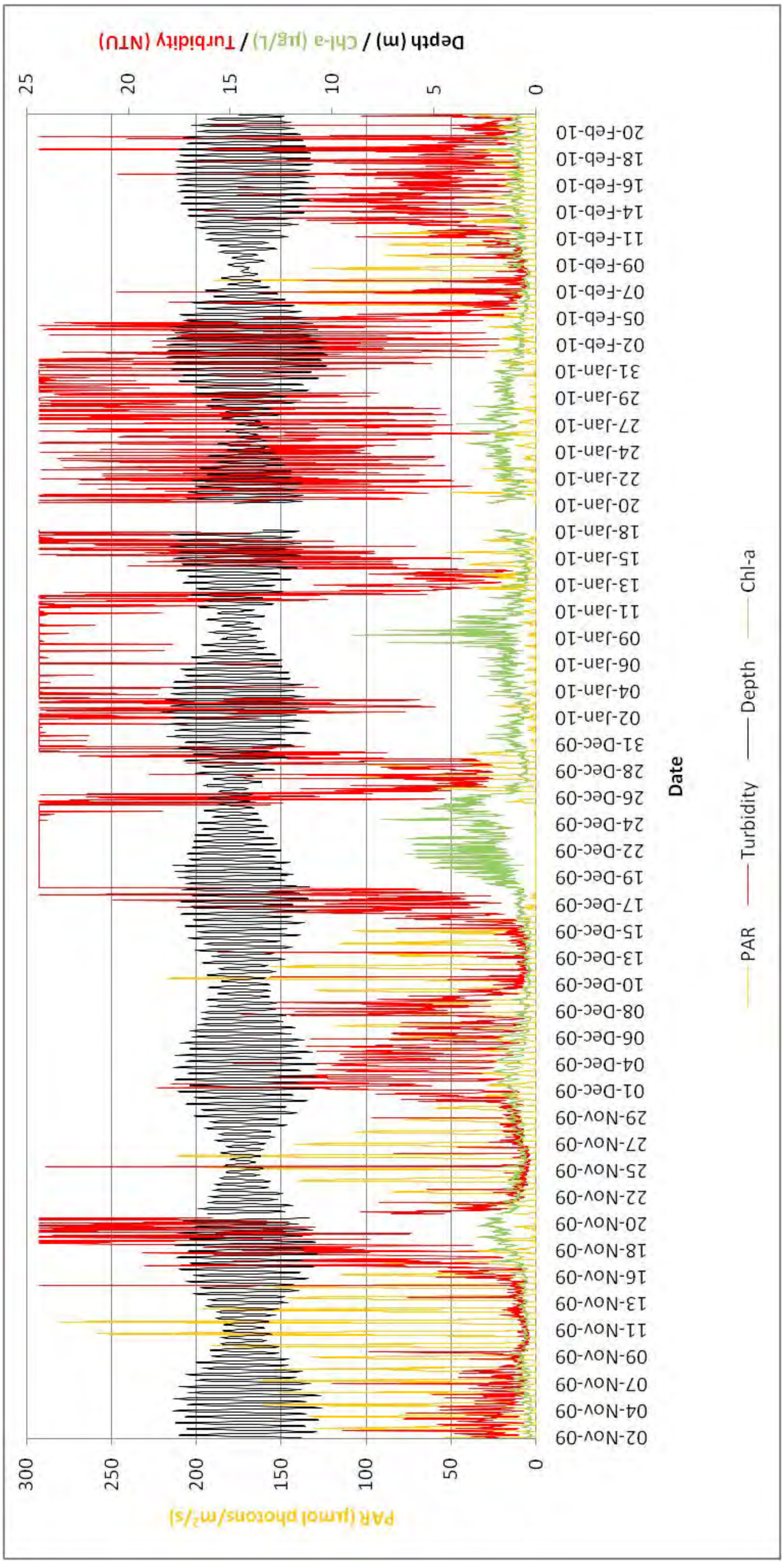

Source: DSD, 2010d; **Appendix C-13**.

- **Figure 1-16 Depth Profiles of Turbidity at Each Monitoring Location on 2 November 2009, 21 November 2009, 20 January 2010 and 25 February 2010.**



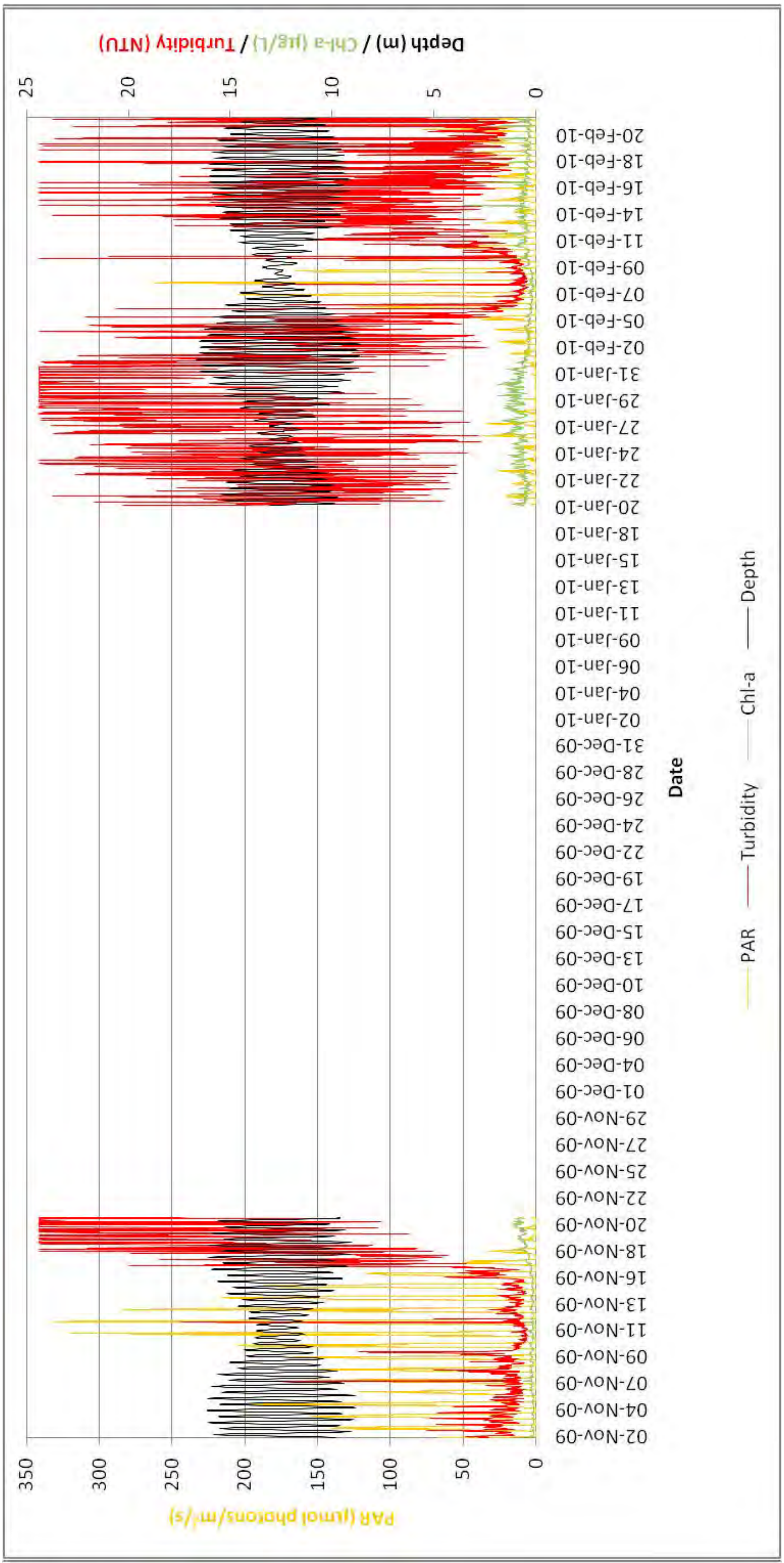

Source: DSD, 2010d; **Appendix C-13**.

- **Figure 1-17 *In situ* Chlorophyll-a, Depth, PAR and Turbidity Measured 1m above the Seafloor at Site 1 between 2 November 2009– 25 February 2010.**



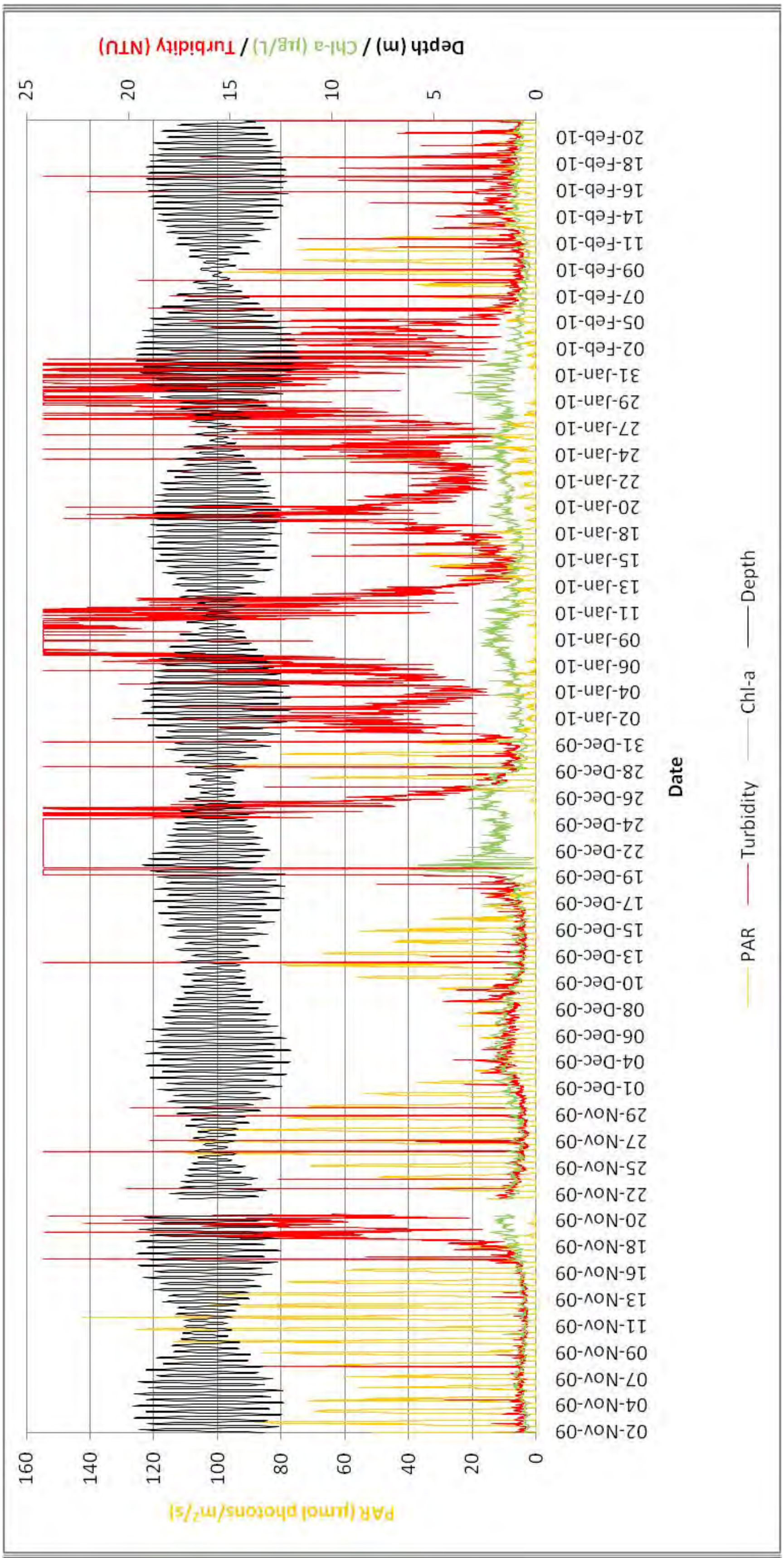

Source: DSD, 2010d; **Appendix C-13**.

- **Figure 1-18 *In situ* Chlorophyll-a, Depth, PAR and Turbidity Measured 1m above the Seafloor at Site 2 between 2 November 2009– 25 February 2010.**



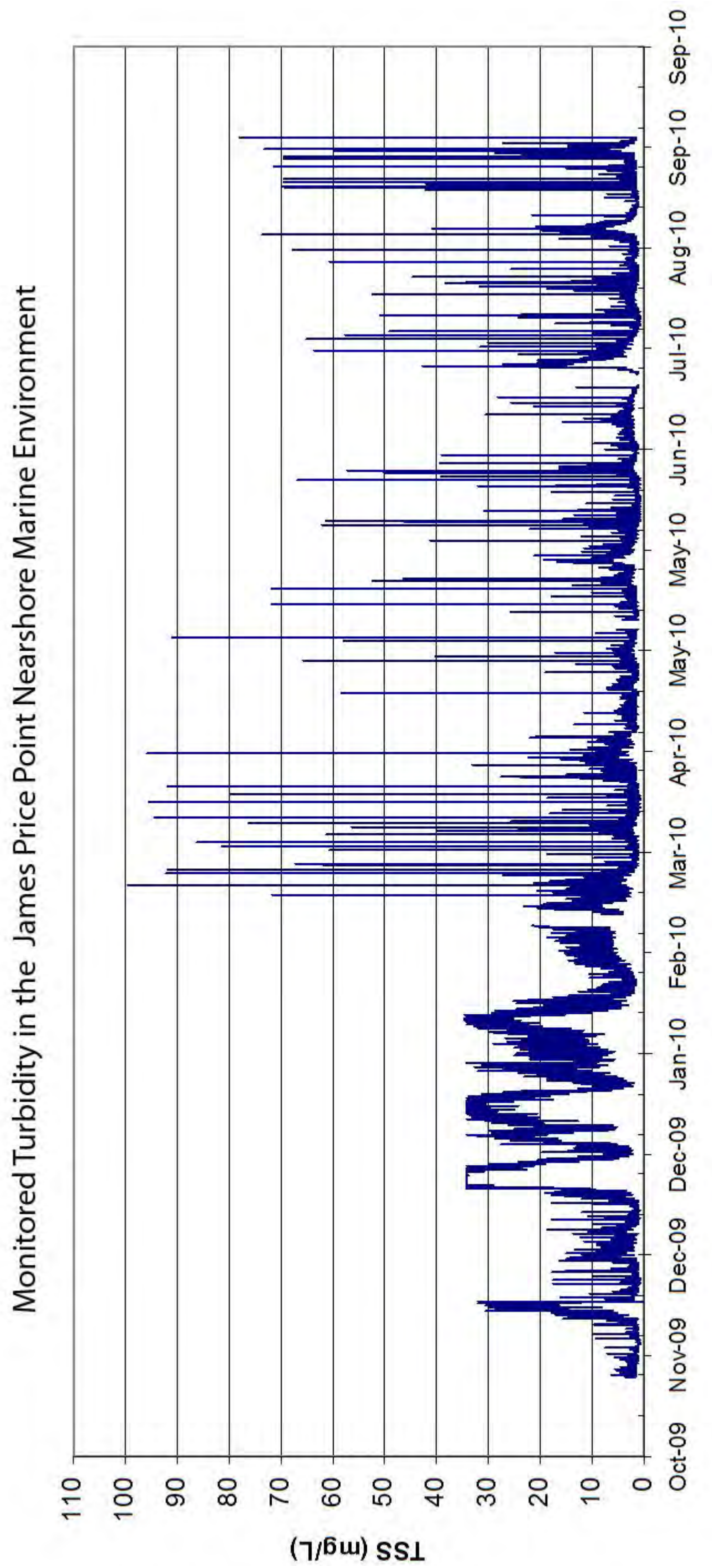

Source: DSD, 2010d; **Appendix C-13**.

- **Figure 1-19 *In situ* Chlorophyll-a, Depth, PAR and Turbidity Measured 1m above the Seafloor at Site 3 between 2 November 2009– 25 February 2010.**




Source: DSD, 2010d; **Appendix C-13**.

- **Figure 1-20** ***In situ*** **Chlorophyll-a, Depth, PAR and Turbidity Measured 1m above the Seafloor at Site 4 between 2 November 2009– 25 February 2010.**




- **Figure 1-21 An Average of TSS Levels at Monitored Sites (Sites 1-4) between 2 November – 6 September 2010.**

Note: Due to equipment constraints turbidity measurements were capped at 25NTU until 25/2/2010. In situ turbidity data was collected as nephelometric turbidity units, with a conversion to TSS made using a formula derived from field measurements; see Section 4.8 of DSD, 2010d (**Appendix C-13**) BLNG Precinct Dredging and Spoil Disposal Assessment.

### 1.3.8. Moderate Resolution Imaging Spectroradiometer (MODIS) Water Quality Study

To compliment the on going nearshore water quality programme, a Moderate Resolution Imaging Spectroradiometer (MODIS) study was initiated to utilise historical satellite imagery to determine long-term spatial and temporal trends in natural background water quality (specifically TSS and benthic light availability). MODIS provided a synoptic coverage at spatial resolution of approximately 250m.

In addition, the existing preliminary water quality data was re-examined to develop a relationship between Total Suspended Solids (**TSS**) (the primary unit of the dredged modelling outputs) and NTU (the turbidity monitoring unit from the ongoing nearshore water quality programme). *In situ* water quality measurements were taken across the James Price Point coastal area to bolster the existing monitoring data and determine spatially and temporally coincident measurements of NTU, TSS and PAR, thereby minimising the effect of spatial variability of suspended sediments in the water. These field measurements were undertaken to establish the use of MODIS satellite imagery to monitor surface water quality properties in the region. A full description of the study and techniques is discussed in DSD, 2010d; **Appendix C-13**. A summary of the results is discussed below.

**MODIS derived Total Suspended Solids**

The median TSS values from the different composite images ranged between 0 – 4mg/L with the greatest concentration of TSS occurring in the vicinity of the Lacepede Islands, located approximately 65km from JPP, with consistent concentrations above 2mg/L. The extent of elevated median TSS concentrations in this area was greatest during spring and flood tides, and the turbid waters around the Lacepede Islands with values of 1.5-2mg/L offshore of James Price Point. The lowest median TSS occurred during neap tides. Median TSS concentrations in the nearshore waters were also highest during the summer and spring tides (in excess of 2mg/L across the full north-south extent of the study area) and lowest during the winter. There was little difference in the distribution of median TSS concentrations (both offshore and nearshore) between winter and ebb tides.

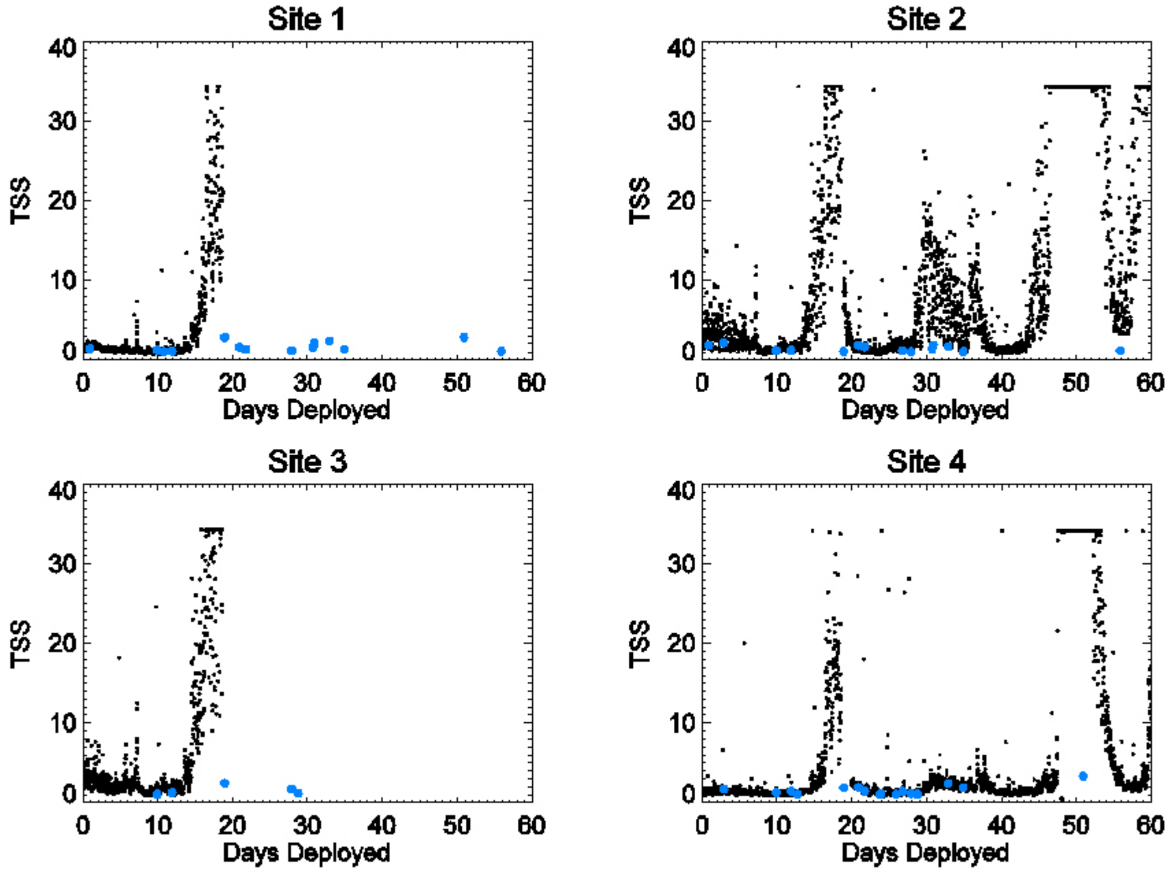
The 95$^{th}$ percentile TSS concentrations ranged from 0 – 6mg/L, with higher concentrations observed around the Lacepede Islands. Composite images of flood and spring tidal cycles showed the greatest distribution and magnitude of TSS in offshore waters compared to the neap and ebb tidal cycles, and during winter. All had quite similar nearshore patterns. The summer period had the largest extent and magnitude of TSS in nearshore waters with elevated TSS concentrations persisting right along the coast, including across the JPP coastal area, and across a large area adjacent to Cape Boileau. TSS concentrations in the offshore areas during summer were patchier compared to those observed during the spring and flood tide cycles.

**Comparison of In-Situ and MODIS Derived Water Quality Data**

To allow comparison of the MODIS derived TSS data with the logger recorded turbidity data, the logger NTU data was converted to TSS using the calibration based on field sampling. There were examples when the magnitude of TSS concentrations derived from the MODIS data were similar to those recorded by the *in situ* loggers for the corresponding time (**Figure 1-22**). However, there were also examples where the logger recorded TSS values (1m above the seafloor) were 10-fold higher than the corresponding MODIS derived values. This is likely to be due to the fact that MODIS derived products relate only to the surface layer (1- 6m depth) and thus, if there is re-suspension of sediment in the bottom layers as has been document, this cannot be accounted for by the MODIS derived product, but is recorded by the *in situ* loggers.

A comparison of the MODIS and logger 95$^{th}$ percentile and median (50$^{th}$ percentile) values (**Table 1-12**) also clearly demonstrates that the MODIS derived products were not able to neither capture nor represent the full range of water quality conditions that occur in the region. There were 82 days between 2 November 2009 and 31 December 2009 when the loggers measured NTU that corresponded to TSS concentrations greater than 20mg/L. Only full coverage MODIS derived products could be produced for nine of these days and partial coverage was available for another four days. The MODIS data for the remaining days did not pass QA/QC checks due to cloud cover and therefore, no data was derived. It is evident that the peaks in TSS concentrations occur during particular meteorological conditions that also result in cloud cover which precludes the use of MODIS data. Consequently, the composite MODIS images and the derived median and 95$^{th}$ percentile values must be interpreted cautiously, as they cannot be considered to reflect the full range of water quality conditions that occur in the area, but only to represent surface water conditions (1 – 6m).

It is also noted that even if full coverage MODIS products can be derived, the temporal variability in the TSS concentrations between and within tidal cycles (**Figure 1-17** to **Figure 1-20**) could mean that the MODIS pass(es) may not coincide with the times of peak water turbidity as measured by the loggers (at 30 minute intervals). This could also result in the MODIS derived products not fully representing the actual range of water quality conditions that may occur in the area.




- **Figure 1-22 Comparison of TSS Concentrations (mg/L) from MODIS Derived (Surface) in Blue and Logger Recorded (Seafloor) in Black.**

Note: For explanation of Sites 1-4 refer to location details on **Figure 1-7**.

- **Table 1-12 Comparison of the 95 Percentiles and Median TSS Levels Derived from the *in situ* Monitoring Data and MODIS Study at each Site.**

| Percentile | Site | Depth (m LAT) | Logger TSS (mg/L) (derived from NTU) 2 Nov 2009 – 6 September 2010 | MODIS derived TSS (mg/L) 1 Jan 2008 – 31 Dec 2009 |
|---|---|---|---|---|
| 95th %ile | 1 | 14.0 | 18.7 | 2.73 |
| | 2 | 16.9 | 34.4 | 2.43 |
| | 3 | 10.4 | 23.0 | 2.66 |
| | 4 | 17.1 | 28.6 | 2.47 |
| Median | 1 | 14.0 | 1.6 | 1.19 |
| | 2 | 16.9 | 3.0 | 1.16 |
| | 3 | 10.4 | 2.8 | 1.25 |
| | 4 | 17.1 | 2.1 | 1.08 |

Note: The equation to convert logger measured NTU to TSS (derived from in situ field measurements of TSS and NTU) was: logger TSS = (1.3967044*logger NTU) + 0.31747855. MODIS derived TSS calculated as reported in IMO (2010).

## 1.4. Ecological Marine Environment

Marine ecosystems comprise two major realms: benthos and pelagic. Benthos describes the biota that colonise the ocean floor. These are marine plants, sessile and mobile epifauna as well as infauna. Marine plants and sessile epifauna attach themselves to the substrates of the seafloor forming specific marine habitats either patchy or extensive in distribution. They can build complex three dimensional structures that in turn are then colonised by diversity of smaller organisms. Examples of this are coral reefs that grow on hard substrates in the tropical marine environment and seagrass beds that colonise sandy/muddy substrates in both temperate and tropical biogeographical regions. They also highlight important ecological processes and functions that are vital to the maintenance of marine ecosystems. Both seagrasses and hard corals are marine BPP deriving all or part of the energy required to build up their biomass from sunlight, having thus, a major influence on the productivity of the ecosystem. Both sessile benthic primary and secondary producers such as sponges and soft corals that can occur as extensive dense communities enhance biodiversity by providing complex habitats and food resources. By definition, benthic organisms live in close association with the substrate. This is particularly evident in the infauna component of the benthos. These organisms live in soft substrates. They can be both diverse and abundant with benthic infaunal communities of intertidal flats known to reach high biomasses that support large numbers of birds. Functionally, they also act as ecosystem engineers (Fraschetti *et al.,* 2008*)* by modifying sediments through bioturbation.

Pelagic describes the biota of the water column, comprised of plankton and nekton. Planktonic organisms move passively with currents unlike, nekton which moves independently. Plankton consists of phyto- and zooplankton with phytoplankton being functionally recognised as primary producers. Plankton shows seasonal and diurnal patterns that are a response to the light and dark cycle, seasonal temperature variation and changes in water chemistry. Water movements such as ocean currents and tidal movements also have a major influence by moving the organisms themselves, influencing stratification of the water column and transporting nutrients. It is noteworthy that this component of the marine ecosystem has no counterpart in terrestrial ecosystems where primary production is contained in terrestrial plants that do not experience the same spatial and temporal fluctuations. Similarly the unique conditions of marine environments result in distribution patterns that are often patchy or discontinuous. As a result, interconnectivity as an ecosystem property occurs at different scales in the marine environment than encountered in the terrestrial environment. For example, populations separated by vast distances can remain biologically connected with the help of an ocean current that transports larval stages. Equally, endemic species populations can exist in isolated locations based on the flow of ocean currents and geomorphic features. The degree of endemicity found in an area is an indication of the interconnectivity that exists.

Biodiversity is an important feature of the marine ecosystem. It encompasses both benthos and pelagial. Biodiversity can be described at different scales ranging from taxonomic diversity at species level to biological communities, habitats and bioregions. Functionally, biodiversity enhances ecosystem productivity and resilience and is therefore an important component of ecosystem integrity.

At a regional scale, NDT (2008a) (**Appendix B-2**) conducted a survey and interpreted work reported by both Fry *et al*. (2008) (**Appendix C-4**) and DEC (DEC, 2009a) with respect to ecosystem properties that describe ecosystem integrity and can be used to assess the ecosystem's resilience to disturbances for sites considered as potentially suitable for the BLNG Precinct. A summary of its findings is presented below (**Table 1-13**).

- **Table 1-13 Relative Ranking of Ecological Sensitivity of West Kimberley Coastal Locations.**

| Site | Biological Diversity | Productivity | Endemicity potential | Overall rating |
|---|---|---|---|---|
| Anjo Peninsula | H | H | H | H |
| Cape Voltaire | H | H | H | H |
| Maret Islands | H | H | H | H |
| Wilson Point | H | H | H | H |
| Koolan Island | H/M | M | M | M |
| Packer Island | H/M | M | M | M |
| Perpendicular North Head | H/M | H | H | H/M |
| Coulomb Point to Quondong Point* | M | H | L/M | M |
| Gourdon Bay | M | L | L/M | M/L |

Source: DEC, 2008.
Note: Rating H=High; M=Medium; L=Low.
* includes James Price Point.

Both broadscale and site specific assessment of the level, distribution and role of marine organisms has occurred or is occurring as the basis of the BLNG Precinct planning and assessment process. These results are described in the following sections.

### 1.4.1. Coastal Marine Substrates

The following section describes the intertidal and subtidal substrates that form benthic habitats.

#### 1.4.1.1. Intertidal Hard Substratum

Intertidal hard substrates can be ecologically diverse in the North West Marine Region, providing habitat for benthic primary producers and an abundance of sessile and mobile benthic organisms (Connell *et al.,* 1997). Rocky shores also are often feeding, resting, spawning and nursery areas for mobile marine fauna, including fish, crustaceans, birds, reptiles and mammals.

**Dampier Peninsula**

Locally, the intertidal hard substratum or rocky shores along the coastline of the Dampier Peninsula consist of cliff backed shorelines, fissured rock pavements or slopes, and rocky shores (Semeniuk *et al.,* 1982). The combination of large tides and high evaporation and insolation rates in this region means that the mid to upper intertidal zone is inhospitable for many organisms. As such, local platform reefs, exposed for long periods during low tide or subject to regular inundation by sediments, do not support extensive benthic primary producer (**BPP**) communities due to the frequent periods of exposure and desiccation and smothering and abrasion by the sand. However, areas of terraced reef, such as those found in the mid to lower littoral areas of James Price Point, often include sheltered rock pools and gutters supporting a greater diversity of organisms.

**James Price Point Coastal Area**

In general, the intertidal zone of the JPP coastal area is typical of the broader North West Marine Region. It is dominated by flat, sandy areas with relatively sparse, intermittent habitat of rocky substratum and reef platforms (**Figure 1-23**) (SKM, 2010b; **Appendix C-3**). The upper-mid littoral reef substrates have very little attached biota, with the exception of organisms that are especially adapted to wave exposure and desiccation. Interstitial and turf algae comprise the floral components while the fauna that can withstand such environmental stresses consists of barnacles, littorinids, chitons and limpets. Molluscs and crustaceans are also prominent among the mobile macrofauna colonising this habitat. Crabs and snails seek refuge in the crevices that the substrate offers and emerge at low tide to feed at the surface. The lower-mid littoral zones can support diverse community assemblages of reef organisms which are typical of the shallow subtidal habitats in the region. The recent intertidal survey at James Price Point and Flat Rock, 10km to the north, found that the majority of the intertidal zone consists of abiotic substrates (bare rock and sand) (SKM, 2010b; **Appendix C-3**). Areas surveyed were dominated by sandy beaches, mud/sand flats, rocky shores and reef platforms. Of these, the lower littoral reef platforms had the greatest diversity and abundance of flora and fauna, including small numbers of hard and soft corals, a diverse and abundant mollusc population, and sparse algal communities. In general, BPP were dominated by

turf algae. Based on data available, the diversity and productivity of flora and fauna at JPP appeared to be low (SKM, 2010a; **Appendix C-5**).

- **Figure 1-23 Typical Intertidal Sand and Rocky Reef Profile Looking North of James Price Point.**

#### 1.4.1.2. Intertidal Soft Substratum

**Regional Environment**

Soft substratum can provide habitat for BPP (including benthic microalgae, macroalgae, seagrass and mangroves), a high diversity of invertebrates and an abundance of sessile and mobile benthic organisms. Even bare intertidal sedimentary habitats have an important ecological function. They are often extensive and play an important role in cross-habitat exchanges of material and energy. Microphytobenthos[1] (**MPB**) can also inhabit intertidal substrates. A recent study from a tropical environment demonstrated that diversity of polychaetes was similar in vegetated and bare intertidal sedimentary habitats, challenging the view that un-vegetated habitats have less ecological significance because of lower biodiversity ratings (Frojan *et al.,* 2009).

Sand flats are common along the open coastal shores of the Kimberley region, adjoining intermittent headlands, rocky shorelines and fringing the low-relief dune hinterland. The width of the intertidal sand flats varies along the coastline as a result of differing nearshore topography, such as the presence of wind and wave-formed dune ridges or deep subtidal trenches.

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[1] Microphytobenthos live amongst or on sediment particles (Environmental Protection Authority (EPA) 2009a). Also referred to as benthic microalgae or sediment microalgae.

**Dampier Peninsula**

Dampier Peninsula is characterised by areas of soft substratum consisting of coarse sand deposited high in the intertidal zone, resulting in a characteristic step (approximately 0.5m high) along the shoreline with a platform of coarse sand above the intertidal slope (Honkoop, *et al.,* 2006). The intertidal beach flat is therefore defined as the area below this step and is characterised by a particle size gradient ranging from fine sediments in the lower intertidal to medium grained coarse sands in the upper reaches of the intertidal zone, adjacent to the beach ridge.

**James Price Point Coastal Area**

Sand flats are a common feature along the James Price Point coastal area. These sand flats were found to typically adjoin intermittent headlands, rocky shorelines, and fringe low-relief dune hinterlands as they do for the wider region. The intertidal sand flats were predominantly un-vegetated with the exception of turf algae. However, the mid to lower littoral unconsolidated sand and mud substrates can provide a three dimensional habitat for burrowing infauna. A recent survey of the intertidal zone examined infauna samples with respect to polychaete worms and found that distinct communities exist to the north and south of James Price Point. A considerable variation in species richness and abundances was detected between these locations with the nearshore areas to the south of James Price Point showing low species richness and abundance (SKM, 2010b; **Appendix C-3**).

### 1.4.1.3. Subtidal Substratum

**Regional Environment**

Subtidal environments within the region may comprise large areas of single habitat or combinations of habitat that may or may not support BPP. Examples of subtidal habitat include, sand, silt, rocky substratum and low/high relief reef structure. Each of these habitats is capable of supporting BPP and mobile or sessile benthic invertebrates such as urchins, ascidians and sponges.

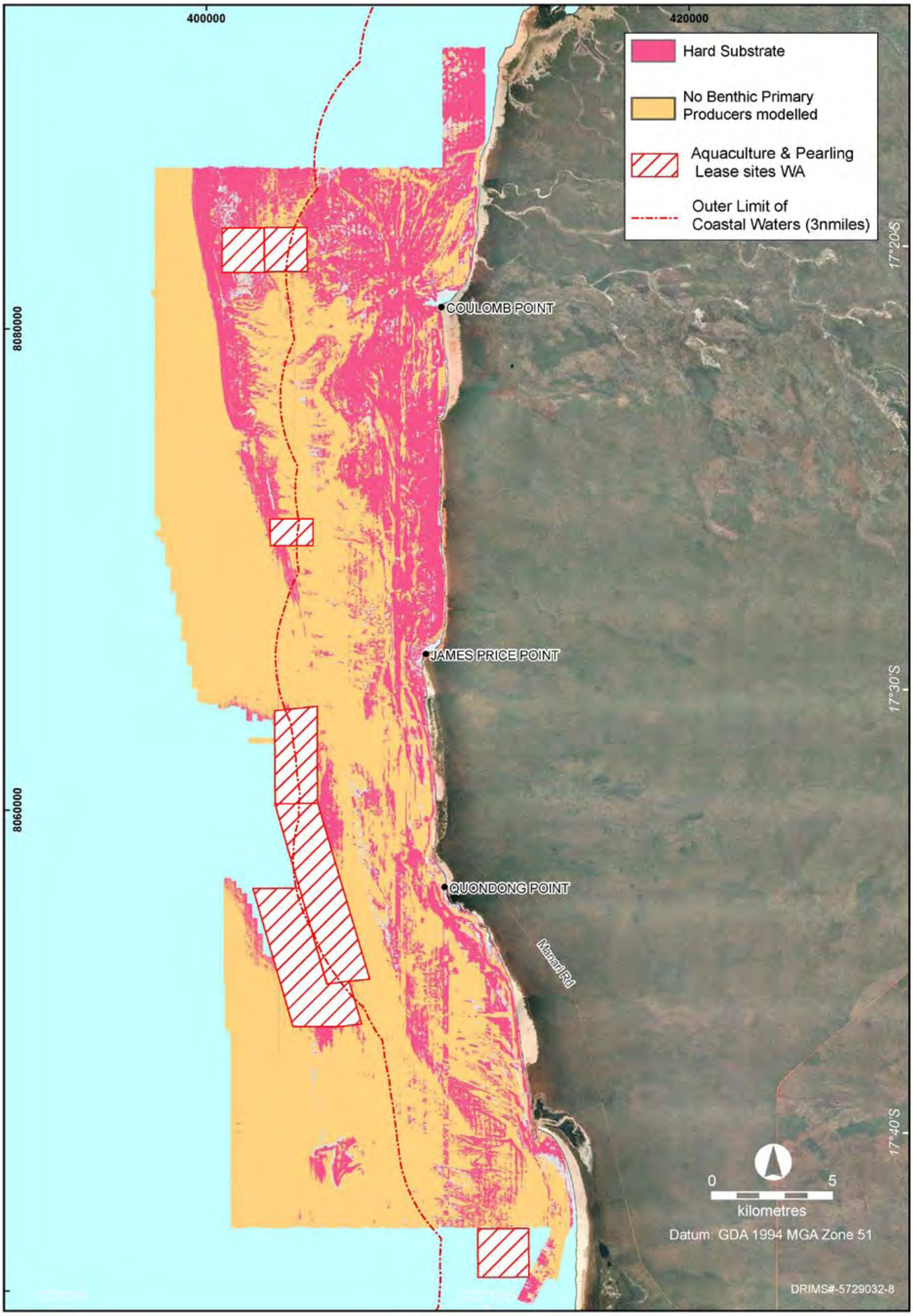
**Dampier Peninsula and James Price Point Coastal Area**

The subtidal substratum was mapped (**Figure 1-24**) using towed video by both the Commonwealth Scientific and Industrial Research Organisation (**CSIRO**) and Australian Institute of Marine Sciences (**AIMS**) (under contract to Western Australian Marine Science Institute and DEC) in 2008 and the results appear in Fry *et al.* (2008) (**Appendix C-4**). This work depicts results of surveys around the West Kimberley and specifically the Dampier Peninsula. This data was then reclassified using Fugro Light Detection and Ranging (**LiDAR**) bathymetry data obtained in 2009 (Fugro LADS, 2009) to examine the subtidal substrates on a finer scale (**Figure 1-24**). Both surveys came to similar conclusions regarding the distribution and coverage of biota in subtidal environment offshore from James Price Point.

A combination of hard and soft substrate was found inshore near James Price Point, whereas mostly soft substrate was found in offshore waters from James Price Point. Hard substrate, soft substrate and a combination of hard and soft substrate were all found in the study area. Hard coral communities in nearshore waters off James Price Point were restricted in area (Fry *et al.,* 2008; **Appendix C-4** and SKM, 2010a; **Appendix C-5**).

Similarly, Fry *et al.* (2008) (**Appendix C-4**) found the offshore seabed was comprised of mostly fine flat sand substratum (70% sand coverage) near Coulomb Point with patches of sand waves and dunes at shallow depths as well as low relief reef structure. Further south, between James Price Point and Quondong Point the subtidal substratum consisted of flat sandy substrate and silty sand. Closer to James Price Point was mostly sand coverage (55% sand coverage) with sand dunes from shallow to deeper depths as well as some low relief reef structure in shallow depths (Fry *et al.,* 2008; **Appendix C-4**).

LiDAR datasets (Fugro LADS, 2009) and habitat data classified from video collected in the field were used to generate a map showing the coastal marine habitats within the vicinity of James Price Point. This habitat included a combination of hard and soft substrates that support a variety of corals (hard and soft), macroalgae and seagrass assemblages (SKM, 2010a; **Appendix C-5**).




Source: SKM, 2010a; **Appendix C-5**.

- **Figure 1-24 Subtidal Hard Substratum of the Nearshore Area.**

#### 1.4.1.4. Phytoplankton

**Regional**

Nutrients and planktonic organisms are transported to and from the NWMR by the southerly movement of the ITF and the south-east and north-west monsoonal wind-driven currents. These conditions provide a particularly strong delivery of nutrient-surface waters into the Kimberley Shelf area of the NWMR (Brewer *et al.,* 2007).

The phytoplankton of the shelf waters of north-west Australia is typically dominated by diatoms, typical of habitats with high silicate concentrations (Hayes *et al.,* 2005) and higher, persistent nutrient availability, although the phytoplankton community is not specifically described and likely to be quite complex (Brewer *et al.,* 2007). Large, morphologically-elaborate, tropical diatoms include *Bacteriastrum*, *Chaetoceros*, *Coscinodiscus*, *Pseudo-nitzschia*, *Rhizosolenia*, *Thalassiosira*, *Thalassionema* and *Thalassiothrix*, with the tropical dinoflagellates *Ornithocercus* and the endemic *Ceratium dens* are also common. Phytoplankton surveys conducted in North West Shelf and northern Australian waters found nanoplankton (2 to 20µm) to be the predominant component of samples collected, accounting for 70 to 97% of total chlorophyll content (Hallegraeff and Jeffrey, 1984). In that study a total of 43 to 63 phytoplankton species were measured in each water sample, with a further 5 to17 species identified from net samples.

The seasonal cycles of biological productivity on the continental shelf, and the spatial distribution of production regimes still remain largely unknown, with the exception of selected areas (for example the Adele-Mavis Banks, (Cresswell and Badcock, 2000). In El Niño years, vertical mixing and upwelling are enhanced and with a lack of precipitation, productivity may increase in the coastal zone. The low levels of runoff from terrestrial sources in such years would not contribute much to this productivity.

At present there is a paucity of information relating to the distribution and abundance of phytoplankton located in the oceanic waters of the Kimberley and Canning Bioregions. However, it is likely that planktonic distributions off the North West coast are broadly applicable to both the local and regional areas.

### 1.4.2. Benthic Primary Producers

Benthic Primary Producers are predominantly marine plants (for example, seagrasses, mangroves and macroalgae) but also include some invertebrates, such as scleractinian corals which acquire a significant proportion of their energy from symbiotic microalgae that live in coral polyps (EPA, 2009a). BPP are organisms attached to the seafloor that convert energy from the sun into organic matter using carbon dioxide (**$CO_2$**) and water. The organic matter that is produced through photosynthesis forms the basis of the marine food web. Although BPPs vary in productivity (**Table 1-14**), each serves an essential role in the ecological functioning of the marine ecosystem. They also provide colonisable substrate and/or habitat for other organisms making the BPP vital to sustainability of the marine ecosystem. BPPs have therefore been given particular consideration in the protection of the marine environment of WA (EPA, 2004a). Benthic primary producer habitat (**BPPH**) includes in its definition BPPs and the substrates that do or can support them.

- **Table 1-14 Productivity of BPP types.**

| BPP taxa | Productivity (grams of Carbon per square metre per day; g C |
|---|---|
| Macroalgae (benthic canopy algae) | 0.1 – 4 |
| Turf algae | 1 – 6 |
| Corals | 0.6 |
| Seagrasses | 1 – 7 |
| Mangroves | 3 – 4 |

Source: Ellison and Simmonds, 2003.

The EPA's Environmental Assessment Guidelines No. 3 (**EAG3**) for the protection of BPPH (EPA, 2009a) recognises the habitat level as a useful ecological unit, with regards to the assessment of environmental impacts, because it characterises the marine environment at a scale relevant to the size of development proposals and reflects key ecological processes of the marine environment. For practical reasons, BPPHs can be combined to form a mosaic BPPH and the proportional impact can be assessed against this unit.

**Regional Environment**

The Canning Marine Bioregion contains an array of habitats (summarised in Fry *et al.,* 2008; **Appendix C-4**) which, in places, supports high levels of biological diversity. The Kimberley bioregion has fringing coral reefs that are more extensive and diverse than Ningaloo and the region may well become known as a coral reef province of global significance. Wood and Mills (2008) state that the region is thought to have retained a high degree of ecological integrity compared with other large tropical marine ecosystems of the world.

Offshore reefs such as Ashmore and Cartier Islands, Seringapatam Reef, Scott Reef and the Rowley Shoals in the North West Shelf Marine Bioregion are marine protected areas. These reefs, in particular Ashmore Reef, are recognised as having the highest richness and diversity of coral species in WA (Mustoe and Edmunds, 2008).

The many inlets, lagoons and gulfs along the NWMR support extensive mangrove communities (over 140, 000ha) (Pedretti and Paling, 2001). The northern extent of NWMR has the most diverse mangrove flora of WA with 14 out of 17 species occurring in this area. There are no mangrove communities located in proximity to the James Price Point coastal area.

Overall distribution of seagrass in the region is poorly documented but extensive seagrass meadows, the largest known for the North West Marine Region, have been reported from around the Buccaneer Archipelago located north of the Dampier Peninsula (Wells *et al.,* 1995). The WA Museum studies noted that benthic algal diversity and abundance was generally low, attributing this to extreme tidal exposure resulting in desiccation and/or high turbidity, reducing light penetration and increasing the possibility of smothering.

**Dampier Peninsula and the James Price Point Coastal Area**

Benthic habitat in the James Price Point coastal area includes hard substrate supporting communities of filter feeders, hard corals and macroalgae, while areas of shallow sandy sediment support seasonal seagrass and macroalgae. There are areas of low relief reef along the coast from Quondong Point to James Price Point which are mostly in waters less than 10m deep (Fry *et al.,* 2008; **Appendix C-4**). Maps of typical seabed type and biohabitat coverage produced by Fry *et al*. (2008) (**Appendix C-4**) are shown in **Figure 1-25** and **Figure 1-26**. Some high relief, rocky and rubble or stone substrates are also common in the nearshore sites along most of the coastline north from Quondong Point to Coulomb Point. North of James Price Point the reef platform extends further offshore (to approximately two km) providing a sheltered lagoon and intertidal platform with pools and crevices supporting a variety of benthic habitat. A summary of the findings from locations along the Dampier Peninsula is provided in **Table 1-15**.

- **Table 1-15 Summary of Dominant Benthos at Representative Locations along the Dampier Peninsula.**

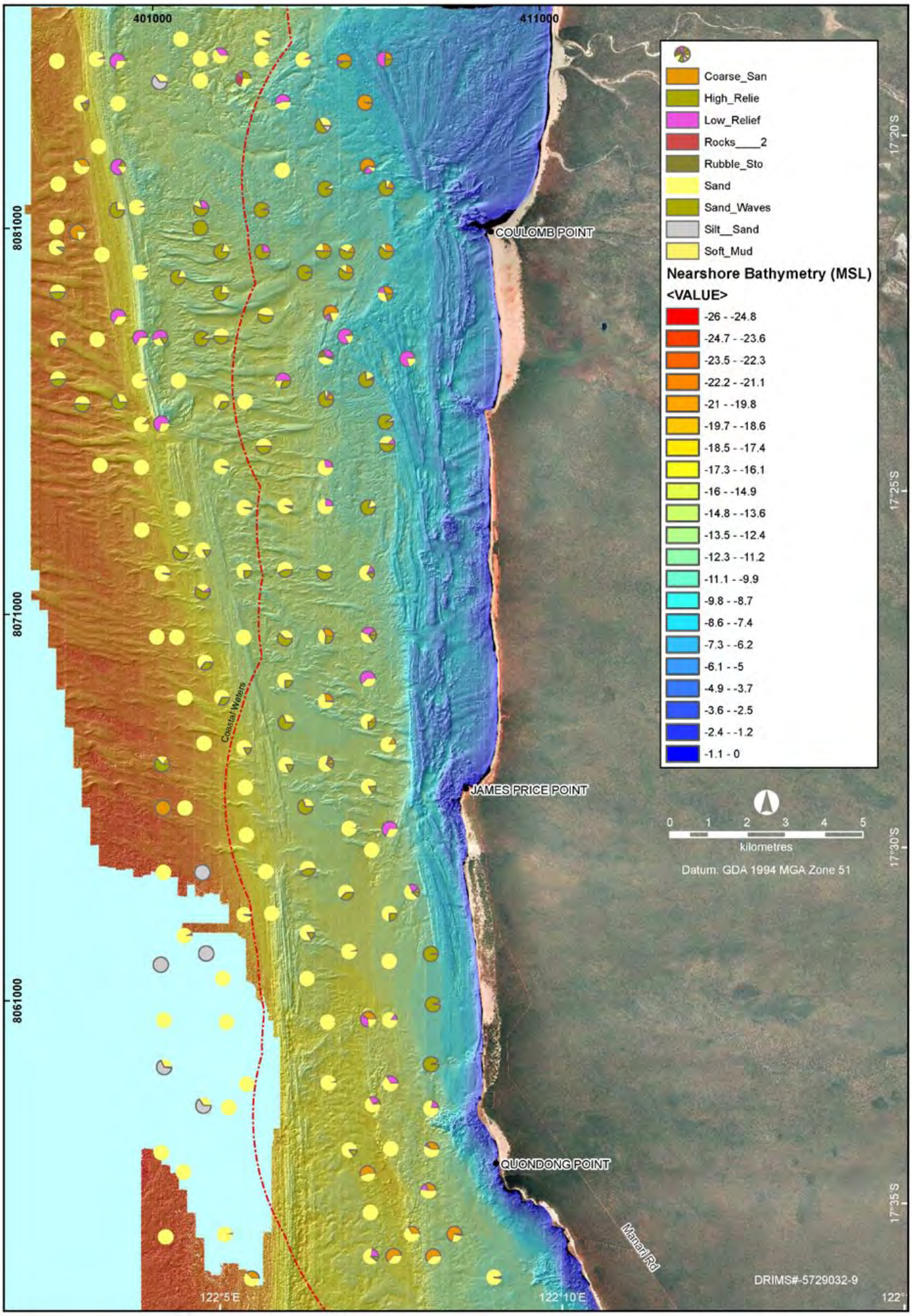
| Sites | Benthic Communities | | | | |
|---|---|---|---|---|---|
| | **Mangroves** | **Coral reefs** | **Filter-feeders** | **Seagrass / macroalgae** | **Soft-sediment** |
| **Coulomb Point** | Not present. | Occasional corals on rocks and pavement to ~10m. Some solitary corals in deeper water. No reef formation. | Extensive filter feeder communities are common and occur below ~10m water depth; very species diverse and abundant in places. | Extensive moderate to dense *Halophila* sp meadows from ~10m on sand amongst filter feeding communities | Not evident. Coarse grained sediments and sand waves indicate high wave energy |
| **James Price Point** | Not present. | Occasional corals on rocks and pavement to ~10m. Some solitary corals in deeper water. No reef formation | Extensive filter feeder communities are common and occur below ~10m water depth; very species diverse and abundant in places. | Low density of *Halophila* sp meadows from ~10m on sand amongst filter feeding communities | Not evident. Coarse grained sediments and sand waves indicate high wave energy |
| **Quondong Point** | Not present. | Occasional corals on rocks and pavement to ~10m. Some solitary corals in deeper water. No reef formation | Extensive filter feeder communities are common and occur below ~10m water depth; very species diverse and abundant in places. | Extensive moderate to dense *Halophila* sp meadows from ~10m on sand amongst filter feeding communities | Not evident. Coarse grained sediments and sand waves indicate high wave energy |

A Benthic Habitat Modelling and Mapping study was undertaken to assess and map the distribution of BPPH, BPP and other marine habitats offshore from the James Price Point coastal area (SKM, 2010a; **Appendix C-5**) (**Figure 1-27**). Biota recorded during the SKM 2010a (**Appendix C-5**) study was largely mixed mosaics and these were more likely to be found in areas of topographic complexity. Algae and sessile invertebrates had the most extensive predicted distribution of the biota classes modelled, typically occurring in areas of low topographic complexity, while seagrass had the most restricted range. Benthic primary producers occurring on hard substrate were found extensively in the north of the study area, adjacent to Coulomb Point, while the area in the vicinity of James Price Point was found to have the lowest coverage of BPP. A mixed mosaic of hard coral, algae, soft coral, seagrass and sessile invertebrates was found across the surveyed area, however sediment substrates dominated the offshore region in waters deeper than 10m. Hard coral communities were small and not well developed in the James Price Point coastal area suggesting they are exposed to periodic natural disturbances. Non-BPP sessile invertebrates (including most sponges, sea whips, gorgonians, ascidians, sea pens and non photosynthesising soft corals), were the most extensive biota mapped throughout the study area (SKM, 2010a; **Appendix C-5**).

The intertidal survey undertaken in 2009 (SKM, 2010b; **Appendix C-3**) found areas north and south from James Price Point were dominated by turf algae. In the same study, corals and macroalgae each had coverage of seabed below 5%. In the lower littoral reefs, benthic communities were composed of hard and soft coral, macroalgae and filter feeding invertebrates. Fry *et al.* (2008) (**Appendix C-4**) describes mixed coral reef communities with coverage of up to 25% colonising medium and high relief reef substrate between Coulomb Point and Quondong Point. The same area hosts extensive filter feeder communities with a small component functioning as BPPs. Dense sponge gardens were observed along a 10m isobath. In general, the diversity and density of the biota increased in the lower littoral zones due to less frequent periods of exposure.

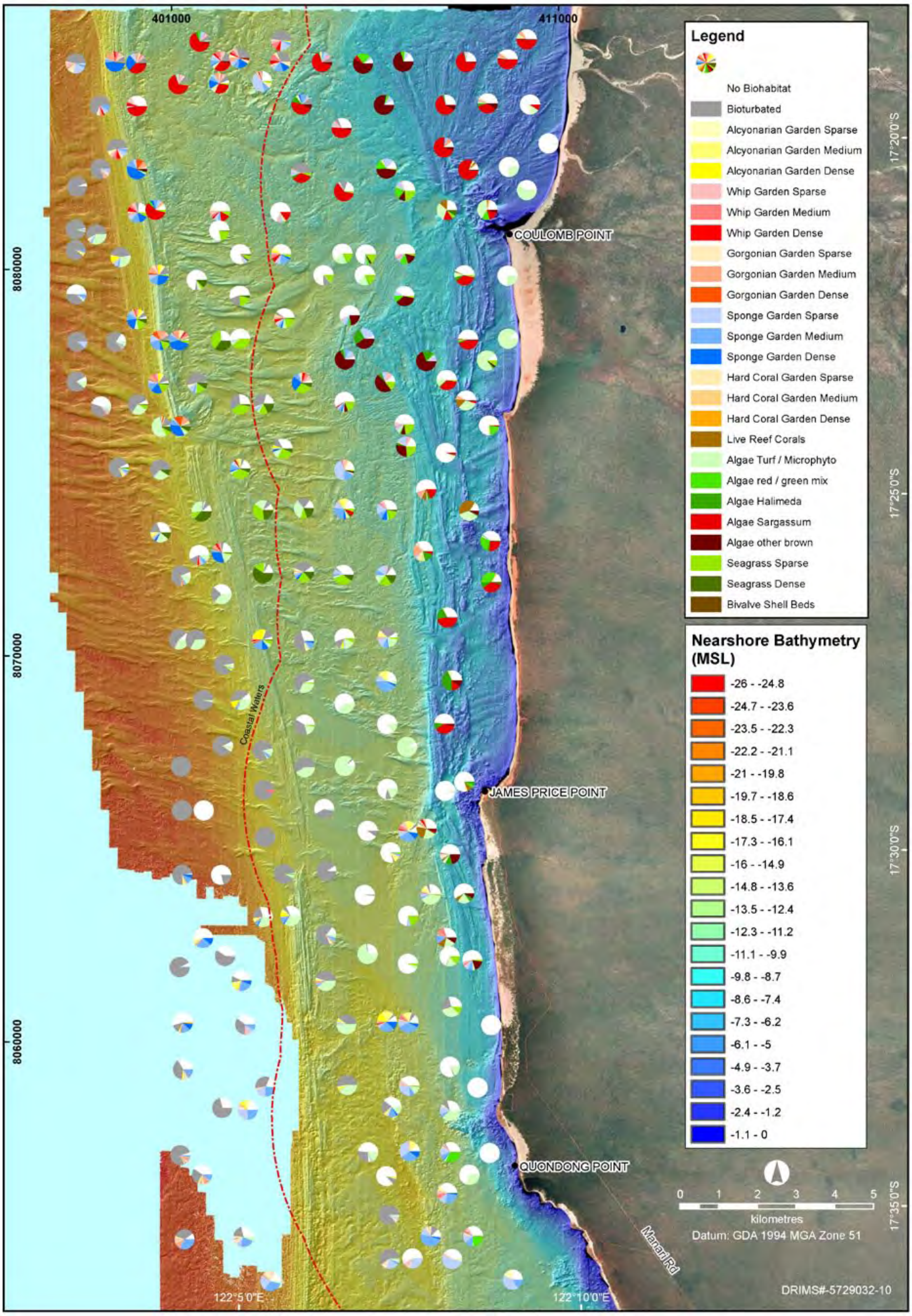
Information on the existing benthic habitats collected to date has established the presence of the following:

- **Algae**. This includes macroalgae and sediment microalgae or microphytobenthos. Large, diverse areas of algal habitat occur in the James Price Point coastal area. These are likely to be used as foraging areas for turtles and habitat for fish and invertebrates. The presence of MPB has been assumed to be associated with bare sediment. In the James Price Point coastal area, where large tides result in constant re-suspension of the surficial sediments, MPB is likely to be highly mobile as sediment. Thus, it is difficult to determine the extent and abundance of MPB. It is assumed that MPB has a high turnover rate and will quickly re-colonise areas following a disturbance. For these reasons, MPB will not be considered further in the impact assessment process.
- **Seagrass**. Throughout the James Price Point coastal area, subtidal seagrass communities are patchily distributed and their abundance changes seasonally. These communities may act as possible feeding areas for transient dugongs and turtles. *Halophila* species were found to be the dominant seagrasses in the area.
- **Hard Coral**. Hard corals are scattered throughout the James Price Point coastal area in generally low densities. Hard corals are more prevalent in nearshore areas on high relief hard substrate but also occur as single colonies mixed with other communities (e.g. filter feeders and macroalgae).
- **Filter feeders (Sessile Invertebrates)**. Filter feeding communities are a prominent component of the benthic environment within the James Price Point coastal area. These organisms were observed in high abundance with a wide distribution and diverse range of species.
- **Infauna and epifauna**. Infauna refers to the organisms that occur within the sediment of the seabed, whilst epifauna are mobile and occur on the surface of the seabed. These are a diverse group of organisms that can be both macroscopic and visible to the eye or microscopic. The diversity and abundance of Infauna and epifauna communities is large unknown within the James Price Point coastal area, compared with other benthos types.
- **Mangroves**: mangroves are abundant throughout the North West Marine Region and occur along the Dampier Peninsula. There are mangrove ecosystems located south of James Price Point at Barred Creek (approximately 20km south) and Willie Creek (approximately 30km south). However, mangrove ecosystems do not occur in the vicinity of James Price Point.



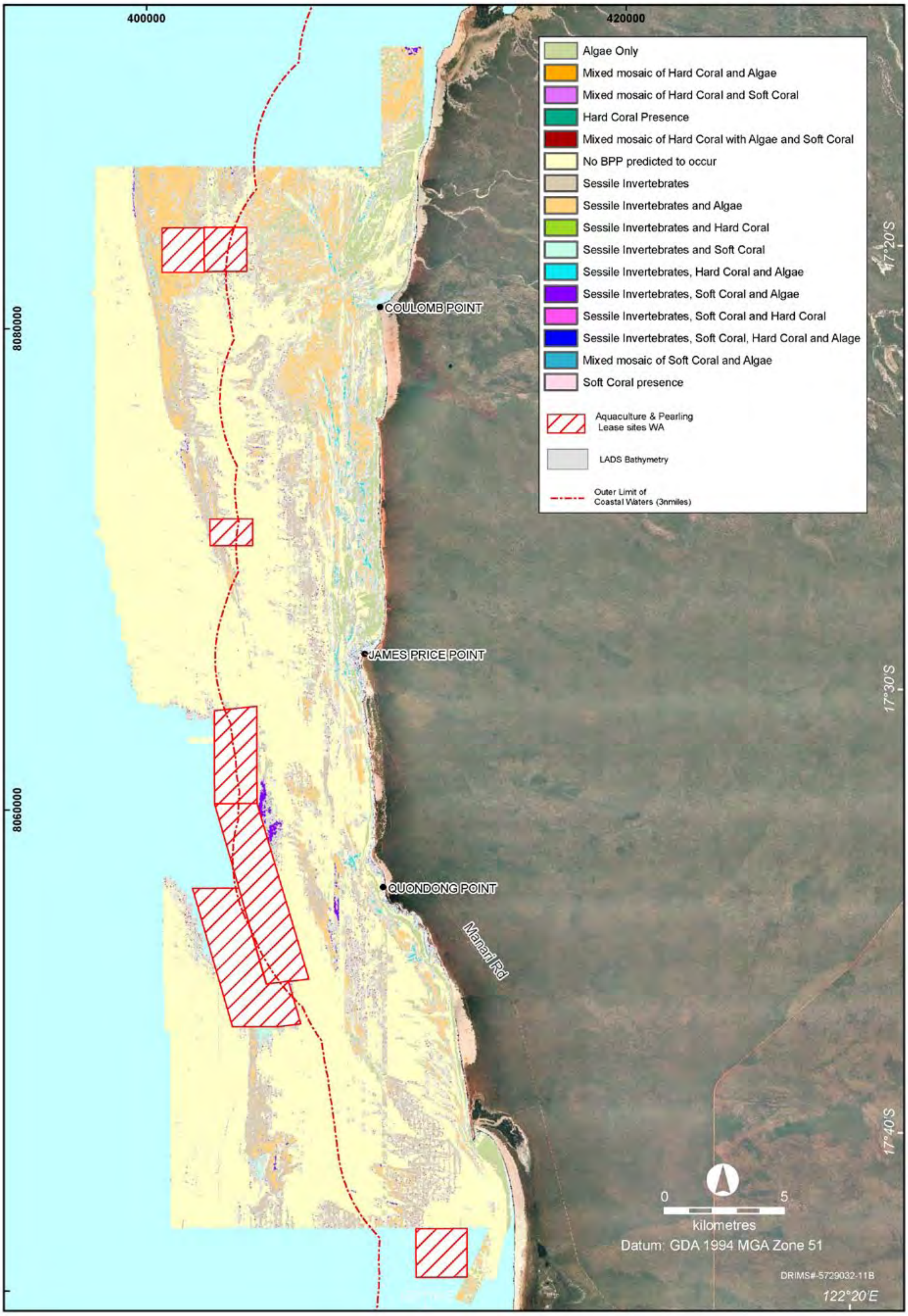

Source: Fry *et al.*, 2008, **Appendix C-4**.

- **Figure 1-25 Substrate Coverage - Coulomb Point to Quondong Point Benthic Habitat Survey.**




Source: Fry *et al.*, 2008; **Appendix C-4**.

- **Figure 1-26 Biohabitat Coverage – Coulomb Point to Quondong Point Benthic Habitat Survey.**




Source: SKM, 2010a; **Appendix C-5**.

- **Figure 1-27 Derived High Resolution Combined Benthic Habitat Map of the James Price Point Coastal Area.**

#### 1.4.2.1. Sediment Microalgae (Microphytobenthos - MPB)

**Regional Environment**

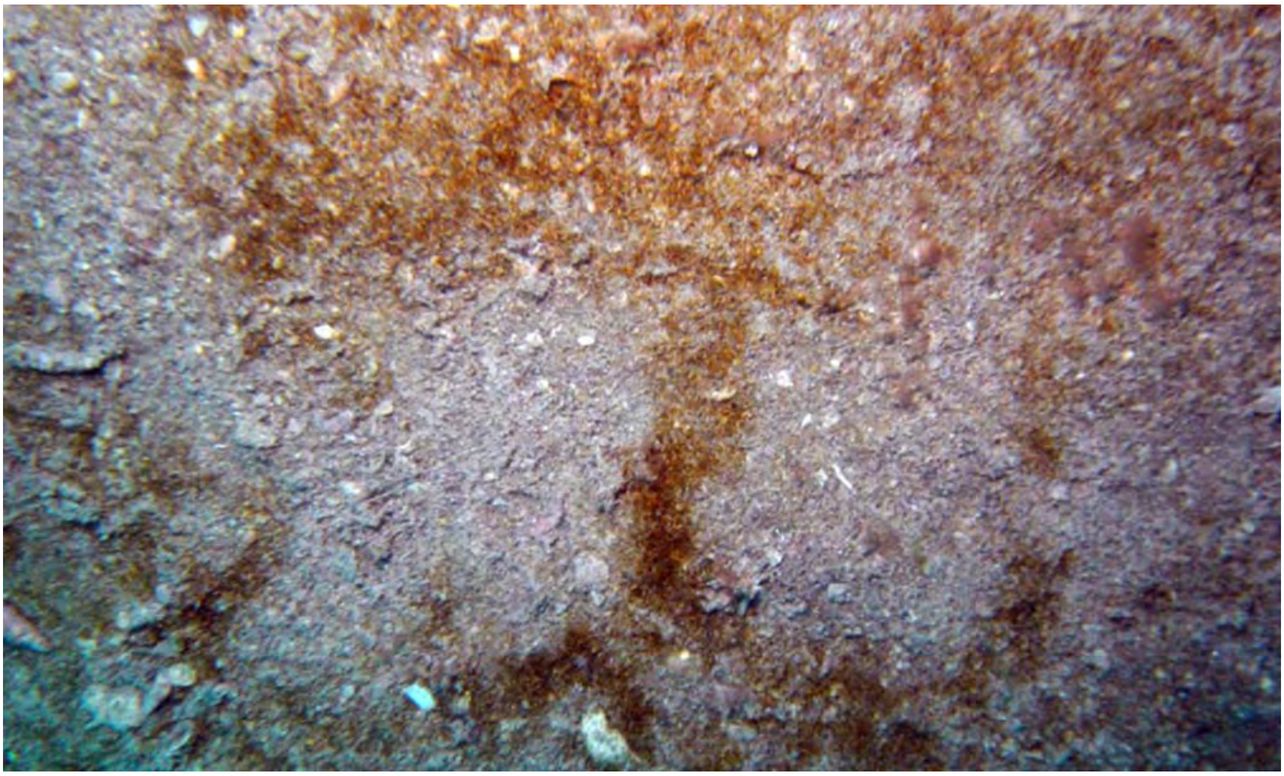
Benthic microalgae are single-celled microscopic plants and cyanobacteria that generally inhabit the top three centimeters of the sediment (Dennison and Abal, 1999). Sediment microalgae (or microphytobenthos) consist of microscopic diatoms that live in the sediment surface layers and are an important primary producer in the NWMR (Mustoe and Edmunds, 2008). MPB are highly mobile and able to migrate between the surface (to utilise sunlight for photosynthesis) and deeper sediments (to acquire nutrients). MPB have rapid growth and reproductive rates and are mainly consumed by sediment infauna including nematodes, crustaceans, molluscan filter-feeders and worm deposit-feeders. Suspension of MPB during tidal movements contributes to the production of plankton and benthic filter feeders in other areas (Mustoe and Edmunds, 2008).

**Dampier Peninsula and James Price Point Coastal Area**

Despite their minute size, sediment microalgae are ecologically important within the marine system, as they are a major source of food for benthic fauna and help stabilise the sediments. The intertidal survey (SKM, 2010b; **Appendix C-3**) within the James Price Point coastal area did not observe any benthic MPB communities. Benthic surveys undertaken by Fry *et al.* 2008 (**Appendix C-4**) and SKM 2010a (**Appendix C-5**) observed extensive coverage of MPB within the study area, suggesting that this habitat plays a key role in the trophic system within the James Price Point coastal area. Underwater imagery of MPB observed in the local area is shown in **Figure 1-28** and **Figure 1-29**.

Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-28 Microphytobenthos and Tufts of Larger Algae on the Crests of Rippled Sand, with Several Small Patches of Seagrass (light green) Evident within the James Price Point Coastal Area.**



Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-29 Close-up of Microphytobenthos on Sand Substrate within the James Price Point Coastal Area.**

#### 1.4.2.2. Seagrass

Seagrass represent key ecological habitats, supporting local fisheries, stabilising sediments, and providing grazing grounds for species such as dugongs and turtles. Seagrass distribution is largely influenced by light availability and substratum stability.

**Regional Environment**

Previous studies identified ten seagrass species have been recorded from sites in the Kimberley region (Walker, 1992; Walker, 1995; Walker, 1996; and Walker, 1997), with eight species identified from the southern Kimberley region (Cape Leveque to Montgomery Reef) (Walker, 1995). *Thalassia hemprichii* is the most common species, often covering 30 - 50% of the substratum, followed by *Enhalus acoroides* and *Halophila ovalis*. *T. hemprichii* was associated with coral rubble at all levels of the shore. *E. acoroides* is typically found in deep fine sediment, usually on the upper part of the shore, often in front of mangroves. The species *H.ovalis* has a tropical distribution, and prefers more exposed conditions than other species of this genus. This species often forms extensive meadows which are commonly an important food source for dugongs in tropical waters (Edgar, 1997).

Extensive and diverse intertidal seagrass meadows are also known to occur at the islands in the North West Marine Region, particularly around Sunday Island (Walker, 1992; Walker, 1995; Walker and Prince, 1987). While some seagrasses were recorded from sites in the central and northern Kimberley region (between the Buccaneer Archipelago in the south and Cambridge Gulf in the north) (Walker, 1996 and Walker, 1997), these areas were not found to be as diverse or extensive as those observed in the Canning Marine Bioregion (Cape Leveque to Montgomery Reef) (Walker, 1995).

**Dampier Peninsula**

In a local context, 11 seagrass species from seven genera have been recorded around the coastal margin of the Dampier Peninsula. The genera include *Cymodocea*, *Halodule*, *Syringodium*, *Thalassodendron*, *Enhalus, Halophila* and *Thalassia* (Kenneally *et al.,* 1996). While these genera occur in a wide range of sediment types, *Halodule pinifolia* and *Halophila* sp. are usually found in finer sediments and only occur in intertidal or shallow subtidal areas (Kenneally *et al.,* 1996). In mixed seagrass communities, where the substrate is fully exposed at low tide, *Halodule uninervis* is the dominant species (Kenneally *et al.,* 1996). *H. uninervis* is a rapid coloniser and plays an important role in maintaining seagrass habitat in areas of high disturbance (Waycott *et al.,* 2004). According to Waycott *et al.* (2004), *H. pinifolia* is a variant of *H. uninervis* with confusion in differentiating between the species common. Other species, such as *Thalassodendron ciliatum*, are located in areas with strong currents, growing directly on reef or coarse shell grit (Kenneally *et al.,* 1996).

Seasonally-abundant subtidal seagrass communities are patchily distributed across large areas along the Dampier Peninsula. The area between Quondong and Coulomb Points has been shown to support extensive, although sparse, seagrass beds consisting of *Halophila* sp. in waters approximately 10m deep (Fry *et al.,* 2008; **Appendix C-4** and SKM, 2010a; **Appendix C-5**).

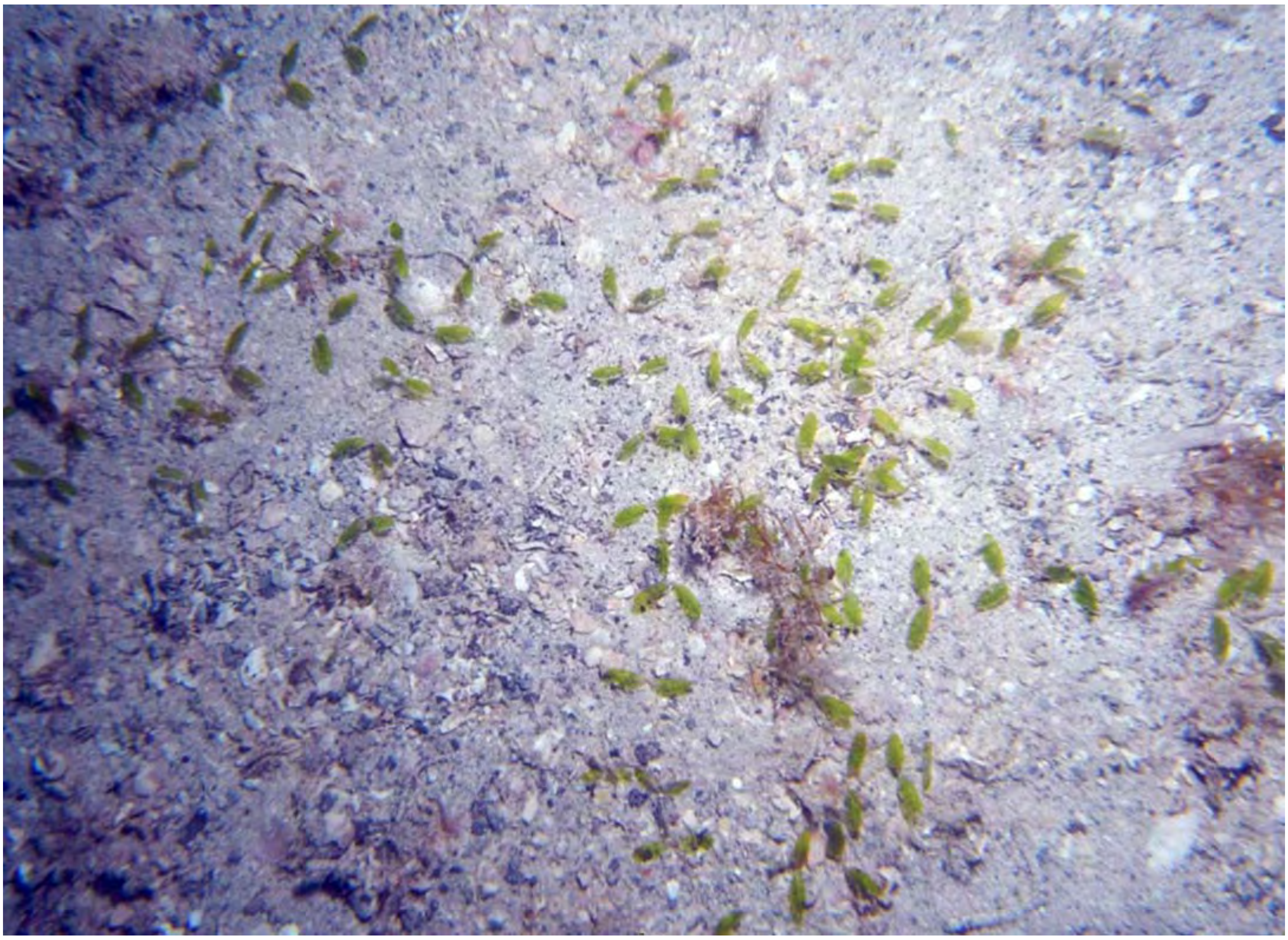
In addition to the benthic habitat surveys conducted by Fry *et al*. (2008) (**Appendix C-4**) and SKM (2010a) (**Appendix C-5**), fifteen epi-benthic trawls were performed from the Dampier Peninsula and Gourdon Bay to identify major species characterising the different biohabitats classified from the video footage (Irvine and Keesing, 2009). In the epi-benthic sled collection, *Halophila decipiens* was the only species identified in four samples (Irvine and Keesing, 2009). *H. decipiens* is the most common seagrass found in deeper waters and also common in reef and sandy habitats. This species sometimes behaves as an annual by growing, flowering, setting seed and dying in a short period of time (Waycott *et al*., 2004).

Numerous sessile taxa are likely to be associated with the seagrass communities may be found offshore of the Dampier Peninsula. These may include sessile benthic organisms and epiphytes such as sponges, gorgonians, hydroids and alcyonarians. In addition, seagrass beds act as key nursery grounds for fish and invertebrates, affording juveniles a level of protection from predators.

**James Price Point Coastal Area**

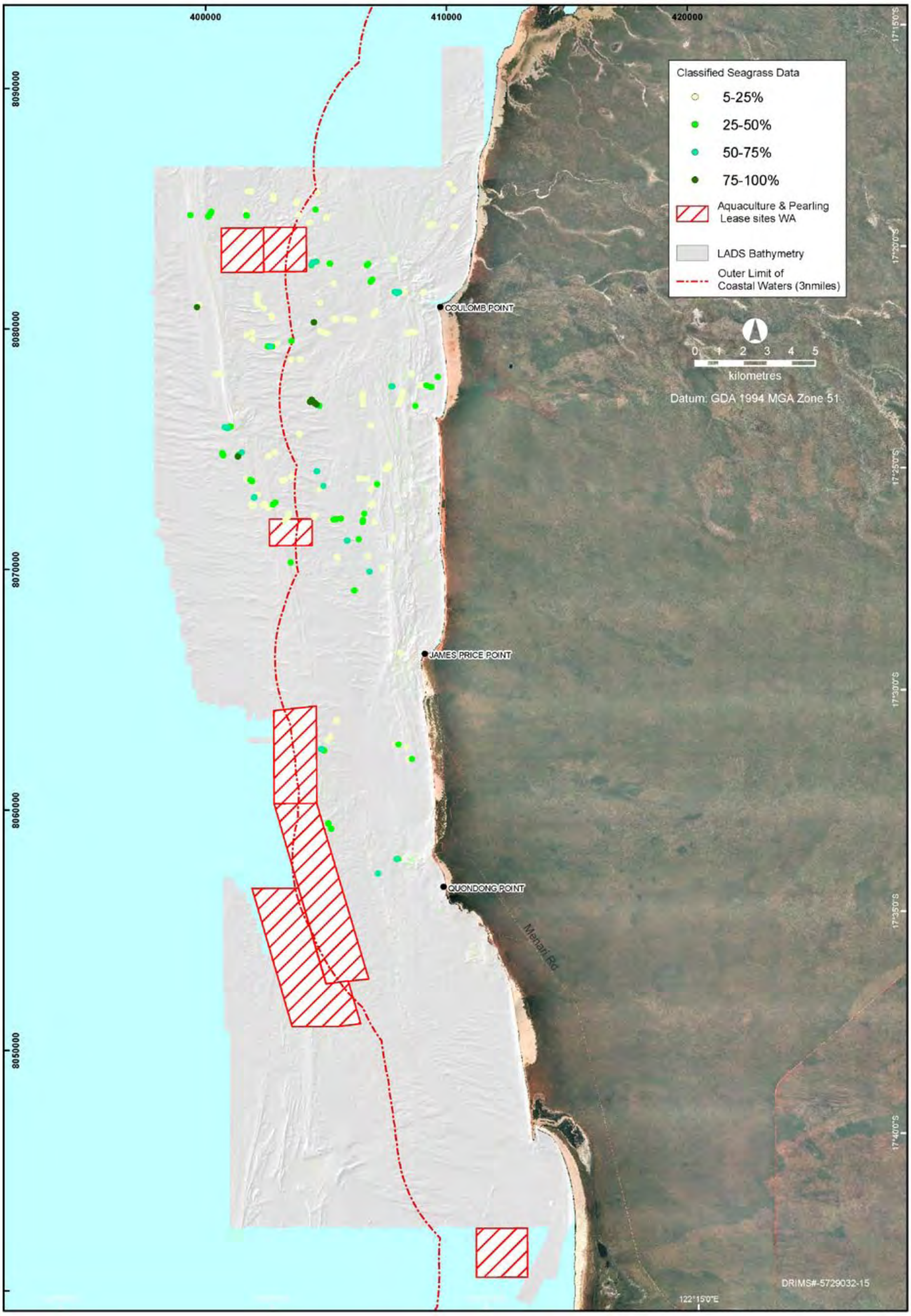
The nearshore benthic habitat modelling and mapping of James Price Point found that seagrass distribution is mainly sparse and patchy across the study area, with *Halophila* sp (**Figure 1-30**) dominant (SKM, 2010a; **Appendix C-5**), although *Halophila decipens*, *H. ovalis*, *H. ovate*, *H. minor* and *H. spinulosa* are common in tropical north-west waters and were assumed to be present in the study area. Other seagrass possibly observed at some sites were *Halodule univervis*, *Cymodocea* spp. and *Syringodium* spp. These species were less commonly observed and in much sparser densities compared with Halophila. The depth range in which seagrass was surveyed was 4.2-19.8m. Seagrass was typically growing in soft sediments in mixed communities between patches of reef hard substrate. Homogenous meadows of seagrass (Halophila spp.) were also observed in various densities and patch sizes (SKM, 2010a; **Appendix C-5**). Overall, less than 6% of the study area was estimated to contain seagrass in 2008 (Fry et al., 2008, **Appendix C-4**). Percent coverage (density) ranged from 1-5% to 75-100% with the majority of seagrass patches being less than 25% (**Figure 1-31**). Surveys conducted in 2008 and 2009 suggest resident seagrass communities within the James Price Point coastal area are temporally variable with changes in distribution and percent cover occurring between June 2008 and July 2009 (SKM, 2010a; **Appendix C-5**). This distribution was consistent with that found by Fry *et al.* (2008) (**Appendix C-4**) who observed patches of sparse and dense seagrass just south of Coulomb Point, within five to 10 metre water depth. Some small patches were also recorded between James Price Point and Quondong Point.

Seagrass communities were first observed during site selection surveys undertaken by the DEC in November 2007 and were found to be well developed with high biomass at James Price Point. Repeat surveys of some locations were undertaken in April 2008 but no seagrass was recorded. Seagrass had re-established in these areas by June 2008 and surveys undertaken by the DEC in December 2008 found prolific seed production in *Halophila* sp, suggesting that recruitment from seed may be an important process for sustaining seagrass communities in this area (Masini *et al.,* 2009). Although the above ground seagrass biomass may vary considerably seasonally, it is possible that subsurface biomass may remain relatively constant (Waycott *et al.,* 2004).



Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-30 Close-up Image of a Sparse Seagrass Patch (*Halophila sp*) on Coarse Sand Substrate within the James Price Point Coastal Area.**




Source: SKM, 2010a; **Appendix C-5**.

- **Figure 1-31 Seagrass Presence and Percentage Cover Map of the James Price Point Coastal Area.**

### 1.4.2.3. Macroalgae

**Regional Environment**

Macro and turf algae are found commonly throughout the North West Marine Region. However, studies within the region have reported the diversity of algal flora on intertidal platforms to be generally low as a result of the extreme tidal exposure and scouring from strong water movement (Walker, 1996). The relatively low abundance of macroalgae in areas is likely to be attributed to the constant turbid waters that reduce light penetration and increase sedimentation. Of the species documented, *Sargassum sp*. (Phaeophyta), along with rhizobenthic algae such as *Halimeda*, *Avrainvillea* and *Udotea* (Chlorophyta), were most abundant on sub-tidal reefs and within patches/pockets of sediment (Walker, 1996). Encrusting coralline algae is likely to be the most prominent algal type in these high energy areas due to its ability to withstand scouring.

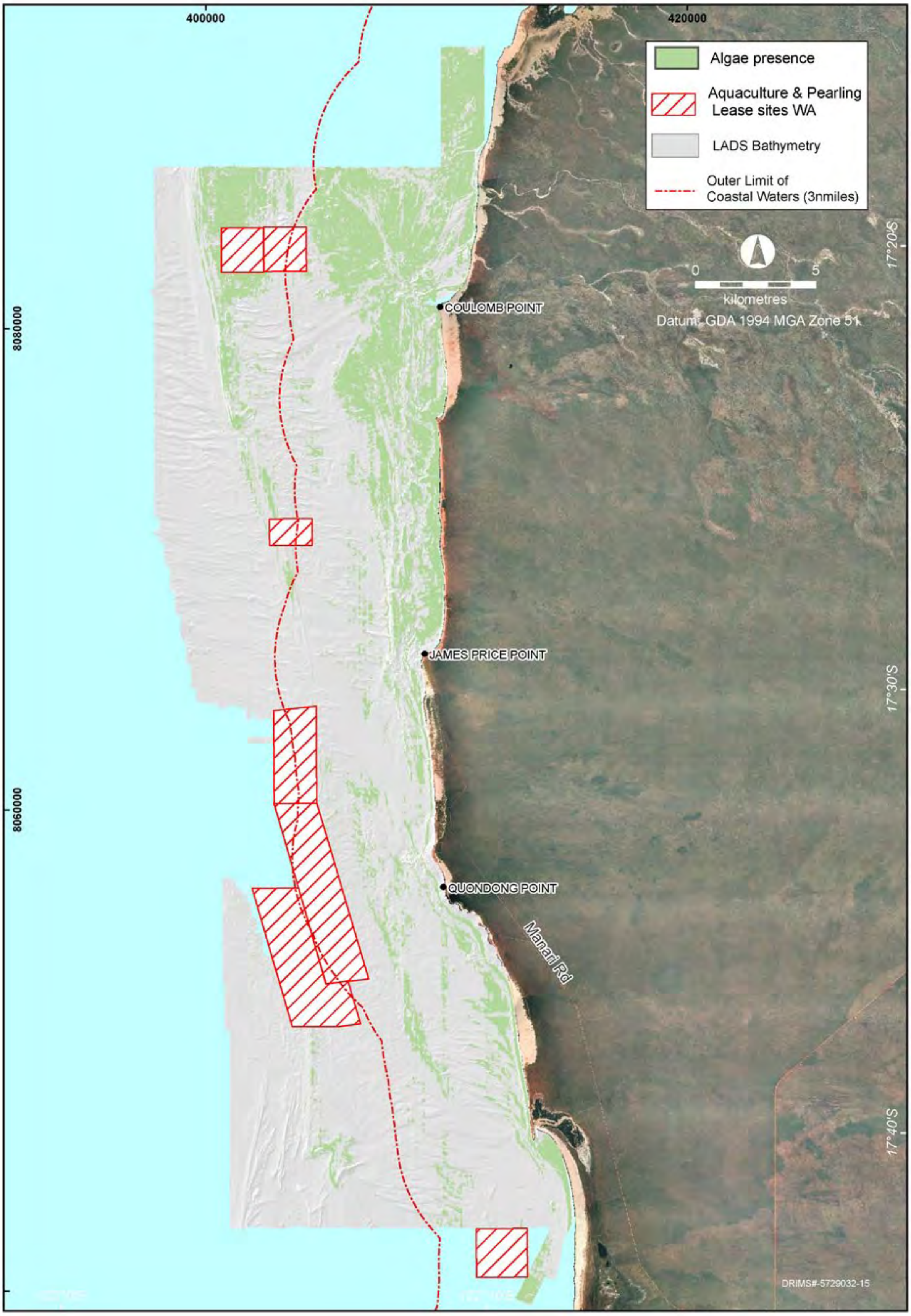
**Dampier Peninsula**

Along the Dampier Peninsula, patches of hard substrate (low/high relief reef structures and rocky substrate) that are suitable for algal growth exist between Quondong Point and Coulomb Point. According to Fry *et al.* (2008) (**Appendix C-4**) green, red and brown macroalgae were common, but were mostly restricted to the shallow areas at Gourdon Bay, Perpendicular Head and Packer Island locations. Along the coast off Coulomb Point, there were extensive patches (mean coverage of seven percent) of the brown macroalgae *Sargassum sp* extending into the deep waters, almost to the seaward extent of the survey boundary. In the deeper waters with sand substrate, green turf algae was most dominant especially in the three northern locations, Quondong – Coulomb Point, Perpendicular Head and Packer Island, with mean percent coverage of seven to 22%. In the epi-benthic samples collected from the north of the Dampier Peninsula to Gourdon Bay, the green algae *Caulerpa* and *Halimeda* were most diverse, with three species from each genera collected (Irvine and Keesing, 2009). The brown algae were represented by seven species belonging to the families Dictyotaceae and Sargassaceae. Several juvenile *Sargassum* plants were also collected in the samples. The red algae were the most diverse group among the collection with 28 species recorded (Irvine and Keesing, 2009).

**James Price Point Coastal Area**

The Benthic Habitat Modelling and mapping predicted and observed macroalgae occurring over a wide portion of the James Price Point coastal area, occupying a diverse array of hard substrates in a variety of water depths (**Figure 1-32**) (SKM, 2010a; **Appendix C-5**). Within the macroalgal classification, the occurrence of small algae was well represented throughout the survey area, both to the north and south of James Price Point (**Figure 1-32**). However, the grouping of small algae only was predominantly absent from offshore reef systems to the south west of James Price Point. This reef system was dominated by groupings of canopy macroalgae only and canopy macroalgae mixed with small algae. Distribution of the grouping 'canopy macroalgae' was primarily found on the edges of hard substrate systems (SKM 2010a; **Appendix C-5**). It should be noted that there was a slight discrepancy between the predicted benthic habitat modelling map and the observed intertidal survey with the distribution of the macroalgae habitat class predicted poorly in the intertidal zone with the model predicting cover over most of the shallow and intertidal areas. However, it was observed over a much reduced area in the intertidal survey and, while the modelling is representing the general trends, its predictions were less accurate higher up in the intertidal zone (SKM, 2010b; **Appendix C-3**).

Large areas of turf algae were recorded from the intertidal areas of James Price Point (SKM, 2010b; **Appendix C-3**). The majority of the species recorded as part of the intertidal survey are typical of rocky shores in the North West Marine Region. Virtually all species recorded in the survey are previously known from the Canning Marine Bioregion (**Table 1-16**). Three exceptions were the filamentous brown alga *Bachelotia antillarum*, the red alga *Gracilaria viellardii* and a potentially new species of the red alga, genus *Erythroclonium*. The presence of *B. antillarum* is not unexpected in tropical WA and likely to have been overlooked previously due to its filamentous structure and appearance similar to that of several locally common genera. *G. viellardii* is widely reported in the tropical Indian and Pacific Oceans (Guiry and Guiry, 2009) while the possible new species of *Erythroclonium* may actually be more widespread and not previously been recognised as a distinct taxon due to misidentification. Underwater imagery of macroalgae observed in the James Price Point coastal area is shown in **Figure 1-33** and **Figure 1-34**.




Source: SKM, 2010a; **Appendix C-5**.

- **Figure 1-32 Derived High Resolution Macroalgae Distribution Map of the James Price Point Coastal Area.**

- **Table 1-16 Algal Species Present within the James Price Point Coastal Area.**

| Benthic Habitat | Species |
|---|---|
| Macroalgae | *Caulerpa racemosa v. Laetevirens*<br>*Caulerpa sertularioides*<br>*Caulerpa verticillata*<br>*Codium* sp<br>*Cystoseira trinodis*<br>*Gracilaria salicornia*<br>*Padina australis*<br>*Portieria hornemanii*<br>*Sargassum decurrens*<br>*Sargassum oligocystum*<br>*Spatoglossum asperum*<br>*Tricleocarpa cylindrica*<br>*Ulva flexuosa* |
| Turf algae | Species unknown (Chlorophyta and Phaeophyta) |

Source: SKM, 2010a; **Appendix C-5**.

Source: Fry *et al.*, 2008; **Appendix C-4**.

- **Figure 1-33 Extensive Patches of Macroalgae (*Sargassum sp*) on Sand Substrate within the James Price Point Coastal Area.**

Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-34 Close up of *Sargassum sp* and a Single Large Sponge on Sand Substrate within the James Price Point Coastal Area.**

### 1.4.2.4. Corals

#### Regional Environment

Coral reef ecosystems support a high diversity of marine flora and fauna (Allen and Steene, 1994) and are therefore afforded a high level of legislated protection by the Commonwealth and WA regulatory authorities (SEWPAC, EPA, DEC). In comparison to other regions of WA, such as Ningaloo Reef and the Dampier Archipelago, coral communities in the Kimberley region have not been extensively studied (Blakeway and Radford, 2005) but existing studies in the broader NWMR (Marsh, 1992 and INPEX, 2008) have documented 280 species from at least 55 genera, exceeding the diversity recorded from the Ningaloo Reef.

It should be noted that coral communities and individual corals colonies are significantly different in their ecological function. Coral communities are assemblages of one or more coral species at a density where individuals interact to produce a greater ecological function than individuals. The density required to transition from an area of isolated individual corals to a coral community is not well defined and likely to be situation-dependent. Elsewhere, working estimates of 5% (SKM, 2009c) and 10% (MScience, 2007) have been adopted.

#### Dampier Peninsula

The Dampier Peninsula contains areas of coral habitat, although at a wider scale they are not as extensive or diverse in terms of regional significance as areas with typical reef building coral communities such as Scott Reef and Ningaloo Reef which lie on the North West Shelf. Along the Dampier Peninsula, the extent of coral growth within the intertidal platforms is likely to be linked to the availability of suitable substrate for colonisation. Areas where the reefs are terraced often include sheltered rock pools and gutters, which may support coral growth. Shallow reef platforms are unlikely to support extensive coral growth due to frequent periods of desiccation during low tide.

Four locations along the Kimberley coast were surveyed by Commonwealth Scientific and Industrial Research Organisation (**CSIRO**) (Fry *et al.,* 2008; **Appendix C-4**), including Gourdon Bay, Quondong-Coulomb Point (including James Price Point), Perpendicular Head and Packer Island. Throughout the survey locations, mixed communities of hard coral, soft coral, ascidians, sponges and algae were recorded. Hard coral communities were observed at each of the four locations, although less than one percent (mean) coral coverage was recorded at any of the locations. Between Quondong Point and Coulomb Point, a few small coral patches were observed in shallow water (less than 10m) and these generally consisted of only a small number of species, with *Turbinaria sp*. and *Acropora sp*. being the most abundant. The coral patches were more abundant along the deeper transects (approximately 20m) around the shoals at Gourdon Bay and in the shallows of the northern half of the Quondong–Coulomb Point location, where hard substrate is present (for example low and high relief reef). At Perpendicular Head and Packer Island, a greater abundance of hard rock or reef substrates, colonised by higher densities of *Turbinaria* sp. and other coral species were recorded. These two sites were also characterised by strong tidal currents and steeper seabeds close to shore, with coral growth mainly restricted to the shallow waters (less than 15m water depth).

In addition, 24 hard corals were collected in the epi-benthic sled samples from the Dampier Peninsula to Gourdon Bay, comprised of six families, 11 genera and 14 species (Irvine and Keesing, 2009). Eight species were collected at the Gourdon Bay location and four species at each of the other three locations (Quondong to Coulomb Point, Perpendicular Head and Parker Island). Azooxanthellate scleractinian colonies were the most abundant group with 44 of the 58 colonies identified to this group (Irvine and Keesing, 2009). In comparison, colonies of zooxanthellate scleractinian species were less abundant (14 of the 58 colonies) but were more diverse in species (nine of the 14 species identified). The most abundant azooxanthallete species was *Cycloseris cyclolites* (31 colonies), while the two most abundant zooxanthellate species were *Turbinaria reniformis* (3 colonies) and *Turbinaria patula* (three colonies) (Irvine and Keesing, 2009).

**James Price Point Coastal Area**

The distribution of hard corals in the subtidal and intertidal area of the James Price Point coastal area are strongly correlated to areas where there is topographic complexity and where hard substrate is raised above the surrounding sediment (SKM, 2010a; **Appendix C-5**). Habitat modelling predicts that although there are some areas of patchy and sparse coral communities, there would be no areas of high coral cover, or typical reef structures surrounding James Price Point. The intertidal zone of the James Price Point coastal area is dominated by flat, sandy areas with relatively sparse, intermittent habitat of rocky substratum and reef platform which is exposed at low tide, and is therefore not suitable for the development of highly diverse or complex coral communities. This feature is typical of intertidal reefs from Mermaid Sound (WA) to Darwin, Northern Territory (**NT**) and beyond, wherever large tidal ranges expose reefs on low tides. Of the hard corals recorded in the intertidal survey, species that were distinctly identifiable in video and digital photographs included *Favites* spp., *Goniopora* sp., *Porites* sp., *Platygyra* sp., *Turbinaria* sp. and *Acropora* sp. (SKM, 2010b; **Appendix C-3**). Refer to **Figure 1-35** for example photography from benthic habitat surveys in the area.

The level of coral community development in the James Price Point coastal area is low, with cover rarely exceeding 10%. Corals are found sparsely amid other dominant benthic biota (**Figure 1-38**), with no hard coral dominant habitats present. Identified corals were encrusting on existing hard substrate and showed no signs of reef formation or community development. Colonies identified in the towed video surveys appear generally small (<1m maximum dimension), suggesting that the area is subject to periodic disturbance events that either remove large colonies or causes mortality which prevents the development of older, larger colonies (SKM, 2010a; **Appendix C-5**).

The density of corals recorded was low (1-5% cover) with isolated individual coral colonies existing between a mosaic of other benthic biota (algae, sessile invertebrates, seagrass). Coral communities with sparse density (5-10% cover) were found along a small band from north of Coulomb Point to James Price Point. Two isolated areas of medium coral cover (10-25%) were found; one in the immediate vicinity of James Price Point and one at Quondong Point to the south (SKM, 2010b; **Appendix C-3**).

The diversity of hard corals is thought to be relatively low compared to other locations throughout the North West Marine Region. The greatest diversity within the wider study area was found off Coulomb Point. Diversity is thought to be relatively similar to some nearshore environments to the south, such as Cape Lambert and Port Hedland (SKM 2009a and SKM, 2010b; **Appendix C-3**), but less than at the Dampier Archipelago or Mermaid Sound (Griffith, 2004 and Blakeway and Radford, 2005).

Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-35 Turbinaria and Favites Hard Coral Colonies Surrounded by a Mosaic of Other Benthic Biota within the James Price Point Coastal Area.**

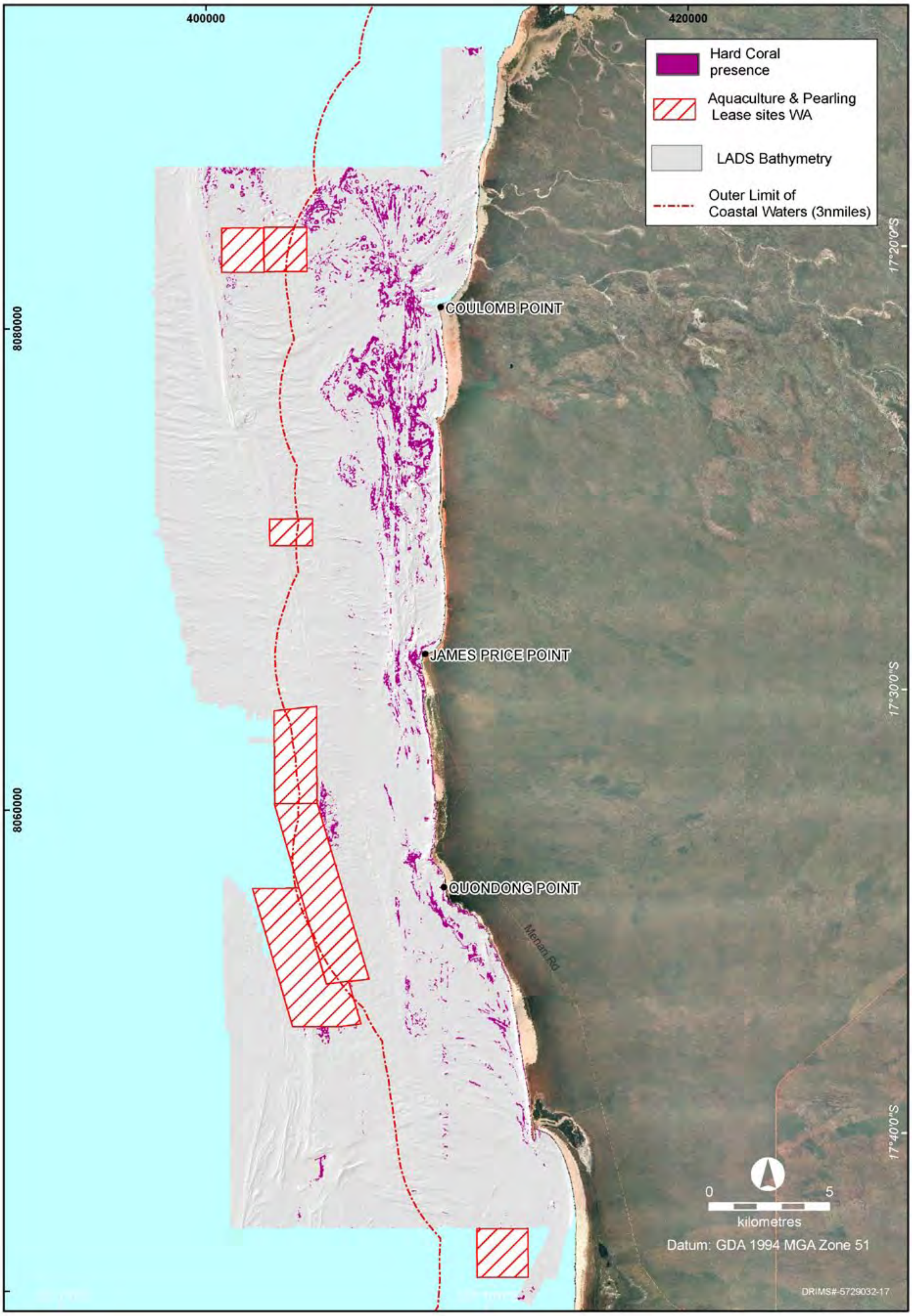
According to the nearshore benthic habitat modelling, soft corals were predicted to occur across both inshore and offshore systems within the James Price Point coastal area. The soft coral grouping was comprised of organisms considered as both BPPs (for example Alyconians such as *Sarcophyton* or *Sinularia sp*.) and non-BPPs (predominantly gorgonian fans and seawhips with occasional non-photosynthesising *Dendronephthya sp*.). The soft coral habitats were largely comprised of non-BPP organisms. The distributions of BPP soft corals across the James Price Point coastal area are very sparse, but still occurred in both the inshore and offshore areas. One large patch of BPP soft coral was predicted to occur inshore and to the south of James Price Point (SKM, 2010a; **Appendix C-5**).

Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-36 Alcyonarian Garden Medium with a Smaller Sparse Barrel Sponge in the Centre within the James Price Point Coastal Area.**

Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-37 Low Density Whip Garden on Bare Sand within the James Price Point Coastal Area.**




Source: SKM, 2010a; **Appendix C-5**.

- **Figure 1-38 Derived High Resolution Hard Coral Distribution Map of the James Price Point Coastal Area.**

#### 1.4.2.5. Mangroves

**Regional Environment**

Mangroves are highly specialised tree species that perform several important ecological functions including stabilising coastal sediments, coastal protection and acting as a nursery grounds for juvenile vertebrate and invertebrate species. These habitats are often found within estuaries and fringing tidal mud flats located along the Kimberley coastline. The mangrove flora of the northern Kimberley region is diverse with 14 species occurring in this area (Mustoe and Edmunds, 2008).

**Dampier Peninsula**

The intertidal coastline of the Dampier Peninsula is characterised by prominent mangrove communities, which generally fringe the head of bays, sheltered inlets and estuary shorelines (Semeniuk, 1980 and Pedretti and Paling, 2001).

Although mangroves are abundant in some parts of the region along the Dampier Peninsula, the majority of the intertidal zone is inhospitable to colonisation by mangroves. This limited colonization is due to the broad intertidal zone with large tidal fluctuations, and a lack of fluvial inputs such that soil salinities in the intertidal zone above the mean high water mark are frequently too high for mangrove flora to tolerate.

**James Price Point Coastal Area**

There are no mangroves at James Price Point. The nearest mangroves to the James Price Point coastal area are more than 20-30km away at Barred Creek and Willie Creek.

### 1.4.3. Marine Invertebrates

**Regional Environment**

A wide range of marine invertebrates are found in the intertidal zones of the North West Marine Region, showing characteristic faunas associated with mangrove stands (tidal creeks and embayments), rocky shore/reef platform, mudflats sandy beach flats, and rubble. The diverse range of invertebrate epifauna present includes sponges, hydroids, anemones, polychaetes, bivalves, barnacles, bryozoans and ascidians. Of these invertebrates, the silver lipped pearl oyster *Pinctada maxima* is of commercial importance. Pearl oysters are harvested both from wild stocks and hatchery-reared farms within the Kimberley region. Soft substrates are the domain of infaunal invertebrates.

Subtidal filter feeding communities, including sponges, soft corals, and ascidians, are often common elements of the sessile fauna in the NWMR and their diversity and abundance is dependent on a range of variables, including the availability of suitable substrate and the level of exposure. On many rocky shorelines, the underside of boulders often has an extremely rich fauna of sponges and ascidians which in turn provide habitat for a variety of polychaetes, crustaceans, echinoderms and molluscs.

While many species are also present in other parts of the Indo-Pacific region, a significant proportion of the benthic fauna is relatively unique to the NWMR (Wood and Mills, 2008).

**Dampier Peninsula and James Price Point Coastal Area**

The most abundant benthic invertebrates found along the Dampier Peninsula between Quondong Point and Coulomb Point were echinoids, crinoids, ascidians and dense patches of sea pens (Pennatulacea) (Fry *et al.,* 2008; **Appendix C-4**). Along the patches of low relief reef at James Price Point, sparse to medium densities of soft corals, sponges, gorgonians and whips have been observed (**Figure 1-36** and **Figure 1-37**). According to Fry *et al.* (2008) (**Appendix C-4**) these communities were very patchy in distribution and most common among the fine sand substrates where they were attached to harder substrates just below a thin sand layer. The filter feeding communities were dominated by sponges, followed by whips and gorgonians. Soft corals and hard corals were recorded within each location, however their abundances were generally low and variable. There were some isolated medium to dense patches of alcyonarians at Coulomb Point and medium to dense patches of *Turbinaria* sp. (flowerpot coral) at Perpendicular Head and Packer Island. Sea pens and heart urchins occurred in dense patches. As examples of abnormal abundance, 1km transect at Perpendicular Head identified the presence of 56,000 heart urchins and at James Price Point several hundred sea pens. Transect sites with higher proportions of low or high relief reef in deeper waters were most strongly associated with mixed filter feeding communities; sponges, gorgonians, whips and alcyonarians and hard coral gardens.

Intertidal surveys along the James Price Point coastal area recorded a relatively low abundance and diversity of species (SKM, 2010b; **Appendix C-3**). The sandy upper littoral zones were sparsely populated. Some dense areas with mobile epifauna (crustaceans) were observed, but in general epi- and infaunal diversity on the sandy beaches of the upper littoral appeared to be low. Mobile macrofauna, dominated by molluscs, were common in the mid to lower littoral zones. The lower littoral zone generally had a more diverse species assemblage. These species were often restricted to tidal pools on the lower littoral reef platform. In the intertidal zones around James Price Point, sponges were limited in distribution and abundance (**Figure 1-39**) which is likely influenced by the patchy nature of hard substrate available for attachment (SKM, 2010b; **Appendix C-3**). The high resolution derived benthic habitat map of sessile invertebrates is presented in **Figure 1-40**.

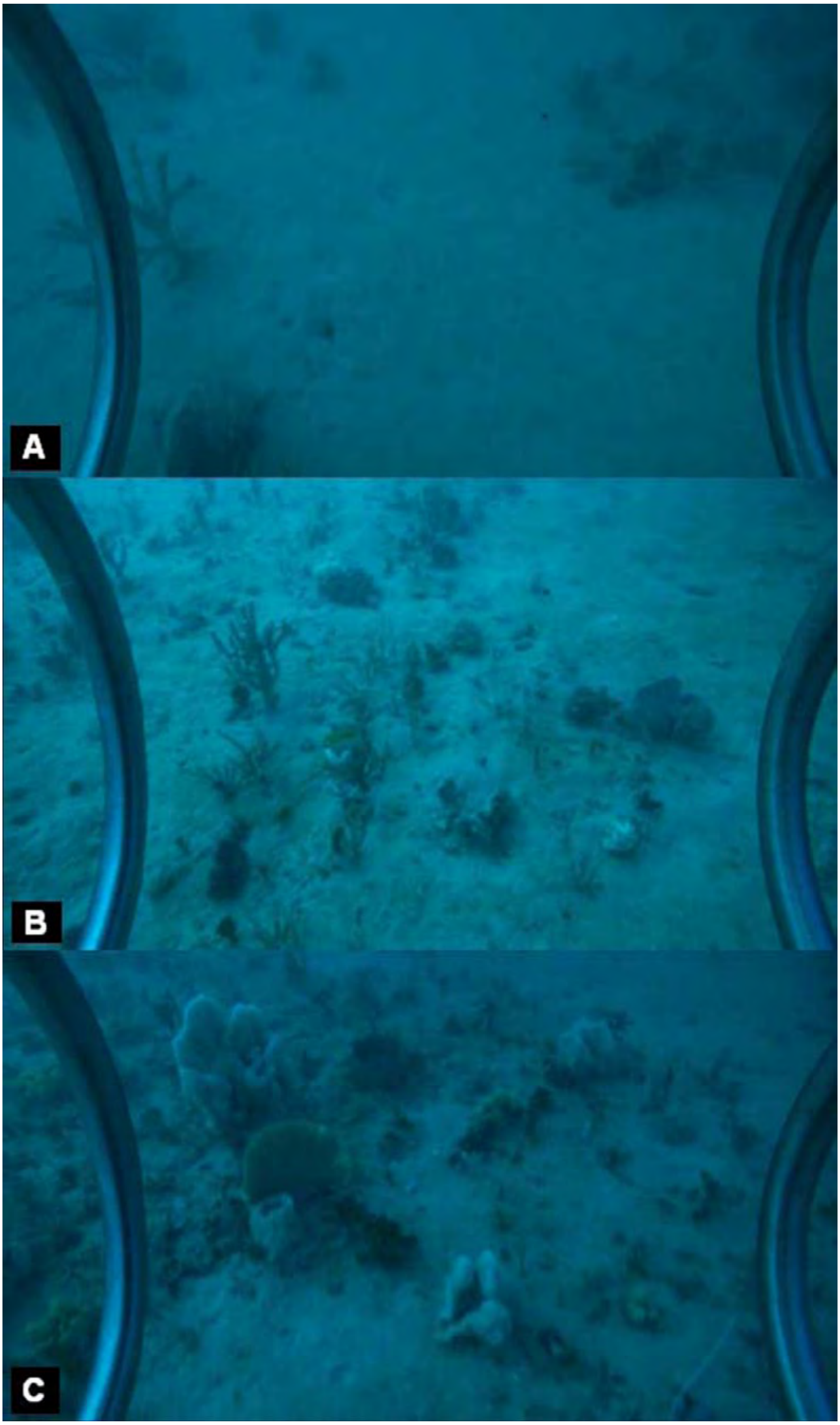
Irvine & Keesing (2009) collected and identified 52 species of tropical marine sponge in the vicinity of James Price Point (Coulomb Point to Quondong Point). Of these, 36 species belong to the class Demospongiae which were identified to species level where possible, remaining species were assigned to the broad Porifera group. A summary of sponge species identified within the James Price Point coastal area are listed in **Table 1-17** below.

No sponges within that list are assigned to species which have been described elsewhere as being phototrophic. However, many of the genera listed here contain species which are known to be phototrophic elsewhere and it is highly likely that some sponges at James Price Point will be phototrophic.

- **Table 1-17 Sponge Species Identified from Epi-Benthic Sled Samples off James Price Point (all Biotic group Sponges, Class Demospongiae).**

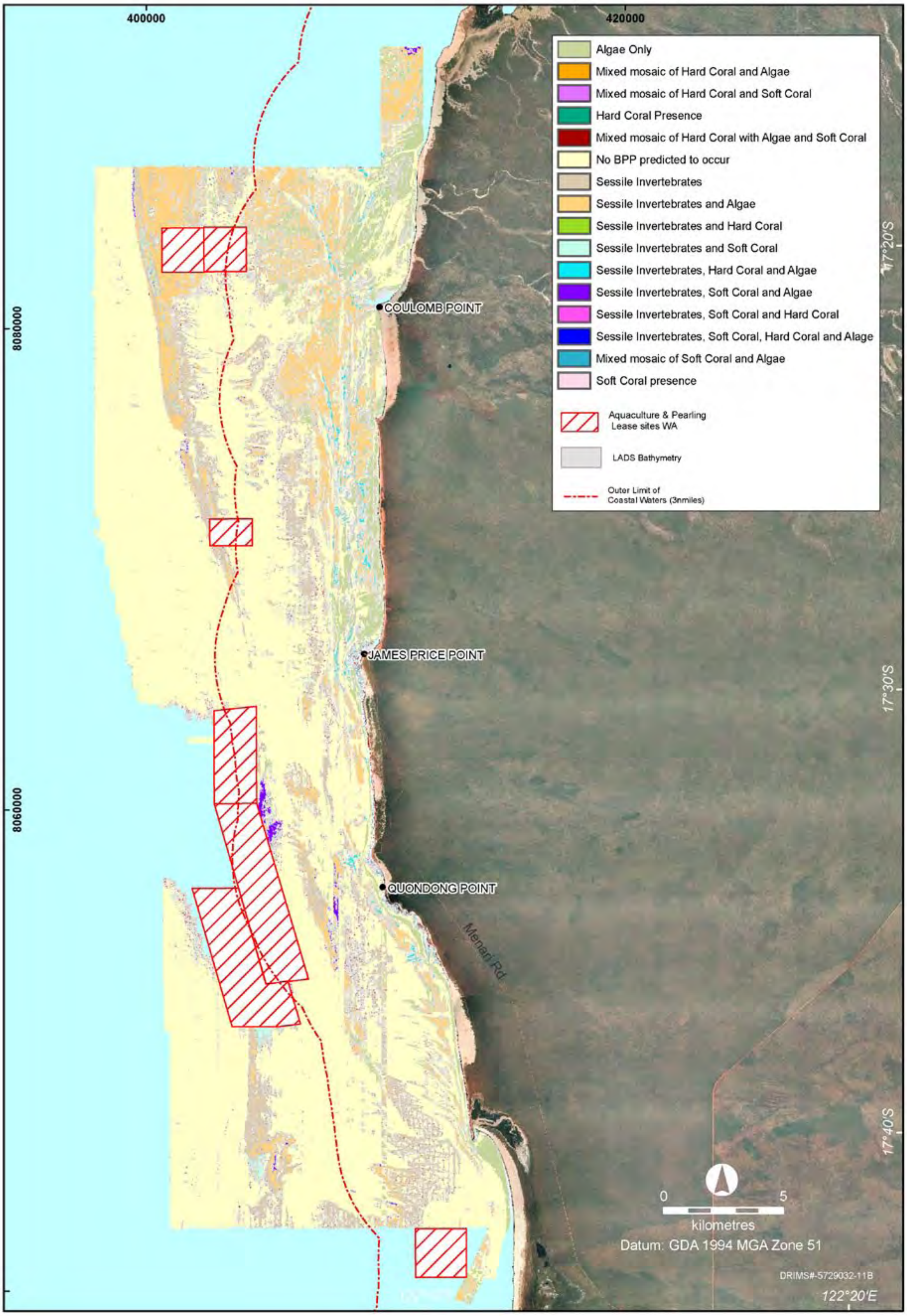
| **Species** | | |
|---|---|---|
| *Anthotethya fromontae* | *Clathria (Thalysias) cf. lendenfeldi* | *Raspailia cf. nuda* |
| *Aplysinidae sp.* | *Cymbastela cf. vespertina* | *Reniochalina cf. stalagmites* |
| *Arenosclera sp.* | *Cymbastela sp.* | *Reniochalina sp.* |
| *Axinella sp.* | *Echinochalina sp.* | *Reniochalina sp.* |
| *Axinella sp.* | *Echinochalina cf. cancellatum* | *Sarcotragus sp.* |
| *Axinella sp.* | *Echinochalina cf. clathrioides* | *Spheciospongia sp.* |
| *Axos flabelliformis* | *Echinochalina clathrioides* | *Spheciospongia sp.* |
| *Callyspongia sp.* | *Ectyoplasia tabula* | *Spheciospongia sp.* |
| *Cinachyra sp.* | *Hippospongia sp.* | *Thorecta sp.* |
| *Cinachyrella? sp.* | *Luffariella sp.* | *Trikentrion flabelliforme* |
| *Ciocalypta sp.* | *Oceanapia cf. macrotoxa* | *Xestospongia testudinaria* |
| *Clathria (Thalysias) abietina* | *Raspailia cf. clathrata* | |

Source: Irvine and Keesing, 2009.




Source: Fry *et al.*, 2008; **Appendix C-4**.

- **Figure 1-39 Still Images from Benthic Video Surveys Illustrating Sponge Garden within the James Price Point Coastal Area.**




Source: SKM, 2010a; **Appendix C-5**.

- **Figure 1-40 Derived High Resolution Sessile Invertebrate Distribution Map of the James Price Point Coastal Area.**

#### 1.4.3.1. Crustaceans

**Regional Environment**

The mixed sandy sediments of the beach and low intertidal sand flats of the NWMR are likely to be home to resident epibenthic, infaunal and meiofaunal invertebrates. Like most intertidal environments, there is a clear pattern of zonation of species in the NWMR, resulting from the combined effect of factors such as the physical environment, animal-sediment relations and species interactions (such as predation and competition). Decapod crustaceans such as Grapsid and Ocypode crabs, forage and burrow in the upper intertidal sand flats. Hermit crabs are also likely to be abundant. The decapod crustacea characteristic of a variety of habitats in the Kimberley region (identified by the Western Australian Museum (WAM) surveys) are summarised in **Table 1-18**.

A number of surveys have been conducted in the NWMR by the WAM and NT Museum. However, collection of species was opportunistic and non-quantitative. The museum surveys have identified more than 200 species of crabs in the Kimberley region, with species belonging to the Xanthidae, Pilumnidae, Trapeziidae and Menippidae dominating the decapod crustacean fauna of the Kimberley region. In general, intertidal areas with the greatest diversity of habitats were found to support the greatest diversity of decapod crustacean species (Davie and Short, 1995; Davie and Short,1996 and Hewitt, 1997).

**Table 1-18 Decapod Crustacea of the Kimberley Region.**

| Habitat | Characteristic Decapod Crustacean Species |
|---|---|
| Mangroves | Hermit crabs (*Clibanarius longitarsus* and *C. taeniatus*)<br>Land hermit crab (*Coenobita spinosus*)<br>Grapsid crabs (particularly *Sesarma* spp. and *Metopograpsus* spp.)<br>*Ocypodid* crabs (particularly *Uca* spp. and *Macrophthalmus* spp.)<br>Xanthid crabs (particularly *Epixanthus* spp. e.g. *Epixanthus dentatus* and *E. frontalis*) (often found under scattered rocks embedded in the mud beneath mangroves; less diverse than in rocky and coral habitats)<br>Mud lobster (*Thalassina squamifera*) (rarely seen but its burrows and chimneys were common)<br>Edible mud crab (*Scylla serrata*) (rarely seen but evidenced by its burrows) |
| Intertidal mud flats / sand flats and shallow sub-tidal | Hermit crabs (particularly *Diogenes* spp. (e.g. *Diogenes gardineri* and *D. avarus)* and *Clibanarius* spp. *Clibanarius virescens* can attain high numbers on rocky substrates especially around tidal pools)<br>Soldier crabs (*Mictyris longicarpus*) (on sheltered sandy beaches)<br>Leucosid (pebble) crabs (*Leucosia* spp., *Myra* spp. and *Philyra* spp.)<br>Portunid crabs (*Thalamita* spp. and *Portunus* spp.)<br>Porcelain crabs (particularly *Petrolisthes* spp.) (occur under rocks and logs on soft sediment flats)<br>The rock lobsters *Panulirus versicolor* and *P. ornatus* were observed in subtidal areas with some coral development, neither appeared common<br>*Ocypode* spp. (sandy beaches) |
| Intertidal rock platforms | Hermit crabs (*Clibanarius virescens*) (often clumping in large aggregations)<br>Xanthid crabs (particularly *Atergatis floridus*)<br>Pilumnid crabs (particularly *Pilumnus vespertilio)*<br>Porcelain crabs |
| Intertidal reef flats | Xanthid crabs (particularly *Atergatis floridus*) and Pilumnid crabs (particularly *Pilumnus vespertilio*) shelter in cavities of the limestone bedrock<br>Xanthids and pagurids (particularly *Pilodius* spp. and *Paguristes* spp.) commonly inhabit areas of rubble and live coral<br>Portunid crabs (particularly *Thalamita* spp.*)* |
| Subtidal coral reefs | Xanthid crabs (particularly *Pilodius* spp.) (numerous and diverse under slabs of rubble)<br>Hermit crabs (*Calcinus* spp. common on or near living hard coral; *Dardanus lagopodes*, *Pagurus* spp.)<br>Porcelain crabs (*Pisidia spinuligera*) (abundant under rubble)<br>*Trapezia* spp. and *Tetralia* spp. (associated with pocilloporid corals) |
| Subtidal reef, rubble and sediment habitat | Decapod crustaceans were most common including crabs, lobsters, prawns and shrimps:<br>Brachyura crabs Pilumnid crabs (hairy crabs) were most common |

Source: Irvine and Keesing, 2009.

In terms of barnacles, the Kimberley region fauna is dominated by species with Indo-West Pacific and Indo-Australian distributions (Jones, 1992 and Jones and Hewitt, 1997). Barnacles were recorded by Jones (1992) from a variety of habitats including mangrove communities, intertidal rocky shores, coral reefs and subtidal habitats. They included cryptic species and species that were epizoic on or commensal in a variety of invertebrate hosts, such as decapod crustaceans, sponges, corals and gorgonians.

**Dampier Peninsula and James Price Point Coastal Area**

A large proportion of the crustacean species recorded from the dredge epi-benthic sled samples from the Dampier Peninsula and Gourdon Bay were representative of soft sediment communities (Irvine and Keesing, 2009). The greatest crustacean diversity was recorded at the Quondong to Coulomb Point location (49 species), followed by the Gourdon Bay location (39 species), Packer Island (21 species) and Perpendicular Head (16 species). Most of the specimens collected belong to the order Decapoda, which contains the most familiar groups of crustaceans – the crabs, lobsters, prawns and shrimps. This order also includes the Anomura (hermit crabs and false crabs), Brachyura (true crabs), Caridea (shrimps) and Thalassinidea (mud shrimps). For Anomura, only specimens of the Diogenidae and Porcellanidae families were represented in the Irvine and Keesing (2009) study. While the decapod collection from the CSIRO survey was quite diverse, there were several major groups not represented. No members of the infraorder Palinura (crayfish, slipper lobsters) were collected, only one member of the Caridae infraoder (shrimp) was collected (family Alpheidae) and the common families of Palaemonidae, Hippolytidae and Rhynchocinetidae were absent. Overall the missing diversity reflects the limited range of habitats surveyed and the limited depth range sampled.

The non-decapod specimens collected belong to the Isopoda (slaters), Cirripedia (barnacles) and Stomatopoda (mantis shrimp). The Isopoda group was represented only by the parasitic Bopyridae family. *Haptosquilla corrugate* and *Gonodactylaceus multicarinata* were two species of Stomatopoda identified both common in tropical Australia waters.

### 1.4.3.2. Molluscs

**Regional Environment**

The Kimberley region molluscan fauna generally occurs over wide areas of the Indo-West Pacific. However, a small proportion of the fauna is endemic to the Kimberley, such as the littorinid *Tectarius rusticus* (Wells, 1992).

Collections of molluscs have been conducted throughout the Kimberley region by the WAM since the late 1980s. Wells (1989) surveyed the molluscan fauna of the Kimberley region Islands from Koolan Island in the south to Cassini Island in the north with samples collected from rocky and sandy shore, coral reefs and mangrove communities. Densities of individual species were high, but the total number of species identified (413) was considered to be moderate. This level of abundance was attributed to the limited number of habitats available at inshore sample sites, most having a low species diversity of molluscs (particularly in mangroves). Species diversity increased further offshore such as Cassini Island and the adjacent Long Reef. However, even at these stations, species diversity did not match diversities found at the offshore atolls of Scott Reef and Ashmore Reef where there is a smaller tidal range and clearer water. Two WA endemic species were observed from the region, *Cronia avellana* and *Chromodoris westraliensis*.

Wells (1992) similarly conducted intertidal and subtidal mollusc surveys along the Kimberley coast from Broome in the south to Wyndham in the north, including some of the offshore islands. Habitats surveyed were similar to the 1989 survey. A total of 317 molluscs were recorded which, when combined with previous surveys, brought the total marine molluscan fauna known from the Kimberley region to 536 species. Collections included five chitons, 224 gastropods, 85 bivalves and three cephalopods.

Another series of surveys were conducted on the southern, eastern and central Kimberley region coast between 1994 and 1996, which included collections of the molluscan fauna. The southern Kimberley region survey encompassed an area between Cape Leveque and Montgomery Reef, and a total of 232 species of molluscs were collected (192 gastropods, 32 bivalves, four chitons and four cephalopods) (Wells and Bryce, 1995). An additional 30 bivalves and 20 gastropods, collected from this region on previous trips, were not found in this survey. The eastern Kimberley region survey was conducted between Cassini Island and Cambridge Gulf (Wells and Bryce, 1996). 265 species were collected (194 gastropods, 62 bivalves, two chitons, six cephalopods and one scaphopod), with an additional 97 species known from the area from previous expeditions (Wells, 1992). The lower number of species collected in 1995 compared to previous expeditions is likely a consequence of the greater proportion of inshore sampling conducted in 1995. The survey of the nearshore islands of the central Kimberley survey (Buccaneer Archipelago to Cassini Island) covered a greater extent of deep subtidal habitats in addition to reef flats, rocky shores and sandy beaches (Bryce, 1997); 292 species of molluscs were collected, including 210 gastropods, 67 bivalves, nine cephalopods, five chitons and one scaphopod. The diversity of species is comparable with the diversity of the other inshore and offshore Kimberley region locations: 232 (Wells and Bryce, 1995) and 265 species (Wells and Bryce, 1996).

**Dampier Peninsula**

A total of 73 species, comprising three cephalopods, 34 gastopods and 36 bivalves were identified in the epi-benthic samples collected from the Dampier Peninsula and Gourdon Bay (Irvine and Keesing, 2009). The greatest diversity of bivalves was recorded at the Gourdon Bay location (30 species), while the greatest diversity of gastropods was recorded at the Quondong to Coulomb Point location (18 species including three opisthobranchs). The venus clams (Veneridae) were the most diverse group with six species from five genera identified. Many of the bivalves collected in the dredge samples are common free-living species of the soft-bottom habitats/communities of tropical northern Australia. These included the arcid species, *Trisidos semitorta*, all of the glycymerid species, post-juvenile *Spondylus victoriae*, the pectinid species *Annachlamys flabellatus* and species of the genus *Lima*, and all of the cariid, semelid, mactrid, crassatellid and venerid species. Those bivalves that were not free-living include byssate species; the arcid species of the genus *Barbatia*, the pteriid species of the genera *Pteria* and *Pinctada*, the mytilid species of the genera *Modiolus* and *Lithophaga*, the pectinid species *Mimachlamys funebris*, the pinnid species of the genus *Pinna*, and the genus *Hiatella*. Three cephalopod species were also recorded of which two from the Octopoda group could not be identified and one Sepiidae species (Irvine and Keesing, 2009).

**James Price Point Coastal Area**

A total of 73 species (covering 40 families and four classes) of mollusc were recorded from the James Price Point coastal area as part of the intertidal survey (SKM, 2010b; **Appendix C-3**). The dominant species observed from the intertidal survey are listed in **Table 1-19**. There was an absence of some molluscan families, such as the Strombidae, Conidae, Chromididae, Phyliidae, Tellinidae and Veneridae and an under representation of others, as well as the high energy nature of the examined habitats including the Cerithidae, Cypraeidae and Fasciolariidae was evident. The shortness of time spent at each station may have contributed to the low numbers observed during the survey.

- **Table 1-19 Dominant Mollusc Species Observed in the James Price Point Coastal Area.**

| Class | Dominant species |
|---|---|
| Polyplacophora | *Acanthopleura gemmata*<br>*Acanthopleura spinosa* |
| Gastropoda | *Morula margariticola*<br>*Morula granulate*<br>*Nerita polita*<br>*Nerita undata*<br>*Patelloida saccharina*<br>*Thais tuberose*<br>*Trochus hanleyanus*<br>*Turbo cinereus* |
| Bivalvia | *Barbatia pistachio*<br>*Brachidontes ustulate*<br>*Pinctada margaritifera*<br>*Saccostrea cuccullata*<br>*Tridacna maxima* |

Source: SKM 2010b; **Appendix C-3**.

#### 1.4.3.3. Other Benthic Invertebrates

**Regional Environment**

Invertebrates have been collected throughout the Kimberley region by the WAM since the late 1980's. The only surveys to report invertebrate abundance and distribution other than molluscs, crustaceans and echinoderms were conducted in 1992 (Morgan, 1992 and Hanley, 1992) and 1995 (Wells *et al.,* 1995).

Surveys of intertidal and subtidal invertebrates were conducted along the Kimberley coast from Broome in the south to Wyndham in the north, including some of the offshore islands (Hanley, 1992). During these surveys, the abundance and distribution of polychaetes were also recorded. Fifty-four species and one subspecies of polychaetes were identified, and

a further 13 higher taxa recorded (Hanley, 1992). Of these, 24 species were scaleworms, including 20 species of polynoids, which reflects the much greater diversity of this family compared to the other scaleworm families. In 1995, surveys were conducted along the southern Kimberley coast between Cape Leveque and Montgomery Reef. A total of 19 species of polynoid scaleworm were collected during the survey (Hanley, 1995).

Due to limited sampling effort and the difficulty of identifying polychaetes to species level, it was not possible to approximate the number of species in the Kimberley region from the data collected in the two surveys (Hanley, 1995). The exception is the scaleworms of the family Polynoidae which, at least in intertidal habitats, was considered to be adequately sampled. A total of 31 species were identified for the region (eight species being common to both surveys). Most species were considered to be relatively common throughout the region, with many having a wide Indo-West Pacific distribution (Hanley, 1995).

**Dampier Peninsula**

Video transects undertaken at Gourdon Bay, Quondong-Coulomb Point, Perpendicular Head and Packer Island found ascidians to be common in Gourdon Bay with a wide distribution throughout most of the survey location, especially within sponge and whip gardens. There were also dense patches of bryozoans in the north east of the survey location; these were attached to patches of dead whips (Fry *et al.,* 2008; **Appendix C-4**).

The diversity of benthic animals at Perpendicular Head was relatively high. Seapens, ascidians and hydroids were among the most widespread groups at both Perpendicular Head and Packer Island. At Packer Island it was noted that seapens generally inhabited the flat sandy patches in the deeper water transects where the currents were quite strong.

Of a total of 154 sponge specimens, 52 species of Demospongia from 18 families were identified in the epi-benthic dredge sled samples (Irvine and Keesing, 2009). The collection did not reflect the extent of the sponge biodiversity expected within the Kimberley region but does give an indication of the high sponge biodiversity recorded from the low number of dredge tows. Of the identified taxa, the greatest sponge diversity was recorded at the Quondong to Coulomb Point location (52 species). This was followed by the Packer Island location (25 species) and Gourdon Bay location (23 species), with only 11 species recorded at the Perpendicular Head location.

Colonial species of ascidian were relatively abundant and three genera: *Aplidium*, *Didemnum* and *Pseudodistoma* represented the majority of the samples (Irvine and Keesing, 2009). These genera are widespread throughout Australia and species from these genera are found in most tropical and temperate waters. The most common solitary ascidians were the genera *Polycarpa* and *Phallusia*.

The crinoids species represented in the epi-benthic dredge samples were generally typical of crinoids communities seen in the NWMR. There were three families represented by eight genera and fourteen species. Nine of these species were from the family Comasteridae, including two from the genus *Comatula*. The diversity of crinoids was greatest at the Gourdon Bay location (11 species) compared to the other three locations (six at Packer Island, five at Quondong to Coulomb Point and four at Perpendicular Head) (Irvine and Keesing, 2009).

**James Price Point Coastal Area**

Polychaetes and echinoderms were two taxonomic groups studied in detail as part of the intertidal survey. The surface deposit feeder, *Scolelepis carunculata* was abundant to the north of James Price Point which most likely indicates the presence of suitable particulate food material at that location (SKM, 2010b; **Appendix C-3**).

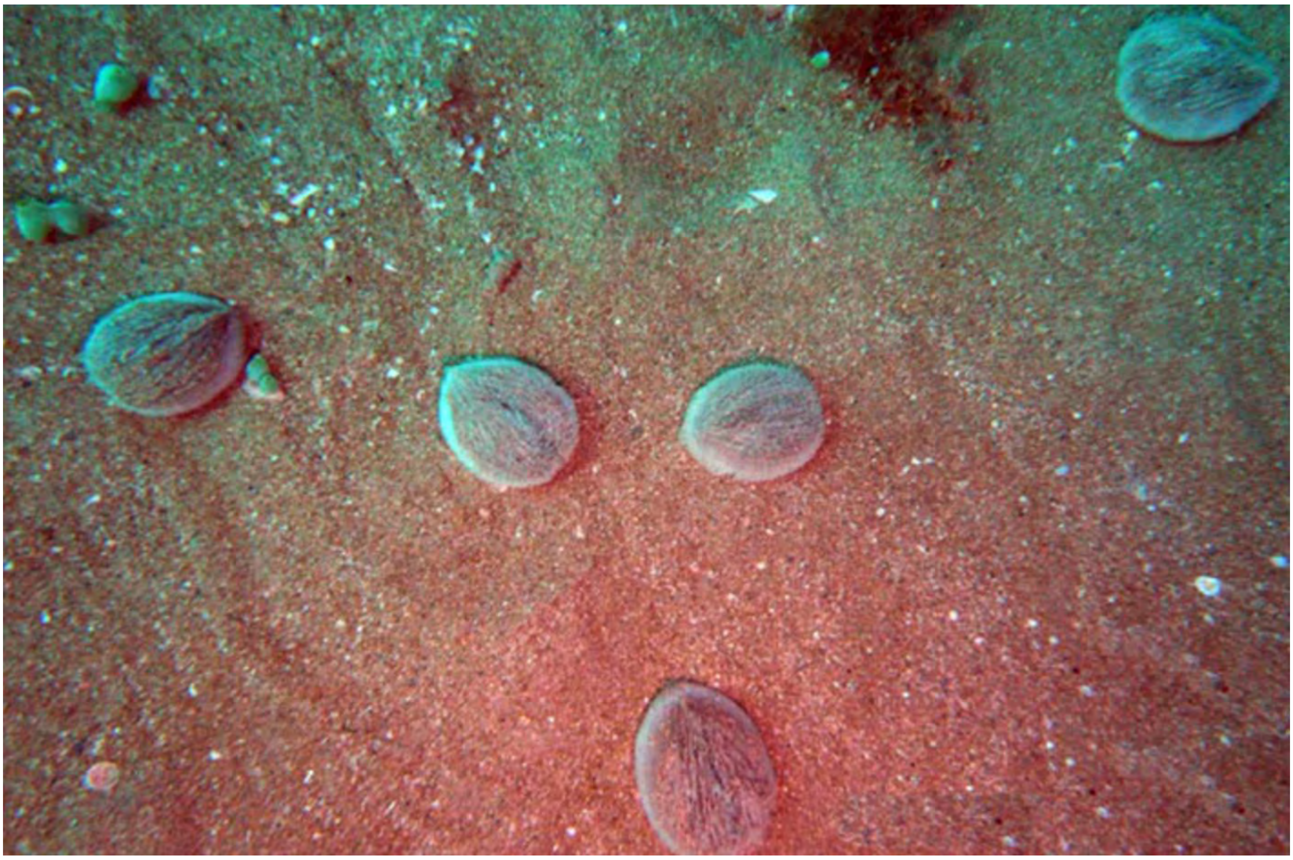
A total of 18 live echinoderm species were collected from the intertidal area from James Price Point and Flat Rock (**Table 1-20**; SKM, 2010b; **Appendix C-3**). Of the specimens fully identified to species, nine (50%) had an Indo West Pacific distribution, four (22%) Indo Pacific, three (17%) Indo Malayan and two (11%) were Australian endemics found only in the northern Australian waters. The majority of the species (16 species, 84%) were either suspension or deposit feeders.

- **Table 1-20 Echinoderm Species Recorded at James Price Point.**

| Class | Family | Species |
|---|---|---|
| Crinoidea | Comasteridae | *Comanthus briareus* (Bell, 1882) |
| | | *Comanthus parvicirrus* (Müller, 1841 |
| | Mariametridae | *Lamprometra palmata* (Müller, 1841) |
| Ophiuroidea | Ophiactidae | *Ophiactis fuscolineata* H.L. Clark, 1938 |
| | Ophiotrichidae | *Macrophiothrix paucispina* Hoggett, 1991 |
| | Ophionereididae | *Ophionereis dubia* (Müller & Troschel, 1842) |
| | Ophiodermatidae | *Ophiarachnella gorgonia* (Müller & Troschel, 1842) |
| | | *Ophiarachnella infernalis* (Müller & Troschel, 1842) |
| | Ophiuridae | *Ophioplocus imbricata* (Müller & Troschel, 1842) |
| Echinoidea | Laganidae | *Peronella orbicularis* (Leske, 1778) |
| Holothuroidea | Holothuriidae | *Holothuria (Halodeima) atra* Jaeger, 1833 |
| | | *Holothuria (Thymiosycia) hilla* Lesson, 1830 |
| | | *Holothuria (Thymiosycia) impatiens* (Forskål, 1775) |
| | | *Holothuria (Mertensiothuria) leucospilota* (Brandt, 1835) |
| | | *Holothuria (Stauropora) modesta* Ludwig, 1875 |
| | | *Holothuria (Lessonothuria) pardalis* Selenka, 1867 |
| | Cucumariidae | *Colochirus crassus* Ekman, 1918 |
| | Phyllophoridae | *Phyrella* sp |
| | Sclerodactylidae | *Afrocucumis africana* (Semper 1868) |

Source: SKM 2010b; **Appendix C-3**.

Fry *et al.,* (2008) (**Appendix C-4**) identified heart urchins (*Breynia desori* and *Lovenia elongata*), crinoids and ascidians as the most abundant benthic invertebrates recorded within the survey location from Quondong Point to Coulomb Point. The heart urchins and crinoids were found mostly on the sandy flats in the offshore areas (see **Figure 1-41**), with densities of up to 30,000 and 33,000 animals per linear km, respectively. The ascidians were generally widespread throughout the survey location, with counts of a few hundred per transect km at many transect sites.



Source: Fry *et al.,* 2008; **Appendix C-4**.

- **Figure 1-41 Heart Urchins (*Breynia desori*) on the Substrate at Gourdon Bay.**

### 1.4.4. Vertebrate Fauna

The regional area supports a diverse fauna community: records from all fauna groups (except other large whale species) were regularly recorded in the area during surveys undertaken to date. However, none of those species are considered to utilise the James Price Point coastal area to a greater degree than other areas such as the Lacepepe Islands (RPS, 2010d; **Appendix C-10**). Conversely, the James Price Point area generally had fewer associated sightings than other locations, such as Carnot Bay, the Lacepede Islands or Roebuck Bay. Moderate densities of dolphins and sea snakes may occur periodically off James Price Point, however survey data indicated, use of the James Price Point area throughout the survey periods was sporadic. The sightings of sharks were widespread but with certain distinct concentrations. Overall, fewer sightings of sharks were recorded adjacent to James Price Point and the area did not appear to represent habitat of particular importance to sharks in the region (RPS, 2010d; **Appendix C-10**). Sharks were well represented during the course of BRUVS (Cappo *et al*., 2010b; **Appendix C-6**)

#### 1.4.4.1. Marine Turtles

Six species of marine turtle are known to occur in the North West Marine Region, all of which are listed as threatened species under the EPBC Act. Extensive marine turtle rookeries are known to occur at the Lacepede Islands and Eighty Mile Beach. Marine turtles are also known to nest along the Dampier Peninsula, however in relation to James Price Point, both Biota (2009b) and DEWHA (2009a) concluded that the site is unlikely to be heavily utilised by nesting turtles, due to many of the beaches being unsuitable, primarily due to regular inundation during high tide.

**Geographical Distribution and Abundance**

Worldwide, seven species of marine turtles are recognised, with six of those occurring in Australian waters. One species, the flatback turtle, is endemic to Australia. Turtle species that occur within Australian waters are outlined in **Table 1-21.** This also provides a summary of the protection status of each species as derived under the EBPC Act and the International Union for Conservation of Nature (**IUCN**) Red List.

■ **Table 1-21 Marine Turtles Potentially Present in the Kimberley Region.**

| Scientific name | Common name | EPBC Act status | IUCN Red List status |
|---|---|---|---|
| *Chelonia mydas* | Green turtle | Vulnerable | Endangered |
| *Natator depressus* | Flatback turtle | Vulnerable | Data Deficient |
| *Eretmochelys imbricata* | Hawksbill turtle | Vulnerable | Critically Endangered |
| *Dermochelys coriacea* | Leatherback turtle | Endangered | Critically Endangered |
| *Lepidochelys olivacea* | Olive ridley turtle | Endangered | Vulnerable |
| *Caretta caretta* | Loggerhead turtle | Endangered | Endangered |

Source: Limpus, 2007; Limpus, 2008a; Limpus, 2008b; Limpus, 2009a and Limpus 2009b.

**Regional Environment**

Of these six species, only the green and flatback turtles are known to nest in significant numbers in the Kimberley and Canning Bioregions (Prince, 1994). However, little is actually known about the population structure of turtles that utilise habitats in these areas (DEC, 2009b). The Kimberley region is characterised by a number of coastal beaches and offshore islands that support marine turtle rookeries, including the Lacepede Islands, which have been recognised as a significant breeding location for green turtles (DEWHA, 2009a).

Previous surveys of the west Kimberley coastline and islands have indicated that some level of nesting has occurred on almost all islands that support suitable beach habitat (DEC, 2009b). Moderate density nesting activity was observed on Albert, Lamarck and Prudhoe Islands, while the highest density of nesting activity was noted on the Lacepede Islands, Cassini Island, Maret Island and east and west Montalivet Island (INPEX, 2008, cited in DEC, 2009b). The nearest of these nesting locations, the Lacepede islands, are approximately 65km north of James Price Point.

Marine turtles are also known to utilise foraging grounds along the Dampier Peninsula coast and offshore from Kimberley region such as Ashmore Reef, King Sound, Maret Islands, Adele Island and Roebuck Bay (Prince, 1994). Feeding areas are typically more widely distributed than rookeries, and may contain individuals from several nesting areas (Limpus *et al.,* 1992). For instance satellite tracking of turtles tagged at Barrow Island (flatback turtles) and off east Java (green turtles) indicated that turtles migrated to waters off the Dampier Peninsula (www.seaturtle.org, cited in DEC, 2009b). As turtles are known to use foraging grounds that are distant from their nesting beaches, the Kimberley coastal waters may provide foraging grounds for additional turtle species that are not known to nest in the area.

A summary of known nesting and foraging habits for turtles in the region is presented in **Table 1-22**.

- **Table 1-22 Known Turtle Nesting Locations and Foraging Habits.**

| Scientific Name | Common Name | Main WA Breeding Location | Feeding and Foraging Habits |
|---|---|---|---|
| *Chelonia mydas* | Green turtle | Ningaloo coast, offshore islands of the Pilbara and Kimberley including the Lacepede Islands, which support one of the largest populations remaining in the world. | Feed on seagrass, algae, mangroves, gelatinous plankton and will also feed on dead fish, crustaceans and jellyfish. |
| *Natator depressus* | Flatback turtle | Northwest Shelf coastal beaches and islands from Exmouth to the Lacepede Islands, which is one of the two breeding populations of WA. | Flatback turtles are carnivorous, feeding mainly on jellyfish and soft invertebrates including sea pens, whips, gorgonians, sea cucumbers, spiny soft corals. |
| *Caretta caretta* | Loggerhead turtle | Dirk Hartog Island to Varanus Island in the Pilbara region, which supports the third largest population remaining in the world. | Forage over both hard and soft bottom habitat on the continental shelf, feeding mainly on molluscs, echinoderms, cnidarians, crustaceans and fish. |
| *Eremochelys imbricate* | Hawksbill turtle | The major rookeries in WA are the Lowendal Island and Dampier Archipelago which supports one of the largest populations remaining in the world. | Forage over coral and rocky reef habitat, feeding mainly on sponges, molluscs and algae. |
| *Dermochelys coriacea* | Leatherback turtle | No confirmed breeding in WA. Likely to pass through WA waters only. | Feed on gelatinous material and pelagic feeding opportunities |
| *Lepidochelys olivacea* | Olive ridley turtle | No recorded breeding in WA, however may occur within Islands of the Kimberley. | Feed on molluscs and gastropods |

Source: Limpus, 2002 and RPS, 2010a; **Appendix C-8**.

**Dampier Peninsula**

In addition to the significant nesting beaches on Lacepede Islands, marine turtles may nest on suitable beaches along the Dampier Peninsula and utilise the coastal waters as foraging habitat. At a DEC workshop in 2009 it was noted that a limited number of areas along the Dampier Peninsula may support marine turtles, these include:

- Lacepede Islands, located 65km north of James Price Point, which provides significant nesting habitat; and
- Coulomb Point Nature Reserve, located 15km north of James Price Point.

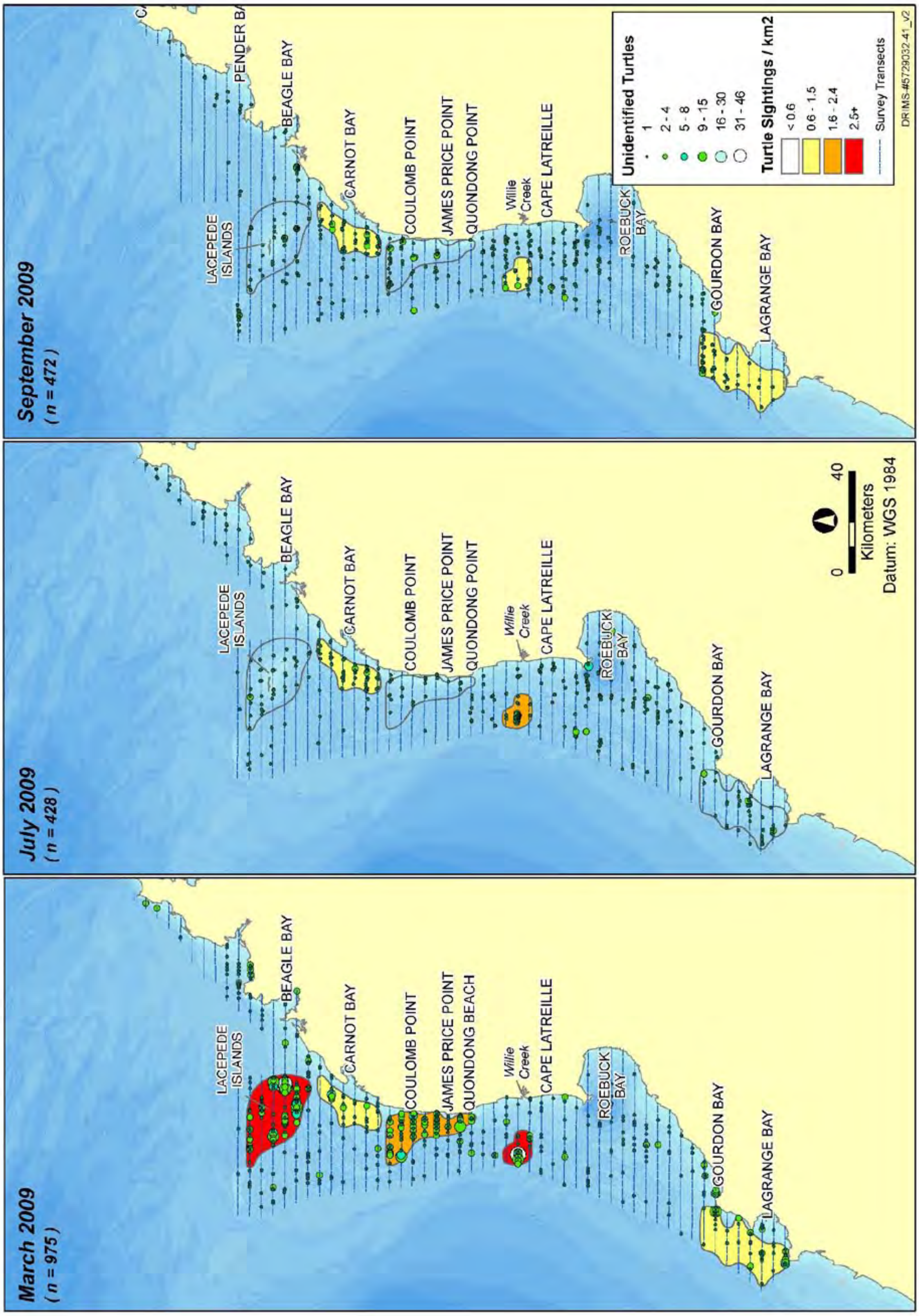
Within the Dampier Peninsula numerous turtles were observed during the Marine Megafauna Aerial surveys undertaken between Cape Bossut to Cape Leveque. Turtles were relatively abundant and present throughout the survey period. During the March 2009 survey, peak turtle numbers (305 turtles; 2.9 turtles/km$^2$) were observed around the Lacepede Island Group (RPS, 2010b; **Appendix C-2**). Smaller aggregations of turtles (164 turtles; 2.4 turtles/km$^2$) were recorded 13km offshore between Coulomb Point and Quondong Point (includes James Price Point) and 20km offshore from Willie Creek (76 turtles; 3.2 turtles/km$^2$) (**Table 1-23** and **Figure 1-42**).

During the July and September 2009 surveys, few turtles were recorded at the Lacepede Island Group (0.4 turtles/km$^2$ and 0.3 turtles/km$^2$ respectively). Moderate densities of turtles were recorded west of Carnot Bay (53 turtles; 1.2 turtles/km$^2$ in July and 44 turtles; 1.0 turtles/km$^2$ in September), 15-20km offshore of Willie Creek (47 turtles; 2.0 turtles/km$^2$ in July and 15 turtles; 0.6 turtles/km$^2$ in September; and between Gourdon Bay and Lagrange Bay (41 turtles; 0.4 turtles/km$^2$ in July and 51 turtles; 0.6 turtles/km$^2$ (**Table 1-23** and **Figure 1-42**).

- **Table 1-23 Number and Densities of Turtle Sightings at Surveyed Locations.**

| Locations | March 2009 | | July 2009 | | September 2009 | |
|---|---|---|---|---|---|---|
| | No. | Density[1] | No. | Density[1] | No. | Density[1] |
| Lacepede Island Group (106.4km$^2$) | 305 | 2.9 | 40 | 0.4 | 37 | 0.3 |
| West of Carnot Bay (44.6km$^2$) | 36 | 0.8 | 53 | 1.2 | 44 | 1.0 |
| Coulomb Point – Quondong Point (67.8km$^2$) | 164 | 2.4 | 20 | 0.3 | 44 | 0.6 |
| West of Willie Creek (23.4km$^2$) | 76 | 3.2 | 47 | 2.0 | 15 | 0.6 |
| Gourdon Bay – Lagrange Bay (92km$^2$) | 83 | 0.9 | 41 | 0.4 | 51 | 0.6 |

Note: [1] Density of Turtle Sightings per km$^2$.




Source: March 2009 (SKM), July and September 2009 (RPS, 2010b; **Appendix C-2**).

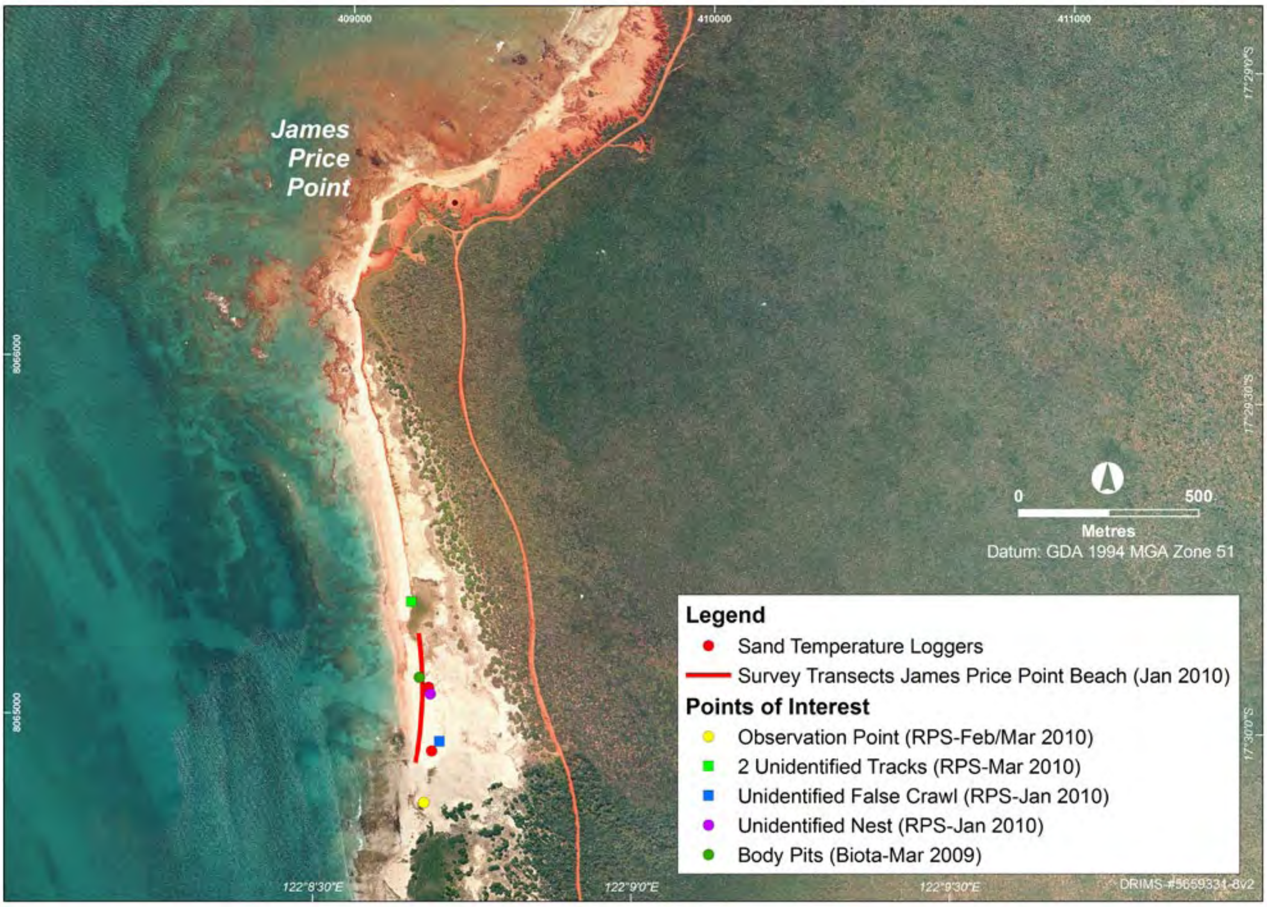
- **Figure 1-42 Distribution, Abundance and Density of Turtles Recorded During the Nearshore Regional Surveys of Waters of the Dampier Peninsula.**

**James Price Point Coastal Area**

Within the James Price Point coastal area, sandy beaches occur south of James Price Point. Significant stretches of loose, aeolian sands present with little vegetative cover, may provide possible substrata composition for opportunistic turtle nesting. While these areas are not specifically known for turtle nesting, any sandy shore could potentially be considered turtle nesting habitat (RPS, 2010b; **Appendix C-2**).

Beach surveys have identified the beaches to the immediate north and south of James Price Point are considered unsuitable for nesting. These beaches are subject to tidal inundation and have rocky shore lines which are not favourable for nesting conditions (RPS, 2010b; **Appendix C-2**).

James Price Point beach, starts at the end of the rocky shoreline approximately 200m south of James Price Point and is approximately 720m long (**Figure 1-43**). It comprises an extensive sandy beach area with a well developed vegetated foredune. The foredune is set back and gradually slopes to a primary dune. There are rocky outcrops on the shore line at the northern and southern extent of the beach. The northern beach area above the high tide comprises a rocky platform covered with a thin veneer of sand (~ 20cm). This section of beach is considered unlikely to be suitable for nesting. Beach surveys did not identify any significant nesting areas on James Price Point beach (RPS, 2010b; **Appendix C-2**). **Figure 1-44** shows photography of a typical coastal beach in the area.




Source: RPS, 2010b; **Appendix C-2.**

- **Figure 1-43 James Price Point Beach – Survey Area and Points of Interest Observed during Beach Studies in 2009 and 2010.**

- **Figure 1-44 Typical Coastal Beach in the Vicinity of James Price Point.**

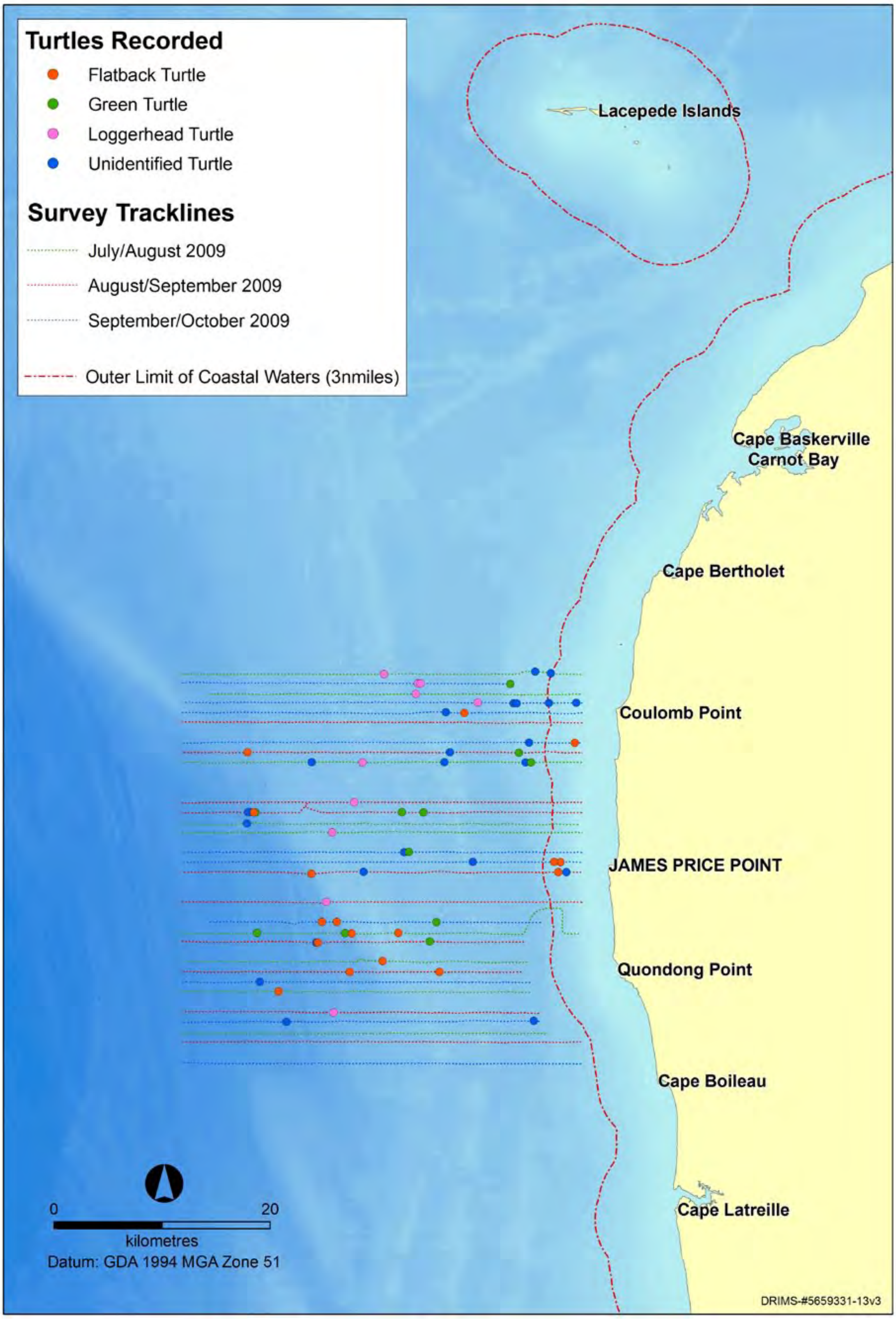
Turtle surveys conducted during the 2009 – 2010 nesting season along the coastline adjacent to the James Price Point area and other suitable beaches in the region observed very limited flatback turtle activity, in the form of only 3 tracks and 1 potential nest, during the entire nesting season (RPS, 2010b; **Appendix C-2**). An opportunistic wet season fauna survey of the James Price Point coastal area in March 2009 also observed very limited activity in the form of tracks and body pits (Biota, 2009b).

Although JPP does not support significant numbers of nesting turtles, it does contain marine turtle foraging grounds in offshore waters, and supports adult and juvenile turtles and migrating turtles from southern rookeries (RPS, 2010b; **Appendix C-2**). All six turtle species may utilise the waters offshore of JPP coastal area during movements and migrations and possibly also as foraging habitat. This is evidenced by the broad distribution of turtles throughout the waters of the Dampier Peninsula. The benthic flora and fauna (invertebrates, macroalgae, *Halophila* sp, and seapens) at James Price Point like other regional nearshore coastal waters provide a food source for flatback and green turtles. James Price Point also has similarities to known sub-adult green turtle habitat (for example shallow subtidal and intertidal limestone platforms are frequently used by green turtles on the Dampier Peninsula) (Pendoley *pers. comm.,* 2009 as cited in RPS, 2010b). Adult loggerhead and hawksbill turtles, when foraging amongst filter feeders and algae during migration, may also derive part of their food source from the James Price Point coastal waters.

During the March 2009 surveys (RPS, 2010b; **Appendix C-2**), the highest densities of turtles were found, at any one time, in the waters around the Lacepede Islands, which is a known nesting area for green and flatback turtles. During subsequent surveys, other numerous turtle sightings were to the west of Carnot Bay, Quondong Point, west of Roebuck Bay and off Cape Latreille. The presence of turtle densities to the north and south of James Price Point during both July and September 2009 surveys indicates that relatively high numbers may pass offshore (**Figure 1-45**).

Green, loggerhead, hawksbill and flatback turtles were found in waters off the JPP coastal area during the non-breeding period (RPS, 2010b; **Appendix C-2**). However, leatherback turtles and olive ridley turtles were not observed. Vessel surveys (RPS, 2010b: **Appendix C-2**) identified that green and flatback turtles were widely distributed across the vessel survey area (**Figure 1-45**). Of the animals identified to species level in JPP coastal area, flatbacks made up the greatest

proportion of sightings (45%), while green turtles made up 30% and loggerheads 25% of sightings. Loggerhead turtles were similarly widely distributed across the survey area but were not recorded in water less than 20m deep. High densities of turtles were recorded in waters around the Lacepede Islands and north of the James Price Point area late in the 2008 – 2009 nesting season. Juvenile turtles were sighted within 50m of the shore at James Price Point beach and Quondong South beach during the 2009 – 2010 nesting season and numbers appeared to be associated with tidal movements with higher numbers observed when the high tide covered the rocky intertidal areas.




Source: RPS, 2010b; **Appendix C-2**.

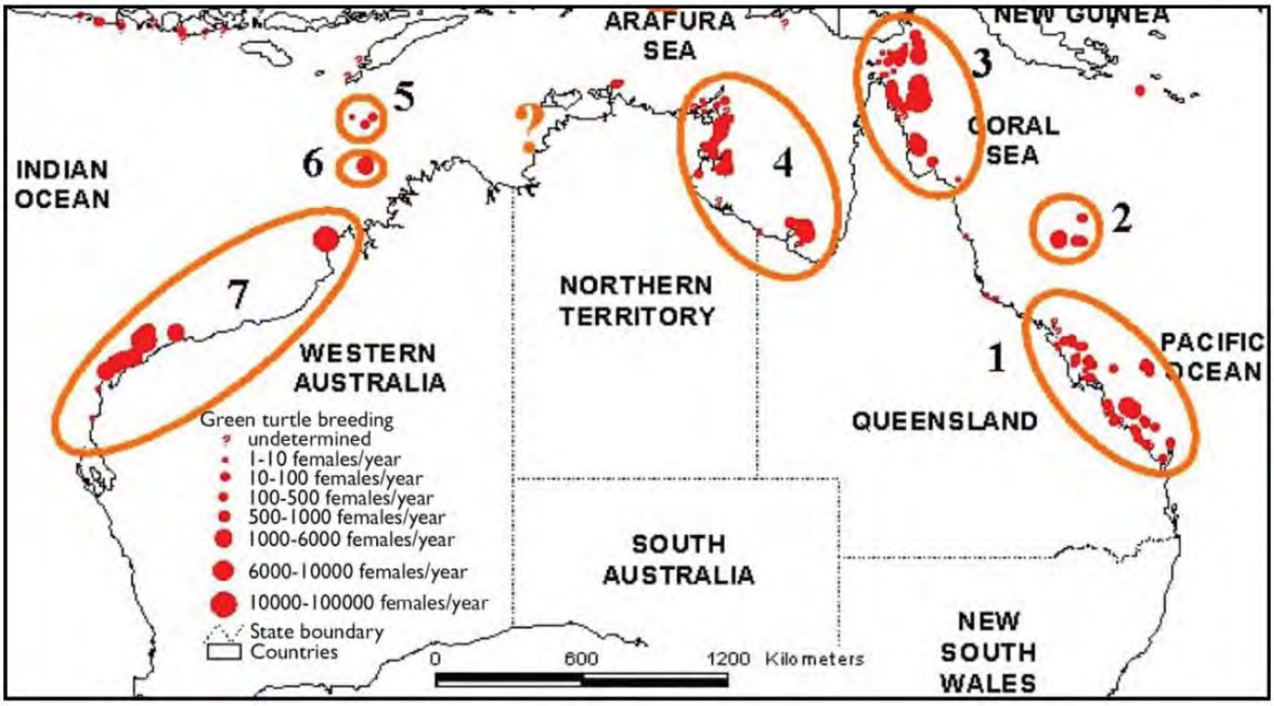
- **Figure 1-45 Distribution and Species Composition of Turtles Observed During Vessel Surveys in the James Price Point Area and Pender Bay, July-October 2009.**

**Species Life History**

Six species of marine turtles are known to occur in the North West Marine Region. However only the green, flatback, hawksbill and loggerhead are expected to be found within the James Price Point coastal area.

*Green Turtles*

The green turtle (*Chelonia mydas*) breeds in WA during summer and is known to have major nesting rookeries on the Lacepede Islands, Browse Island, Barrow Island, Montebello Islands and North West Cape. Those found on the North West Shelf, between Barrow Island and the Lacepede Islands form a genetically distinct breeding stock (FitzSimmons and Jenson, 2008) (**Figure 1-46**).

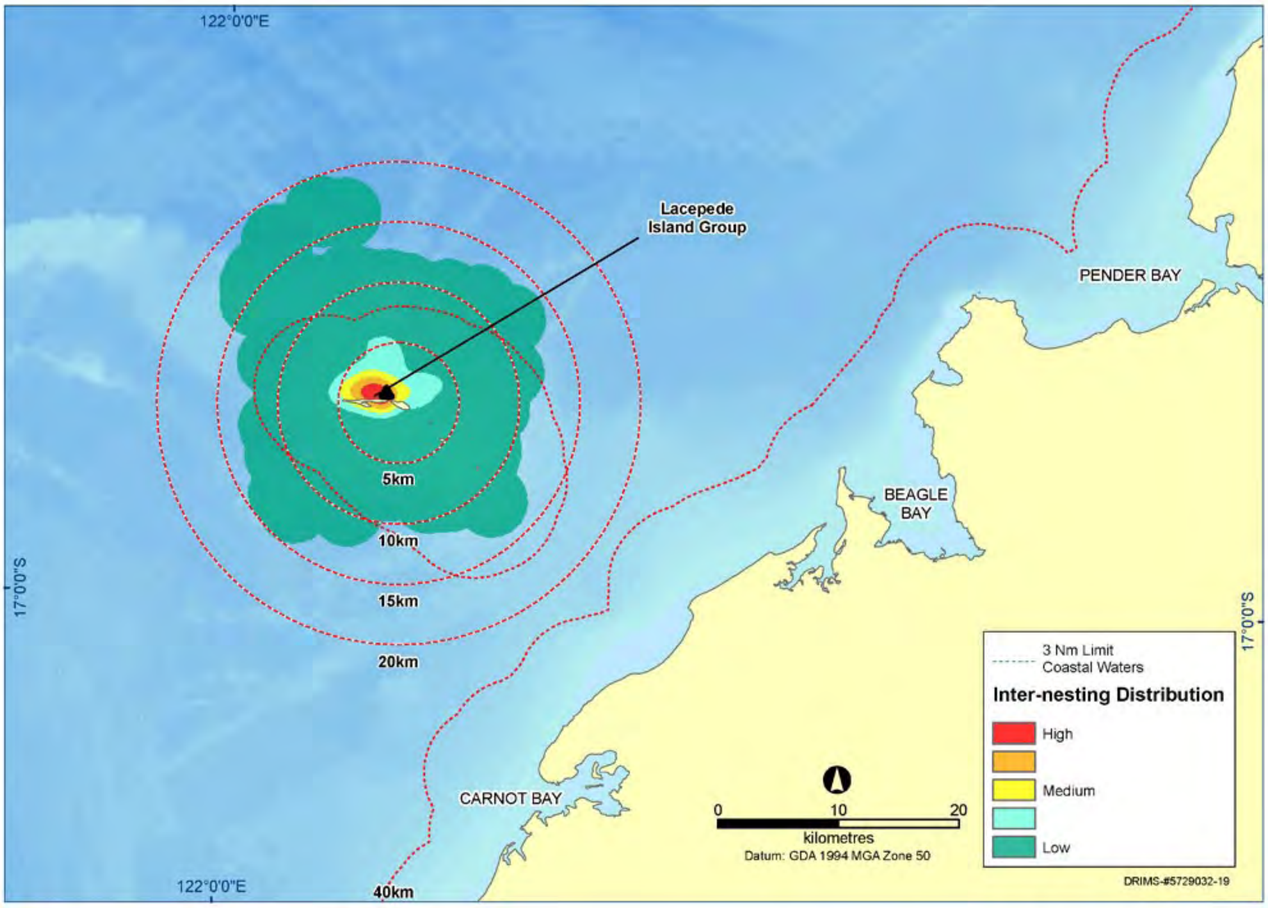



Source: RPS, 2010b; **Appendix C-2**.

- **Figure 1-46 Distribution of Known Green Turtle Management Units in Australia.**

Dethmers *et al.* (2006) estimated the population size of female green turtles in the North West Shelf area to be approximately 125,300 individuals, which is considered one of the largest green turtle populations in the world (Limpus, 2008b). The Lacepede Islands are known to be critical nesting and inter-nesting habitat for green turtles, supporting a total population of 5,000-10,000 individuals (Environment Australia, 2003; Dethmers *et al.,* 2006; DEWHA, 2008a and Masini *et al.,* 2009). The prevalence of green turtles during the inter-nesting period around the Lacepede Islands was evidenced by a distinct area within 15km of the Islands (**Figure 1-47**). A number of smaller nesting sites can also be found on the mainland between the Ningaloo and Kimberley coast. There are no records of green turtles nesting on the mainland beaches of the Kimberley region including the Dampier Peninsula and the coastal area of James Price Point. Prince (1994) suggested that green turtles nest at Eighty Mile Beach however this has not been confirmed. The green turtle is harvested by the indigenous people of the Dampier Peninsula as a food source, however, exact numbers taken are unknown (Limpus 2002).

Green turtles in WA primarily nest between November and March (Prince, 1994 and Pendoley, 2005), however, it has been suggested that green turtles may nest all year round at island rookeries in far northern WA (DEC, 2009a). The Lacepede Island rookery is the most significant green turtle rookery in WA (DEWHA, 2009a).




Source: RPS, 2010b; **Appendix C-2.**

- **Figure 1-47 Inter-nesting Distribution of Green Turtles.**

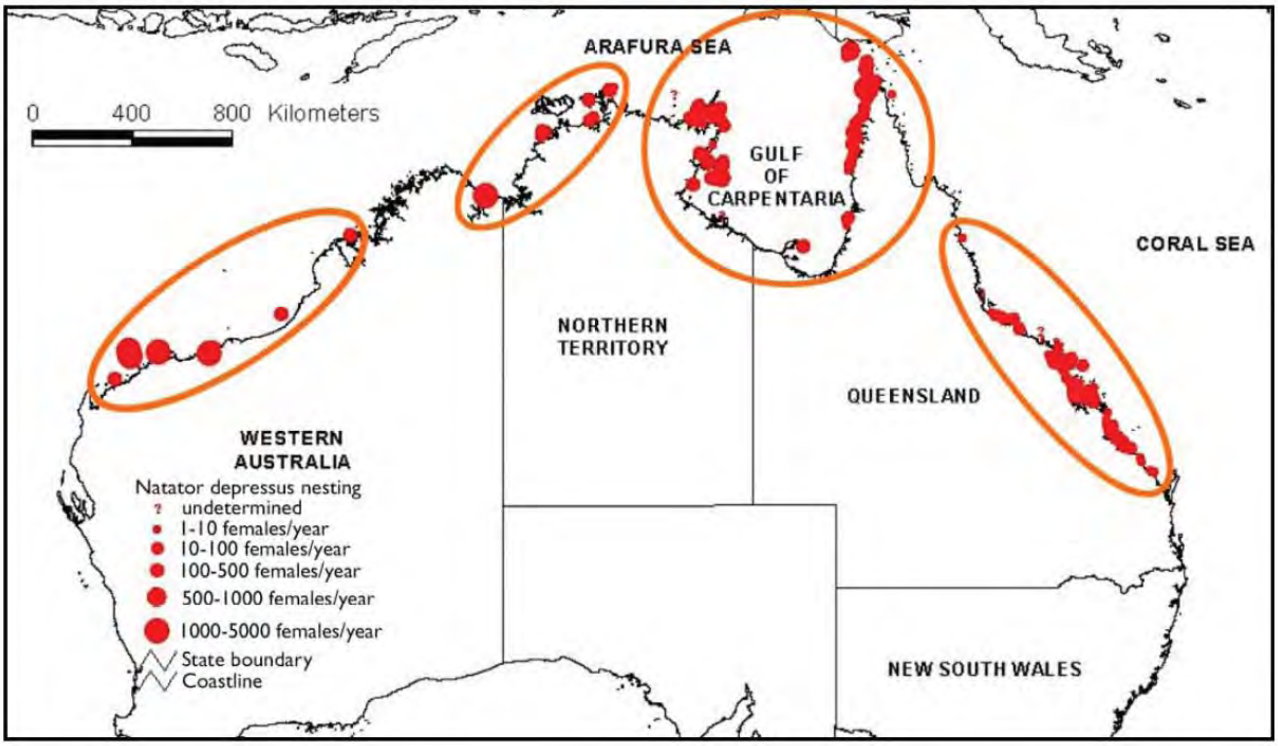
Tagging studies have found that the distance between nesting and foraging sites can range between 2 and 2,600km (Limpus *et al.,* 1992). Recent 2009 – 2010 satellite tagging results show distance of travel by post nesting females in northerly and southerly directions in the order of at least hundreds to thousands of kilometres (**Figure 1-48**). It has been noted that adult green turtles return to specific areas for different stages of their life-cycle throughout their lives, indicating a high level of fidelity to foraging sites (DEWHA, 2008a)


Source: RPS, 2010b; **Appendix C-2**.

- **Figure 1-48 Post-nesting Migration Pathways of Green Turtles Tagged at the Lacepede Island Group.**

*Flatback Turtles*

The flatback turtle (*Natator depressus*) is known to have major nesting rookeries in northern WA. Breeding has been recorded from Exmouth in the Pilbara to Cape Domett on the Kimberley Coast and represents one of the four genetic stocks in Australia (Limpus, 2007) (**Figure 1-49**). Breeding along the North West coast occurs in summer, with several rookeries on Barrow Island, Montebello Islands, Thevenard Island, Lowendal Islands, and the islands of the Dampier Archipelago and Kimberley coast (Limpus *et al*., 1983).



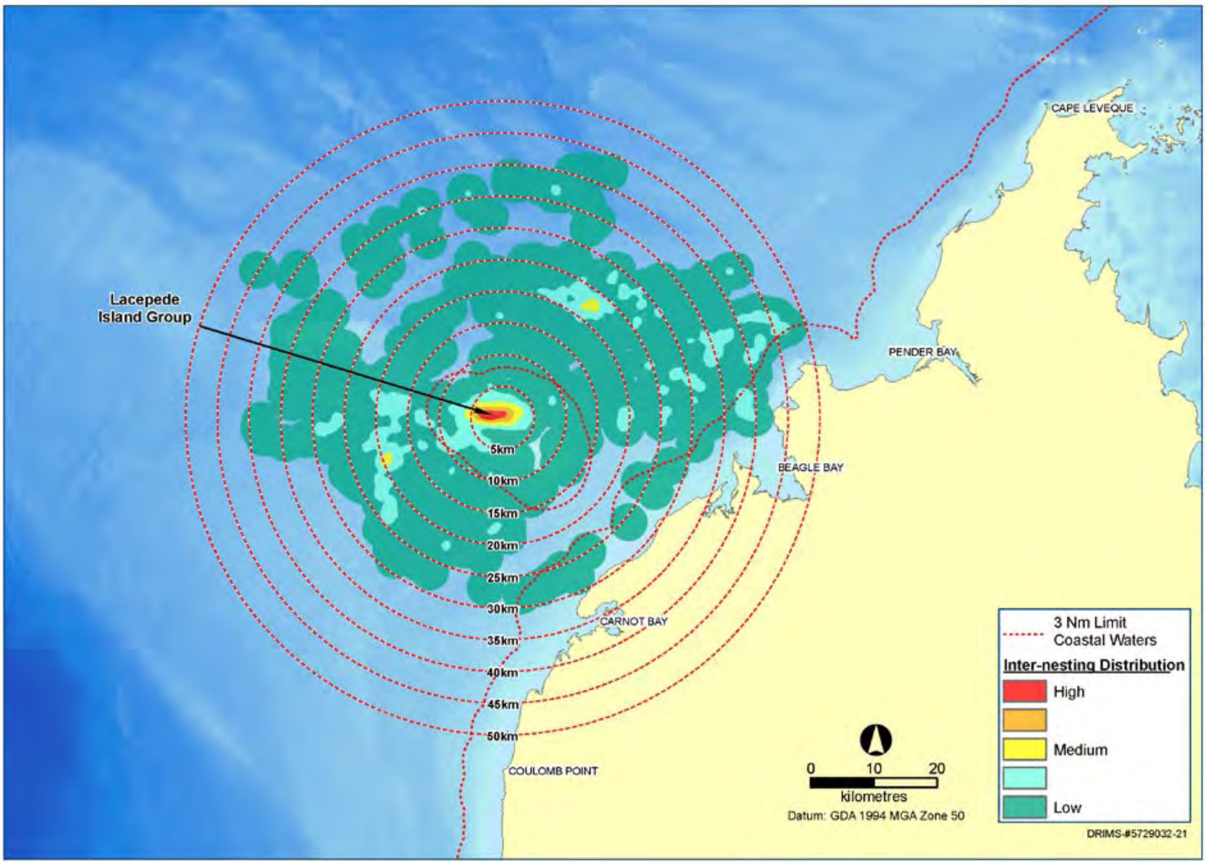

Source: RPS, 2010b; **Appendix C-2**.

- **Figure 1-49 Distribution of Known Flatback Turtle Management Units in Australia.**

Nesting has also been recorded on the Lacepede Islands (Kenneally *et al*., 1996). Within the region, Eighty Mile Beach, south of Broome, is a known nesting area for flatback turtles supporting 100 to 500 turtles according to the Marine Turtle Interactive Mapping System (United Nations Environment Programme/Convention on the Conservation of Migratory Species of Wild Animals www.unep-wcmc.org) (Limpus, 2007). Flatback turtles, which are known to nest at Barrow Island, have also been reported in waters near Quondong Point (DEWHA, 2008a and Seaturtle Org., 2010).

Turtle nesting activity (potentially flatbacks) was recorded in March 2009 at Quondong Beach and to the south of Quondong Point (recent tracks and numerous body pits respectively) and to the south of James Price Point (Biota, 2009a). The nesting density in the area has not been quantified, but is likely to be relatively very low due to the unsuitability of the local beaches (Biota, 2009a). There are no available records of the nesting characteristics (for example number of clutches laid, size of clutches, clutch success, re-nesting interval or nest site fidelity) for flatback turtle rookeries in the Kimberley. Based on field observations during peak nesting and hatching activity (period from November – March), the beaches of James Price Point coastal area do not to provide a significant rookery (RPS, 2010b; **Appendix C-2**).

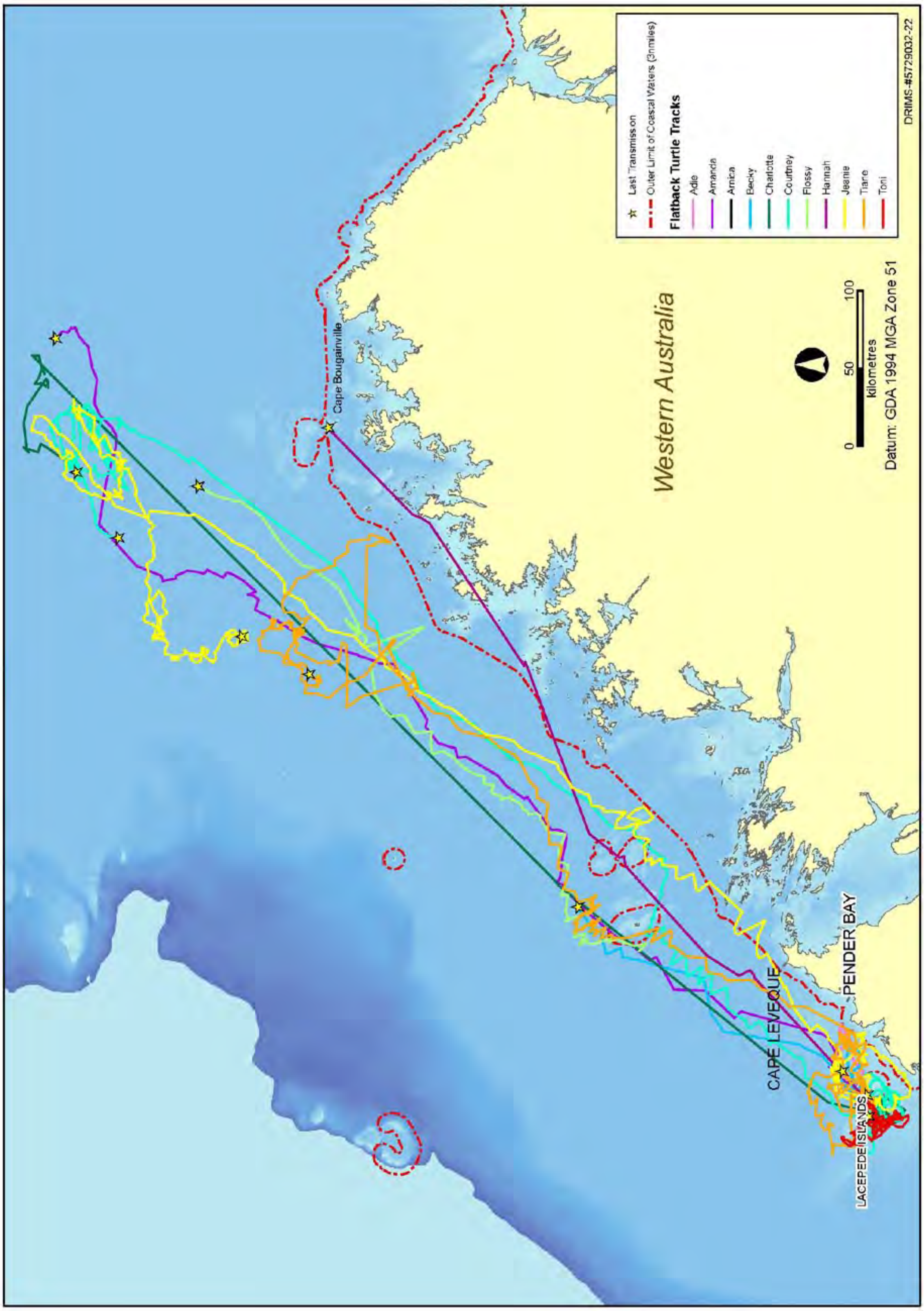
Based on inter-nesting behaviour and survey data, the peak flatback nesting season at the Lacepede Islands is during the summer months (November to February) (**Figure 1-50**). At Cape Dommett, 735km north east of James Price Point in the East Kimberley, nesting occurs year round with a winter peak (June to August) (DEC, 2009a).




Source: RPS 2010b; **Appendix C-2**.

- **Figure 1-50 Inter-nesting Distribution of Flatback Turtles.**

Flatback turtles are known to feed throughout Australian continental shelf waters (Limpus, 2004). Workshop minutes (DEC, 2009a) document that tag recovery and satellite-tracking programs indicate migration along the continental shelf. During the inter-nesting period, satellite-tracked flatback turtles remained within approximately 50 km of the nesting location at the Lacepede Islands (**Figure 1-50**). Satellite-tracked flatback turtles outside the nesting periods have been shown to move large distances (exceeding hundreds of km) from the Pilbara to the Kimberley (RPS, 2010b; **Appendix C-2**). 2009 – 2010 satellite tracking data show post nesting migration of female flatbacks from the Lacepede Islands consistently moving towards the north east, away from the Dampier Peninsula coastline (**Figure 1-51**).




Source: RPS, 2010b; **Appendix C-3**.

- **Figure 1-51 Post-nesting Migration Pathway of Flatback Turtles Tagged at the Lacepede Island Group.**

*Hawksbill Turtles*

The hawksbill turtle (*Eretmochelys imbricata*) breeds predominantly in WA from North-west Cape to the Dampier Archipelago (Moritz *et al.,* 2002 and Dutton *et al*. 2002). The major rookeries for Hawksbill Turtles are in the Dampier Archipelago, the Montebello Islands and the Lowendal Islands (Limpus, 2004) well to the south of the west Kimberley region. Hawksbill turtles nest all year round, but the peak nesting period is typically between July and September in northern Australia (Limpus *et al.,* 1992). Therefore, the peak hatching period in WA is expected to be between December and March. The feeding areas of hawksbill turtles in WA are largely unknown, however, it has been suggested that they commonly feed on the reefs adjacent to the mainland Kimberley coast (Prince, 1994), and may migrate up to 2,400km between their nesting and foraging grounds (DEWHA, 2008a). There were no confirmed sightings of hawksbill turtles during the 2009 surveys (RPS, 2010b; **Appendix C-2**), but they are generally associated with rocky and coral reef habitats, foraging on sponges and soft corals (Pendoley, 2005) so it may occur along the Dampier Peninsula nearshore waters.

*Loggerhead Turtles*

Loggerhead turtle (*Caretta caretta*) rookeries in WA generally occur between Shark Bay and Ningaloo (Dutton *et al.,* 2002), and occasional records as far north as Ashmore Reef (DEWHA, 2008a). The survey conducted (RPS, 2010a; **Appendix C-8**) found loggerhead turtles were widely distributed but were not recorded in water less than 20m deep. At the DEC (2009c) workshop it was stated that a loggerhead turtle tag was recovered by the WA DEC from the immediate area of James Price Point. It was also noted that loggerheads move north from the Lacepede Islands to an unknown location inside the continental shelf. It is likely that loggerhead turtles migrate through the Kimberley region between foraging and breeding areas (RPS, 2010a; **Appendix C-8**) and animals were observed foraging in coastal waters off the Canning Marine Bioregion during 2009 surveys. Loggerheads are known to forage across a wide range of habitats including rocky and coral reefs, seagrass patches and estuaries (DEWHA, 2008a).

*Leatherback Turtles*

The leatherback turtle (*Dermochelys coriaceae*) is unlikely to occur near James Price Point given that no confirmed breeding occurs in WA and its populations within the Indo-Pacific region are in significant decline (Limpus, 2004). There were no confirmed sightings of leatherback turtles during the (RPS, 2010b; **Appendix C-2**) surveys. High densities of foraging leatherback turtles are not likely to occur in the vicinity of the proposed development sites (RPS, 2010b; **Appendix C-2**). At the DEC (2009a) workshop it was stated that leatherbacks may occur but not likely frequently in WA waters. Queensland EPA tag recovery programs indicate leatherback turtles move between WA and Indonesia.

*Olive Ridley Turtles*

Olive ridley turtles (*Lepidochelys olivacea*) are not known to nest in WA, or further west than Darwin in the NT (DEWHA, 2009a). Records of this species come from a few individuals caught by fishers off the Kimberley-Pilbara coast (Robins *et al.,* 2002), however they are known to forage as far south as the Dampier Archipelago (DEWHA, 2008a). The species is known to forage in habitats ranging in depth from 6 to 35m (DEWHA, 2008a). There were no confirmed sightings of olive ridley turtles during RPS (2010a; **Appendix C-8**) surveys. Olive ridley turtles have been recorded nesting in WA only twice, both times in the Kimberley region (RPS, 2010b; **Appendix C-2**). Given the very low density of olive ridley turtles nesting in WA, it is unlikely that olive ridley turtles aggregate in the Kimberley region for mating.

#### 1.4.4.2. Crocodiles

Both saltwater (*Crocodylus porosus*) and freshwater (*C. johnstoni*) crocodiles are known to occur within marine and estuarine waters of the Kimberley region and are listed marine species under the EPBC Act 1999. The James Price Point coastal area supports neither estuarine nor mangrove environments so is not considered a significant crocodile habitat. Whilst crocodiles were not recorded during the July or September 2009 surveys, one individual and evidence of another were observed during a turtle survey on the Lacepede Islands (RPS, 2010b; **Appendix C-2**). During a turtle survey that occurred in December 2009, one saltwater crocodile of almost 2m in length was observed basking on the eastern beach of West Island of the Lacepedes. In January 2010, a fresh crocodile track was noted on Manari Beach, approximately 10km north of James Price Point. The limited number of crocodile sightings throughout the surveys indicates that none of the areas surveyed, including onshore and offshore areas of the potential development footprint, provide important habitat or foraging areas for these animals (RPS, 2010a; **Appendix C-8**). Individuals present are likely to occur only infrequently and to be transient in their seaward migrations to favourable estuarine habitats elsewhere in the region.

### 1.4.4.3. Sea Snakes

**Regional Environment**

Sea snakes have been recorded along the Kimberley coastline in large numbers. In the wider region, the offshore reefs are an important area for sea snakes. Few areas have such a diversity or abundance of sea snake species (Guinea and Whiting, 2005). For example, large populations have been recorded at Ashmore Reef (approximately 600km from James Price Point), studies from 1994 to 1998 estimated the sea snake population at approximately 40,000 or 228/km$^2$ (Guinea and Whiting, 2005). All species of sea snakes are listed under the EPBC Act. All but five of Australia's sea snake species are found in the Kimberley. The species of sea snakes that may occur in the James Price Point area are discussed below.

**Dampier Peninsula**

Aerial surveys conducted in 2008 along the southwest Kimberley coastline observed a total of 169 individuals over ten survey days between July and October (Jenner and Jenner, 2009; **Appendix C-11**). An aerial survey along the Dampier Peninsula (up to approximately 150km north-north east of James Price Point), observed a total of 80 sea snakes over a series of 63 aerial transects from the 19 to the 26 March 2008 (Jenner and Jenner, 2009; **Appendix C-11**). The highest density of sea snakes was recorded between Cape Latreille and Low Sandy Point with all sightings beyond the 10m depth contour (**Figure 1-52**). These sightings could not be identified to species level, however, species known to occur in the region include the olive sea snake (*Aipysurus laevis*) (Lukoschek *et al.,* 2007).

**James Price Point Coastal Area**

Sea snakes were the most commonly sighted fauna group along the Dampier Peninsula coast during the nearshore regional aerial surveys (RPS, 2010d; **Appendix C-10**). The species of sea snakes that may occur in the James Price Point area are provided in **Table 1-24**.

- **Table 1-24 Sea Snakes that may be Found in the James Price Point Coastal Area.**

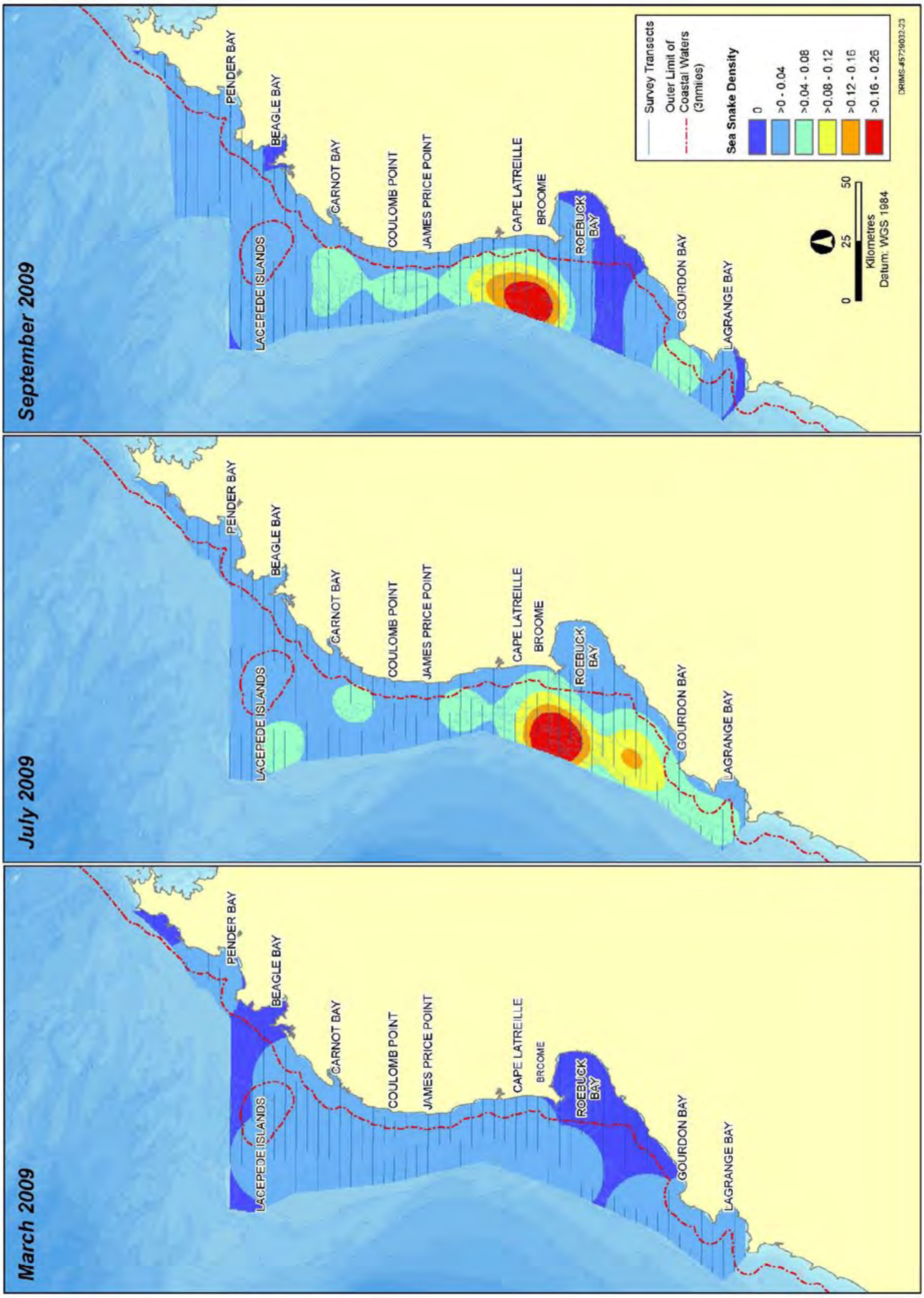
| Common Name | Scientific Name |
|---|---|
| Horned sea snake | *Acalyptophis peronii* |
| Short-nosed sea snake | *Aipysurus apraefrontalis* |
| Dubois' sea snake | *Aipysurus duboisii* |
| Spine-tailed sea snake | *Aipysurus eydouxii* |
| Leaf-scaled sea snake | *Aipysurus foliosquama* |
| Dusky sea snake | *Aipysurus fuscus* |
| Olive sea snake | *Aipysurus laevis* |
| Brown-lined sea snake | *Aipysurus tenuis* |
| Stokes' sea snake | *Astrotia stokesii* |
| Spectacled sea snake | *Disteira kingie* |
| Olive-headed sea snake | *Disteira major* |
| Turtle-headed sea snake | *Emydocephalus annulatus* |
| North-western mangrove sea snake | *Ephalophis greyi* |
| Black-ringed mud/sea snake | *Hydrelaps darwiniensis* |
| Elegant sea snake | *Hydrophis elegans* |
| Small-headed sea snake, McDowell's sea snake | *Hydrophis mcdowelli* |
| Spotted sea snake | *Hydrophis ornatus* |
| Spine-bellied sea snake | *Mapemis hardwickii* |

During the BRUVS 2009 survey (which primarily targeted fish), two sea snakes were recorded and identified to species level: the olive sea snake (at 12.3% of sites) and the ornate sea snake (at 0.6% of sites) (Cappo *et al.,* 2010b; **Appendix C-6**). While sea snakes occur throughout the region, the James Price Point coastal area is not known to represent an important sea snake habitat.

Sea snakes were distributed across the entire nearshore regional survey area and throughout the other survey areas, from Lagrange Bay north to Pender Bay (**Figure 1-52**).The majority of sightings during July and September were in waters between 10 to 50m deep. As most species of sea snake occupy small home ranges (DEWHA, 2008a), these animals are likely to be resident in the region, in abundance, rather than being highly mobile and variable through the year (RPS, 2010d; **Appendix C-10**).

The highest relative density of sea snakes was approximately 30km west of Broome in ocean depths of 10 to 20m. Regular sightings of sea snakes were also obtained west of Carnot Bay, west of Lacepede Island and west of Cape Latouche Treville. Previously, sea snakes in the Kimberley have been reported to be in highest numbers in Pender Bay, however, the more recent study did not specifically target sea snakes (RPS, 2010d; **Appendix C-10**).

Although the spatial pattern of sea snake density was generally similar between July and September 2009, there was a relatively low density of sea snakes in and around Roebuck Bay in March and September. Sea snakes were at a consistently moderate density over the 10 to 20m isobaths offshore from Carnot Bay, James Price Point and Cape Letouche Treville, in relation to surrounding areas (RPS, 2010d; **Appendix C-10**).




Source: RPS, 2010d; **Appendix C-10**.

- **Figure 1-52 Sea snake Density (animals per km$^2$) in the James Price Point Coastal Area during March, July and September 2009 Aerial Surveys.**

#### 1.4.4.4. Cetaceans

**Geographical Distribution and Abundance**

A large number of cetaceans occur in the Kimberley region and many are listed as specially protected species under Commonwealth and WA (State) legislation. As matters of National Environmental Significance (**NES**), the EPBC Act protects two threatened cetacean species and seven migratory cetacean species that may occur or are likely to occur within the Kimberley region:

- humpback whale (*Megaptera novaeangliae*) – vulnerable, migratory;
- pygmy blue whale (*Balaenoptera musculus brevicauda*) – endangered, migratory;
- Antarctic minke whale (Dark-shoulder minke whale) (*Balaenoptera bonaerensis*) – migratory;
- Bryde's whale (*Balaenoptera edeni*) – migratory;
- snubfin dolphin (*Orcaella heinsohni*) – migratory;
- killer whale, orca (*Orcinus orca*) – migratory;
- sperm whale (*Physeter macrocephalus*) – migratory;
- Indo-Pacific humpback dolphin (*Sousa chinensis*) – migratory; and
- spotted bottlenose dolphin (Arafura/Timor populations) (*Tursiops aduncus*) – migratory.

These species are considered in further detail below. The EPBC Act also gives status to other cetaceans as 'listed marine' species including toothed whales and dolphins.

Recent aerial and vessel-based surveys were undertaken during the period of July to mid-October 2009 with a focus on James Price Point but extending along the west Kimberley coast to acquire regional data. A number of small cetaceans were identified through the course of the surveys. Dolphins were commonly sighted throughout the survey period and area and included bottlenose, spinner, Indo-Pacific humpback and snubfin species. Only two sightings of Indo-Pacific humpback dolphins were recorded and snubfin dolphin observations were restricted to Roebuck Bay. Bottlenose dolphins were the most frequently observed and it is likely that both species of bottlenose (*Tursiops truncatus* and *T. aduncus*) are present in the survey area year round (RPS, 2010d; **Appendix C-10**).

**Humpback Whales**

The humpback whale (*Megaptera novaeangliae*) is a moderately large baleen whale with a maximum recorded length of 17.4m. Females are generally 1.0–1.5m longer in length in comparison to males (DEWHA, 2009c). Humpback whales annually migrate between their summer feeding grounds in Antarctica to their tropical breeding grounds in winter. The exact timing of the migration period can vary from year to year, depending on water temperature, sea ice, predation risk, prey abundance and the location of the feeding ground (DEWHA, 2009e). The Kimberley region is considered particularly important for the 'Group IV' humpback whale population (that is the group which migrates along the WA coast), whose breeding and calving grounds are thought to be between the Lacepede Islands and Beagle Bay in the south and Camden Sound in the north with high concentrations of humpbacks observed in the region between early June and September each year (DEWHA, 2009e, and Jenner *et al.,* 2001).

Humpback whale feeding primarily occurs in summer in Antarctic waters south of latitude 55°S with krill (in particular *Euphausia superba*) forming the major part of their diet (DEWHA, 2009c). Feeding appears to be related to krill density rather than particular bathymetric features. Research has shown the peak feeding season is mid-January to February with dispersal as the season progresses (Kasamatsu *et al*., 1996). Some feeding has been observed in Australia's coastal waters but this is thought to primarily be opportunistic and forms only a small portion of their nutritional requirements (DEWHA, 2009c).

Knowledge of the humpback whales along the Kimberley region has increased considerably since the mid-1990s. Since cessation of whaling for humpback whales off WA's coast and in the Southern Ocean, the 'Group IV' population has increased by about 10% per annum and, in 2008, was estimated to comprise some 21,750 (95% CI:17,550-43,000) animals during the northward migration (Hedley *et al.*, 2009).

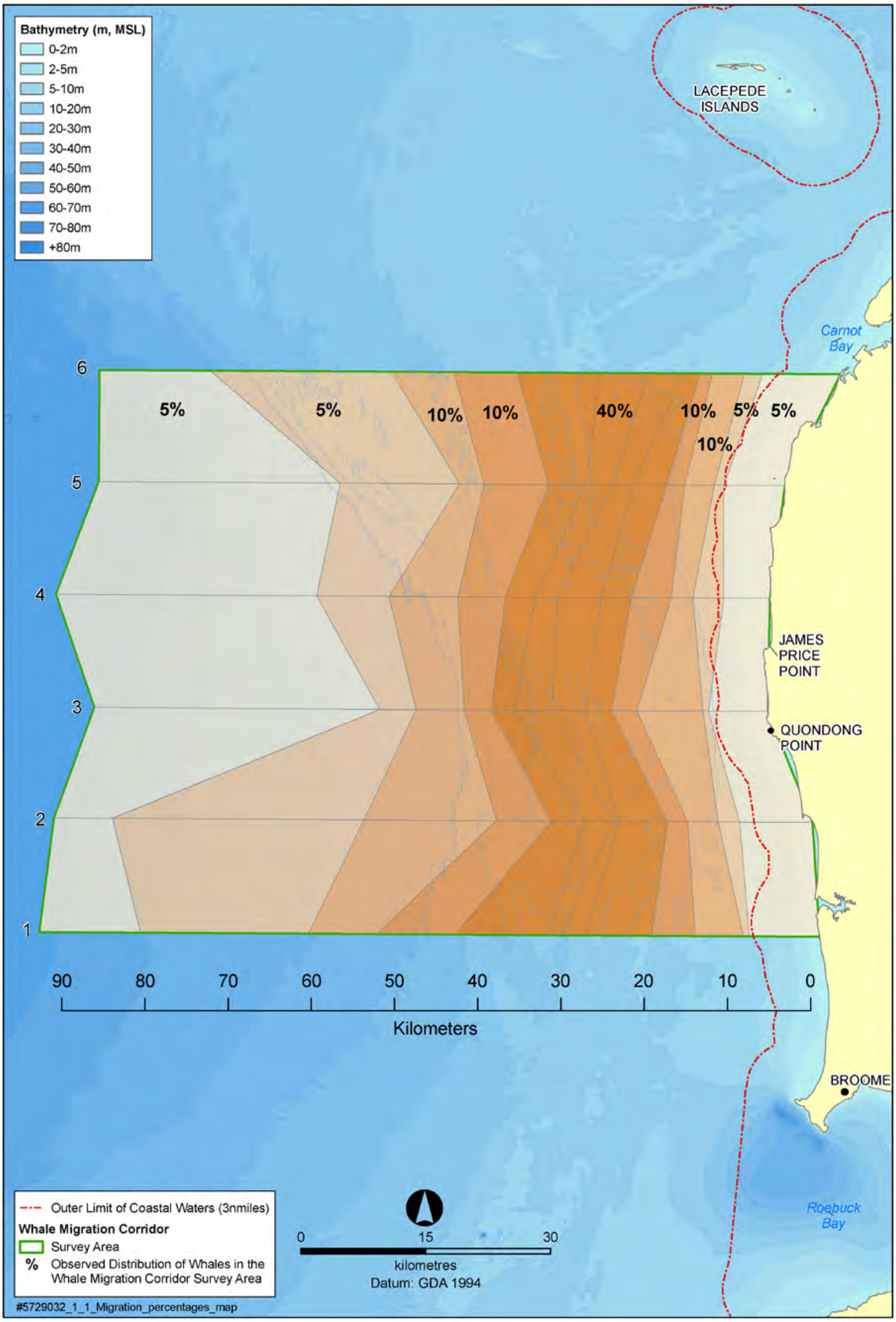
During migration, there is a temporal separation of individuals related to sex and reproductive status. On the northern migration, lactating females accompanied by weaning yearlings are first to migrate, followed by immature males and

females, followed by mature males together with resting females and then pregnant females. On the southern migration, mixed females (including those in early pregnancy) and immature males and females are first to migrate, followed by mature males and then females with calves in early lactation (DEWHA, 2009c). Rates of natural mortality are unknown but humpback whale calves are particularly vulnerable to predation by killer whales and sharks, and may also die from natural parasitic or disease events (DEH, 2005b).

Humpback whales reach sexual maturity at four to eight years (average five years). Life expectancy is recorded as at least 48 years but is likely to be significantly longer as shown in other baleen whales. For humpback whales, breeding peaks in the winter and the gestation period is 11 to 12 months. Lactation extends over 10 to 12 months although calves have been seen independently feeding at six months of age. The mean calving interval is 2.4 years although it ranges from one year to more than five years. This low rate of reproduction has implications for the ability of a population to recover (DEWHA, 2009c) and this should be interpreted relative to the known trend of increasing humpback whale Group IV population abundance.

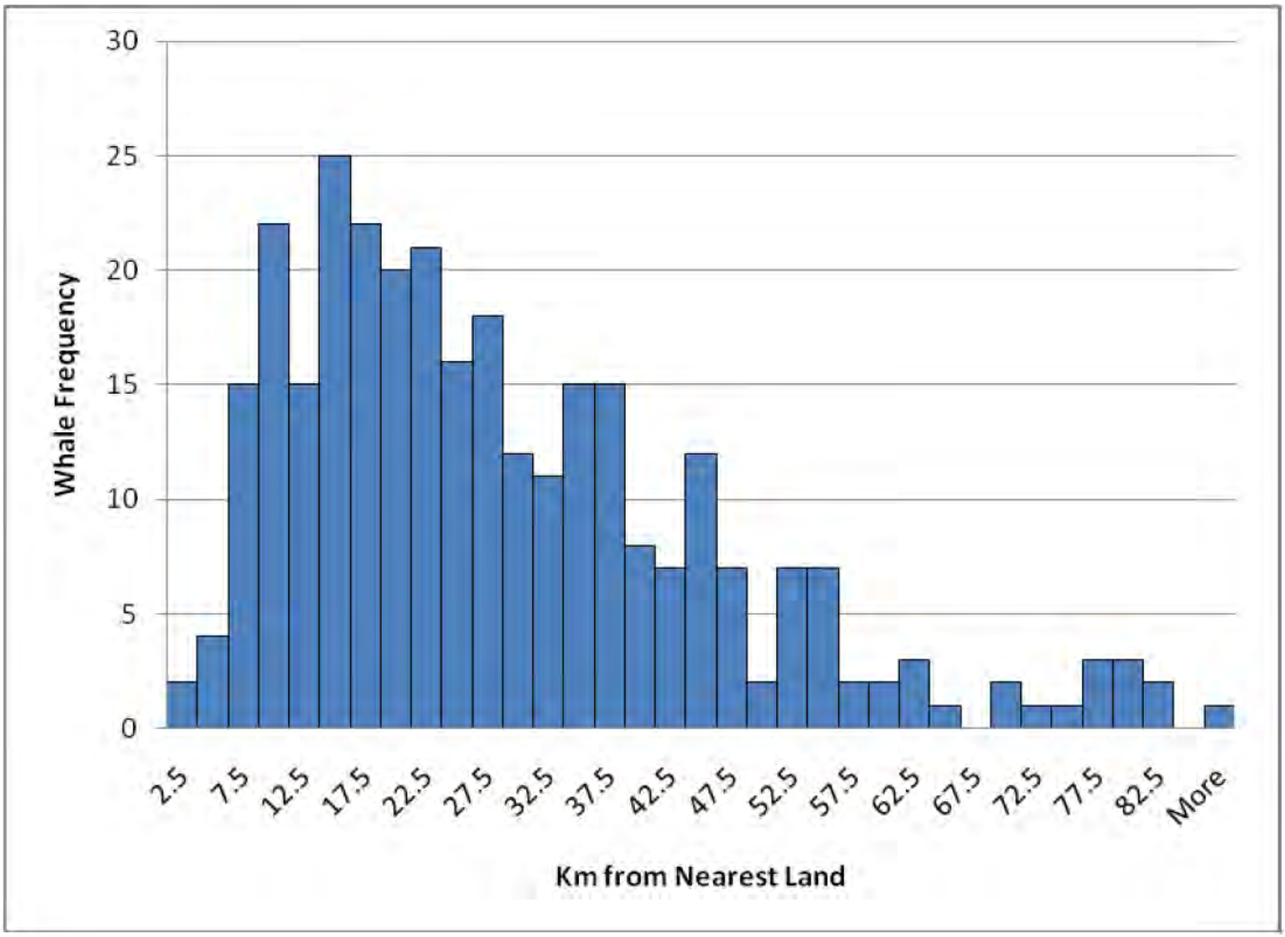
During the 2009 migration season, a series of aerial and vessel surveys were conducted with a focus on the migration corridor offshore the Dampier Peninsula (centred offshore from James Price point) but also extending along the coast of the Canning Bioregion and offshore to Scott Reef. During the northward migration approximately 13,000 (95% CI: 3,138–36,729) humpbacks were estimated to pass through the James Price Point migration corridor survey area. This indicates that potentially a substantial portion of the population may bypass the area, either travelling further offshore than the migration corridor survey area (further than 90km offshore) or terminating their migration further to the south (RPS, 2010a; **Appendix C-8**).

The 2009 migration corridor survey showed that the majority of humpback whales passing the Dampier Peninsula coast follow a corridor that extends from approximately 8 to 42km from the shore within the 10 to 50m depth contours (**Figure 1-53** and **Figure 1-54**) (RPS, 2010a; **Appendix C-8**). 95% of humpback whales travel further than 8km off the James Price Point Coastal area, with a mean distance for adults of 27km from the shore and 24km for calves indicating that calves were travelling slightly closer to shore (RPS, 2010a; **Appendix C-8**). Sightings ranged from 0.2km to 86.5km from shore, but were generally concentrated between 8km to 42km from shore and particularly along the 20m depth contour (**Figure 1-53**). Whales were also sighted in lower numbers offshore at the very western end of survey transects, suggesting that some whales also migrated further offshore.




Source: RPS, 2010a; **Appendix C-8**.

- **Figure 1-53 James Price Point Migration Corridor Survey Area.**




Source: RPS, 2010a; **Appendix C-8**.

- **Figure 1-54 Humpbacks Sightings between Carnot Bay and Cape Latreille from July to September 2009.**

Note: Distance from the nearest landfall as a proportion of total counts (n=304).

During migration, individuals travel alone or in temporary aggregations of generally non-related individuals (cow-calf pairs being the exception) (DEWHA, 2009e). The whales aggregate on the breeding grounds where males compete for access to females in oestrous. The exact timing of the migration period can vary from year to year, however the northern humpback whale migration occurs generally from June to early September, with the peak of the northward migration occurring in August. Breeding and calving takes place in the Kimberley in an area north of the Dampier Peninsula between the Lacepede Islands and Camden Sound (Jenner *et al*., 2001) between mid-August and early September. The southern migration peaks for cows with calves generally in mid September (RPS, 2010a; **Appendix C-8**).

Aerial surveys found that the peak in the northern migration of adult humpback whales occurs over approximately a three week period (RPS, 2010a; **Appendix C-8**). Offshore from James Price Point, peak numbers of adult whales were recorded during early August in the 2008 season and slightly later in mid August in the 2009 season (Jenner and Jenner, 2009; **Appendix C-11** and RPS, 2010a; **Appendix C-8**). Cow-calf pairs were present for the entire survey period from early July to mid October, however, the peak in calf numbers offshore of the JPP coastal area occurred in early September during both the 2008 and 2009 surveys, 2-3 weeks later than adult humpback whales (RPS, 2010a; **Appendix C-8**).

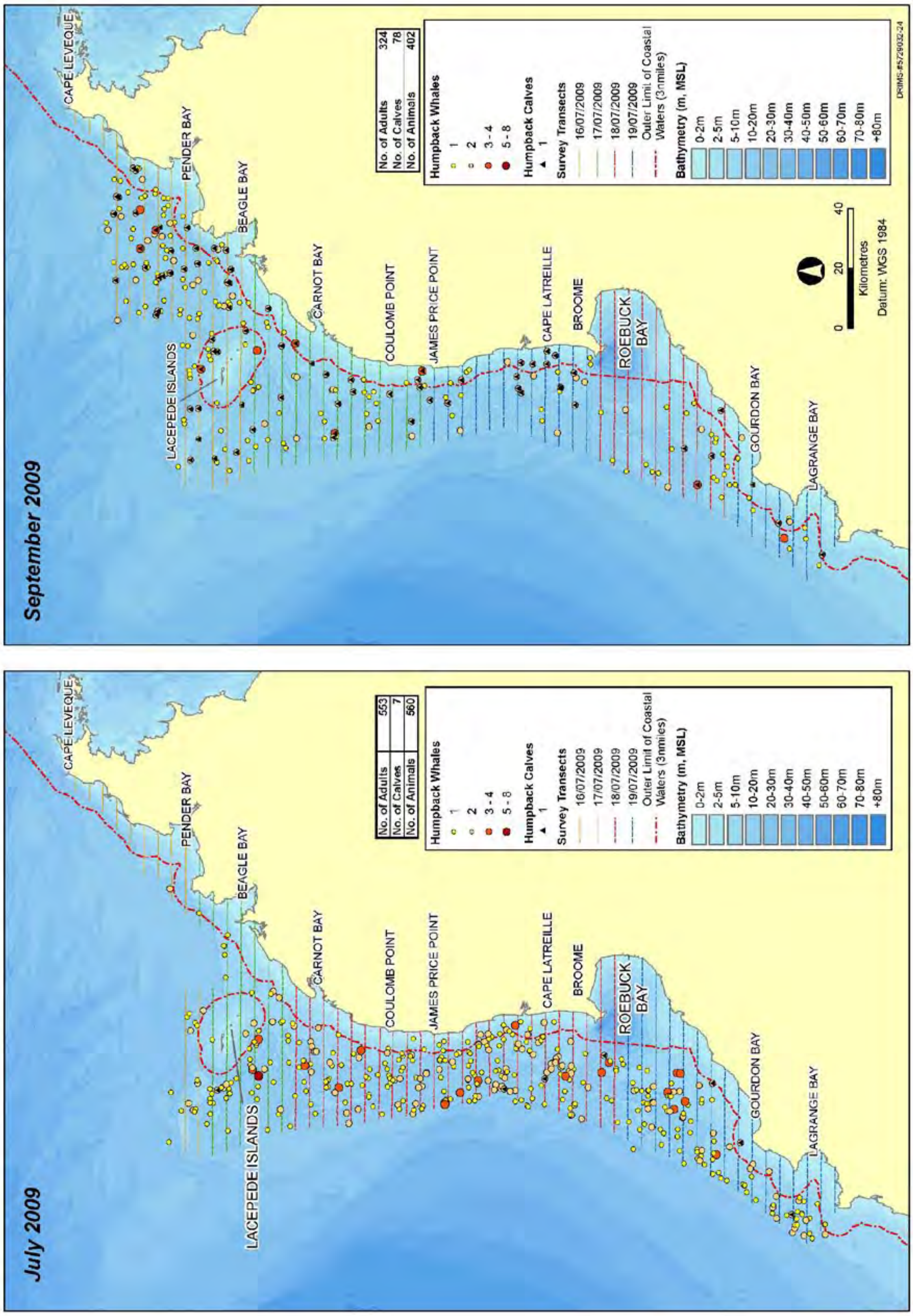
Observations of the direction of travel during the 2009 surveys indicated that most humpback whales recorded prior to mid August were heading north. Between mid August and mid September there was no discernable trend in travel direction and after mid September the trend was in a south and west direction (RPS, 2010a; **Appendix C-8**).

Behavioural activity in the JPP coastal area was dominated by travelling (approximately 50% of the time), with resting (approximately 20%) and surface active (about 5%) also common. There was no significant difference in the proportion

of time devoted to resting, active and travelling behaviours between James Price Point and Pender Bay and the speed that whales were recorded travelling was similar in both areas.

The relative abundance patterns showed that humpback numbers increased from south to north, based on intensive survey at three locations, with Gourdon Bay the “least occupied” location, James Price Point of “intermediate use” and Pender Bay occupied significantly more with the highest mean number of calves and adults. Pender Bay appears to be an area of particular importance to humpback whales, supporting 1.5 times more adult whales and three times more calves than at James Price Point survey area throughout the 2009 season (RPS, 2010a; **Appendix C-8**).

During the July nearshore regional surveys, high densities of humpback whales were observed along the coast of the Dampier Peninsula from Gourdon Bay in the south, passing offshore from James Price Point, as they migrate northwards (**Figure 1-55**) (RPS, 2010a; **Appendix C-8**). During the mid September surveys, the highest density of animals was recorded west of Pender Bay.




Source: RPS, 2010a; **Appendix C-8**.

- **Figure 1-55 Humpback Whale Density During the July 2009 (left panel) and September (right panel) Nearshore Regional Aerial Surveys.**

Note: Animals continue to move through the survey area northwards towards Camden Sound.

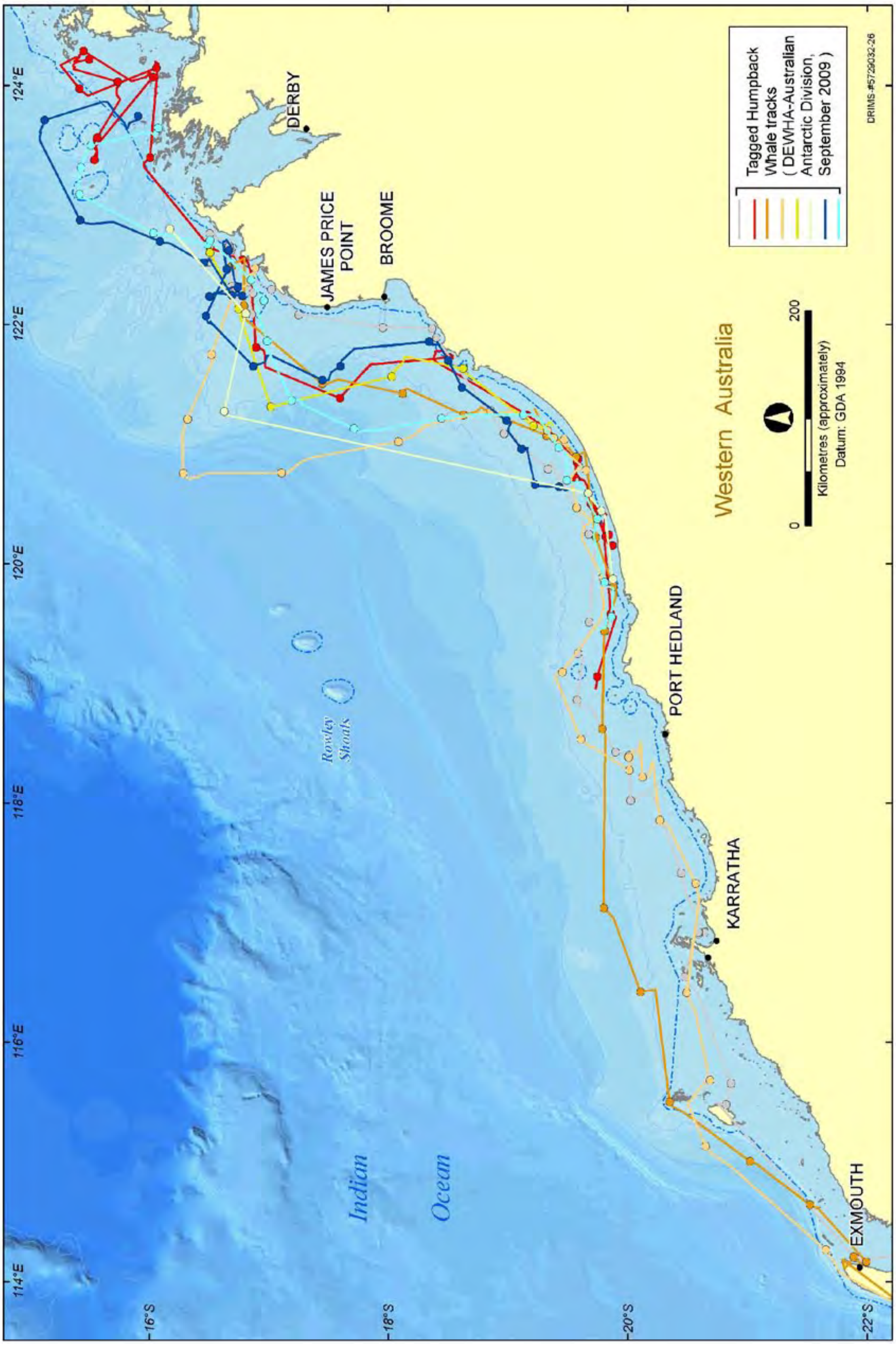
On the basis of data collected over a 10 year period, there is an important humpback whale calving and resting area between the Lacepede Islands and Beagle Bay in the south and Camden Sound in the north (DEC,2009b; Jenner *et al*., 2001 and Jenner and Jenner, 2009; **Appendix C-11**). The significantly higher numbers of calves recorded at Pender Bay than either James Price Point or Gourdon Bay throughout the 2009 survey supports the assertion that the calving grounds lie to the north of Lacepede Islands and Beagle Bay (RPS, 2010a; **Appendix C-8**).

The 2009 survey results, along with those of a satellite tagging study conducted by Double *et al.* (2010), indicate the existence of a split migratory pathway in the region. An unquantified number of whales appear not to migrate past James Price Point and Gourdon Bay on the northward migration and many humpback whales and calves apparently travel due west from Pender Bay on the southward migration, remaining far offshore of James Price Point.

During the northward migration approximately 13,000 (95% CI: 3,138–36,729) humpbacks were estimated to pass through the James Price Point migration corridor survey area. This indicates that potentially a substantial portion of the population may bypass the area, either travelling further offshore than the migration corridor survey area (further than 90km offshore) or terminating their migration further to the south.

During the southward migration whales appear to be more widely dispersed, with no distinct peak migration period being detected during the migration corridor surveys. These observations were further supported by the results of a satellite tagging survey undertaken in September 2009 (Double *et al.,* 2010). Of the eight female humpback whales with calves tracked between Pender Bay (80km north of James Price Point) and Eighty Mile Beach (south of Broome) during their southern migration, seven migrated westward around the Lacepede Islands (**Figure 1-56**) and only one cow calf pair migrated southwards between the coastline and the Lacepede Islands and continued following closely to the Dampier Peninsula coast (Double *et al.,* 2010). Some of the cow calf pairs were tracked travelling up to 200km out to sea before turning south and re-connecting with the coast near Eighty Mile Beach.

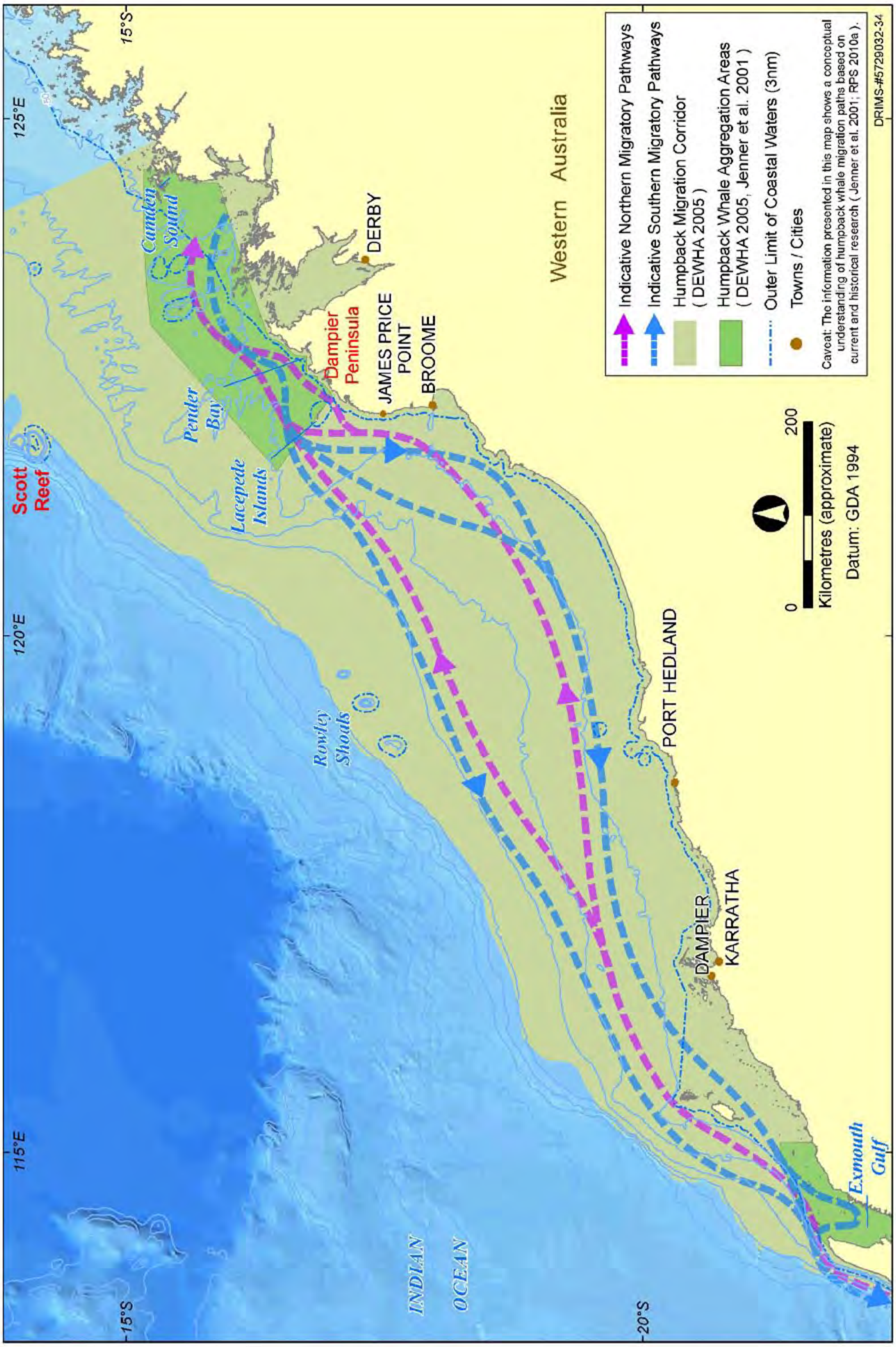
**Figure 1-57** illustrates the current knowledge of the migration route with some humpbacks moving through the coastal migration corridor and a portion remaining further offshore during the northern migration, while the southern migration is more dispersed with fewer whales using the coastal corridor.




Source: Double *et al*., 2010.

- **Figure 1-56 Tracks Obtained from 17 of the 23 Satellite-tagged Female Humpback Whales.**

Note: Six tags provided few or no location data so not used.




- **Figure 1-57 Indicative Northern and Southern Migratory Pathways of the Humpback Whale along the North West Shelf and Kimberley Region.**

### Pygmy Blue Whale

The pygmy blue whales are a smaller subspecies of the southern blue whale growing to about 25m in length. In general, the pygmy blue whale is found in oceanic waters north of 55°S, and is largely confined to the tropical waters of the Indian Ocean, southern Australia and east to New Zealand (DEWHA, 2008a). Although little information is known about winter breeding grounds or aggregation patterns, the species is thought to aggregate in feeding areas, and then migrate to winter breeding grounds in tropical waters (DEWHA, 2010a). Three known areas of significance for the species are summer foraging grounds located at: the Perth Canyon, 22km west of Rottnest Island, WA; the Bonney Upwelling, South Australia and Victoria; and the Duntroon Basin, South Australia (DEH, 2005a). Other areas along the WA coastline may be used as migratory waypoints (DEWHA, 2008a), however, much of the Australian coastal waters are not considered to be significant to the whales (DEWHA, 2010a).

This baleen whale species was not identified during any of the 2009 surveys (RPS, 2010a; **Appendix C-8**). The pygmy blue whale was detected by noise loggers offshore from Scott Reef and suggests that the presence of this species in areas surveyed may be intermittent (CMST, 2010).

### Antarctic Minke Whale

The Antarctic minke whale has been recorded in waters offshore from all States except the NT (Bannister *et al.,* 1996), however, the distribution of the species along the west coast of Australia is currently unknown (DEWHA, 2010b). During the Australia summer, the species is typically found throughout the southern hemisphere between 55°S and the Antarctic ice edge. However, during the Australian winter, the species retreats to oceanic breeding grounds in temperate to tropical waters (Mustoe and Edmunds, 2008). Although the species is likely to migrate through the Canning Bioregion, the Antarctic minke whale typically occupies offshore and pelagic habitats in temperate waters (Bannister *et al.,* 1996). In 2009, one dwarf minke whale was recorded in waters approximately 100m deep, halfway between the Kimberley coast and Scott Reef (RPS, 2010a; **Appendix C-8**). No Antarctic minke whales were observed RPS (2010a; **Appendix C-8**) in the 2008 and 2009 surveys respectively, however noise loggers detected calls in low numbers around Scott Reef over winter periods only (CMST, 2010).

### Bryde's Whale

The Bryde's whale is typically found in tropical and warm temperate waters between 40°N and 40°S, in both oceanic and inshore waters (DEWHA, 2010c and Bannister *et al.,* 1996). The species is the least migratory of the baleen whales, and is considered a tropical water specialist (Mustoe and Edmunds, 2008). The Bryde's whale is possibly a resident of the North-West region of Australia throughout the year (DEWHA, 2008c), concentrating its feeding in areas of high productivity over the continental shelf (Mustoe and Edmunds, 2008). In 2009, one Bryde's whale was recorded in waters approximately 20m deep, during the August/September vessel transect survey about 10km west of Coulomb Point (RPS, 2010a; **Appendix C-8**).

### Sperm Whale

The sperm whale is known to occur throughout the deep waters of the world's oceans, from the equator to the edges of the polar pack-ice, while females and young males are restricted to warmer waters (DEWHA, 2010d). It is thought that females and young male sperm whales would occur in the North-West region of Australia throughout the year (DEWHA, 2008a). Sperm whales are uncommon in waters shallower than 300m as they typically inhabit deep offshore waters from 600m depth (DEWHA, 2010d). They are therefore thought to be associated with canyons and areas where the seabed rises steeply from great depths (Bannister *et al.,* 1996 and DEWHA, 2008a).

### Killer Whale

The killer whale is the largest member of the dolphin family (DEWHA, 2008a), occurring throughout all oceans and neighbouring seas. The species are most populous in areas of high productivity, typically coastal and cool temperate waters (DEWHA, 2010e). The killer whale is highly mobile (migratory under the EPBC Act) and ranges over large distances often associated with occurrence of prey. In Australia, killer whales are generally found along the continental slope near seal colonies, but they are also known to follow migrating humpback whales, and are therefore likely migrants through the Kimberley region. Two killer whales were recorded during the humpback surveys (RPS, 2010a; **Appendix C-8**). One killer whale was recorded during the James Price Point migration corridor survey in water between 25 and 50m deep and approximately 35km north-west of James Price Point. Killer whales may be present in the Kimberley in greater numbers during the winter when humpback whales are present (RPS, 2010a; **Appendix C-8**).

#### Australian Snubfin Dolphin

The snubfin dolphin (*Orcaella heinsohni*) is known to occur within the waters off northern Australia, extending north from Broome in Western Australia to the Brisbane River in Queensland (DEWHA, 2010f). Surveys have indicated that the species is typically found in protected shallow nearshore waters, generally less than 20m deep, adjacent to river and creek mouths close to seagrass beds (DEWHA, 2010f).

The snubfin dolphin was not recorded during any of the aerial surveys undertaken for the project, but were observed in Roebuck Bay from vessels on several occasions (RPS, 2010d; **Appendix C-10**). Based on the extensive survey effort and amenable conditions within the James Price Point coastal area during survey, it is concluded that this species is seldom found outside of shallow and sheltered bays and inlets. However, it is thought that this species transits between sheltered areas, and therefore it is possible that individuals may occur within the coastal waters adjacent to James Price Point while not being resident (RPS, 2010d; **Appendix C-10**).

#### Indo-Pacific Humpback Dolphin

The Indo-Pacific humpback dolphin is typically found in tropical waters extending east from the Exmouth Gulf in WA to the Queensland/ New South Wales border (DEWHA, 2010g). A resident population of Indo-Pacific humpback dolphins are known to occur at Ningaloo Reef and Barrow Island (DEWHA, 2008a). The species is known to occur between estuarine and continental shelf waters, but is more commonly located in shallow coastal waters in depths of less than 20m (Mustoe and Edmunds, 2008 and DEWHA, 2008a). The species is also found in areas of high turbidity (Mustoe and Edmunds 2008), however, they display no preference for turbid or clear water (DEWHA; 2010g). Seven Indo-Pacific humpback dolphins were recorded during the vessel-based regional surveys in waters 20m deep during 2009 (RPS, 2010d; **Appendix C-10**). There were too few sightings (only two) of this species to establish any trends over time from the data. Indo-Pacific humpback dolphins are likely to be present in low numbers in nearshore waters (around the 20m isobath) and may also have been part of the unidentified dolphin records (RPS, 2010d; **Appendix C-10**) (**Figure 1-58**).

#### Bottlenose Dolphin

Bottlenose dolphins (*Tursiops spp.)* are distributed worldwide in temperate and tropical waters, in both coastal and offshore locations (DEWHA, 2009a and IUCN, 2009). These dolphins tend to be coastal, frequenting shallow coastal areas including estuaries, bays, lagoons and rivers (IUCN, 2009). In Australia, however, bottlenose dolphins have generally been found in offshore waters deeper than 30m, although they have also been recorded in some coastal areas (DEWHA, 2009a).

Bottlenose dolphins (*Tursiops spp.)* (DEC Priority 4), together with spinner dolphins, were the most commonly recorded small cetacean species offshore of James Price Point and Pender Bay, but were recorded mostly in small groups of up to five, and occasionally up to ten individuals (RPS, 2010d; **Appendix C-10**). The largest cluster of bottlenose dolphin groups was sighted in September 2009 (some 10 to 15km) south-west of James Price Point and the largest group with an estimated 25 animals, was recorded approximately 15km west of Gourdon Bay (RPS, 2010d; **Appendix C-10**) (**Figure 1-58**). It was not possible during the aerial and vessel surveys to determine whether they were spotted or common bottlenose dolphins, but it is likely that both species were present.

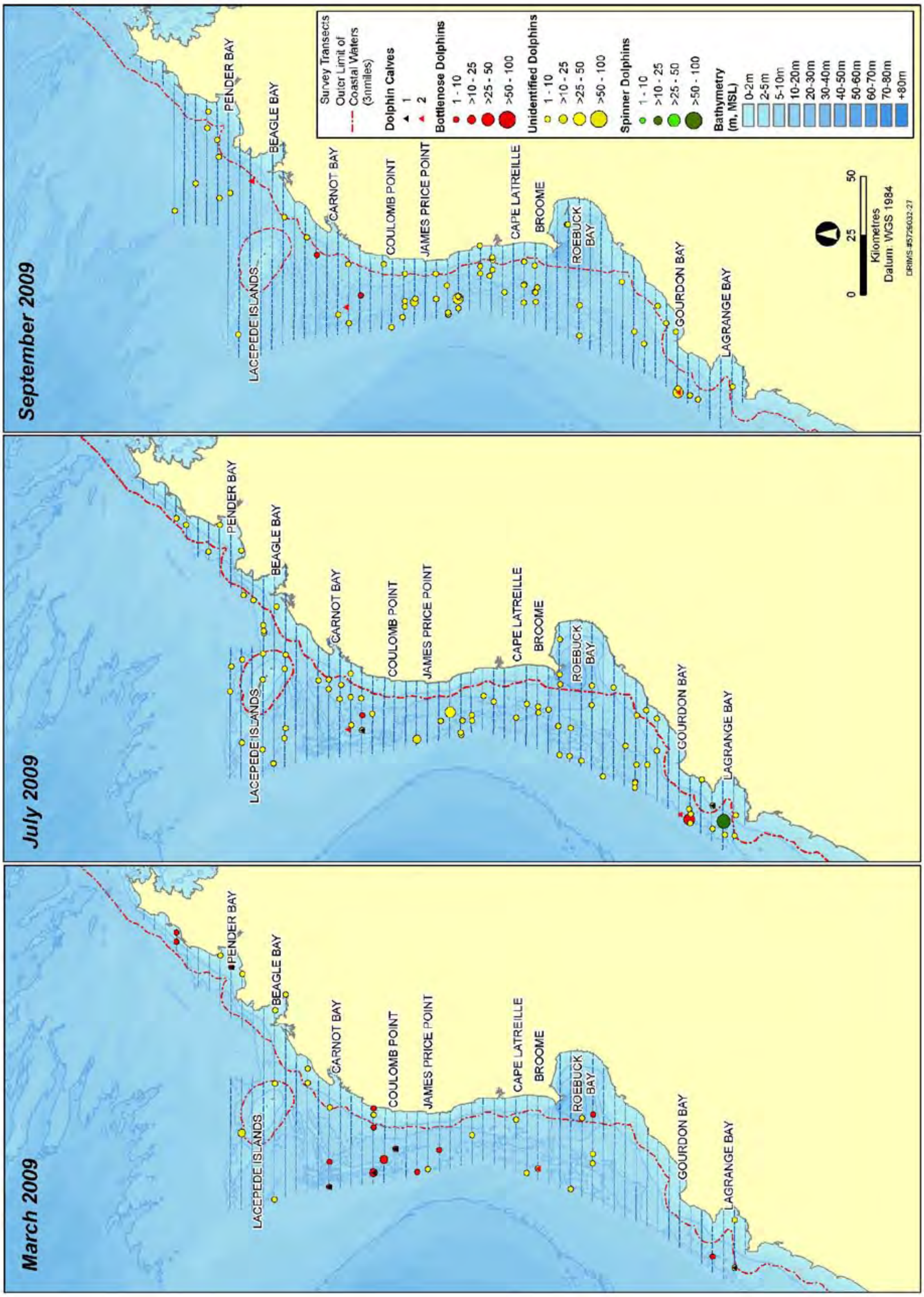
Bottlenose dolphins were widely distributed across the survey area between Cape Latrielle and Pender Bay, and were generally found in waters less than 50m but greater than 10m. They were also occasionally recorded from the air several hundred kilometres offshore just south of Scott Reef, showing that they are widely distributed.

#### Spotted-Bottlenose Dolphin

The spotted-bottlenose dolphin is widespread and found throughout the Indian Ocean, Indo-Pacific region and the western Pacific Ocean in tropical and subtropical coastal shallow offshore waters (DEWHA, 2010h). Resident populations of spotted-bottlenose dolphins are known to occur at Shark Bay and Barrow Island (DEWHA, 2008a).

Varying movement patterns are displayed by spotted bottlenose dolphins in Australia, including small areas of residency as well as long-range migrations. The spotted bottlenose dolphin mainly feed along, preferring a variety of fish and cephalopods (DEWHA, 2009a).

Aerial and vessel surveys did not differentiate between spotted or common bottlenose dolphins and therefore they are included in the bottlenose dolphin discussion above.




Source: RPS, 2010d; **Appendix C-10**.

- **Figure 1-58 Bottlenose Dolphins Recorded during the March, July and September 2009 Nearshore Regional Survey.**

**Spinner Dolphin**

Spinner dolphins (*Stenella longirostris*) are distributed across both the northern and southern hemispheres, in tropical and subtropical zones, ranging from 40°N to 40°S (IUCN, 2009). In Australia they are known to occur as far south as Bunbury in Western Australia and extending north around the top of Australia to the east coast near the NSW/QLD border (DEWHA, 2009a). Spinner dolphins are primarily pelagic however, in some regions, they are known to occur in shallow pelagic habitats over the continental shelf (Bannister et al., 1996). They are not known to be migratory, however they may undertake seasonal movements in response to the presence of warm oceanographic currents such as the Leeuwin Current in Western Australia.

The spinner dolphin (DEC Priority 4) was the most numerous of the small cetacean species recorded offshore of James Price Point during the aerial and vessel surveys (**Figure 1-58**) (RPS, 2010d; **Appendix C-10**). Spinner dolphins were either sighted in pairs or in groups ranging commonly up to thirty individuals, with the largest group up to an estimated 100 individuals. Although fewer groups of spinner dolphins were recorded than bottlenose dolphins, they were often seen in large groups, and were therefore, the most numerous of the dolphin species recorded.

The largest group of spinner dolphins (estimated up to 100 individuals) was recorded during the nearshore regional aerial survey approximately 15km west of Lagrange Bay in water 10 to 20m deep (RPS, 2010d; **Appendix C-10**). Spinner dolphins were widely dispersed from around the 10m isobath and out to the limit of the survey where the water was around 50m deep and were only seen on one occasion closer than 5km from the coast. Two sightings of groups of spinner dolphins (approximately 10 and 25 animals) halfway between the mainland and Scott Reef occurred during offshore surveys of Scott Reef, indicating that the species is also widely distributed offshore. This species is also likely to be present throughout the year based on the records during the survey periods.

### 1.4.4.5. Dugongs

Dugongs are protected under the *Wildlife Conservation Act 1950* (WC Act, 1950) and are listed as migratory and marine species under the EPBC Act. They are herbivores that feed exclusively on seagrass and are found in shallow, protected waters in tropical and sub-tropical regions. The distribution of dugongs in Australia ranges from Shark Bay in WA, and extending around the Australian north coast to Moreton Bay in Queensland (DEC, 2001).

**Life History**

Almost all information on life history parameters of the Australian dugong population has been determined from studies on populations in the northeast of Australia. Data from WA populations is limited. Dugongs are long-lived with a low reproductive rate, long (12 to 15 month) gestation period, and a high investment in each offspring (Marsh, 1999). Dugongs are aged using growth rings on their tusks, and the oldest dugong on record was estimated at 73 years of age.

Dugong mating appears to vary spatially (Marsh *et al.,* 2002). At Shark Bay, WA, Anderson (1997) observed male dugongs defending mutually exclusive territories (leks) in which unique behaviours were displayed in order to attract females. This behaviour suggests that dugong can have extremely strong site fidelity and disturbance within these territories may affect the fecundity of a population. It is not known whether lekking behaviour occurs along the Kimberley coast. Dugongs are slow breeders, with females bearing their first calf between 6 (Kwan, 2002) and 17 (Marsh *et al.,* 2003) years of age. Calves suckle for up to 18 months, and the period between successive calvings is spatially and temporally variable; estimates range from 2.4 years (Kwan, 2002) to 7 years (Marsh *et al.,* 2003). Important breeding areas in Western Australia occur in Shark Bay; Ningaloo Marine Park and Exmouth Gulf; Pilbara coastal and offshore regions (Exmouth Gulf in Western Australia to Grey River); and Eighty Mile Beach and the Kimberley coast region.

Population simulations indicate that, even with optimistic combinations of life-history parameters (for example low natural mortality and no human-induced mortality), a dugong population is unlikely to increase at more than 5% per year (Marsh et al., 2002). The rate of change in dugong population size is most sensitive to change in adult survivorship. A slight reduction in adult survivorship as a result of habitat loss, disease, hunting or incidental drowning in nets, can cause a chronic decline making the dugong vulnerable to over-exploitation (Marsh *et al.,* 2002).

The distribution of dugongs is likely to be influenced by three main factors: bathymetry, bottom type and the large tidal range, all of which may influence the distribution of or access to their main food source, seagrass. Dugongs in the region are primarily found in shallow coastal waters, mainly in water shallower than 20m deep and often below 10m. The daily local movements of dugongs are dictated by tides in areas with large tidal amplitude or where seagrasses grow

intertidally (Anderson, 1982) such as the southern Kimberley region, for example Roebuck Bay. Large-scale movements likely occur as a result of episodic loss of seagrass from events such as cyclones, floods and outbreaks of toxic algae such as Lyngbya species (Preen and Marsh, 1995; Marsh *et al.,* 2003; Gales *et al.,* 2004 and Marsh *et al,.* 2004).

During spring and summer months there is some level of seasonality in terms of mating and calving (DEWHA, 2008a), although no specific breeding season is known for dugongs.

**Regional Environment**

Shark Bay one of the most globally significant areas of dugong habitat. Approximately 10% of the world's dugongs (over 10,000 individuals) occur in this area (Marsh et al., 2002 and Gales et al., 2004). Shark Bay is approximately 1,400km south west of the Dampier Peninsula.

While dugong surveys have been undertaken within the Canning Bioregion (discussed below), there is a lack of quantitative data on dugong abundance and distribution in the broader Kimberley region. Furthermore, given the large tidal variation and turbid water that is typical of the Kimberley region, standard survey methods (aerial) can be difficult to implement (DEC, 2009a). Additionally, little is known regarding the degree of connectivity between populations, and population structure (DEC, 2009a).

There is little known about the population trends of dugongs in the Kimberley and Canning Bioregions. Resident populations are thought to occur at Beagle Bay and the Montgomery Islands (Mustoe and Edmunds, 2008 and RPS, 2010c; **Appendix C-9**) and large numbers of dugongs have also now been recorded in Roebuck Bay (RPS 2010c; **Appendix C-9**). The area between Coulomb Point and Cape Bertholet is potentially important for dugongs along the Dampier Peninsula, given the regular sightings of dugongs and proximity to seagrass beds mapped (Fry *et al.,* 2008; **Appendix C-4**). This is supported by relatively high densities of dugongs between Carnot Bay and Coulomb Point in the 2009 surveys (RPS, 2010c; **Appendix C-9**).

Due to the dugong's low metabolic rate, seasonal movements to warmer waters have been observed at the limits of their geographic range. For example, the distribution of dugongs in Shark Bay changes seasonally with animals moving distances of over 100km from the east to the warmer west side of the bay during winter (Anderson, 1982; Marsh *et al.,* 1994 and Gales *et al.,* 2004). Temperature-related migrations are not likely to occur along the Kimberley coast due to the relatively consistent warm sea temperatures.

The maximum speed of dugong movements has not been scientifically tested and is only observed as flight behaviour in response to threats such as predators or approaching boats. Anecdotal observations suggest dugongs can sustain fast travel for a relatively short time (Hodgson, 2004). Fast travel in dugongs is likely to be energetically costly if, as predicted, they have low metabolic rates similar to manatees, their close relative (Preen, 1992).

Coastwatch flights of the Dampier Peninsula in 1984 provided the first qualitative data of dugong distribution in the region (Prince, 1984) although this form of sampling was unable to determine population abundance (Holley and Prince, 2008). In April, July and October of 1985, strip transect surveys along the Dampier Peninsula recorded a total of only 27 individual dugongs with sightings concentrated around the Point Coulomb and Cape Leveque areas (Holley and Prince, 2008). Research undertaken by Holley and Prince (2008) has suggested that there is a degree of connectivity between populations of dugongs of the Dampier Peninsula or that individuals are part of a single large population. The research has also provided evidence to support the use of seagrass beds as an indicator for dugong distribution with individuals recorded to have travelled from northern Pender Bay (on the Dampier Peninsula, approximately 160km north east of James Price Point).

Tropical cyclones are the major regional temporal and spatial disturbance factor affecting the quality of dugong habitat along the Kimberley coast. Habitat disturbance factors during cyclones include intense wave action and water movements, sustained exposure to freshwater from flooding and turbid outflow plumes. The effect of tropical cyclones on the natural variability of the regions' marine ecosystems, and especially the status of the shallow waters where the seagrass forage resources utilized by dugongs are found, is not well understood due to the absence of long-term datasets.

**Dampier Peninsula**

Nearshore regional aerial surveys were conducted during March, July and September 2009 to provide a dugong population estimate in the Canning Bioregion. During all three surveys, dugongs were concentrated mainly in Roebuck Bay, near Carnot Bay and south of Beagle Bay. During July, dugong numbers were seen to increase in an area offshore and to the south from James Price Point. The surveys determined that the average density of dugongs within the Canning Bioregion ranged from 0.10km$^2$ (March survey) to 0.19km$^2$ (July survey) (**Figure 1-59**).

The population size appeared to increase from the wet to the dry season, suggesting links to other areas. Migratory links to other areas have been confirmed by preliminary satellite tagging by Campbell and Holley (2010); a dugong tagged at Beagle Bay travelled almost 500km south to east of Port Hedland (RPS, 2010c; **Appendix C-9**). Dugongs were primarily found in shallow coastal waters, mainly in water shallower than 20m deep. RPS (2010c; **Appendix C-9**) found that certain sections of the coast had greater habitat importance than others. The southern parts of the survey area had the highest population estimate and supported the highest number of calves in all survey periods. Of particular note was Roebuck Bay which appeared to have the most stable population of dugongs, including calves, within the Canning Bioregion. Areas inshore of the Lacepede Islands (off Beagle Bay) and around Carnot Bay also supported a greater number of dugongs.

Based on the data collected during 2009, coastal waters of the Canning Bioregion between Cape Leveque and Cape Bossut supported a dugong population estimated at between 930 to 1774 animals, broadly comparable to that in Exmouth Gulf, but considerably smaller than that recorded for Shark Bay (Hodgson, 2007).

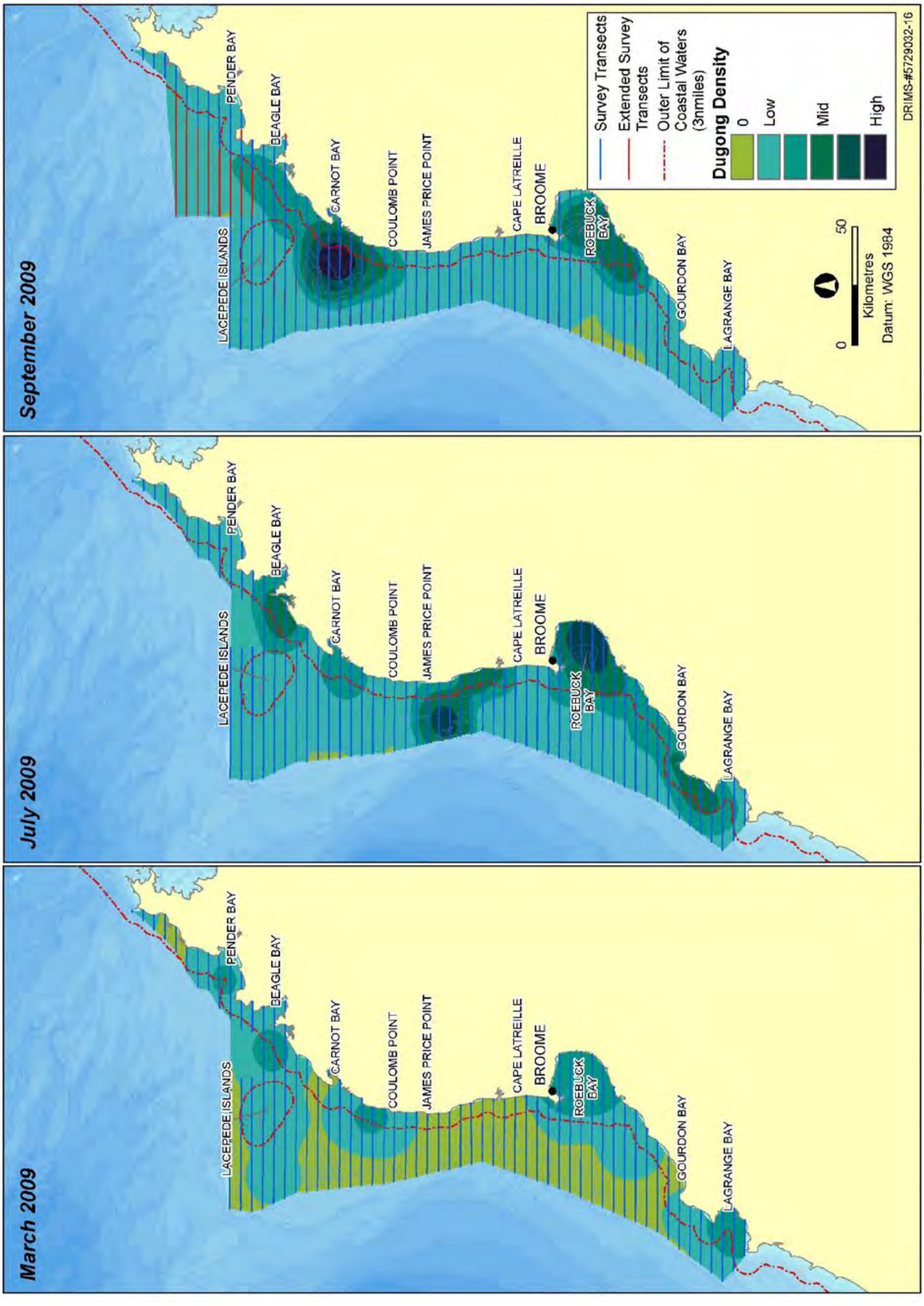
**James Price Point**

Of the animals estimated to inhabit inshore waters of the Canning Bioregion (between 930 and 1,774), dugong distribution and densities in the James Price Point coastal area were relatively low. In July 2009, relatively higher density of dugongs was apparent approximately 15km offshore from Quondong Point between the 10 and 20m isobaths. It is expected that the animals were transiting the area. The James Price Point coastal area did not appear to have any particular significance for the distribution of dugongs, adults or calves, within the surveyed areas. Analysis of numbers sighted within designated areas indicated no statistically significant trends in dugong distributions through the survey area. Dugong numbers recorded in the coastal area from Broome north to Carnot Bay (which includes the James Price Point coastal area) were lowest in March increasing in both July and September (RPS, 2010c; **Appendix C-9**).

Although dugongs are likely to be visitors to any subtidal seagrass within the inshore waters of the Canning Bioregion including in the vicinity of James Price Point, the extent of the seagrass in the James Price point area is limited and seasonally variable (RPS, 2010c; **Appendix C-9**), supporting the observation of relatively low densities of animals. Seagrass does not feature widely in the James Price Point area, with only small patches present. Larger, more contiguous patches exist to the south of Coulomb Point and further offshore. These model results (SKM, 2010b; **Appendix C-3**) were consistent with those found by Fry *et al.* (2008; **Appendix C-4**) who observed patches of sparse and dense seagrass just south of Coulomb Point, within 5 to 10m water depth. Some small patches were also recorded between James Price and Quondong Points. Given that seagrass communities are seasonally abundant, the results of the modelled distributions in this study should be interpreted cautiously, particularly given that seagrasses were not recorded during the intertidal survey (SKM, 2010b; **Appendix C-3**). Dugongs are also known to resort to eating marine algae when seagrass is scarce (DEWHA, 2008a).

Seagrasses were first observed along Dampier Peninsula during site selection surveys undertaken by the DEC in November 2007 and were found to be well developed with high biomass. Repeat surveys of some locations were undertaken in April 2008 but no seagrass was recorded at James Price Point. Seagrass had re-established in these areas by June 2008 and surveys undertaken by the DEC in December 2008 found prolific seed production in *Halophila sp*, suggesting that recruitment from seed may be an important process for sustaining seagrass communities in this area (Masini *et al.,* 2009). Although the above ground seagrass biomass may vary considerably seasonally, it is possible that subsurface biomass may remain relatively constant (Waycott *et al.,* 2004).

The presence of seagrass in the James Price Point coastal area (DEC, 2009a) suggests that this area may provide food for the species, however as described above, the extent of the seagrass in the James Price Point area is limited and seasonally variable (SKM, 2010b; **Appendix C-3**) and it is likely that dugongs would also utilise areas elsewhere in the region.




Source: RPS, 2010c; **Appendix C-9**.

- **Figure 1-59 Dugong Density in the Canning Bioregion.**

#### 1.4.4.6. Fish

Within the Kimberley region, a large diversity of fish species is known to occur, including endemic species (DEWHA, 2008a). There are three conservation significant fish species that have the potential to occur within or migrate through the James Price Point coastal area along the nearshore waters of Dampier Peninsula – the freshwater, green and dwarf sawfishes. Although none of these species were observed during the 2009 surveys undertaken near James Price Point (Cappo *et al.,* 2010b; **Appendix C-6** and RPS, 2010d; **Appendix C-10**), the green and dwarf sawfish have been recorded previously in the region.

**Fish Communities**

The marine fish fauna in the coastal Kimberley region has been the focus of previous ecological studies. Species checklists (for example Allen, 1992; Allen, 1997; Newman *et al.,* 2003 and Travers *et al.,* 2006) consider the fish fauna to be low in diversity in comparison to fish species found well off the Kimberley coast such as the Rowley Shoals (Allen, 1992).

The inshore fish fauna of the Kimberley can be best described as belonging to the Indo-Australian subprovince of the Indo-West Pacific region and are primarily inshore coastal fishes that are adapted to silty environments associated with large tidal fluctuations (Allen, 1992). Nearshore shallow waters (less than 2m depth) act as a nursery area for some fish species in tropical waters (Blaber *et al.,* 1995), as the waters provide an abundant source of food for juvenile fish and provide protection from predators (Newman *et al.,* 2003).

In 1991, a survey of aquatic fauna was conducted around the Kimberley islands and reefs from King George River to the Lacepede Islands (Allen, 1992), which recorded a total of 311 species of marine fishes, including 49 new records and at least four undescribed species. Hutchins (1995) recorded 197 species of marine fish from nearshore shallow reefs in the Buccaneer Archipelago (approximately 125km north east of James Price Point).

Hutchins (2003) surveyed the fish fauna of the Dampier Archipelago in the WA Pilbara region, recording a total of 736 species, comprised predominantly of tropical species. Seventy-five percent of the species recorded were wide-ranging, and therefore likely to occur in habitats such as the Canning and Kimberley Bioregions. The greatest diversity of species were reef dwellers (476 species), followed by mangrove fishes (121), and lastly inhabitants of soft bottom habitats (117) (Hutchins, 2003). All three habitats are typical of the Kimberley too; however, mangrove habitats are limited along the southern section of the Dampier Peninsula.

**Regional Environment**

Newman *et al.* (2003) sampled nearshore, shallow waters on beaches and in mangroves and intertidal pools in three regions along the Pilbara and Kimberley (Port Smith) coasts during the wet and dry periods of two consecutive years (between December 2000 and November 2002) with fish catches from all habitat types collectively yielding 170 species representing 66 families. Conservation significant species were recorded during the surveys including green sawfish, dwarf sawfish and several pipefish species (Newman *et al.,* 2003). It was found that the species composition of the fish assemblages was influenced not only by habitat type, but also by season and region and also apparently the extent of tidal action and thus turbidity (Newman *et al*., 2003).

The offshore survey component of Newman *et al.* (2003) sampled over reefs using fish traps and over soft substrates using an otter trawl net in both shallow (approximately 15m) and deeper inshore waters (approximately 22m). Sampling at seven regions along the Pilbara and Kimberley coasts, including Dampier Peninsula, yielded 132 fish species caught over reefs and 279 species over soft substrates.

The Department of Fisheries (**DoF**) (Fletcher and Head, 2006) conducted a 12-month creel survey (Dec 1999 to Nov 2000) of recreational fishing to provide an estimate of the recreational catch and fishing effort for the Pilbara region including Broome. The recreational boat-based fishing effort was high in Broome particularly during the dry season (**Figure 1-60**). The most common recreational species caught by fishers in Broome were stripey seaperch (*Lutjanus carponotatus*), blue-lined emperor (*Lethrinus laticaudis*), threadfin salmon and trevally (including giant and golden trevally) species.

**Dampier Peninsula**

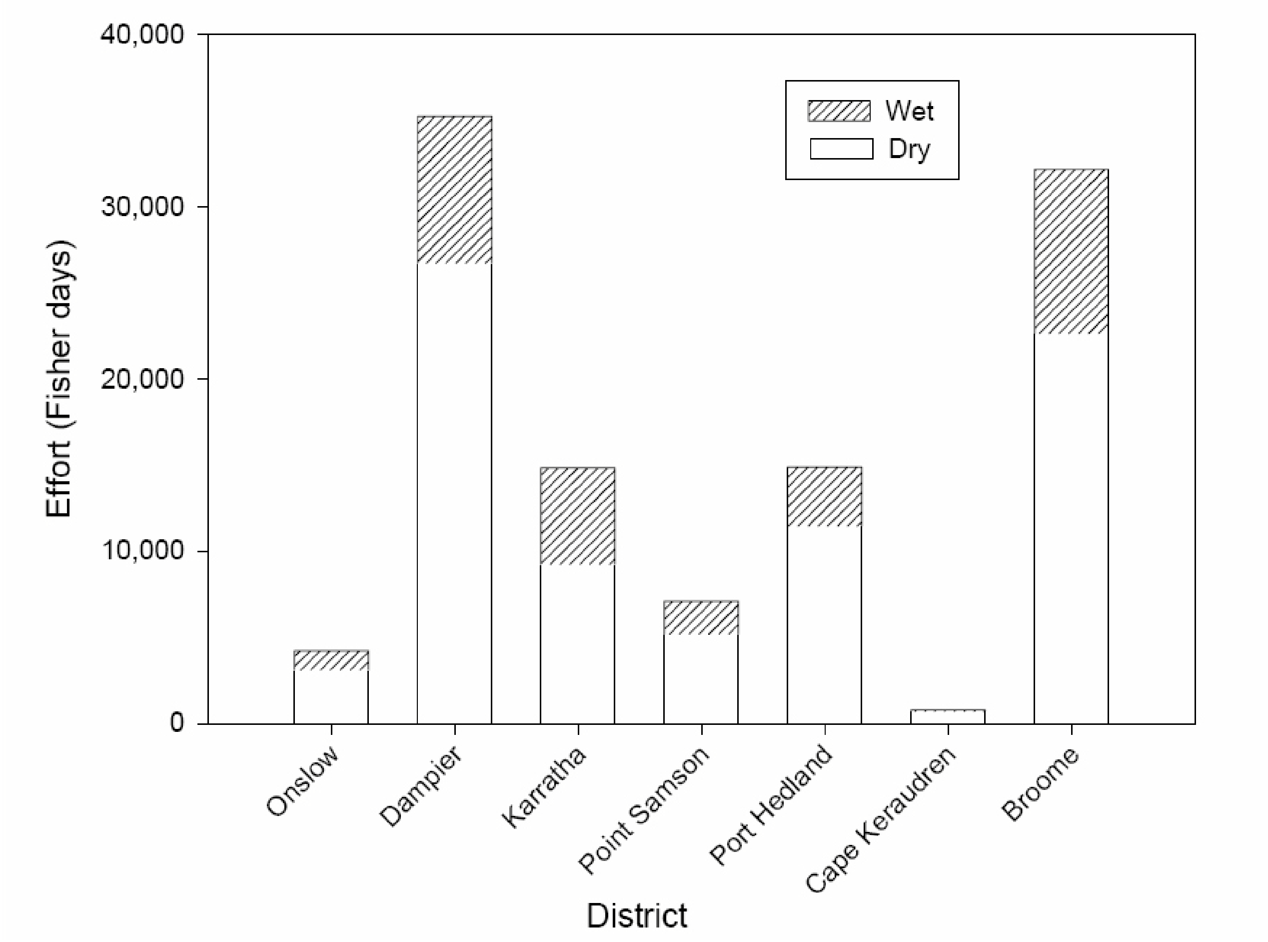
Fish and fish schools were recorded during the Nearshore Regional Aerial Surveys (RPS, 2010d; **Appendix C-10**) as they provide potential indications of the productivity of the area and an indication of food sources for larger marine fauna such as dolphins. A total of 63 records of fish were recorded during the September 2009 survey and 89 during the July

2009 survey (**Figure 1-61**). Records of fish sightings were low on the list of data collection priorities for the field surveys and, therefore, are not considered complete (RPS, 2010d; **Appendix C-10**).

**James Price Point Coastal Area**

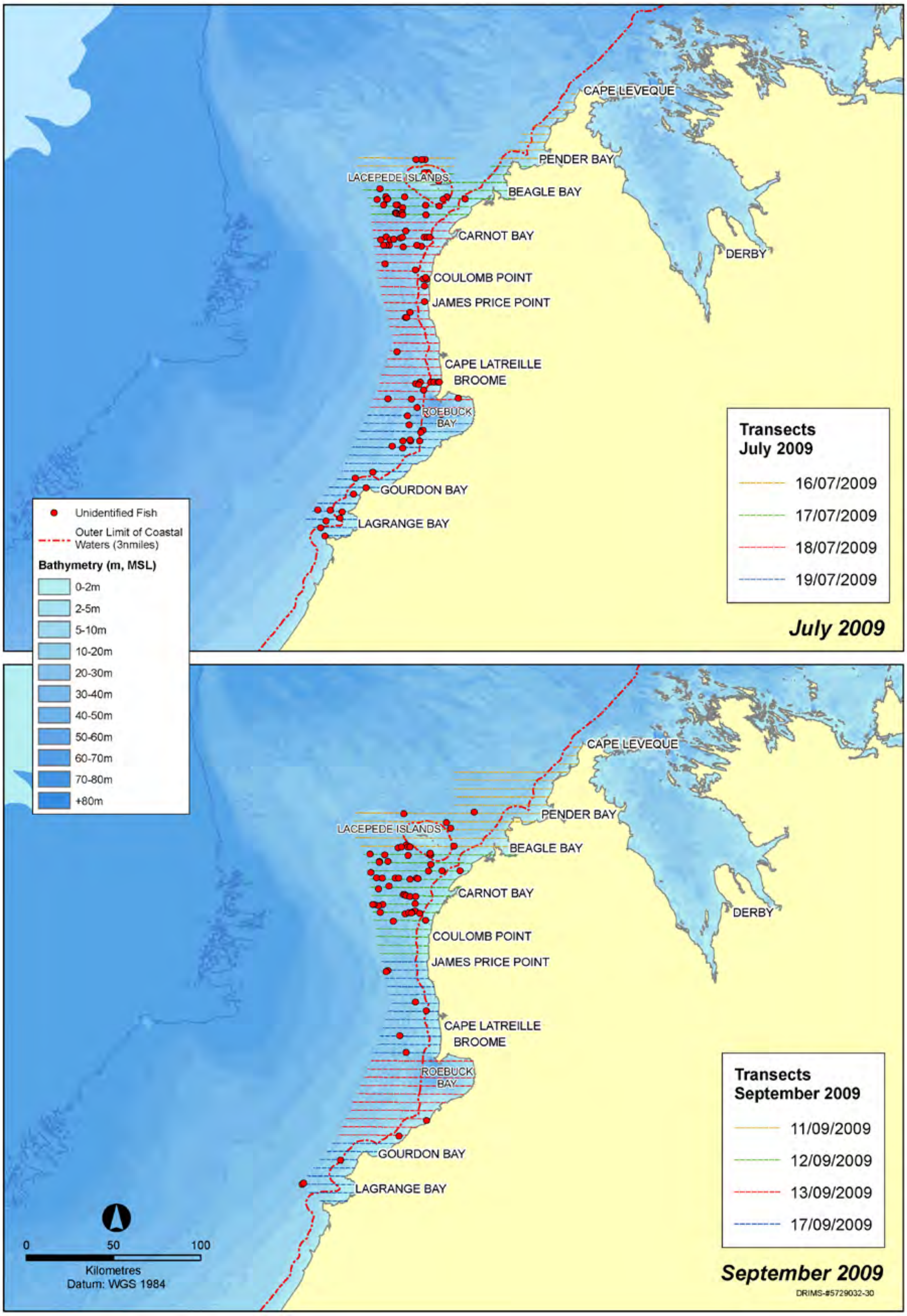
In October 2009, over 150 Baited Remote Underwater Video Stations were deployed in coastal waters between just north of Coulomb Point to Cape Boileau (south of Quondong Point) at a median depth of 15m (**Figure 1-62**). The 2009 BRUVS survey of the inshore fish fauna identified a total of 7,108 individuals from 116 species of fishes, sharks, rays and sea snakes (Cappo *et al.,* 2010b; **Appendix C-6**). Bony fishes were represented by eight orders, dominated by perch-like fishes (Perciformes 79 species including mackerel, trevally, bream, seaperch, emperors, ponyfish), with Tetraodontiformes (nine species of puffers, leatherjackets and triggerfishes), Anguilliformes (two species of moray eels), and Aulopiformes (lizardfishes), Scorpaeniformes (scorpionfishes), Clupeiformes (sardines), Elopiformes (giant herring) and Siluriformes (catfishes) each with a single species (Cappo *et al.,* 2010b; **Appendix C-6**).

Approximately 45% of the species sighted between Coulomb Point to Quondong Point were of economic importance to fisheries, but they contribute less than 25% numerically (Cappo *et al.,* 2010b; **Appendix C-6**) (**Table 1-25**). The species identified are typical of the fish communities described within the Kimberley region (Newman *et al.,* 2003). There was an abundance of small pelagic fish such as carangids and clupeids accompanied by a corresponding high occurrence and abundance of schooling, predatory carangids and scombrids known to include fish in their diets.



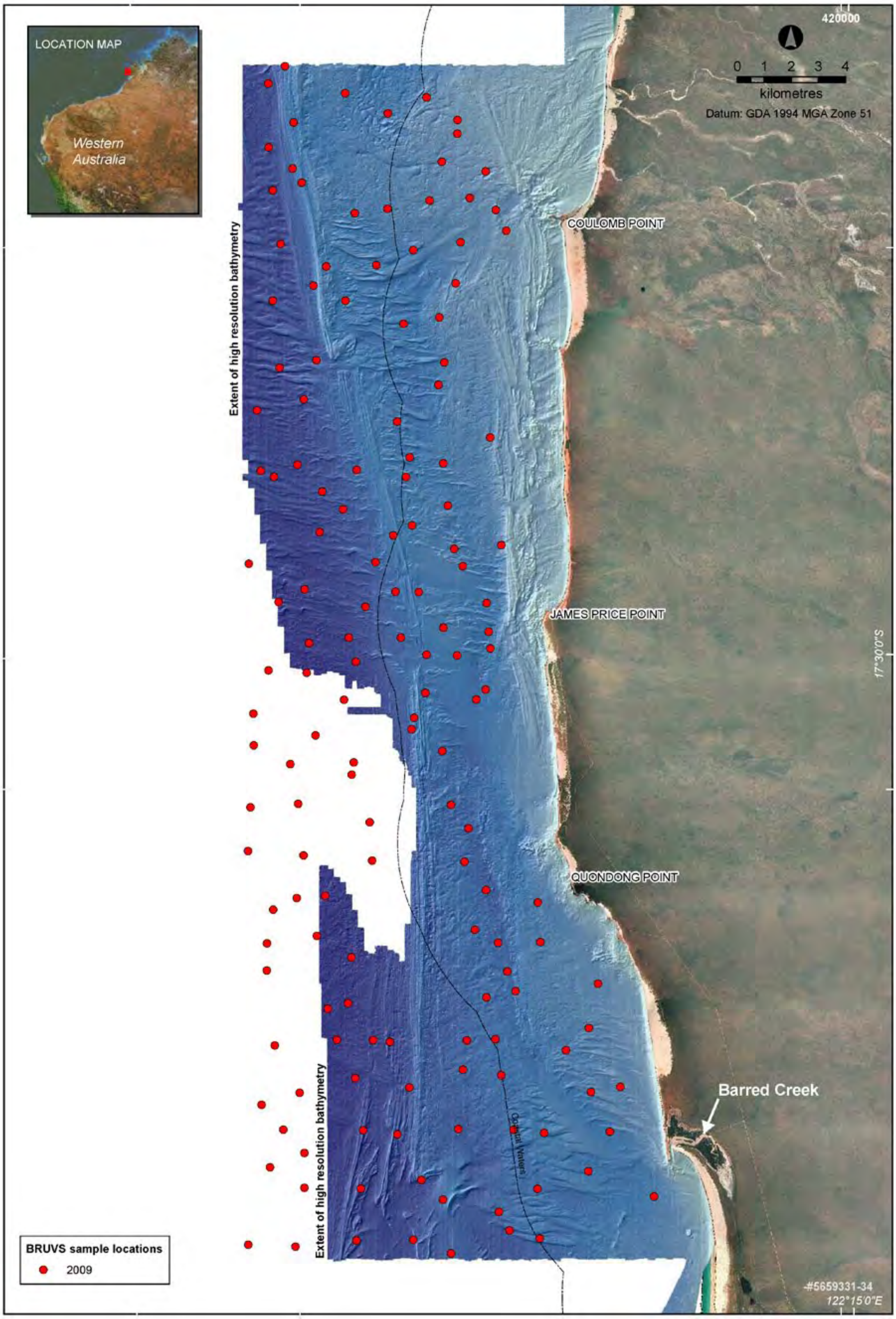

Source: DoF, 2006.

- **Figure 1-60 Estimated Seasonal Fishing Effort for Boats Launched from Public Ramps in the Pilbara Region.**




Source: RPS, 2010d; **Appendix C-10**.

- **Figure 1-61 Fish (other than Sharks and Rays) Recorded during the July and September 2009 Nearshore Regional Surveys.**




Source: Cappo *et al*., 2010b; **Appendix C-6**.

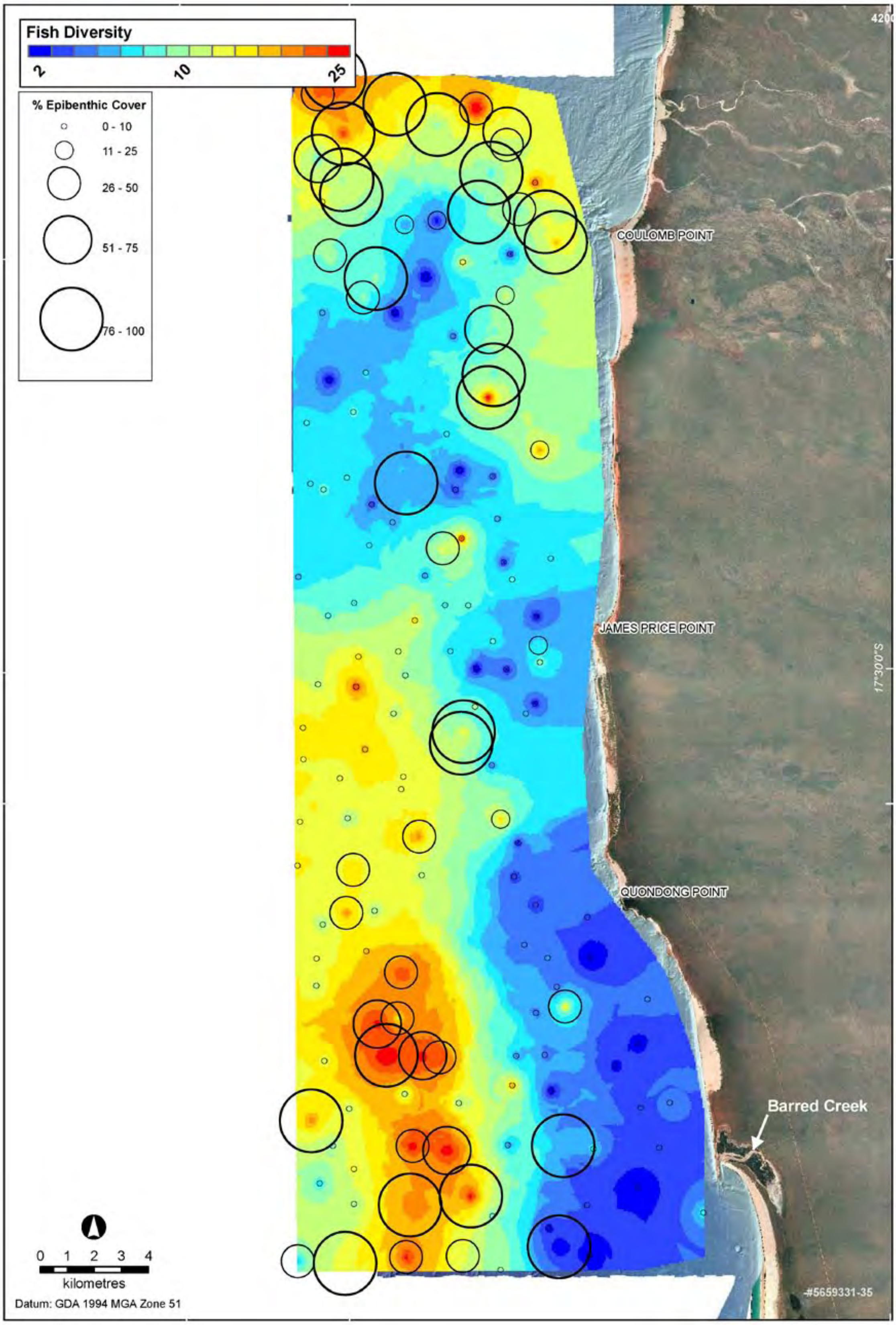
- **Figure 1-62 Location of Sites in the James Price Point Coastal Area that were Surveyed using BRUVS.**

- **Table 1-25 Summary of Recreational Take Species of Fish (Newman *et al*., 2003) Relative to Observed BRUVS Species.**

| Rank | Common Name | Broome landings % weight | Rank | % BRUVS sets with fish specimen present |
|---|---|---|---|---|
| 1 | Blue-lined emperor | 14.1 | 7 | 1.9 |
| 2 | Stripey seaperch | 11.4 | 2 | 26.0 |
| 3 | Giant trevally | 9.6 | 4 | 8.4 |
| 4 | Golden trevally | 9.0 | 1 | 29.2 |
| 5 | Giant salmon catfish | 9.0 | 6 | 2.6 |
| 6 | Spanish mackerel | 8.7 | 5 | 3.9 |
| 10 | Blackspot tuskfish | 5.5 | 3 | 13.0 |

Source: Derived from Cappo *et al.,* (2010b); **Appendix C-6**, Table 2.

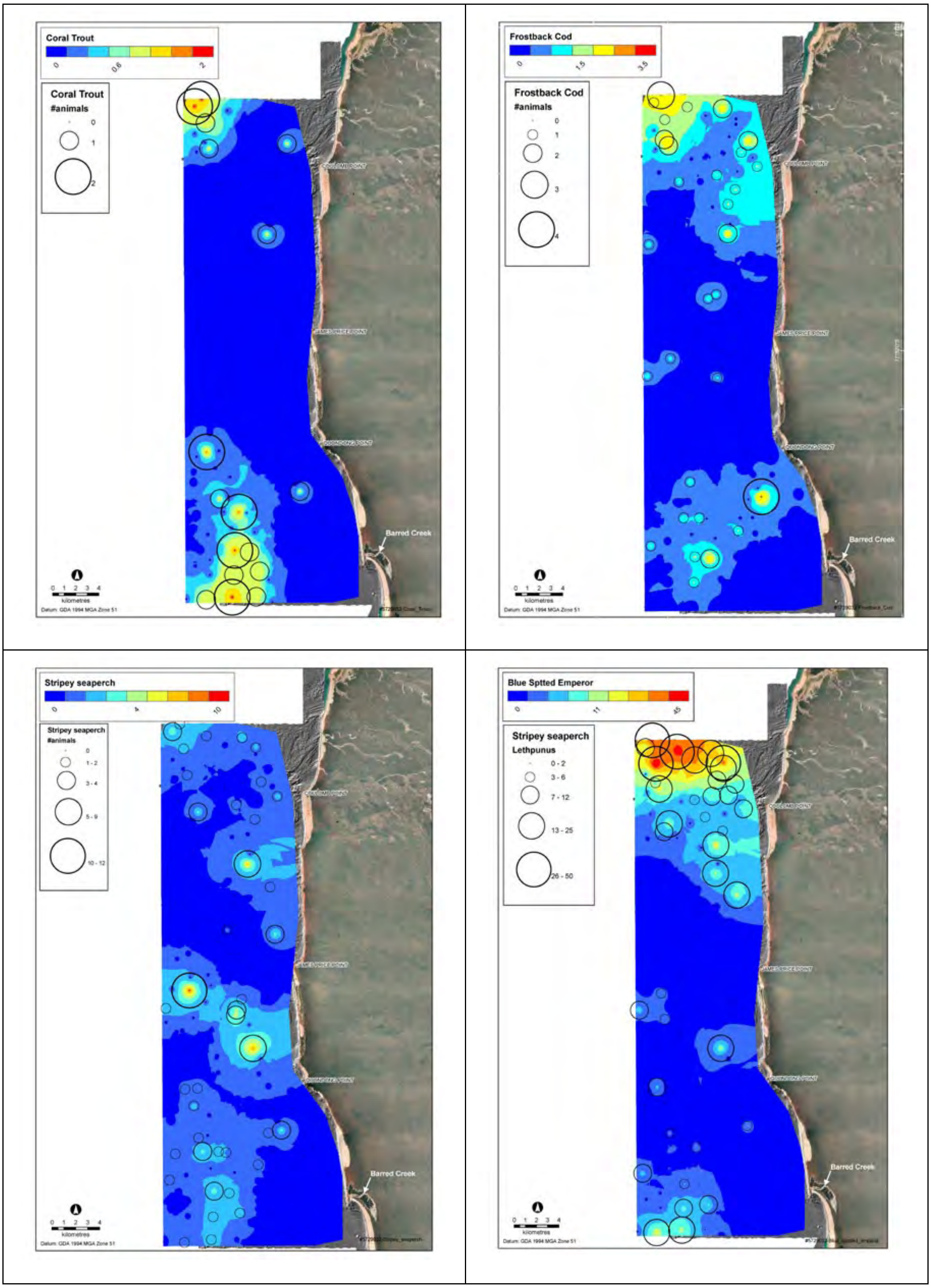
The benthic habitats at the northern and southern ends of the survey area contained macroalgae, filter feeders and some seagrass communities which were clearly important to many species. Diversity patterns showed that there were two coarse groups of sites with both high fish species richness and more habitat complexity; one to the north of Coulomb Point, and one to the south of Quondong Point (approximately 10km south of James Price Point) (**Figure 1-63**). Some demersal carnivores (e.g. tuskfish and emperors) were associated more with the epibenthic communities in the north and south of the survey area rather than with bare sandy substrata (**Figure 1-64**). The presence of epibenthic biotic habitat in the north and south of the study area is clearly important to many species. The blue-spotted emperor is endemic to north-western Australia, and was notable in its local abundance in such areas. The species was clearly most abundant in the north of the study area (**Figure 1-64**) where marine plants and filter-feeders were most common, but it was not restricted to this region. The stripey seaperch was patchily distributed in loose association with the offshore belt of epibenthos (Cappo *et al.,* 2010b; **Appendix C-6**).




Source: Cappo *et al*., 2010b; **Appendix C-6**.

- **Figure 1-63 Smoothed Spline Fits of the Total Number of Species Recorded at BRUVS Sites.**

Note: Site symbols on the left panel are scaled to the amount (percentage cover) of epibenthos seen in the field of view within each BRUVS set.




Source: Cappo *et al*., 2010b; **Appendix C-6**.

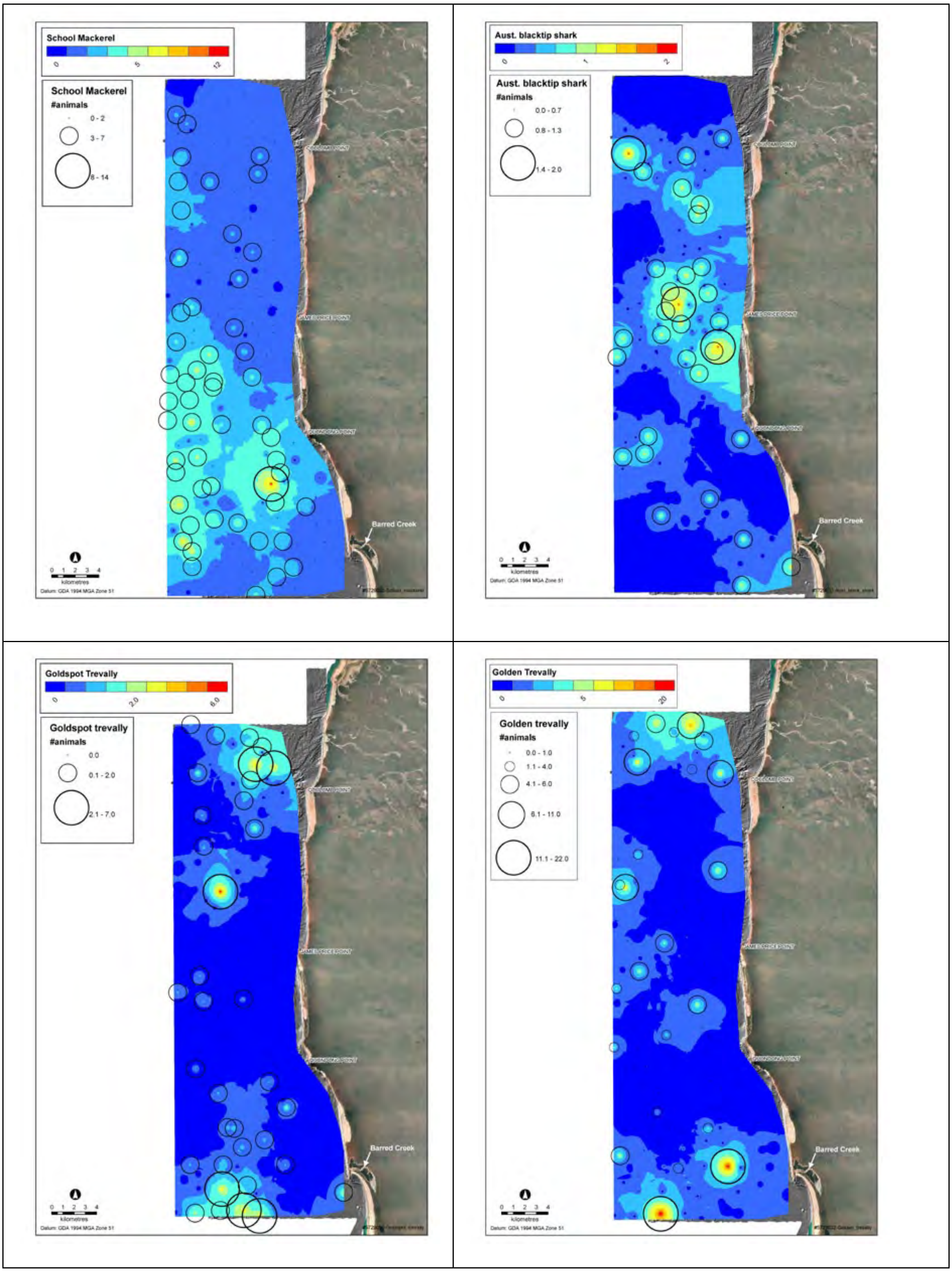
- **Figure 1-64 Smoothed Spline Fits of the Abundance of Economically Important Demersal Species.**

There was a wide number of ubiquitous species, such as *Scomberomorus queenslandicus* (school mackerel) and *Pentapodus porosus* (false whiptail), which were present throughout the study area and not strongly associated with any particular habitat type. In general, no species identified were unique to the James Price Point coastal area with all species well represented elsewhere in the Kimberley region. The BRUVS fish census (Cappo *et al.,* 2010b; **Appendix C-6**) determined that the fish communities were diverse and abundant, despite the shallow depth and lack of topographical features on the seabed.

The key regional recreational species frequently found during BRUVS surveys were golden trevally, stripey seaperch, blackspot tuskfish and giant trevally. Summary distributions show these species (**Figure 1-64** and **Figure 1-65**) generally located north and/or south of James Price Point or for stripey seaperch concentrated approximately 5km seaward from James Price Point.

The sandy seabed offshore from James Price point was inhabited by a “deep sandy” fish assemblage, which “intruded” inshore across the study area. Adjacent to James Price Point coastal area were shallow, northern and deeper, southern assemblages inhabiting “gardens” of macroalgae, filter-feeders and some seagrass beds. A variety of demersal micro- and macro-carnivores inhabited the sites with epibenthic communities and many of these (e.g. tuskfish, emperors, angelfish, triggerfish and sweetlips) have specialist feeding morphology to take advantage of infauna, epifauna and natant invertebrates known to inhabit such seafloor types (Cappo *et al.,* 2010b; **Appendix C-6**).

The benthic habitats at the northern and southern ends of the survey area were clearly important to many species, but in general there appeared to be little association of particular fish species or biotic habitat types with the James Price Point area itself. The study area was notable for the diversity and abundance of the fauna, given the shallow depth, lack of rugose seafloor topography and lack of sub-tidal coral reefs in the area sampled. Coarse comparison with the fauna at similar distance to shore in similar latitudes in the Burrup Peninsula and the Kimberley indicated that the study area had more small pelagic planktivores and more large semi-demersal predators (Cappo *et al.,* 2010b; **Appendix C-6**).




Source: Cappo *et al*., 2010b; **Appendix C-6**.

- **Figure 1-65 Smoothed Spline Fits of the Raw Abundance of Economically Important Pelagic Species.**

Note: The Southern and Northern peaks in abundance of Trevallies, the ubiquitous presence of school Mackerel and the concentration of Blacktip Sharks near James Price Point over sandy seabeds.

**EPBC Act Listed Fish Species**

The Kimberley region is host to a number of marine fish species of which three are listed as threatened and protected under the EPBC Act including freshwater sawfish (*Pristis microdon*), green sawfish (*Pristis zijsron*) and dwarf sawfish (*Pristis clavata*). A total of 27 pipefish, pipehorses and seahorses (Family: Syngnathidae) are also listed under the EPBC Act as marine species and may occur in the James Price Point coastal area. Species from the Family Syngnathidae may occur in seagrass and macroalgal habitats around James Price Point and along the coast of the Dampier Peninsula. These species were not observed by Cappo *et al.,* (2010b), although the survey was conducted in 15m isobath.

The 2009 BRUVS fish census determined that no fish species classified as threatened under the EPBC Act were noted during their surveys (Cappo *et al.,* 2010b; **Appendix C-6**). However, it is reported that these species have been caught in the vicinity of James Price Point and are likely to transit through the area on their way to and from estuarine habitats (such as the Fitzroy River) (Morgan *et al.,* 2009; **Appendix C-7**).

*Sawfish:* There are four species of sawfish that are known to occur in northern Australia (DoF, 2008a), three of which are EPBC listed species. Sawfish were not recorded during any of the surveys in the James Price Point coastal area (RPS, 2010d; **Appendix C-10** and Cappo *et al.,* 2010b; **Appendix C-6**). The site is unlikely to support a suitable habitat to the threatened sawfish species. However, all of the EPBC listed sawfish species may pass through the James Price Point coastal area while migrating from nursery grounds to feeding grounds (Morgan *et al.,* 2009; **Appendix C-7**). The Kimberley gillnet fishery (defined as 'all Western Australian waters lying north of 19° S latitude and west of 129°E longitude and within 3Nm seaward of the low water mark of the mainland of WA and the waters of King Sound of 16°21.47´S latitude and Jacks Creek, Yardogarra Creek and in the Fitzroy River north of 17°27´ S latitude') inadvertently takes sawfish specimens, which are released alive as far as is practicable, with such impacts unlikely to be significant because of low fishing effort (DoF, 2008b). This record confirms the presence of these species in the Canning marine bioregion coastal waters.

*Freshwater sawfish (Pristis microdon):* The centre of their distribution, and the most important nursery site known, is the Fitzroy River in the Kimberley (Morgan *et al.,* 2009; **Appendix C-7**). Within the Fitzroy River, all freshwater sawfish are immature, with few immature fish located elsewhere. Records of immature freshwater sawfish are limited to the major tributaries of King Sound including Goodenough Bay. Mature individuals are those greater than 3m total length and have been recorded at Eighty Mile Beach, Roebuck Bay and King Sound (Morgan *et al.,* 2009; **Appendix C-7**). New recruits utilise very shallow waters of generally less than 1m deep whereas older fish occupy deeper habitats. Females are thought to be philopatric and thus return to their natal river to give birth. It is therefore possible that each of these larger females found along the Eighty Mile Beach and in Roebuck Bay may move to the mouth of the Fitzroy River to pup (Morgan *et al*., 2009; **Appendix C-7**). While the population estimate is unknown, freshwater sawfish assemblages have been observed to have greatly declined throughout their range, being completed eliminated in some areas. Northern Australia appears to be one of the last regions with viable populations (Pogonoski *et al.,* 2002).

*Green sawfish (Pristis zijron):* This species inhabits muddy seabed habitats and estuaries of northern Australia (Allen, 1997 and Stead, 1963). Individuals less than two and a half metres in length are more common in coastal waters, as well as estuaries and river mouths, but do not venture into freshwater. Larger individuals greater than 2.5m in length are found in both inshore and offshore waters (Thorburn and Morgan, 2004). The green sawfish has been recorded from Coral Bay in WA to the WA/NT border (Morgan *et al.,* 2009; **Appendix C-7**). However, the majority of capture locations are between Karratha and One Arm Point, with very few specimens recorded in King Sound, in contrast to the freshwater sawfish (Morgan *et al.,* 2009; **Appendix C-7**). Most captures of the species have been from nearshore, however interactions have been reported from commercial fisheries in over fifty metres depth of water (Morgan *et al.,* 2009; **Appendix C-7**). Previously found as far south as New South Wales on the east coast of Australia, green sawfish have not been reported in those waters since 1960 (Stevens *et al.,* 2005). A great decline in *Pristis spp.* captures in Queensland's Beach Control Program between 1969 and 2003 (Stevens *et al.,* 2005) provided further evidence of population reductions. Virtually extinct throughout South-East Asia, northern Australia is likely the last place to host significant populations (Stevens *et al*., 2005). Newman (2003) studied fish fauna in the Kimberley-Pilbara bioregion. Newman captured *P. zijsron* at three sites between Port Hedland and Broome. These collection sites were associated with nearby mangrove systems at Cape Keraurdren and Port Smith.

*Dwarf sawfish (Pristis clavata):* The majority of capture locations for the dwarf sawfish have occurred within King Sound and the lower reaches (tidally influenced) of the major rivers of King Sound, such as Fitzroy River, Mary River and Robinson River, as well as from Cape Keraudren and Eighty Mile Beach in the Pilbara (Morgan *et al*., 2009; **Appendix C-7**). Dwarf sawfish are typically found on silt/sandflats in tropical shallow waters often influenced by large tides. While

the majority of capture sites are from shallow, tidally influenced systems, some reports are from considerably deeper water (from trawls) (Morgan *et al*., 2009; **Appendix C-7**). While a population estimate is unknown, collected evidence demonstrates a large decline in *Pristis spp*. in Australian waters within the last 15 to 20 years (Stevens *et al.,* 2005).

*Pipefish and seahorses:* Pipefish, pipehorses and seahorses (of the family Syngnathidae) are widely distributed across northern Australia and are listed as marine species under the EPBC Act. The EPBC Act protected matters search tool (Appendix B to the SoSA (DSD, 2010c; **Appendix A-3**)) indicated 27 species may occur in the vicinity of the James Price Point. In addition, Hutchins (2003) recorded six species from the family Syngnathidae in the Pilbara's Dampier Archipelago that are not listed under the DEWHA Protected Matters Search Tool. These listed marine species are all widely distributed around northern Australia and in the greater Indo-West Pacific Region (Lourie *et al.,* 1999 and DEWHA, 2008a), so it is likely that they occur in the vicinity of James Price Point, as they do elsewhere.

Most pipefish prefer seagrass habitats (Steffe *et al.,* 1989), while seahorses are also known to occur in macroalgal habitats (Browne *et al.,* 2008). Species in the Syngnathidae family avoid predation through mimicking seagrass or macroalgae, and are often difficult to observe due to their cryptic camouflage (Browne *et al.,* 2008). Species in this family are egg brooders rather than broadcast spawners (the females lay their eggs in a brood pouch on the males' chest, and the male then fertilizes and incubates the eggs).

#### 1.4.4.7. Shark and Rays

There are two conservation significant shark and ray species that have the potential to occur within or migrate through the James Price Point coastal area along the nearshore waters of the Dampier Peninsula. These are the whale shark and the northern river shark. These species were not observed during the 2009 surveys undertaken near James Price Point (Cappo *et al.,* 2010b; **Appendix C-6** and RPS, 2010d; **Appendix C-10**).

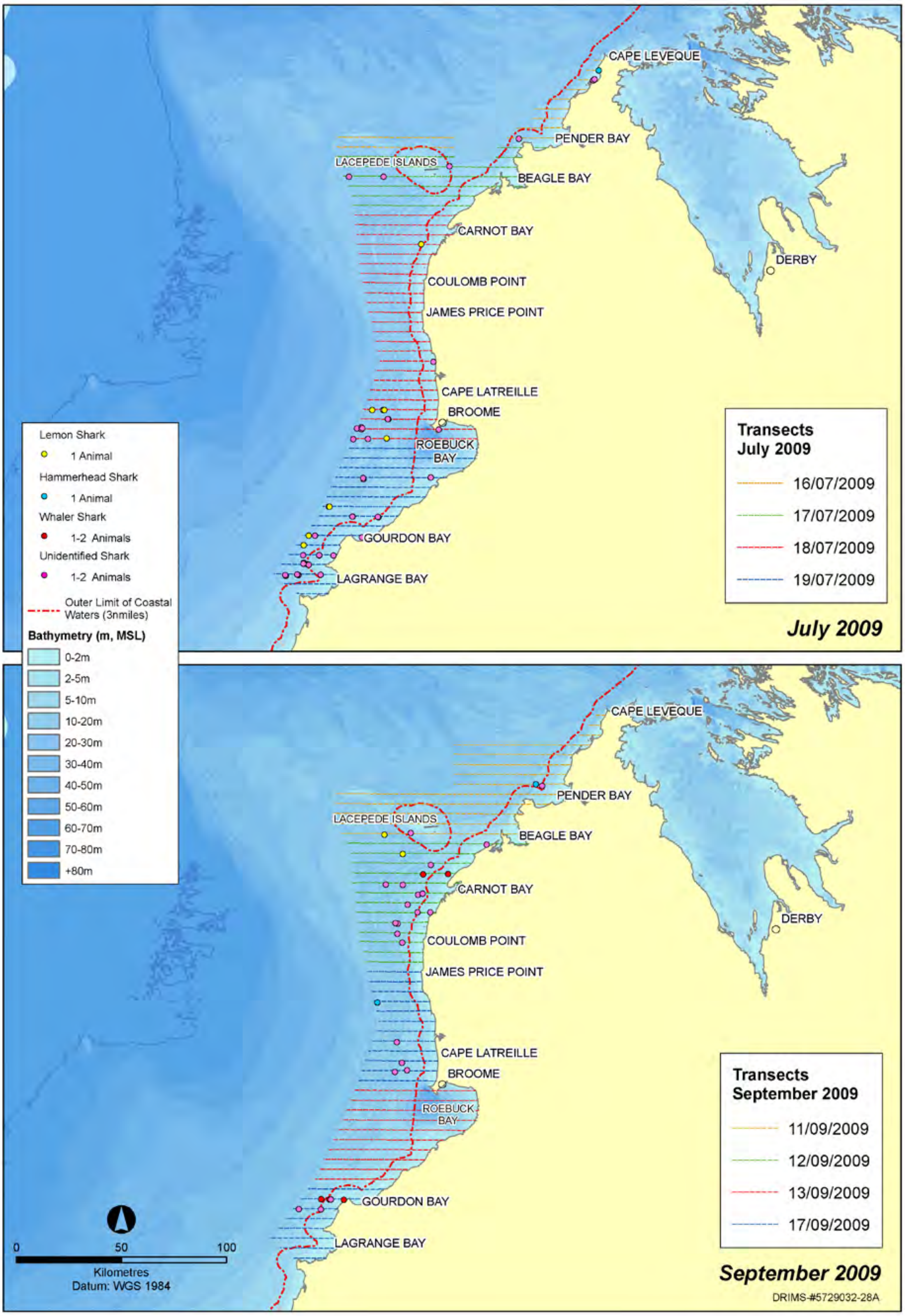
**Dampier Peninsula**

A combination of aerial and vessel surveys were undertaken from early July to mid October 2009 between Cape Leveque (approximately 150km north east of James Price Point) and Cape Bossut (approximately 130km south west of James Price Point (RPS, 2010d; **Appendix C-10**). Sharks were distributed across the entire megafauna survey area from Lagrange Bay in the south to Scott Reef in the north. During the nearshore regional survey, most sharks appeared to be somewhat closer to shore during September than in July 2009 (**Figure 1-66**). Opportunistic data from these surveys identified a total of 28 sharks in July 2009 and 32 in September 2009. Those individuals that were identified to species included the hammerhead shark, lemon shark, tiger shark, whaler shark, leopard shark and great white shark. Individuals were observed across the entire extent of the area surveyed in generally shallow water (< 50m deep), however only one great white shark was sighted during the survey. Generally, more sharks were distributed in the north of the survey area during July, and more in the southern part during September.

Rays were also widely distributed across the survey areas from the shallow nearshore out to deep water surrounding Scott Reef. Several groups of rays comprising up to 15 individuals were sighted, the largest of which was recorded just west from Roebuck Bay (**Figure 1-67**) (RPS, 2010d; **Appendix C-10**). Rays were often sighted in nearshore waters off Roebuck Bay, Gourdon Bay and around the Lacepede Islands.

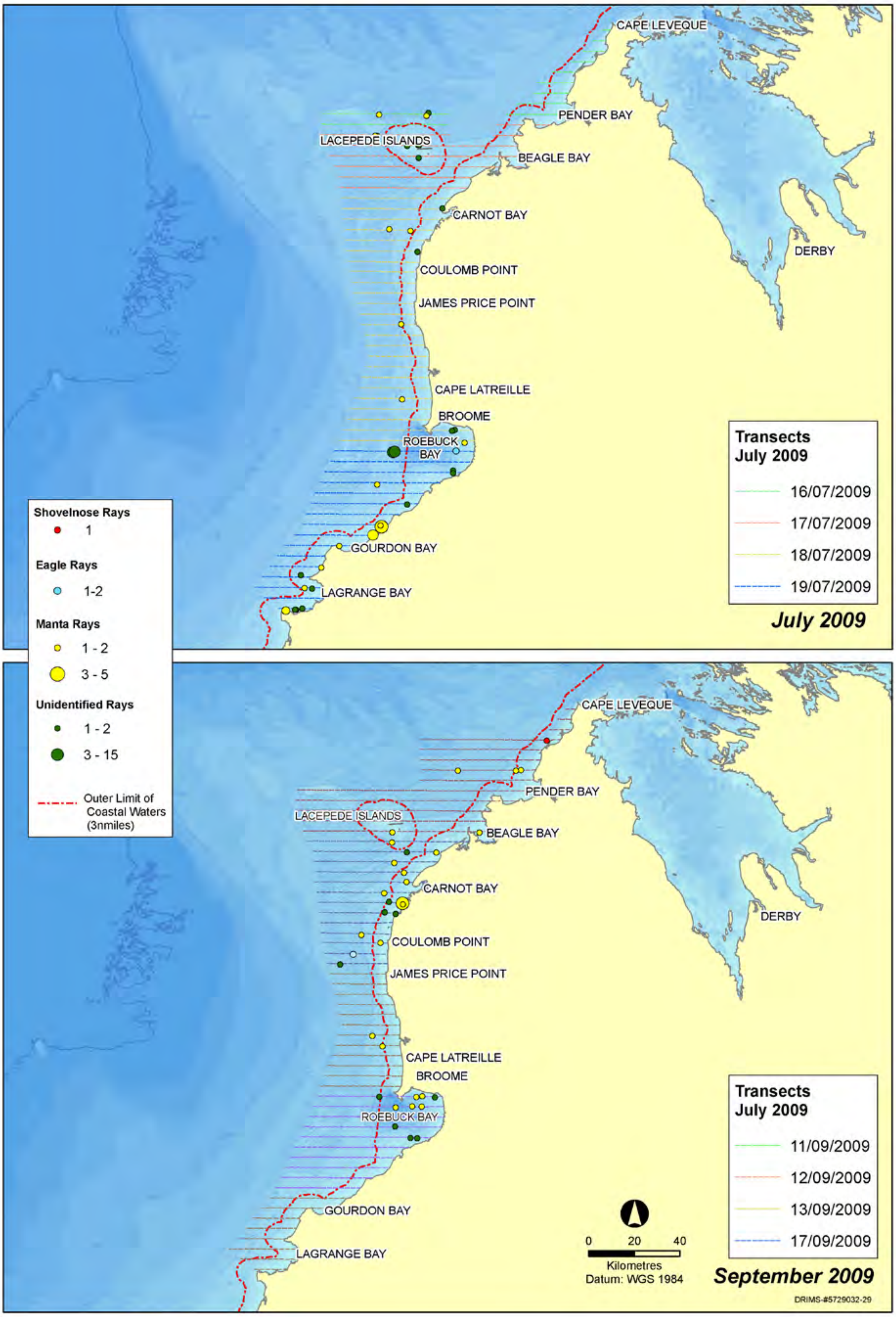
**James Price Point Coastal Area**

The 2009 BRUVS survey of the inshore fish fauna identified a total of 7,108 individuals from 116 species of fishes, sharks, rays and sea snakes (Cappo *et al.,* 2010b; **Appendix C-6**). Chondrichthyans were well represented by the Carcharhiniformes (nine species of sharks), Rajiformes (seven species of stingrays and shovelnose rays) and Orectolobiformes (3 nurse sharks) (Cappo *et al.,* 2010b; **Appendix C-6**). Apex predators including carangids, and carcharhinid (whalers) and sphyrnid (hammerhead) sharks were common and abundant (Cappo *et al.,* 2010b; **Appendix C-6**).




Source: RPS 2010d; **Appendix C-10**.

- **Figure 1-66 Sharks Recorded during the July and September 2009 Nearshore Regional Survey.**




Source: RPS 2010d; **Appendix C-10**.

- **Figure 1-67 Rays Recorded during the July and September 2009 Nearshore Regional Survey.**

**EPBC Act Listed Shark and Ray Species**

The Kimberley region is host to a number of shark and ray species, of which two are listed as threatened and protected under the EPBC Act. These are the whale shark (*Rhincodon typus*) and the northern river shark (*Glyphis garricki*). Although the Kimberley region is beyond the typical range for the EPBC listed great white shark (*Carcharodon carcharias*), one individual of this species was recorded in the survey area (RPS, 2010d; **Appendix C-10**). It was sighted west of Carnot Bay close to the 50 metre isobath and approximately 67km north-west of James Price Point. This single sighting of a great white shark is of interest as the Kimberley is considered to be outside of its known range. However, this shark is known to follow migrating humpback whales and to undertake extensive migrations that can extend beyond its normal range. Whilst it may not be entirely vagrant at this location, it is likely to be a rare visitor (RPS, 2010d; **Appendix C-10**).

The 2009 BRUVS fish census determined that no shark species classified as threatened under the EPBC Act were noted during their surveys (Cappo *et al.,* 2010b; **Appendix C-6**). However, it is reported that northern river sharks have been caught in the vicinity of James Price Point and are likely to transit through the area on their way to and from estuarine habitats (such as the Fitzroy River) (Morgan *et al.,* 2009; **Appendix C-7**).

*Whale shark*: The whale shark is listed as a vulnerable/ migratory marine species under the EPBC Act and "totally protected" under the WA Fisheries Management Act. The whale shark occurs in both tropical and temperate waters, and is generally encountered in areas where the water surface temperature is between 21 and 25°C with upwelling of colder (17°C or less) water, and a salinity range of 34 to 34.5ppt (Colman, 1997). The whale shark may utilise the region for migration and possibly opportunistic foraging. Whale sharks are known to aggregate seasonally March to June in the coastal waters off Ningaloo Reef and individuals travel up the coast of WA using both inshore and offshore habitats, spending over 40% of their time in shallow waters less than 15m deep (Wilson *et al*., 2006). From Ningaloo Reef, tagged sharks migrated as far north as Ashmore Reef before moving offshore into the Indian Ocean. Of the time spent in the shallow water depths, 42.6% was during daylight hours and 57.4% was at night. Whale sharks have previously been recorded in the Kimberley region, however, were not observed during the 2009 surveys (RPS, 2010d; **Appendix C-10**). The species may potentially pass through the region between June and October. Although the presence of whale sharks in the area at other times cannot be excluded because of its absence during any of the 2009 surveys, it is unlikely to occur in the area in high numbers (RPS, 2010d; **Appendix C-10**).

*Northern river shark (Glyphis garricki):* The northern river shark is listed as an endangered marine species under the EPBC Act. The majority of capture locations for the northern river shark have come from King Sound in the west Kimberley (Morgan *et al*., 2009; **Appendix C-7**). Most collections in WA have occurred in turbid, macrotidal mangrove systems of King Sound in salinities greater than 20ppt over sandy to silty substrates (Morgan *et al.,* 2009; **Appendix C-7**). Current population numbers are unknown, but are estimated to be small due to their rarity (Pogonoski and Pollard, 2003).

## 1.5. Marine Management Framework

SEWPAC (formerly DEWHA) administers the EPBC Act for the Commonwealth. In WA, DEC is responsible for implementing management plans for marine wildlife (for example whale shark), threatened marine fauna (for example turtles, dugong) and the state's marine conservation reserves. The WA DoF has a role in managing and conserving 'fish and fish habitat'. The EPA prepares environmental policies, strategic environmental advice and environmental impact assessment recommendations for consideration by government.

In terms of marine resource management, the WA government has designated DEC as the lead State agency for monitoring the establishment and progress of a long-term state biodiversity conservation strategy. SEWPAC has Commonwealth government mandate for marine bioregional planning and it is identifying new marine protected areas (**MPAs**) to contribute to Australia's National Representative System. The marine bioregional planning process for the northwest of Australia is currently underway (DEWHA, 2009a).

### 1.5.1. Commonwealth Threatened Marine Fauna

The EPBC Act provides a legislative framework to protect threatened species and provides a list of marine species that are protected. A search of the EPBC Act protected matters search tool was undertaken within 120km north, 84km east, 140km south and 145km west of the James Price Point coastal area on 20 April 2009 (Appendix B to the SoSA, DSD 2010c; **Appendix A-3**). The search identified ten threatened marine species. A concurrent search of threatened species

within 50km of James Price Point was undertaken by DEWHA and taking into account other sources a further six species were identified (**Table 1-26**).

- **Table 1-26 Threatened Marine Species (Endangered or Vulnerable) Determined to Potentially Occur within 50km of James Price Point, as Identified in the Scope of Strategic Assessment.**

| Scientific Name | Common Name | EPBC Act Species Status** | Search results study area | Recorded in fauna surveys | Source |
|---|---|---|---|---|---|
| *Balaenoptera musculus* | Blue whale | Endangered/ Migratory/ Cetacean | May occur | - | EPBC Act database search |
| *Balaenoptera musculus brevicauda* | Pygmy blue whale | Endangered/ Migratory/ Cetacean | May occur | - | DEWHA Aug/DEC advice 2008 (North-west Marine Bioregional Plan, Bioregional Profile (DEWHA, 2008a)). |
| *Balaenoptera musculus intermedia* | Southern blue whale | Endangered/ Migratory/ Cetacean | May occur | - | DEWHA Aug/DEC advice 2008 (North-west Marine Bioregional Plan, Bioregional Profile (DEWHA, 2008a)). |
| *Megaptera novaeangliae* | Humpback whale | Vulnerable/ Migratory/ Cetacean | Recorded (breeding) | Yes (**RPS, 2010a; Appendix C-8**) | EPBC Act database search |
| *Caretta caretta* | Loggerhead turtle | Endangered/ Migratory/ Marine | May occur | Yes (**RPS, 2010b; Appendix C-2**) | DEWHA Aug/DEC advice 2008 (North-west Marine Bioregional Plan, Bioregional Profile (DEWHA, 2008a)). Advice from marine turtle experts at the DEWHA marine turtle workshop (Mar 09) and preliminary results from Woodside 2009 surveys. |
| *Chelonia mydas* | Green turtle | Vulnerable/ Migratory/ Marine | May occur | Yes (**RPS, 2010b; Appendix C-2**) | DEWHA Aug/DEC advice 2008 (North-west Marine Bioregional Plan, Bioregional Profile (DEWHA, 2008a)). Advice from marine turtle experts at the DEWHA marine turtle workshop (Mar 09) and preliminary results from Woodside 2009 surveys. |
| *Dermochelys coriacea* | Leatherback turtle | Endangered/ Migratory/ Marine | May occur | - | Advice from marine turtle experts at the DEWHA marine turtle workshop (Mar 09). |

| Scientific Name | Common Name | EPBC Act Species Status** | Search results study area | Recorded in fauna surveys | Source |
|---|---|---|---|---|---|
| *Eretmochelys imbricata* | Hawksbill turtle | Vulnerable/ Migratory/ Marine | May occur | Yes (**RPS, 2010b; Appendix C-2**) | Advice from marine turtle experts at the DEWHA marine turtle workshop (Mar 09). |
| *Lepidochelys olivacea* | Olive ridley turtle | Endangered/ Migratory/ Marine | Not in Environmental Reporting Tool | - | DEWHA Aug/DEC advice 2008. Advice from marine turtle experts at the DEWHA marine turtle workshop (Mar 09). |
| *Natator depressus* | Flatback turtle | Vulnerable/ Migratory/ Marine | May occur | Yes (**RPS, 2010b; Appendix C-2**) | DEWHA Aug/DEC advice 2008 (North-west Marine Bioregional Plan, Bioregional Profile (DEWHA, 2008a)). Advice from marine turtle experts at the DEWHA marine turtle workshop (Mar 09) and preliminary results from Woodside 2009 surveys. |
| *Glyphis sp. C* | Northern river shark | Endangered/ Marine | Not in Environmental Reporting Tool | - | DEWHA Aug/DEC advice 2008 may occur (records south of Broome) |
| *Carcharodon carcharias* | Great white shark | Vulnerable/migratory | May occur | - | EPBC Act database search |
| *Pristis clavata* | Dwarf sawfish | Vulnerable/ Marine | May occur | - | EPBC Act database search |
| *Pristis microdon* | Freshwater sawfish | Vulnerable/ Marine | Likely to occur | - | EPBC Act database search |
| *Pristis zijsron* | Green sawfish, dindagubba, narrowsnout sawfish | Vulnerable/ Marine | May occur | - | EPBC Act database search |
| *Rhincodon typus* | Whale shark | Vulnerable/ Migratory/ Marine | May occur | - | EPBC Act database search |

Note: ** A description of the status classification of species can be provided at SEWPAC website [www.environment.gov.au].

The EPBC Act protected matters search also identified 24 wetland and 17 marine migratory species (Appendix B to the SoSA) that may potentially occur within the area. An assessment of significance criteria for fauna species that are listed under the EPBC Act is discussed in **Part 6, Section 2** (Matters of National Environmental Significance).

### 1.5.2. State Protected Marine Fauna

To inform the assessment a search of the Western Australian DEC Threatened Fauna database was undertaken. Search results are listed below.

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

- humpback whale (Megaptera novaeangliae);
- blue whale (Balaenoptera musculus);
- green turtle (*Chelonia mydas*);
- leatherback turtle (*Dermochelys coriacea*);
- loggerhead turtle (*Caretta caretta*);
- hawksbill turtle (*Eretmochelys imbricate*);
- flatback turtle (*Natador depressus*);
- olive ridley turtle (*Lepidochelys olivacea*); and
- green sawfish (*Pristis zijsron*).

**Schedule 4 – Other specially protected fauna**

- dugong (*Dugong dugon*); and
- saltwater Crocodile (*Crocodylus porosus*).

**Priority 1 and 2 – Fauna with few, poorly known populations**

- dwarf sawfish (*Pristis clavata*); and
- northern river shark (*Glyphis* sp.).

**Priority 3 – Fauna with several, poorly known populations**

- freshwater sawfish (*Pristis microdon*).

**Priority 4 – Fauna in need of monitoring**

- Australian snubfin dolphin (*Orcaella heinsohni*);
- Indo-Pacific humpback dolphin (*Sousa chinensis*); and
- spinner dolphin (*Stenella longirostris*).

No marine plant species is specifically listed under wildlife conservation legislation.

### 1.5.3. State and Commonwealth Protected Areas

In October 2010 the Western Australian Government announced the formation of the Kimberley Wilderness Parks, as a key component of the State Government's Kimberley Science and Conservation Strategy. As part of this announcement, four new marine parks are proposed, including:

- Camden Sound Marine Park. The proposed park is located about 300 kilometres north-east of Broome and covers approximately 7,062 square kilometres (or 706,200 hectares), which will make it the second largest marine park in Western Australia behind Shark Bay. An indicative Management Plan was released for public comment on 22 October 2010.
- Three additional marine parks for North Kimberley, Roebuck Bay and Eighty Mile Beach. Indicative management plans will be prepared for each marine park and released for public comment.

The Camden Sound and North Kimberley marine parks are proposed to be managed together as the Great Kimberley Marine Park. The Great Kimberley Marine Park will extend from Montgomery Reef in the south up to Cape Londonderry in the north and will cover more than 17 per cent of WA waters making it Australia's second largest marine park in coastal waters behind the Great Barrier Reef Marine Park.

The Great Kimberley Marine Park will include two sanctuary zones which are designated no-take areas, that will exclude extractive uses such as commercial and recreational fishing; shell collecting; aquaculture; seismic survey and mineral or petroleum exploration; drilling and production.

Currently, there are no existing State or Commonwealth Marine Protected Areas (MPAs) in the West Kimberley or Dampier Peninsula region. The closest existing State Marine Protected Area is the Rowley Shoals Marine Park, located approximately 290km northwest of Broome.

Under the EPBC Act, the Commonwealth manages an estate of MPAs within the Kimberley area, including:

- Ashmore Reef National Nature Reserve, located in the Timor Sea about 610km north of Broome. Ashmore Reef lies at the western extremity of the Sahul Shelf where it is one of only three emergent reef systems;
- Cartier Island Marine Reserve, which includes Cartier Island (about 45km from Ashmore Reef) and the surrounding reef, including the substrata to a depth of 1,000m below the sea floor; and
- Mermaid Reef Marine National Nature Reserve, which is located about 300km west of Broome.

The total area of the Marine National Nature Reserve is 53,984ha and the declaration includes the seabed and subsurface to a depth of 1,000m. Mermaid Reef is the most north easterly atoll of the Rowley Shoals. The Commonwealth government is implementing a series of marine bioregional plans for Commonwealth marine waters, including one for the northwest of Australia (DEWHA, 2008a). These plans are designed to consolidate available knowledge about marine ecosystems and human activities in the regions, and provide an improved basis for decision-making about the conservation and use of the Commonwealth's marine estate.

### 1.5.4. Other Considerations

The operations in the marine environment are subject to a variety of planning strategies, summarised below.

#### State Water Quality Management Strategy

The State Water Quality Management Strategy No. 6 (DoE, 2004) outlines the framework for WA for fresh and marine water quality, and water quality monitoring and reporting. The framework requires that all significant resources in WA are spatially defined on a priority basis and that environmental values are developed for each of these resources.

Details of environmental values for marine resources of the Kimberley are discussed previously in this chapter. Importantly, the environmental value considered in an impact assessment perspective is ecosystem health, including ecological and social values/objectives (**Table 1-27**).

**Table 1-27 Environmental Values and Environmental Quality Objectives of the Marine Resources for the Kimberley.**

| Environmental Values | Environmental Quality Objectives |
|---|---|
| Ecosystem Health (ecological value) | Maintain ecosystem integrity - maintaining the structure (the variety and quantity of life forms) and functions (e.g. the food chains and nutrient cycles) of marine ecosystems. |
| Recreational and Aesthetics (social use value) | Water quality is safe for recreational activities in the water (e.g. swimming).<br>Water quality is safe for recreational activities on the water (e.g. boating).<br>Aesthetic values of the marine environment are protected. |
| Cultural and Spiritual (social use value) | Cultural and spiritual values of the marine environment are protected. |
| Fishing and Aquaculture (social use value) | Seafood (caught or grown) is of a quality safe for eating.<br>Water quality is suitable for aquaculture purposes. |
| Industrial Water Supply (social use value) | Water quality is suitable for industrial supply purposes. |

Source: Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives (DoE, 2006).

#### Commonwealth Marine Bioregional Planning

The Federal Government is developing a series of Marine Bioregional Plans for Australia's Exclusive Economic Zone, not including State coastal waters (DEWHA, 2008c). These plans are designed to provide an improved basis for decision-making about the conservation of the marine environment and to identify new Marine Protected Areas. The north-west marine plan covers Commonwealth waters from the WA/NT border to Kalbarri, south of Shark Bay, and encompasses Commonwealth waters adjacent to the Dampier Peninsula and Kimberley region. A bioregional profile report exists (DEWHA, 2008c) to support the set of key interests and considerations in the development of a Marine Regional Plan. This plan, once gazetted, will be followed by an implementation strategy with the likely outcome a declaration of an MPA network at some future time after a series of consultations.

#### The North-West Marine Bioregional Plan

James Price Point is located within the North West Province (DEWHA, 2008c) a vast bioregion between North-West Cape and Cape Bougainville. The bioregional profile provides a description of the North-West region's ecological characteristics, conservation values, the process by which new Marine Protected Areas will be identified and the current human activities that occur there.

The following environmental values have been identified within the bioregion:

- important rookeries and critical nesting and inter-nesting habitat for flatback turtles;
- high species richness (but relatively low endemicity);
- home to globally significant populations of internationally threatened species;
- biological productivity follows boom and bust cycles, which is sporadic and significantly geographically dispersed; and
- coral reefs in the region are of especially high species diversity. Reefs to the south of Ashmore reef are mostly composed of scleractinian corals (i.e. hard corals).

While the Kimberley region contains some significant environmental values, such as endangered and vulnerable species, typically these values are either distributed widely throughout the entire province or they occur in areas which are not in the vicinity of the proposed BLNG Precinct.

#### State Regional Marine Planning

The recent announcement of the Kimberley Wilderness Parks will support the State's initiative to progress the development of multiple-use, regional marine plans applying to State coastal waters off the Kimberley coast. A marine policy stakeholder group was advising the government of a policy framework. The policy framework will be developed to provide for regional plans to better integrate the activities of the various marine sectors and to achieve protection, maintenance and sustainable use of the marine environment. The strategic plan will be based on the best available science while, at the same time, taking into account the views of marine users. Government departments, agencies, maritime industries, nongovernment organisations, community groups and the general public will play a role in regional marine planning.

#### EPA's Environmental Assessment Guidelines for the Protection of Benthic Primary Producer Habitat in Western Australia's Marine Environment (EAG3)

The stated aim of EAG3 (EPA, 2009a) is to protect the underlying ecosystem functions provided by BPPH and the BPP it supports. The EAG3 defines BPP as:

*"Predominantly marine plants (e.g. seagrasses, mangroves, seaweeds and turf algae) but include invertebrates such as scleractinian corals, which acquire a significant proportion of their energy from symbiotic microalgae that live in coral polyps. These organisms grow attached to the seabed (i.e. subtidal and intertidal), sequester carbon from surrounding seawater or air and convert it to organic compounds through photosynthesis."*

The guideline (EPA, 2009a) also defines BPPH as:

*"…both the BPP communities described above as well as the substrata that can/do support these communities."*

In undertaking an impact assessment to BPPH/BPP, EAG3 (EPA, 2009a) requires an estimate of historical and cumulative loss of BPP and their habitats to be developed for each BPPH type in each management unit. Within EAG3, the following definition of management unit is provided:

"*A specific geographical area which provides the most effective boundaries for management of cumulative environmental impacts on marine habitats."*

The guideline goes on to qualify this definition by stating:

*"There is no accepted scientific method for determining ecosystem or management unit boundaries. However, an understanding of spatial hierarchies in natural systems and a recognition of the spatial scales of human impacts can assist in defining management units required to determine cumulative loss of BPPH using the guidance provided in this document."*

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# 2. Marine Factors

The following chapter provides an assessment of the impacts to the marine factors pertinent to the construction and operation of the BLNG Precinct. The factors have been identified and their potential impacts assessed by providing an overview and objectives for each factor, identifying the potential impacts, consideration of the sensitivity and resilience of the factor, describing the proposed management and mitigation actions and assessing the significance of the residual impacts following implementation of management and mitigation actions.

The key marine factors identified through the assessment process described in **Part 2**, **Section 8** are:

- marine water quality;
- benthos (including benthic primary producers);
- marine mammals; and
- marine reptiles.

A detailed impact assessment is presented for each of these key environmental factors.

Other marine factors identified as being relevant to the assessment are:

- tidal regimes, wave climate, currents and hydrodynamics;
- marine sediments;
- fish; and
- marine ecosystem integrity.

Although relevant to the assessment, these factors were determined as not requiring detailed assessment or management measures beyond standard practice. As such, only a brief description of the potential impacts and proposed management measures are presented for these factors.

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## 2.1. Relevant Factor: Tidal Regimes, Wave Climate, Currents and Hydrodynamics

The development of the B LNG precinct may affect sediment transport and coastal processes interacting with the proposed port, channel and marine infrastructure (i.e. a breakwater). The alteration of these natural coastal processes may result in an impact on marine ecological communities and physical processes.

### 2.1.1. Current Knowledge

The following sub-sections describe regulatory expectations with respect to tidal regimes, wave climate, currents and hydrodynamics, and provide a summary of key site features relevant to potential impacts.

Site specific information on tidal regime, wind, waves and currents within the James Price Point coastal area were determined from two primary sources:

- Browse LNG Development - Hydrodynamic Model Validation of the James Price Point Region (DHI, 2010c); and
- Browse LNG Development - Coastal Processes Sediment Transport Study (DHI, 2010b).

These studies were undertaken using data from a Department of State Development (**DSD**) Metocean programme to calibrate and validate the hydrodynamic model.

#### 2.1.1.1. Key Statutory Requirements, Environmental Policy and Guidance

There are a number of key statutory requirements, environmental policy and guidance that apply to the Strategic Assessment in relation to Tidal Regimes, Wave Climate, Currents and Hydrodynamics.

**State Guidance and Policies**

The EPA objective relevant to tidal regimes, wave climate, currents and hydrodynamics is:

"*to maintain the integrity, ecological functions and environmental values of the seabed and coast*" (EPA, 2009f).

The following guidelines and regulatory frameworks are applicable to tidal regimes, wave climate, currents and hydrodynamics:

- Draft Environment Protection (State Marine Waters) Policy 1998
- EAG No.3 for Protection of Benthic Primary Producer Habitat in WA's Marine Environment (EPA, 2009a)
- WA State Coastal Planning Policy 2006
- *Marine Act 1982*
- Navigable Waters Regulations 1958
- Port and Harbour Regulations 1966.

**International Conventions**

- United Nations Convention on the Law of the Sea (UNCLOS) 1982.

**Commonwealth Protection, Guidance and Policies**

- *Offshore Petroleum and Greenhouse Gas Storage Act 2006.*

#### 2.1.1.2. Description of Factor

Existing information on hydrodynamics and coastal processes relevant to the nearshore environment of the BLNG Precinct site and in the general James Price Point coastal area are described in **Part 3**, **Section 1.1** (Environmental Overview). Relevant key findings include:

- James Price Point is located in a region of seasonal tropical cyclone activity (November through April). Historical statistics derived from the Bureau of Meteorology indicate that a cyclone affects the area at an average frequency of once every four years (DHI, 2010c).
- Winds are likely to occur predominantly from the west-south-west (**WSW**) through west-north-west (**WNW**) with speeds of 5 to 15m/s for the summer (October to March) period, whilst the winter (April to September) winds are likely to be from the north-east (**NE**) through south-east (**SE**) with speeds of 8 to 15m/s.
- The James Price Point coastal area is subject to weak alongshore currents (<0.1m/s) flowing in a southerly direction.
- The combination of strong tide, undulating topography and year round strong solar heating generates a water column that is vertically well mixed with strong topographical forcing.
- The depth-averaged current speed during the peak of the spring tide ranges from 0.3m/s to 0.6m/s, with a corresponding maximum tidal excursion of approximately 2km.
- The tidal range at James Price Point is about 7.8m (2010 Highest Astronomical Tide) with tidal forcing likely to dominate the current regime.
- While waves are important for turbulent mixing processes, they do not seem to contribute significantly to net horizontal movement of fluid particles.
- The sand beaches appear to be eroding with extensive low, steep cliffs observed along the backshore indicating intermittent erosion during major storms and cyclones. Recovery of eroded material after storms is apparently slow, indicating a possible overall net loss of material.

### 2.1.2. Identification of Key Aspects

#### 2.1.2.1. Definition of Relevant Aspects

Aspects associated with the development and operation of the BLNG Precinct and associated infrastructure that may have an environmental impact on tidal regimes, wave climate, currents and hydrodynamics were identified in the Scope of the Strategic Assessment and considered in this assessment. These aspects include:

- site disturbance and excavation; and
- physical presence (i.e. the introduction and long-term physical presence of the nearshore marine infrastructure).

Additional detail on the nearshore marine infrastructure and facilities can be found in **Part 2**, **Section 5** (Description of Activities and Facilities under the Plan).

#### 2.1.2.2. Sources of Impact

**Site Disturbance and Excavation**

The construction of the BLNG Precinct marine infrastructure will require dredging, dredge spoil disposal, drilling and coring of boreholes, positioning of jack-up barges and other marine activities (e.g. piling). These activities which are associated with the dredging of the approach channel and turning basin, LNG export jetty installation, breakwater construction and pipeline trenching have the potential to change local coastal processes.

**Physical Presence**

A range of coastal and nearshore marine facilities will be constructed for the BLNG Precinct. These facilities are likely to include export jetty facilities, ship berthing pockets (with loading platforms, breasting and mooring dolphins), a breakwater (if required), a marine offloading facility, all-weather vessel harbouring facilities and other facilities to support marine port operations. Pipeline infrastructure within the nearshore marine environment will include the feedstock gas pipelines and other ancillary pipelines.

**Nearshore Infrastructure**
Supporting marine infrastructure, including the marine offloading facility and vessel all-weather harbouring facilities will be constructed in nearshore marine waters to facilitate the initial construction phase of the BLNG Precinct. These facilities will then be used during ongoing operation of the BLNG Precinct. Construction of supporting marine infrastructure may be phased.

It is anticipated that the LNG export facilities within the BLNG Precinct will require approximately one berth for every 10Mtpa of LNG production. Consequently, export facilities will be phased in line with the precinct production capacity, with approximately six berths anticipated for a 50Mtpa LNG Precinct.

**Pipeline Infrastructure**
There will be up to eight hydrocarbon feed gas pipelines to convey hydrocarbons from the upstream production facilities at the offshore gas fields to the BLNG Precinct. Depending on the final design, there is option for an additional two pipelines for $CO_2$ export and an additional four hydrate inhibitor (e.g. mono ethylene glycol (**MEG**)) pipelines. Like nearshore marine construction activities, pipeline infrastructure may be phased during the development lifecycle.

#### 2.1.2.3. Sensitivity and Resilience

**Physical Presence**
The coastline and coastal processes at James Price Point and surrounding beaches are not currently subject to the influence of any significant anthropogenic activity (e.g. coastal development, ports or slip ways) with the closest anthropogenic feature being the Port of Broome, approximately 60km south.

Sediment transport in the James Price Point coastal area is significantly influenced by the geology. Alongshore sediment transport is restricted by the presence of headlands, rock platforms and beach rock, with cross-shore transport restricted by cliffs, rock platforms and storm deposits (acting as revetments) and complex inshore reef systems. The incident wave energy and angle of the breaking waves is influenced by the nearshore bathymetry.

Alterations to the tidal and current flow due to the physical presence of infrastructure may lead to changes in coastal processes, such as limiting longshore sediment drift, possibly contributing to beach erosion and/or accretion and impacting coastal morphology. A visual assessment of aerial photography from 1949, 1996, 2000 and 2007 was conducted to determine the long-term shoreline change and potential response of active foredunes to tropical cyclonic forcing. The majority of changes observed were the erosion of Pindan sediments at low elevations along Manari Road north of James Price Point; and erosion of vegetated foredunes and reworked Pindans, likely to have occurred during Tropical Cyclone Rosita based on the comparison of the 1996 and 2000/2001 imagery, with some recovery noted in the 2007 imagery. The foredunes could retreat 1–15m landward during tropical cyclone events. As some of these foredunes can be approximately 1–6m in elevation, this could represent mobilisation of sediments in the order of 1–90$m^3$/m of beach width. This approximation should be added to the potential mobilisation of sediments from the foreshore determined above to determine the total potential for sediment mobilisation during tropical cyclone events.

### 2.1.3. Predicted Impacts

Potential impacts on physical factors from the construction and operation of the BLNG Precinct are discussed below and summarised in **Table 2.1-4**. Both direct and indirect impacts are considered within these sections. For the purpose of this assessment it is considered that direct impacts would largely be confined to areas of direct disturbance within the BLNG Precinct, and other locations where development activities are proposed to occur.

The BLNG Precinct marine infrastructure has the potential to impact upon local coastal processes through changes to the seabed and the introduction of fixed infrastructure at the port. As a conceptual port design has not been developed yet, a hydrodynamic and sediment transport modelling has not been undertaken associated with specific port designs. A Coastal Processes Sediment Transport Study (DHI, 2010b) has however been undertaken to give an insight into the current dynamics of the local coastal processes and therefore, the relative influences of the various oceanographic ‘drivers’ which may be impacted. The initial results of the study came to the following conclusions for the identified key aspects.

#### 2.1.3.1. Marine Site Disturbance and Excavation

A deepening of the seabed through dredging will alter the incident waves propagating towards the local shoreline through nearshore wave processes such as refraction and shoaling, induced by the dredged seabed profile. The local current regime has the potential to be steered by changes to the seabed. The change to the local wave and current climate will be minor relative to the semi-diurnal tidal inundations and oscillations naturally experienced in the James Price Point coastal area.

It is likely that the marine site disturbance and excavation of the nearshore infrastructure will affect local hydrodynamic and coastal geomorphological processes. It is expected that potential impacts to coastal processes can be successfully mitigated by the application of management and mitigation measures such as demonstration of design measures to minimise impacts on coastal processes from onshore and nearshore marine infrastructure supported by hydrodynamic modelling and closure planning. A more detailed description of proposed mitigation measures is presented in **Section 2.1.4**. However, residual impacts would take the form of minor disturbances to well represented landform and/or habitats and localised coastal re-adjustment. The significance of residual impacts on local hydrodynamic and coastal geomorphological processes is assessed to be very low, as changes will be localised and minor relative to the semi-diurnal tidal inundations and oscillations naturally experienced in the James Price Point coastal area.

#### 2.1.3.2. Physical Presence

The potential impacts associated with the physical presence of the BLNG Precinct, include:

- the impoundment of sediment against shore-crossing structures;
- modification of inshore tidal currents and sediment transport pathways; and
- changes to the transportation of sediment along the James Price Point coastal area.

The presence of shore-crossing structures has the potential to cause impoundment of sediment, the undermining or smothering of facilities due to Aeolian transport and the loss of sediment into dredged areas upsetting the balance of the cross-shore exchange of sediment on the perched beaches.

In addition to the potential mobilisation of sediments associated with the activation of the ephemeral creek adjacent to the proposed facility, the modification of inshore tidal currents and sediment transport pathways are likely to be enhanced during tropical cyclone events.

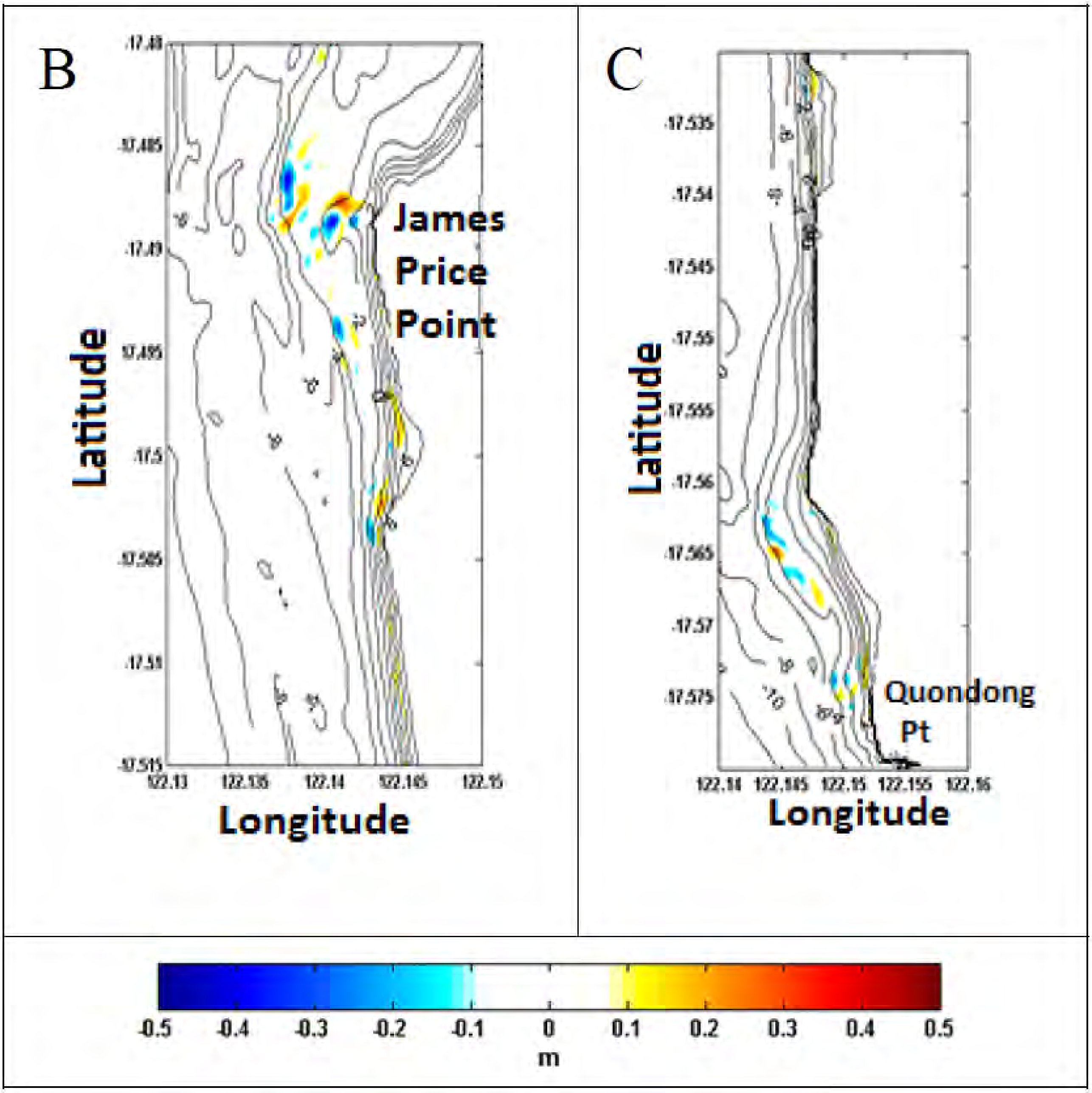
Under the prevailing conditions, it is likely that sediment will be transported alongshore from the beaches perched in front of cliffs to the dune fields to the north in the vicinity of the proposed marine offloading facility and pipeline crossing (see **Part 3**, **Section 1.3.1** for reference to the existing coastal geomorphology in the vicinity of the BLNG Precinct). Impoundment of sediment was evidenced during the field survey on the southern side of elevated rock platforms. Beach elevations, rates of alongshore and cross-shore transport would vary across a spring-neap cycle. In the Canning Bioregion, concentrations of suspended sediments in the water column vary by an order of magnitude between spring and neap tides (Margvelashvili *et al.*, 2006).

A conservative estimate of the volume of beach sediments that may become mobile is between 27m$^3$/m and 45m$^3$/m in the alongshore direction. For a 150m section of sandy beach, this equates to between 2,700m$^3$ and 6,750m$^3$ of mobilised sediments due to the action of waves and tidal currents over a strong spring tide event (~5 days). **Figure 2.1-1** shows the total bed change after 30 days for the March-April 2009 simulation period showing areas of deposition and erosion.

The modelling of morphological changes shows intermittent patterns of erosion and deposition within the model area. It is noted that this may be partly due to the changes in local sediment properties and the existence of reef/rocky areas around the headlands and in other sections. The morphological evolution further shows accretion and steepening of the beaches (erosion in the near shore area and accretion along the shoreline).

It is expected that potential impacts to coastal processes from physical presence of infrastructure can be successfully mitigated by the application of best practice management and mitigation measures such as the requirement for derived proponents to demonstrate the minimisation of impacts on coastal processes from onshore and near shore marine infrastructure. A more detailed description of proposed mitigation measures is presented in **Section 2.1.4**. The significance of the residual impacts on marine physical factors (i.e. currents, tides, wind) resulting from the presence of

nearshore infrastructure are deemed to be low, given the dynamic nature of the local marine environment, including the regular occurrence of tropical cyclones, and potential impacts from the physical presence of marine infrastructure are likely to be highly localised.




- **Figure 2.1-1 Bed Change After 30 Days for the March-April 2009 Simulation Period Showing Areas of Deposition and Erosion.**

Note: The solid black lines are topographical contours at a 2m interval starting at +8m AHD on the eastern extent of the figure. The colour bar at the base of the figure shows the magnitude of the bed change in metres.

### 2.1.4. Mitigation Measures and Safeguards

Mitigation measures and safeguards that have been identified to manage potential impacts to tidal regimes, wave climate, currents and hydrodynamics are outlined below in **Table 2.1-1**, **Table 2.1-2** and **Table 2.1-3**.

Local impacts can be managed by refining the infrastructure design. A regular shoreline and dune survey program should also be developed to monitor local influences from the BLNG Precinct marine infrastructure, and potentially implement appropriate measures if impacts are detected, in order to achieve acceptable outcomes.

**Table 2.1-1 State Government Measures for Tidal Regimes, Wave Climate, Currents and Hydrodynamics.**

| State Government measure | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area. | DoT | On approval of BLNG Precinct |

**Table 2.1-2 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Tidal Regimes, Wave Climate, Currents and Hydrodynamics.**

| Condition No. | Proposed Environmental Conditions for the Strategic Proposal |
|---|---|
| M1.1 | Proponents of derived proposals shall demonstrate application of best practice measures to be implemented to minimise impacts on coastal processes from onshore and nearshore marine infrastructure. Design measures should be supported by detailed hydrodynamic modelling. |
| M1.2 | Proponents of derived proposals shall develop a Final Closure Plan, in consultation with key stakeholders, to be submitted to the Chief Executive Officer of DEC at least five years prior to the planned date of closure. The Plan shall address:<br>• detailed measures to be implemented for final closure;<br>• the schedule and timing of final closure activities;<br>• completion criteria for closure; and<br>• closure monitoring requirements. |
| M1.3 | Proponents of derived proposals shall implement the Final Closure Plan required by condition 1.2 until such time that the Minister for Environment, on advice from the Chief Executive Officer of DEC, determines that the derived proponents closure and decommissioning responsibilities have been fulfilled. |

**Table 2.1-3 Requirements to be Addressed via Development of a Management Plan to Support a Derived Proposal Potentially Affecting Tidal Regimes, Wave Climate, Currents and Hydrodynamics.**

| Derived Proponent Requirements | Timing |
|---|---|
| Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework. | Prior to commencement of associated construction activities |

### 2.1.5. Environmental Outcome of Category A Activities

#### 2.1.5.1. Direct Impacts

Direct impacts from physical presence of port infrastructure are limited to alterations to sediment transport processes. This impact would be localised and altered coastal processes would reach a dynamic equilibrium through time. Detailed hydrodynamic and sediment transport modelling should be an integral part of the engineering design process which would allow the design and layout of the proposed infrastructure to incorporate measures to minimise the changes in hydrodynamic processes and local coastal morphology.

The direct impacts of Category A activities would include:

- localised shoreline change and supra-tidal and intertidal erosion/accretion from the introduction of dredged channels and fixed marine infrastructure including breakwaters, Marine Facility and pipeline shore crossings; and
- limited sub tidal erosion/accretion from the introduction of shipping channels, dredge spoil areas, breakwaters and seabed pipelines.

Potential impacts to coastal processes are likely to be localised due to the weak alongshore drift (DHI 2010b) and minor in comparison to existing natural processes such as the movement of sediment by tidal forces and tropical cyclones. Further modelling of current port infrastructure design and coastal processes is being undertaken to confirm the extent of potential impacts associated with sediment erosion/accretion, and will be made publicly available during the public consultation period for the SAR.

Practicable responses can be engineered in the design phase. Measures to accommodate unexpected events will be included in the relevant management plan prepared for the BLNG Precinct. These impacts would be identified through a monitoring programme to determine if the observed changes differ significantly from those predicted.

#### 2.1.5.2. Indirect Impacts

The indirect impacts of Category A activities include:

- alteration to small areas of beach; and
- alteration to relatively small areas of intertidal and subtidal benthic habitat by accretion of sediments reducing the foraging area including primary and secondary producers (macroalgae; seagrass; invertebrates) and vertebrates such as turtles, fish and snakes.

These impacts are expected to be very limited in spatial extent. Resources potentially affected are not of significant regional value. Refer **Part 3**, **Section 2.3** (Marine Water Quality) and **Part 3**, **Section 2.4** (Benthos (including BPP)) for further discussion on impacts to water quality and benthos.

Because these impacts are expected to be very limited and resources potentially affected are not of significant value in a regional context, any potential impacts can be identified and managed (if appropriate) through the implementation of appropriate design measures and adherence to the relevant management plan.

### 2.1.6. Cumulative Impacts of the Proposal and Associated Activities

#### 2.1.6.1. Category B Activities

The majority of Category B activities are related to increased population and provision of a workforce and marine services in Broome. Category C effects arise from offshore exploration and developments that may occur. The source of cumulative impacts are summarised below.

Category B activities identified centre around onshore actions supporting the BLNG Precinct but not subject to the current State or Commonwealth approval process. Only two activities have the potential to affect marine physical resources: expansion of Broome port to accommodate marine traffic; and the increase in marine traffic associated with the Precinct at Broome. However, it is anticipated that vessels calling at the Port of Broome during early pioneering activities, would be accommodated within the current capacity of the port.

The impacts on the physical processes (tides, currents, and hydrodynamics) from an expansion of Broome Port and the increase in marine traffic would be limited. Natural deep water conditions currently exist. Improvements would likely be to existing port areas. Expansion or development at new areas does not appear to be required, however these would result in localised impacts with limited or no impacts through the region. Increases in recreational activities would have no impact on physical processes.

#### 2.1.6.2. Category C Activities

Similar to the Category B actions, the geographic separation of the projects identified as Category C actions would also not be expected to add cumulatively to those of the BLNG Precinct. Impacts resulting from physical presence of Category C pipeline infrastructure in the vicinity of BLNG Precinct marine infrastructure are unlikely to affect coastal processes significantly.

Category C activities which have the potential to impact on coastal processes are limited to upstream development activities and the development of industrial services such as supply base. These activities are unlikely to present cumulative impacts.

**Table 2.1-4 Impact Assessment Summary for Physical Factors (Tidal Regimes, Wave Climate, Currents and Hydrodynamics).**

<table>
<tr><th rowspan="2">Environmental Aspect</th><th rowspan="2">Potential Impacts</th><th colspan="3">Mitigation Measures</th><th rowspan="2">Significance of Residual Impact</th></tr>
<tr><th>State Government Measures</th><th>Proposed Environmental Conditions</th><th>Future Proponent Management Plans</th></tr>
<tr><td>Site disturbance / excavation</td><td>Changes to local coastal processes</td><td rowspan="2">Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area.</td><td rowspan="2">Proponents of derived proposals shall demonstrate application of measures to be implemented to minimise impacts on coastal processes from onshore and nearshore marine infrastructure, in line with ALARP principles. Design measures should be supported by detailed hydrodynamic modelling.<br>Proponents of derived proposals shall develop a Final Closure Plan, in consultation with key stakeholders, to be submitted to the Chief Executive Officer of DEC at least five years prior to the planned date of closure. The Plan shall address:<br>• detailed measures to be implemented for final closure;<br>• the schedule and timing of final closure activities;<br>• completion criteria for closure; and<br>• closure monitoring requirements.<br>Proponents of derived proposals shall implement the Final Closure Plan until such time that the Minister for Environment, on advice from the Chief Executive Officer of DEC, determines that the derived proponents closure and decommissioning responsibilities have been fulfilled.</td><td rowspan="2">Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.</td><td>Very Low</td></tr>
<tr><td>Physical presence</td><td>The impoundment of sediment against shore-crossing structures<br>Modification of inshore tidal currents and sediment transport pathways<br>Changes to the transportation of sediment along the James Price Point coastal area.</td><td>Low</td></tr>
</table>

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## 2.2 Relevant Factor: Marine Sediments

The following section describes the potential threats and associated impacts that may impact marine sediment quality as a result of activities, facilities and other characteristics to be implemented under the Plan for the BLNG Precinct.

### 2.2.1 Current Knowledge

Current knowledge with respect to key policy documents and regulatory requirements, as well as a summary of known existing sediment quality characteristics in the vicinity of the proposed precinct are presented in the section below.

#### 2.2.1.1 Key Statutory Requirements, Environmental Policy and Guidance

A number of Commonwealth and State guidelines, strategies, policies and regulatory frameworks are applicable and provide the context for assessing the key issues relating to threatening process to marine sediments and expectations for management.

**Commonwealth Protection, Guidance and Policies**
Commonwealth legislation, policy and guidance relevant to marine sediment quality include:

- *Offshore Petroleum and Greenhouse Gas Storage Act 2006.*
- Petroleum (Submerged Lands) (Management of Environment) Regulations 1999.
- *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006.*
- *Environment Protection (Sea Dumping) Act 1981.*
- National Assessment Guidelines for Dredging 2009 (NAGD) (DEWHA 2009e).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality: Chapter 3, Section 3.5, Guidelines for Toxicants in Sediments (ANZECC/ARMCANZ, 2000).

**State Protection, Guidance and Policies**
The overarching EPA objectives for this factor are:

"...*maintenance of the abundance, diversity, geographic distribution and productivity of flora and fauna at ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge"*

and

*"…to maintain the integrity, ecological functions, and environmental values of the seabed and coast*" (EPA, 2009f).

State guidelines and policies relevant to marine sediment quality include:

- *Environmental Protection Act 1986.*
- Draft Environmental Protection (State Marine Waters) Policy 1998.
- *Conservation and Land Management Act 1984.*
- Environmental Assessment Guidelines (EAG) No.3. Protection of Benthic Primary Producer Habitat in Western Australia's Marine Environment (EPA, 2009a).
- An Environmental Quality Management Framework is available for certain WA state waters. In the absence of a Kimberley specific framework, the WA Department of Environment and Conservation (2006) "Pilbara Coastal Water Quality Consultation Outcomes. Environmental Values and Environmental Quality Objectives" will be used for guidance.

**International Conventions**

- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (also known as the London Protocol).

#### 2.2.1.2 Description of Factor

The following sub-sections describe the sediment content, deposition rates, particle size distribution (PSD) and characteristics of the marine sediments as determined from studies conducted within the James Price Point coastal area.

**Sediment Content**

Sediments in the Canning marine bioregion are characterised as predominantly carbonates (83-91.4% by weight (Brewer *et al*., 2007) and 40-100% (Baker *et al*., 2008)) in the form of oolites, pellets and in filled biogenic particles reflecting a dominant marine origin. Low amounts of terrigenous sediments (silicate) were observed at sites in close proximity to river discharge sites.

**Sediment Deposition Rates**

Sediment deposition (from sediment traps) was measured as part of a nearshore water quality monitoring program during three surveys between November 2009 and February 2010 (results summarised in **Appendix C-13**). Gross deposition during November 2009 was highest at the site furthest inshore, with rates of approximately 880g/m$^2$ per day recorded (**Table 2.2-1** and **Figure 2.2-1**). The lowest sedimentation rate was at a site southern end of the James Price Point coastal area and was estimated to be 165g/m$^2$ per day. Settled material was predominantly sand (size fraction from 0.063 to 2mm in diameter) and was observed to be finer to the south of the James Price Point coastal area while coarser material was observed at the more northern sites.

- **Table 2.2-1 Particle Size Distributions from sediments collected in sediment traps at the Nearshore Water Quality Monitoring Sites.**

| Location | Percent silt and Clay <0.063mm (%) | Percent Sand 0.063 – 2.0mm (%) | Percent Gravel >2.0mm (%) |
|---|---|---|---|
| **2 November 2009 – 22 November 2009** | | | |
| Site 1 | 7.9 | 81.9 | 10.2 |
| Site 2 | 8.4 | 91.3 | 0.3 |
| Site 3 | 9.4 | 90.6 | 0 |
| Site 4 | 19.9 | 80.0 | 0 |
| **22 November 2009 – 20 January 2010** | | | |
| Site 1 | 16.1 | 80.5 | 3.4 |
| Site 2 | - | - | - |
| Site 3 | - | - | - |
| Site 4 | - | - | - |
| **20 January 2010 – 25 February 2010** | | | |
| Site 1 | 44.6 | 55.4 | 0 |
| Site 2 | 63.1 | 36.9 | 0 |
| Site 3 | 57.3 | 42.7 | 0 |
| Site 4 | - | - | - |

Source: DSD, 2010d; **Appendix C-13**.

**Particle Size Distribution**

As part of preliminary nearshore geotechnical investigations (Aurecon, 2010), three boreholes were bored to completion approximately 20–22.5m below the sea bed. A fourth borehole was terminated at a depth of approximately 7m below the sea bed (**Figure 2.2-2**). The dominant material encountered was fine and sometimes silty red brown sand. Reworked sands were generally overlaid by either a hard 1m thick layer of calcarenite or a marine deposit of fine grained carbonate sand. Generally, the marine deposit was a loose surficial material of very fine to fine grained carbonate sand, silt, shell fragments and various other organic matter. It was predominantly grey to light grey in colour and quite uniform in consistency throughout the deposit. The marine sediment ranged between 0.25m and 7.25m in thickness in the completed boreholes (**Table 2.2-2**). Weathered rock encountered at the base of each of the completed boreholes was estimated to be very low strength sandstone.

A study undertaken by Gardline Marine Sciences during June and July 2009 within the offshore Calliance and Torosa Fields along the hydrocarbon feedstock pipeline route and into the coastal area near James Price Point (**Figure 2.2-3**) characterised the particle size distribution at sediment sampling locations, two of which were in the immediate vicinity of the James Price Point coastal area. Results indicated that the finest sediments were located in deeper waters, offshore and in the north of the area sampled. The greatest percentage of fines was found in waters in the Calliance Field where fines made up to 93% of the sediment. Higher proportions of sand (83.8 and 85.2%) and coarse gravel, with a relatively low surface fines content (14.2 and 10.4%), were recorded at shallower sites along the hydrocarbon feedstock pipeline route and in the immediate vicinity of the James Price Point coastal area.

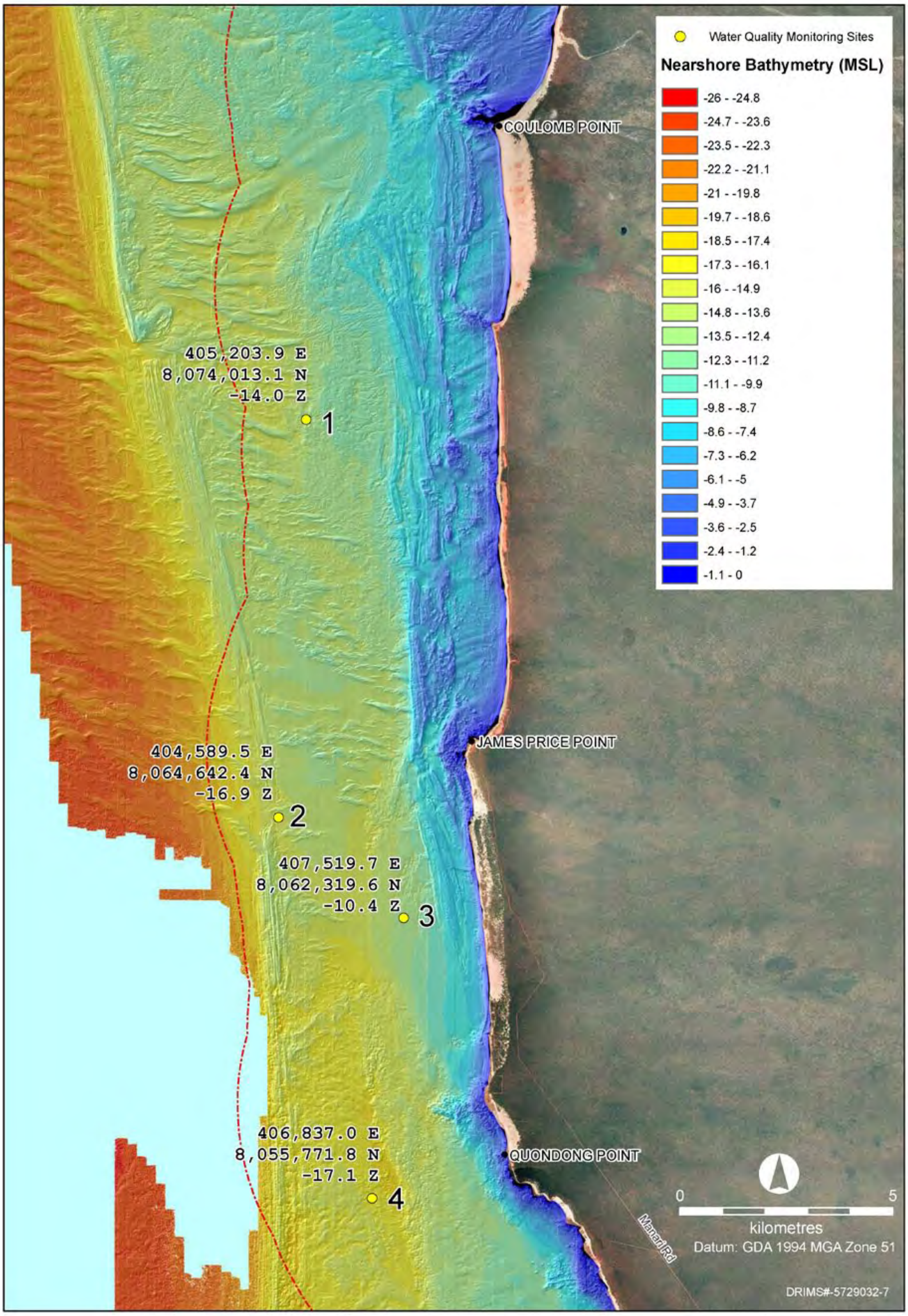
- **Table 2.2-2 Geotechnical Data from Four Boreholes at James Price Point.**

| Borehole ID | Seabed Level | Marine Sediment (Carbonate Sand) | | Calcarenite | | Reworked Sand | | Bed Rock | End of Hole Depth (mean sea level) |
|---|---|---|---|---|---|---|---|---|---|
| | | Top of layer (mean sea level) | Layer Thick-ness | Top of layer (mean sea level) | Layer thick-ness | Top of layer (mean sea level) | Layer thick-ness | Top of layer (mean sea level) | |
| BH1 | -14.92 | -14.92 | 4.85 | -- | -- | -- | -- | -- | -22.42 |
| BH2 | -13.23 | -13.23 | 0.25 | -13.48 | 1.05 | -14.53 | 14.65 | -29.18 | -34.23 |
| BH3 | -14.71 | -14.71 | 7.25 | -- | -- | -21.96 | 7.1 | -29.06 | -37.21 |
| BH6 | -12.98 | -12.98 | 0.55 | -13.53 | 1.1 | -14.63 | 16.6 | -31.23 | -32.98 |

Source: Aurecon, 2010.

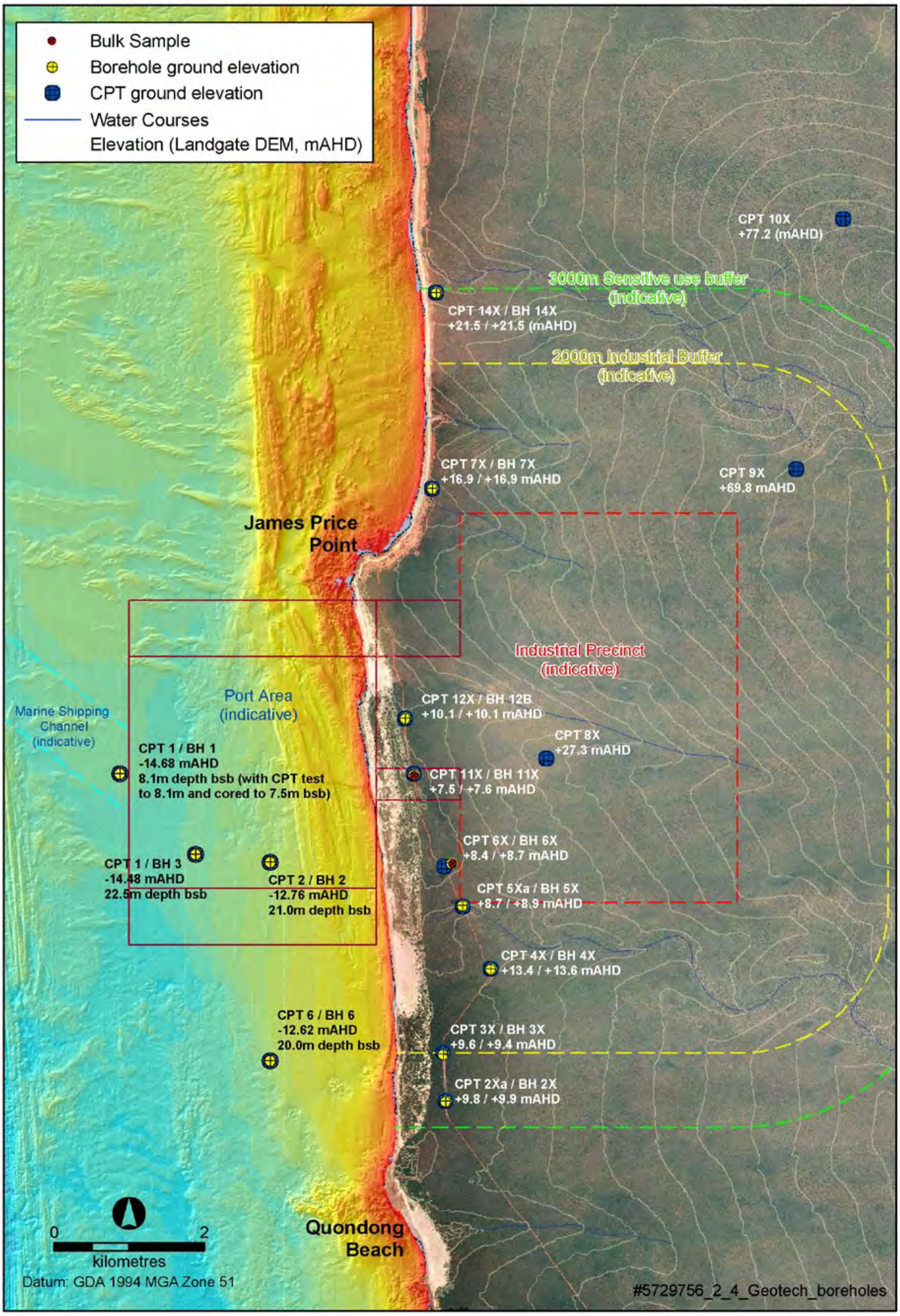
**Sediment Characteristics**

Results on surficial sediment quality characteristics, obtained by Gardline Marine Sciences (2009), showed that TN concentrations varied considerably throughout the area from which samples were taken, ranging between 40µg/g and 1900µg/g, with a mean of 520µg/g. Within the immediate vicinity of the James Price Point coastal area, TN concentrations were 340µg/g and 440µg/g. The nitrite/nitrate ($NO_x$) concentration varied between less than 0.100µg/g to 0.617µg/g. In the immediate vicinity of the JPP coastal area, nitrate and nitrite concentrations were 332µg/g and less than 0.10µg/g, respectively. The mean TP concentration was 584µg, yet concentrations at sites near the James Price Point coastal area were 1390µg/g and 1400µg/g, which were higher than elsewhere in the offshore part of the study area. TOC within sediments at all sites did not exceed 0.91% and were even lower near the BLNG Precinct area (0.19 and 0.17%) indicating that nutrient enrichment was low. ANZECC (2000) does not stipulate interim sediment quality guidelines (ISQG) for any of the nutrients presented above. The National Assessment Guidelines for Dredging (2009) (DEWHA, 2009e) stipulate a practical quantification limit for typical sediment contaminants, and other analytical parameters. A limit of 0.1mg/kg is stated for nutrients and ammonia.



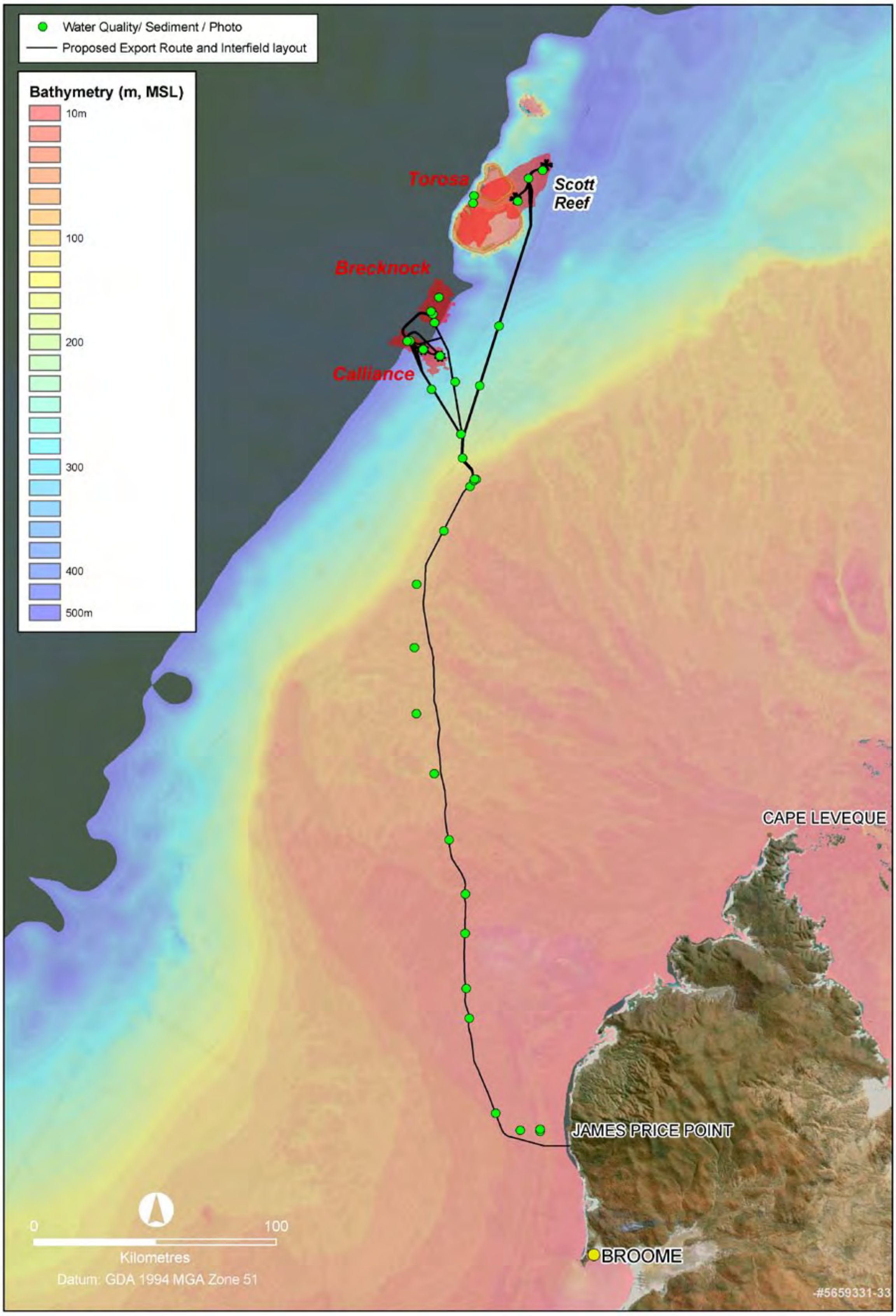

Source: DSD, 2010d; **Appendix C-13.**

- **Figure 2.2-1 Location of Sites from which Sediment Deposition Rates Were Measured within the James Price Point Coastal Area.**




Source: DSD, 2010d; **Appendix C-13.**

- **Figure 2.2-2 Location of Nearshore Geotechnical Bore Holes.**




Source: Gardline Marine Sciences, 2009.

- **Figure 2.2-3 Location of Sediment Sampling Sites within the Offshore Calliance and Torosa Fields Along the Hydrocarbon Feedstock Pipeline Route and James Price Point Coastal Area.**

The concentrations of anthropogenic compounds such as tributyltin (TBT) were below detection levels (less than 0.5µg Sn/kg) and also below the ISQG trigger value and National Assessment Guidelines for Dredging (2009) screening level of 9µg Sn/kg. Total petroleum hydrocarbon (TPH) concentrations were all below the limits of detection indicating no existing anthropogenic contamination of bed sediments (Gardline Marine Sciences, 2009).

Metal concentrations within the sediment, obtained by Gardline Marine Sciences (2009), throughout the area from which samples were taken varied. Although levels were typically low relative to their corresponding ISQG trigger levels. Radionuclides at each of the two sites within the James Price Point coastal area were below the means for the study area of 16.3Bq/kg and 6.7Bq/kg for radium 226 and radium 228, respectively, indicating that at inshore sites radionuclides were relatively low compared to the offshore area.

During the nearshore geophysical survey (November 2009) undertaken by Gardline Marine Sciences (2009) within the James Price Point coastal area several surface sediment samples were collected and sent to a NATA accredited laboratory for analysis. A broad suite of parameters were tested for, including: total petroleum hydrocarbons; trace metals; poly-aromatic hydrocarbons; organo-chlorine pesticides; organo-phosphate pesticides; polychlorinated biphenyls; and organotins. All parameters except trace metals and total organic carbon (TOC) were below laboratory detection limits. Trace levels of many heavy metals are frequently encountered in natural sediments. The toxic risk associated with heavy metals is dependent on a variety of factors such as the chemical form of the element bioavailability, and water properties (i.e. acidity/alkalinity), in addition to the concentrations at which they occur. Surface sediment samples collected at James Price Point in 2009 identified trace levels of the common metals; however these were all at concentrations below National Assessment Guidelines for Dredging (NAGD) screening levels. NAGD screening levels are set at concentrations below which toxic effects on organisms are very unlikely occur. The NAGD recognise the low risk associated with deeper consolidated geological materials and therefore do not normally require analysis of these strata.

Given the geological history of the site (e.g. lack of riverine inputs, mangroves, and estuarine systems), and the dominance of relatively inert materials (e.g. silica sands), it is considered unlikely that problems associated with acid sulphate soils or volatile organic compounds would be encountered. Surface samples collected in 2009 contained very low levels of organic material – particularly in the nearshore region.

### 2.2.2 Identification of Key Impacts

#### 2.2.2.1 Definition of Relevant Aspects

Aspects associated with the development and operation of the BLNG Precinct and associated infrastructure that may have an impact on marine sediment quality were identified in the Scope of the Strategic Assessment and considered in the assessment. These aspects are:

- marine site disturbance and excavation;
- sediment deposition and turbidity; and
- marine discharges, routine and non-routine events.

Additional detail on the nearshore marine infrastructure and facilities can be found in **Part 2**, **Section 5** (Description of Activities and Facilities under the Plan).

#### 2.2.2.2 Sources of Potential Impact

**Marine Site Disturbance and Excavation**
The construction of the BLNG Precinct marine infrastructure will require dredging of the approach channel and turning basin, LNG export jetty installation, breakwater construction and pipeline trenching have the potential to change the local sediment quality or constituents.

**Sediment Deposition and Turbidity**
Sources suspended sediment and sediment deposition include dredging, offshore dredge spoil disposal, pipeline installation, pipeline trenching, reclamation, propeller wash, vessel anchoring and export jetty construction. The construction of the BLNG Precinct will require a capital dredging (and subsequent maintenance dredging) and dredge spoil disposal program to develop the shipping channel, turning basin(s) and berth pockets. Details of the dredging campaign are yet to be finalised, however, based on similar recent dredging programmes, the dredging techniques and

associated equipment are expected to include a combination of Trailer Suction Hopper Dredgers, Cutter Suction Dredgers, Mechanical Dredgers (backhoes dredge, grab dredge) and jack up drill and blast barge vessel.

**Marine Discharges**

*Routine Marine Discharges*
Routine discharges will include cooling water, hydrotest water, process water, brine from desalination, produced formation water, stormwater, grey water and treated sewage. These waste streams will be controlled within the Precinct facilities and are likely to be discharged into the nearshore marine environment via ocean outfall(s).

*Non-routine Marine Discharges*
A review of the proposed BLNG Precinct facilities has indicated a number of hydrocarbon fluids will be stored within the Precinct Project area. The presence of these fluids introduces an inherent risk of spills to the area and surrounding marine environment. Hydrocarbon inventories for the BLNG Precinct facilities will likely include LNG, condensate, marine diesel, lube oil and bunker fuel. Minor spills may result from accidental releases of hydrocarbons or chemicals. Major accidents such as vessel collisions, rupture of an LNG / condensate tanker or catastrophic failure of a production pipeline could result in the rapid release of a large volume of LNG, condensate, diesel or bunker fuel. Loading and shipping activities have the potential for a large release volume. Alternatively, the rupture of the main production pipeline has the potential to release a large volume of LNG within the pipeline section. The likelihood of an event of this nature occurring is considered to be highly unlikely although the environmental consequences could be significant.

#### 2.2.2.3 Sensitivity and Resilience

Some toxicants persist in the environment and may accumulate in sediments or in biological tissues to levels higher than water column concentrations. The process of accumulation of toxins in the tissue of organisms is known as bioaccumulation and can lead to impacts either directly in the affected organism or indirectly in higher trophic levels that consume affected organisms.

The accumulation of toxins in marine sediments is influenced by the characteristics of the environment and sediment type. Many toxicants reaching marine environments have a high affinity for fine-grained sediment. The concentrations of some toxicants are therefore controlled to a certain extent by processes governing sediment transport and deposition. In tidally dominated nearshore and intertidal environments fine sediments can be trapped. In comparison, the propensity for contaminants to persist in well-flushed rocky reef environments may be relatively low. Dissolved oxygen can influence redox conditions and influence the uptake or release of nutrients and other contaminants by sediments. Equally, pH, dissolved organic carbon (DOC) and suspended particulate matter can have a major effect on the bioavailable concentrations of most heavy metals.

Many contaminants accumulate in marine sediments and can affect sediment infauna. Chronic effects of bioaccumulated toxicants in organisms include alterations of growth, reproductive success, competitive abilities and deformities such as imposex. Susceptibility to contaminants varies between species and there are mechanisms (such as species replacement) that may mask the effects of contaminants on diversity per se (Washington, 1984). Hence there are a range of differential sensitivities of habitat types and differential impacts of contaminant classes on sediment infauna.

Infaunal communities in metal contaminated sediments are typically dominated by metal-tolerant opportunistic deposit-feeding polychaetes (Belan, 2004; Lancellotti & Stotz, 2004). A reduction in diversity of infaunal communities in nutrient-enriched sediments may paradoxically be accompanied by overall increases in abundance of organisms such as deposit-feeding polychaetes and opportunistic copepods. These organisms thrive in organic-rich environments, are tolerant of high sulfide concentrations and low oxygen levels and monopolize communities under these conditions (Gao *et al*., 2005; Gee *et al*., 1985; Karakassis *et al*., 2000).

Many deposit-feeding infauna and epifauna that process sediment through their alimentary tract to obtain nutrients are highly selective of the grain sizes that they will ingest, often preferring finer sediments that possess relatively high organic content (Gage & Tyler, 1992). Consequently, deposit feeding infauna and epifauna are more sensitive to changes in the particle size distribution of surface sediments appose to sediment organisms which feed via filtering the water column. Marine sediments are relatively resilient to disturbances, and processing and perturbation by re-colonising marine benthos and infauna over time enhances recovery of the new seabed/water column interface.

### 2.2.3 Predicted Impacts

Potential impacts on marine sediment quality resulting from aspects associated with the proposed BLNG Precinct are discussed below and presented in **Table 2.2-6**. Both direct and indirect impacts are considered within these sections. For the purpose of this assessment it is considered that direct impacts would largely be confined to areas of direct disturbance within the BLNG Precinct, and other locations where development activities are proposed to occur.

#### 2.2.3.1 Potential Impacts to Marine Sediments due to Marine Site Disturbance and Excavation

The dredging and disposal of dredge spoil would result in increased suspended sediment and sediment deposition within the area around the marine construction activities.

The greatest impacts predicted to occur from marine site disturbance and excavation are changes in the sediment structure and particle size distribution at disturbed sites, mobilisation of bioavailable contaminants (only likely to occur during maintenance dredging), de-oxygenation of sediments and a reduction in sediment infauna and epifauna.

During construction, removal of dredged material will expose underlying sediments and seabed strata, altering the exposed substratum at the seabed and those sediments at the sediment/water column interface. This impact is localised to the areas of disturbance and as such is considered to be low.

Changes in particle size distribution may occur where clean, dredged material is released at the spoil disposal ground. A strategic review of potential offshore spoil disposal locations has been undertaken (see Section 2.2 of **Appendix C13**). The review identified and mapped the key environmental and social constraints in the region with the objective of identifying an area of minimal constraints in which a spoil ground could be located. The proposed spoil disposal ground, likely to be approximately 7km west of the BLNG Precinct, provides the most suitable areas for the disposal of dredged material (see **Part 3**, **Section 2.4** (Benthos (including BPP)). The Gardline Marine Sciences (2009) surveys indicated that there was a gradient of decreasing sediment size from inshore (at the BLNG Precinct) to the offshore fields, however, the difference in particle size distributions between the dredged area and the dredged spoil disposal grounds is likely to be small. A change of sediment type will be of more importance if buried calcareous material or silicates are encountered at depth in the dredge zone and deposited on the bed at the DSDG, effectively changing not only the particle size distribution but the substratum type on the surface. This would provide a different substratum from that currently existing and facilitate biological re-colonisation by benthic organisms not previously found at the dredged spoil disposal grounds. This impact would be localised to the areas of disturbance and as such is considered to be minor.

The high sediment quality currently within the BLNG Precinct area suggests that there is a low likelihood of impact from mobilisation of contaminated sediments from the capital dredging program. There is a remote chance for mobilisation of contaminants during maintenance dredging where there has been an accumulation of material during the life of the BLNG Precinct, although this impact has not been observed within the existing port at Dampier which Woodside uses to support activities associated with their Karratha Gas Plant Operations.

De-oxygenation of surface sediments can occur when dredged material is deposited, preventing oxygen transfer from the water column to the upper layers of natural sediments. As organic material within the sediments decomposes, reduced oxygen transfer will create anoxic layers. Dredged material transferred to the dredged spoil disposal grounds creates a new upper layer forming the new interface between water and the seabed. These sediments are likely to be similar in character to existing sediments by virtue of the relatively short distance that they will be transported. The impacts are highly localised and likely to be temporary and as such considered to be minor.

Infauna and epifauna at the dredged spoil disposal grounds will be temporarily affected by disturbance and smothering. As sediment is processed on the seabed at the dredged spoil disposal grounds, they will be re-colonised by marine biota through a process of colonisation and succession. Thus, impacts to infauna and epifauna are likely to temporary (< 5 years) and localised to the dredged spoil disposal ground.

It is expected that potential impacts to marine sediments from marine site disturbance and excavation can be successfully mitigated by the application of management and mitigation measures such as the implementation of a Dredging and Dredge Spoil Disposal Management Plan (**DSDMP**) demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts, a Port Facilities Construction Environment Management Plan (**PFCEMP**) and associated ecological and water quality monitoring. A more detailed description of proposed mitigation measures is presented in **Section 2.2.4**. The impact to sediment quality would be a

short-term, small reduction in sediment quality. The significance of the residual impact is deemed to be low, with no exceedance of applicable ANZECC Sediment Quality Guidelines.

#### 2.2.3.2 Potential Impacts to Marine Sediments due to Sediment Deposition and Turbidity

Sediment deposition would potentially impact marine sediment quality via changes to deposition regimes, particle size distribution and the diversity and abundance of benthic infauna and epifauna. In addition, contaminants accumulated over the operational life of the BLNG Precinct may be disturbed during maintenance dredging and deposited within the extent of the dredge plume.

Changes to particle size distribution are predicted occur at both the dredge site and dredged spoil disposal grounds during dredging activities. Larger, heavier particles would drop out of suspension first and potentially change the particle size distribution at a given location and replace fine, surface sediments with coarser grain sizes. These changes in particle size distribution would potentially impact sediment infauna and epifauna by altering and/or reducing the populations and communities that can persist.

Contaminants that have accumulated in the port sediment over the operational life of the BLNG Precinct may be disturbed during maintenance dredging and deposited within the extent of the dredge plume.

While changes to the sediment quality are possible, the impacts would be localised and short term given the natural coastal processes. It is expected that potential impacts to marine sediments from sediment deposition and turbidity can be successfully mitigated by application of management and mitigation measures such as implementation of a DSDMP to minimise potential dredging impacts and an ecological and water quality monitoring program. A more detailed description of proposed mitigation measures is presented in **Section 2.2.4**. The significance of the residual impact from the BLNG Precinct on sediment quality is assessed to be low because of the localised and short term nature of impacts and taking into account the application of proposed measures.

#### 2.2.3.3 Potential Impacts to Marine Sediments due to Marine Discharges

**Routine Marine Discharges**

Treated wastewater from the BLNG Precinct will be routinely discharged to the marine environment. The wastewater outlet infrastructure will be sited in well-mixed, highly flushed marine environment. Semi-diurnal tides, with up to 8m tidal ranges, produce currents with high velocities and high seabed sheer stress. This dynamic environment promotes rapid mixing and is likely to accelerate dilution of any routine discharge. It is unlikely that significant barriers to mixing would form and any contaminants entering receiving waters from the BLNG Precinct operations would be not be detected above background levels except at only short distances from the discharge location (i.e. within the prescribed mixing zone).

The main impact associated with routine discharges is the potential accumulation of contaminants, organic material and nutrients in the marine sediments of the receiving environment. Changes to dissolved oxygen can alter redox conditions and influence the uptake or release of nutrients by sediments. Equally, pH, dissolved organic carbon and suspended particulate matter can have a major effect on the bioavailable concentrations of most heavy metals. Potential indirect impacts are the subsequent mobilisation and transfer of these materials into the water column and surrounding seabed where they would potentially impact marine fauna and flora. For a 50Mtpa Precinct, the potential effect of routine marine discharges on the marine environment outside a defined mixing zone is likely to be very low, as discussed below.

Routine discharges of treated sewage and greywater could be a source of organic and nutrient material which could be adsorbed to the surface of sediment particles. However, given the likely final quality of the treated wastewater discharges, accumulation of persistent elements, compounds or residues is unlikely. Routine monitoring of the water column and sediments around the release would be employed as a mitigation measure and check for unexpected accumulations. The impact to marine sediment quality from wastewater discharges from the BLNG Precinct are low given that impacts would be localised and the quality of discharged water would be controlled to ensure acceptable reductions in sediment quality.

Treated discharge water is likely to contain low levels of petroleum hydrocarbons; phenols; organic acids; metals and process chemicals. Volatile hydrocarbons are unlikely to have any significant effect on marine sediments as, upon discharge, they are highly volatile and will evaporate and biodegrade prior to reaching the seabed.

Persistent elements are potentially limited to metals. While metals in produced water are treated, heavy metals may be present in low concentrations in treated discharges as dissolved mineral salts. Metals oxidise at the seabed surface and will form insoluble precipitates. The amount of precipitate is very low, and these precipitates will be spread widely under the local tidal regimes, so that the impact is considered insignificant. Performance monitoring of operational desalination plants occurs in WA. These are not known to have resulted in the accumulation of contaminants in adjacent marine sediments.

It is possible that routine discharges may result in a localised impact on marine sediment quality. The impact to marine sediment quality from wastewater discharges from the BLNG Precinct is low given that impacts would be localised and the quality of discharged water would be controlled to ensure acceptable reductions in sediment quality. Routine monitoring of the water column and sediments around the release will be required. The significance of the residual impact is assessed to be low, given the treatment prior to discharge and the high-dispersive capability of the receiving environment.

Wastewater discharge modelling is being undertaken to confirm the predicted mixing and dilution of treated wastewater discharges beyond the outfall, and to substantiate expected environmental outcomes associated with routine marine discharges from the proposed BLNG Precinct. Results of this modelling will be made publicly available during the public release of the SAR.

**Non-routine Marine Discharges**

Non-routine discharge of hydrocarbons to the marine environment arising through an uncontained spill via shipping collision, accidental spill or pipeline rupture would potentially impact sediment quality. At particular risk are intertidal sediments which are potentially exposed to hydrocarbons, if an uncontained spill were to be blown or washed onshore. Hydrocarbon spills would tend to float, given the lower density of hydrocarbons compared to seawater and therefore the potential impact to marine sediments outside of the intertidal zone is very low.

Whilst the likelihood of a major hydrocarbon spill (e.g. vessel collision or pipeline rupture) is considered extremely unlikely, the consequence may be severe if appropriate response measures are not effectively implemented. The establishment of the Broome Port Authority as the statutory port authority for the BLNG Precinct will ensure supplies of oil spill response equipment are as required under the State Emergency Management Plan for Marine Oil Pollution (West Plan) to undertake an immediate oil spill response. Major hydrocarbon spills may also require deployment of additional equipment stockpiled in the Fremantle and Dampier ports, or other stockpiles under the National Plan, to minimise the extent of hydrocarbons and reduce potential impacts to sensitive environmental receptors. The oil spill modelling required by future proponents during the derived proposal process will be used to inform a Hydrocarbon and Chemical Spill Contingency Plan, which will be implemented in the event of a large hydrocarbon or chemical spill. An Emergency Response Plan will also be develop outlining emergency response procedures to be implemented by the port authority in the event of an oil spill emergency.

Weathering of an oil spill breaks down hydrocarbons, with one of the processes of breakdown resulting in sedimentation which occurs over a period of up to a month after a spill (Clarke, 2005). The vast majority of spilled hydrocarbon which is not salvaged during clean up operations would evaporate. Hydrocarbon weathering by-products, which fall out of the water column to marine sediments, would be dispersed over larger areas and are unlikely to pose any risk to the quality of subtidal sediments. If adsorbed onto the surface of sediments in the intertidal zone, rates of hydrocarbon biodegradation would be high. The effect of a hydrocarbon spill on sediment quality within the intertidal zone is largely dependent on the nature of the substrate. If oil becomes buried under sediments, it would not biodegrade rapidly and retains toxic characteristics for some time. Penetration of fine grained or compacted sediments is unlikely and mechanical cleanup can limit volumes (Clarke, 2005).

High tidal regimes and the resulting high velocities would disperse hydrocarbons. In the unlikely event of an oil spill intercepting intertidal sediments, the high tidal velocities would likely remove hydrocarbons from mobile coarse sediments and rocky shores. The relatively coarse, mobile sediments of the BLNG Precinct area are likely to be oxygenated, facilitating biodegradation of any hydrocarbons, and high tidal regimes and the resulting high velocities are predicted to promote rapid dispersal of hydrocarbons.

It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures such as the implementation of Hydrocarbon and Chemical Spill Contingency Plans and Ship-Board Oil Pollution Emergency Plans to ensure application of measures to reduce the risk of leaks and spills, and the response

procedures should they occur. A more detailed description of proposed mitigation measures is presented in **Section 2.2.4**. The significance of the residual impact for non-routine discharges is assessed to be low and it is considered by the proponent that, with the application of proposed preventative and mitigation measures, impacts can be managed to achieve acceptable outcomes. These predicted environmental outcomes from non-routine discharges will be confirmed by hydrocarbon spill modelling currently being undertaken for the BLNG Precinct and relevant activities. The results of this supplementary modelling will be made publicly available during the public consultation period for the SAR.

### 2.2.4 Management Measures

Mitigation measures and safeguards that have been identified to manage potential impacts to marine sediment quality are outlined in **Table 2.2-3**, **Table 2.2-4** and **Table 2.2-5**.

Refer also to the Management Arrangements specifically defined for Commonwealth matters, summarised in **Part 6**, **Section 3**.

- **Table 2.2-3 State Government Measures for Sediment Quality.**

| State Government measure | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area. | Department of Transport (DoT) | On approval of BLNG Precinct |
| The Port Authority will prepare a BLNG Precinct Environmental Management Plan (BPEMP) for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms. | Broome Port Authority | Prior to approval of marine related derived proposals |

- **Table 2.2-4 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Sediment Quality.**

| Condition No. | Proposed Environmental Conditions for the Strategic Proposal |
|---|---|
| M2.1 | Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95th percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone the proponent will ensure that the 95$^{th}$ percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels. |
| M2.2 | Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants. |
| M2.3 | Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary to ensure ongoing compliance to the General Manager of the OEPA. |
| **Proposals involving dredging** | |
| M2.4 | Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• consideration of the re-use of suitable dredge material for MOF construction, where practicable;<br>• design of the MOF including construction of bunds to isolate fill material from wind and wave action;<br>• consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives;<br>• measures to minimise dredging impacts during sensitive ecological windows;<br>• a monitoring strategy for ecological receptors and health during marine construction (including baseline surveys);<br>• the development of trigger levels for benthic communities and water quality that define additional management responses;<br>• mechanisms to audit and assess environmental performance of proponents during construction.; and<br>• a communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. |

- **Table 2.2-5 Requirements to be Addressed via Development of a Management Plan to support a Derived Proposal Potentially Affecting Sediment Quality.**

| Derived Proponent Requirements | Timing |
|---|---|
| Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework. | Prior to commencement of associated construction activities |
| Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to commencement of associated construction activities |
| All vessels will be required to have in place a Ship-Board Oil Pollution Emergency Plan (SOPEP) and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea. | Prior to construction and updated for ongoing operational requirements |
| Prepare and implement a Marine Wastewater Discharge Management Plan (MWDMP), to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to construction of marine discharge facilities |

### 2.2.5 Environmental Outcome

After management and mitigation measures have been applied, it is expected that the BLNG Precinct aspects (Category A activities) involved in marine site disturbance and excavation, sedimentation and turbidity, and routine and non-routine marine discharges will result in the following key potential direct and indirect impacts in relation to marine sediment quality.

#### 2.2.5.1 Direct Impacts

It is predicted that the BLNG Precinct marine facilities in the Port area may result in the following direct impacts in relation to marine sediment quality:

- local changes to deposition regimes;
- changes to particle size distribution over surficial sediments with ecological consequences directly limited to localised impacts on marine benthos, infauna and epifauna;
- changes to sediment structure at disturbed sites;
- de-oxygenation of surface sediments during dredging;
- temporary reduction and/or permanent loss in sediment infauna and epifauna diversity and abundance;
- maintenance dredging activities mobilising and/or transferring contaminants into the water column or onto the seabed;
- accumulation of contaminants, toxins, nutrients and discharge material within sediments in the vicinity of the BLNG Precinct port area and restricted to the harbour seabed and berths; and
- possible accumulation of LNG, condensate and other hydrocarbons in the unexpected event of spills and leaks.

Taking into account mitigation measures as outlined in **Section 2.2.4**, the proposed development activities are not anticipated to result in adverse impact on marine sediments. The residual environmental impact is determined to be low, with impacts considered to be manageable with appropriate controls.

#### 2.2.5.2 Indirect Impacts

The indirect impacts will mainly be the temporary reduction and/or permanent loss of marine benthic infauna and epifauna associated with the accumulation of sediment contaminants, changes to particle size distribution and changes to sediment structure. In addition, there is the potential indirect impact to marine fauna from the mobilisation and/or transfer of contaminants into the water column or onto the seabed during maintenance dredging.

### 2.2.6 Cumulative Impacts of the Proposal and Associated Activities

#### 2.2.6.1 Category B Activities

The majority of Category B activities are related to increased population and provision of workforce and marine infrastructure and services in Broome Port. Category C impacts are centred on the oil and gas exploration and developments proposed offshore. The cumulative impacts are summarised below.

There is a very low risk of widespread change, within the James Price Point coastal area, to ambient marine sediment quality conditions caused by the accumulation and interaction of Category A, B and C activities. Sediment quality disturbances typically have localised footprints and are very unlikely to interact across the broader Canning marine bioregion. Only three activities have the potential to affect marine sediment quality resources. They are, (1) the further development of Broome Port to accommodate more marine traffic, (2) the increase in small vessel marine traffic, and (3) the development of housing and infrastructure in the catchment leading to increased sediment loads in runoff water after heavy rainfall events.

Except for some early pioneering activities, which would result in vessels calling at the Broome Port and would be accommodated within the current capacity of the port, the increased demand in these areas would primarily be linked to increases in recreational and boating activities. The impacts on marine sediment quality from these Category B activities would be limited. Improvements at the port would likely be to existing areas (i.e. port and current recreational boat ramp). Expansion or development at new areas do not appear to be required however these would result in localised effects with limited or no impacts as far north as the BLNG Precinct area or through the Canning marine bioregion.

An increase in industrial boating activity can impact marine sediment quality via; a direct and limited disturbed area of seabed in the intertidal and near sub-tidal environments; introduction of potential contaminants such as heavy metals and hydrocarbons from vessel release; and potential for transfer of sediments during any future port maintenance dredging. These impacts are predicted to minimal, localised to the Broome Port area and are not anticipated to add cumulatively to existing impacts from Category A activities.

Increases in urban development or recreational activities would have no impact on marine sediment quality if managed by catchment strategies and management actions.

#### 2.2.6.2 Category C Activities

Category C activities include upstream development (explorative and construction activities) of the Browse Basin gas field and the operation of the upstream extraction of hydrocarbons. Upstream development activities will be subject to further environmental and development approvals. Category C activities which have the potential to impact on marine sediments are largely restricted to seabed disturbances and liquid discharges (routine and non-routine).

Construction of the additional export pipeline will involve excavation and reburial of pipelines with some disturbance to the seabed and potential impacts on sediment quality, including changes to sediment particle size distribution and substratum type, exposure of previously buried anoxic sediments and changes to substratum type at the designated dredge spoil disposal ground (**DSDG**).

The geographic separation of the activities identified as Category C means that all other impacts would not be expected to add cumulatively to those of the BLNG Precinct across the Canning bioregion. In addition, the localised nature of most impacts from Category C activities minimises the overall impact to marine sediment quality.

**Table 2.2-6 Impact Assessment Summary for Marine Sediment Quality.**

<table>
<tr><th rowspan="2">Environmental Aspect</th><th rowspan="2">Potential Impacts</th><th colspan="3">Mitigation Measures</th><th rowspan="2">Significance of Residual Impact</th></tr>
<tr><th>State Government Measures</th><th>Proposed Environmental Conditions</th><th>Future Proponent Management Plans</th></tr>
<tr><td>Marine Site Disturbance and Excavation</td><td>Changes to particle size distribution.</td><td rowspan="2">Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area.<br>The Port Authority will prepare a BPEMP for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the</td><td rowspan="2">Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a DSDMP, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• Measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction</td><td rowspan="2">Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br>Prepare and implement a</td><td>Low</td></tr>
<tr><td>Sediment Deposition and Turbidity</td><td>Changes to deposition regimes, particle size distribution and the diversity and abundance of benthic infauna and epifauna.</td><td>Low</td></tr>
</table>

<table>
<thead>
<tr><th rowspan="2">Environmental Aspect</th><th rowspan="2">Potential Impacts</th><th colspan="3">Mitigation Measures</th><th rowspan="2">Significance of Residual Impact</th></tr>
<tr><th>State Government Measures</th><th>Proposed Environmental Conditions</th><th>Future Proponent Management Plans</th></tr>
</thead>
<tbody>
<tr><td>Marine discharges (routine)</td><td>Accumulation of contaminants, organic material and nutrients in the marine sediments of the receiving environment.</td><td rowspan="2">port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms.</td><td rowspan="2">related activities within the area.<br>The DSDMP will be subject to assessment under the Environment Protection (Sea Dumping) Act 1981 (Cwth), including appropriate stakeholder consultation.<br>Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95th percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone the proponent will ensure that the 95th percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels.<br>Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants.<br>Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary to ensure ongoing compliance to the General Manager of the OEPA.</td><td rowspan="2">Marine Wastewater Discharge Management Plan (MWDMP), to the satisfaction of the Western Australian Minister for Environment. See Part 3, Section 2.3 (Marine Water Quality).<br>Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See Part 3, Section 2.3 (Marine Water Quality).<br>All vessels will be required to have in place a Ship-Board Oil Pollution Emergency Plan (SOPEP) and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea.</td><td>Low</td></tr>
<tr><td>Marine discharges (non-routine)</td><td>Hydrocarbon contamination of marine sediments</td><td>Low</td></tr>
</tbody>
</table>

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## 2.3. Key Factor: Marine Water Quality

Healthy and diverse marine ecosystems are dependent on the maintenance of commensurate water quality. The construction and operation of the proposed BLNG Precinct has the potential to impact ambient water quality and the environmental values dependent upon it. This section assesses the potential impact to water quality. Indirect impacts that may occur as a result of changes in water quality are addressed separately in **Part 3**, **Section 2.4** (Benthos (Including BPP)), **Section 2.6** (Marine Mammals) and **Section 2.7** (Marine Reptiles).

### 2.3.1. Current Knowledge

Current knowledge with respect to key policy documentation and regulatory requirements, as well as a summary of known existing water quality characteristics in the immediate vicinity of the project, are presented in sections below. Site specific information on nearshore water quality within the James Price Point coastal is summarised in **Appendix C13** (Browse LNG Development - Precinct Dredging and Spoil Disposal Assessment). This appendix summarises the results of the Nearshore Marine Water Quality Study undertaken to date, and provides an assessment of the potential water quality impacts from dredging to inform the Strategic Assessment.

#### 2.3.1.1. Key Regulatory Requirements, Environmental Policy and Guidance

The overarching EPA objective for this factor is the maintenance of:

"...*the abundance, diversity, geographic distribution and productivity of flora and fauna at ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge*" and "… *to maintain the integrity, ecological functions, and environmental values of the seabed and coast*" (EPA, 2009f).

A number of Commonwealth and State guidelines, strategies, policies and regulatory frameworks are applicable and provide the context for assessing the key issues relating to threatening process to marine water quality and expectations for management.

**Commonwealth Legislation, Guidance and Policies**

The key Commonwealth legislation, policy and guidance relevant to marine water quality is the National Water Quality Management Strategy (NWQMS).

The NWQMS:

- defines environmental values;
- promotes an understanding of links between human activity and environmental quality (based on site specific data);
- sets management goals; and
- identifies appropriate water (or environmental) quality objectives.

Environmental values are defined in the NWQMS as "*particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health, and which require protection from the effects of pollution, waste discharges and deposits*" (ANZECC/ARMCANZ, 2000). Environmental values for water quality typically reflect the importance that the community places on the marine environment for its intrinsic biodiversity and ecosystem functions, its recreational and cultural attributes, and its commercial and industrial uses.

ANZECC/ARMCANZ (2000) established a framework to characterise environmental values for Australian waters and implement the NWQMS. With respect to the marine environment, the most relevant parts of the NWQMS are the:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Guideline 4).
- Australian Guidelines for Water Quality Monitoring and Reporting (Guideline 7).

Marine waters surrounding Australia are also protected by the *Environment Protection (Sea Dumping) Act 1981* which regulates the loading and dumping of materials at sea. This Act fulfils Australia's international obligations under the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972* (the London Protocol) to prevent marine pollution by controlling dumping of wastes and other matter. Dumping of dredge material is regulated under this Act. Specifically, the Act aims to minimise pollution threats by:

- prohibiting the ocean disposal of waste that is considered too harmful to be released in the marine environment; and
- regulating waste disposal to minimise environmental impacts.

In accordance with the *Environment Protection (Sea Dumping) Act 1981*, any disposal of dredged material will require a sea dumping permit. Any application for sea dumping will be prepared in conjunction with the National Assessment Guidelines for Dredging (NAGD) (DEWHA, 2009e). The NAGD specify stringent criteria for assessing dredged material including:

- alternatives for sea dumping;
- testing for contaminants;
- testing for bioavailability of contaminants; and
- testing for toxicity and bioaccumulation of contaminants.

**State Legislation, Guidance and Policies**

State guidelines and policies relevant to marine sediment quality include:

- Draft Environment Protection (State Marine Waters) Policy 1998.
- *Conservation and Land Management Act 1984.*
- Environmental Assessment Guidelines (EAG) No.3. Protection of Benthic Primary Producer Habitat in Western Australia's Marine Environment (EPA, 2009a).
- In the absence of a Kimberley specific framework, the WA Department of Environment and Conservation (2006) "Pilbara Coastal Water Quality Consultation Outcomes. Environmental Values and Environmental Quality Objectives" will be used for guidance.

#### 2.3.1.2. Description of Factor

A continuous water quality monitoring program was initiated in November 2009 at four sites within the nearshore James Price Point coastal area (see **Part 3**, **Section 1** (Environmental Overview)). To complement the *in situ* monitoring study, a Moderate Resolution Imaging Spectroradiometer (MODIS) study was undertaken. This study used historical satellite imagery (2008-2009) to determine medium-term spatial and temporal trends in natural (background) water quality. A full discussion of background water quality within the assessment area is presented in **Part 3**, **Section 1.1**.

The key findings from the studies relevant to this factor are:

- Preliminary water quality data indicates that variable levels of turbidity occur within the nearshore James Price Point coastal area, often associated with the macro-tidal regime and meteorological perturbations.
- Photosynthetically active radiation (PAR; the portion of solar irradiance that is usable by biota for photosynthesis) reaching the benthos is reduced by as much as 200-fold during peak turbidity conditions compared to low turbidity conditions.
- Natural elevations in turbidity are largely restricted to the bottom layer of the water column presumably resulting from natural re-suspension of sediments.
- The median TSS level (November 2009–September 2010 data, average of all sites) was determined to be 2.8mg/l, with a summer median of 7.5mg/l and a winter median of 2.3mg/l.
- The $95^{th}$ percentile TSS level (November 2009–September 2010 data, average of all sites) was 28.6mg/l, with a summer and winter $95^{th}$ percentile level of 34.3mg/l and 9.8mg/l respectively.

### 2.3.2. Identification of Key Aspects

Aspects associated with the construction and operation of the BLNG Precinct (Category A activities) that have the potential to impact marine water quality include:

- marine site disturbance and excavation; and
- marine discharges (routine and non-routine).

#### 2.3.2.1. Marine Site Disturbance and Excavation

The BLNG Precinct marine infrastructure will include an approach channel and turning basin, LNG export jetty, breakwater and product pipelines. The construction of this infrastructure will require dredging, dredge spoil disposal, drilling and coring of boreholes, positioning of jack-up barges and other marine activities such as piling.

As it is anticipated that the LNG export facilities within the BLNG Precinct will require approximately one berth for every 10Mtpa of LNG produced, construction of export facilities will be staged to match the precinct production capacity, with approximately six berths anticipated for a 50Mtpa LNG Precinct. Preliminary estimates of the total dredged volume for the nearshore infrastructure based on conceptual site layout options shown in **Part 2**, **Section 5** (Description of Activities and Facilities under the Plan) are of the order of 21Mm$^3$.

Dredging activities have the potential to impact water quality through increased suspended sediment concentration and the liberation of contaminants bound within sediments on the seafloor.

The proposed development is a multiple proponent Precinct, therefore the capital dredging and offshore spoil disposal may occur in distinct stages. Initial dredging will be required for the installation of the major infrastructure for the foundation proponent, with further dredging required for individual berth 'pockets' of subsequent proponents. It is anticipated that during the initial foundation proponent stage, 80% of the total dredged volume will be excavated, with the remainder to be dredged by future proponents. This impact assessment addresses the full phase development (i.e. total dredged volume over all phases).

Depending on prevailing sediment transport and deposition processes, maintenance dredging and associated disposal may be required during operations. Although the method and effect of dredging and spoil disposal for maintenance dredging is similar to that for capital dredging, the volume of dredged material from a single maintenance campaign would be significantly less than that removed during capital dredging.

It is currently proposed that dredged material will be disposed of at an offshore spoil ground. There is the potential that some dredge spoil, if it is of adequate quality for construction, may be reclaimed onshore for the construction of the nearshore Marine Facility. If this is the case, it is likely that sedimentation and turbidity will be increased in the immediate vicinity of reclamation works, due to dewatering.

In addition, construction of the nearshore marine infrastructure (i.e. piling and rock dumping) may result in further disturbance to the seabed resulting in a localised increase in turbidity and sedimentation, though this will be minor in comparison with dredging and spoil disposal activities.

#### 2.3.2.2. Marine Discharges

Potential discharges to the marine environment from construction and operation of the BLNG Precinct are listed in **Table 2.3-1**.

- **Table 2.3-1 Marine Discharges from Construction and Operations of the Browse LNG Precinct.**

| Activity Source | Phase of Project | | Discharge Scenario | |
|---|---|---|---|---|
| | Construction | Operations | Routine Discharges | Non-Routine Discharges |
| **BLNG Precinct marine discharges (onshore and marine facilities)** | | | | |
| Sewage and grey water | ✓ | ✓ | ✓ | |
| Brine from desalination | | ✓ | ✓ | |
| Produced water and process water | | ✓ | ✓ | |
| Stormwater | ✓ | ✓ | ✓ | |
| Hydrotest fluids | ✓ | | ✓ | |
| Hydrate inhibitors (MEG) | | ✓ | | ✓ |
| LNG storage | | ✓ | | ✓ |
| Fuel and chemical storage | ✓ | ✓ | | ✓ |
| **Vessel marine discharges** | | | | |
| Deck drainage | ✓ | ✓ | ✓ | |
| Sewage and grey water | ✓ | ✓ | ✓ | |

Sewage and grey water will be routinely produced during both the construction and operational phases of the project at a rate of approximately 0.3 – 0.4Gl/year (for a 50Mtpa plant). These waste streams potentially add organic material, nutrients, suspended solids, biological oxygen demand and trace metals. Treatment technologies limit the impact of discharges.

Hydrotest water will be used routinely during commissioning to ascertain the structural integrity of the piping systems. Untreated hydrotest water has the potential to affect water quality through its concentrations of biocide, oxygen scavenger and dyes. Similarly, produced formation and process water streams have potential to impact water quality due to low levels of hydrocarbons; biocide; dissolved oxygen and elevated thermal content. Volumes are estimated at 2.0Gl/year for a 50Mtpa plant.

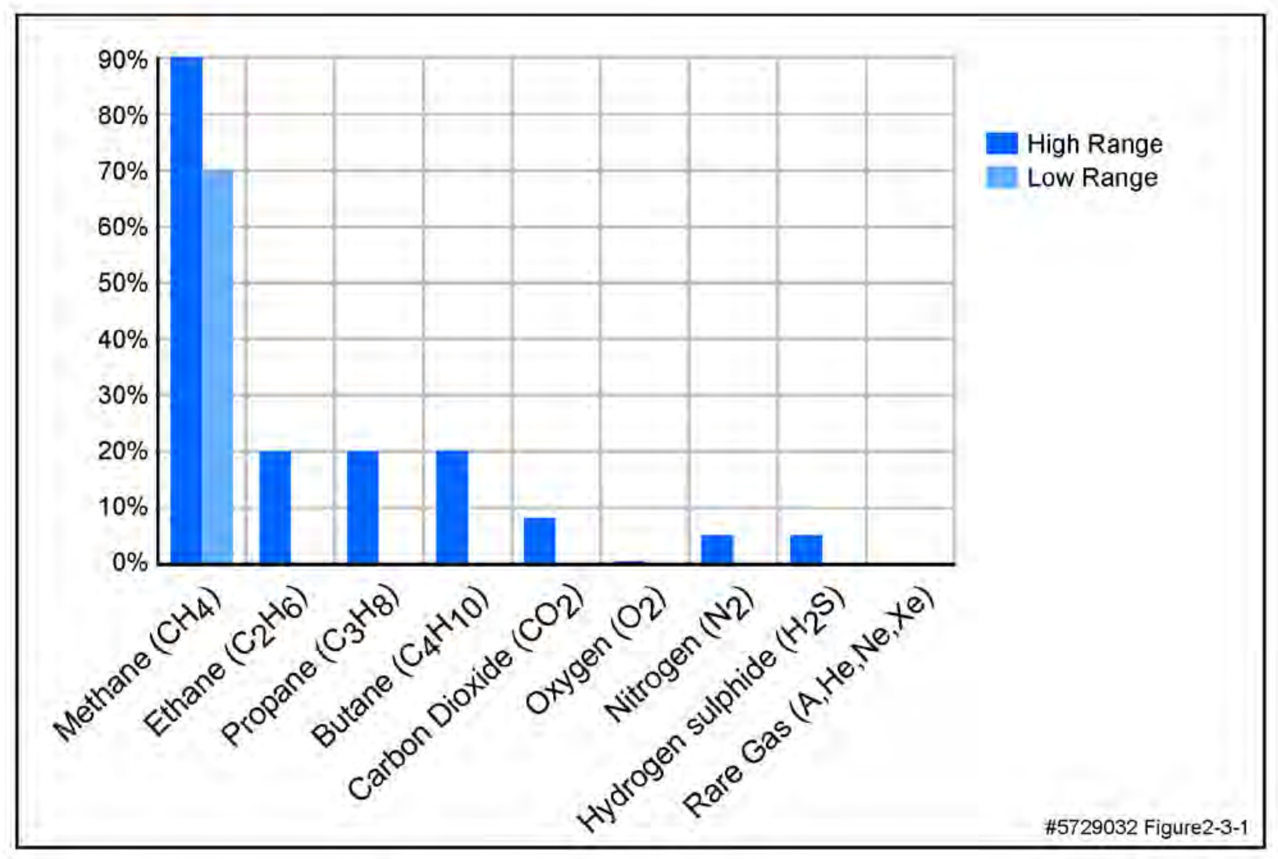
Desalination is being considered as a potential supply of freshwater for the BLNG Precinct. Discharges from desalination plants contain dense, highly saline water, process chemicals (anti-scalants and antifouling treatment chemicals for reverse osmosis membranes for example) and may be a slightly different temperature to marine waters. Desalination volumes may be more than 20Gl/year for a 50Mtpa plant.

Cooling water is unlikely to be a key discharge from the BLNG Precinct, as proponents are likely to adopt more efficient air cooling technologies for their LNG processing facilities. However, in the event that cooling water is required, it would be discharged via an outfall diffuser above ambient temperatures and may contain low levels of biocide and oxygen scavenger chemicals.

Routine stormwater runoff during construction and operations will occur during and subsequent to large rainfall events. The first flush of a runoff event removes contaminants from surfaces (particularly impervious surfaces). Treatment technologies for contaminants such hydrocarbons and metals limit the impact of constituents in discharges. Routine stormwater runoff from the process areas has been estimated at 8Gl/year for a 50Mtpa plant.

A number of hydrocarbon fluids will be stored within the Precinct Project Area. There is the potential for these fluids to spill into the surrounding marine environment. Hydrocarbon inventories for the BLNG Precinct facilities are likely to include LNG, condensate, marine diesel, lube oil and bunker fuel. Minor spills may result from accidental releases of hydrocarbons or chemicals. Major accidents such as vessel collisions, rupture of an LNG/condensate tanker or catastrophic failure of a production pipeline could result in the rapid release of a large volume of hydrocarbons, condensate, diesel or bunker fuel. Loading and shipping activities have the potential to release large volumes. In addition, the rupture of the main production pipeline has the potential to release a large volume of LNG, however, the likelihood of an event of this nature occurring is considered to be ‘highly unlikely’, although the environmental consequences could be significant.

Typical low range and high range constituents of Australian natural gas are presented in **Figure 2.3-1**. Prior to liquefaction, natural gas consists almost entirely of methane ($CH_4$) (around 85 to 95 %). The remaining few per cent consists of ethane, propane and butane, pentane and trace amounts of nitrogen. The exact composition of natural gas (and the LNG formed from it) will vary according to source and processing history (NGSA, 2010). Natural gas will contain some acid gas (carbon dioxide or hydrogen sulphide) as well as mercury; however, these are removed before liquefaction (Yang *et al.,* 2006).




Source: Natural Gas Supply Association (NGSA), 2010.

- **Figure 2.3-1 Typical Composition of Natural Gas.**

### 2.3.3. Sensitivity and Resilience of Receiving Environment

#### 2.3.3.1. Turbidity

Extensive water quality programmes have been associated with several dredging campaigns conducted on the North West Shelf of Western Australia, including at Barrow Island for the Gorgon Project (Chevron Australia, 2009a), at Cape Lambert for the Rio Tinto Port B Development (SKM, 2009a and SKM, 2009b) and at the Burrup Peninsula for the Pluto LNG project (MScience, 2008). The water quality data demonstrate that naturally occurring high turbidity and gross sedimentation are driven by seasonal weather conditions (i.e. cyclones and strong winds). These natural perturbations often exceeded and/or masked the effects from the dredging and disposal activities.

#### 2.3.3.2. Visual Amenity

It is likely that the recognition of plumes will be dependent on many factors including the observation point; the observer; the weather and sea state; the plume material and colour relative to water outside the plume; and the background turbidity levels.

Experience in the waters of Mermaid Sound in the Pilbara Region suggest that an experienced observer may be able to visually detect a plume with a total concentration >2mg/L when surrounding waters are very clear (<1mg/L); and a plume with a total concentration of >10mg/L when background is ~5mg/L (MScience, unpublished observations). Based on these observations, the critical difference between background and plume could be expressed as:

critical difference = a + b*background (mg/L), where a = 2 and b = 0.6.

One of the few published studies on the ability of observers to perceive changes in water quality suggests that a 30% decline in clarity is a level that can be detected by most observers (Davies-Colley & Smith 1990, cited in ANZECC /ARMCANZ, 2000). This study was based on perceptions of water quality in a small stream, and thus is unlikely to be relevant in terms observation point and sea conditions. Baseline water quality monitoring in the JPP nearshore marine environment indicates a summer median of 10-15mg/L and a winter median of 2-3mg/L. As this data is collected near to the seabed, a reduction of approximately 50% could be expected between the seabed and the surface, resulting in a summer median of 5-7.5mg/L and a winter median of 1-1.5mg/L. Based on these surface values, critical differences (using the above formula) would be ~6.5mg/L in summer and ~2.9mg/L in winter. Based on these calculations, the conservative nature of the model inputs (refer to Section 3.1 of **Appendix C-13** - BLNG Precinct Dredging and Spoil Disposal Assessment), and inherent inaccuracies associated with simulating sediment transport processes, a value of 5mg/L has been used as a critical threshold for visual amenity.

### 2.3.4. Predicted Impacts

Potential impacts on water quality resulting from aspects associated with the proposed BLNG Precinct are discussed below and summarised in **Table 2.3-5**. Both direct and indirect impacts are considered within these sections. For the purpose of this assessment it is considered that direct impacts would largely be confined to areas of direct disturbance within the BLNG Precinct, and other locations where development activities are proposed to occur.

#### 2.3.4.1. Impacts on Water Quality from Marine Site Disturbance and Excavation

Construction, dredging and spoil disposal associated the site disturbance and excavation will impact water quality through an increase in turbidity (i.e. total suspended sediments) and a reduction in benthic light availability (i.e. increased light attenuation). The impacts associated with the construction dredging and spoil disposal activities have been predicted through sediment dispersion modelling detailed in **Appendix C-13** (BLNG Precinct Dredging and Spoil Disposal Assessment).

The impacts associated with the proposed dredging program can be considered in terms of both direct and indirect impacts. Direct impacts (discussed in **Part 3**, **Section 2.4** (Benthos (Including BPP)) are those involving with physical removal of substrate and deposition of spoil directly on a disposal ground. Indirect impacts are those associated the secondary action of sediment released into the water column (a plume) that may impact on flora and/or fauna as a result of increased turbidity and/or sedimentation. Direct impacts are typically more predictable as they are closely tied to the infrastructure footprint of the facility and spoil ground. The scale of indirect impacts is less predictable and is susceptible to variability in the model assumptions and input data. See Section 3.1 of **Appendix C-13** (BLNG Precinct Dredging and Spoil Disposal Assessment) for a full discussion on the model assumptions and inherent conservatism of the assessment.

The model was used in the first instance to obtain an approximation of the dispersion of sediments from a nominal source location offshore of James Price Point. This model described the spreading, sedimentation and re-suspension of dredged sediments under the influence of water movements and the associated dispersion processes. The modelling focused on the dispersion of fine sediments (<63µm) as the primary influence on water quality, because coarse, non-cohesive sediments are likely to settle out of the water column in close proximity to the dredging or disposal activities.

As the strategic assessment needs to provide flexibility for future proponents in the development of derived dredging proposals, it was important to develop a suitable ‘base case’ dredging scenario that could be modelled to provide a conservative indication of potential environmental impacts. A sensitivity analysis was carried out using a number of potential dredging scenarios and model inputs to determine whether the base case was suitably conservative (Section 5.5 of **Appendix C-13** (BLNG Precinct Dredging and Spoil Disposal Assessment). Only the results of base case simulations are described here. Results of simulations undertaken during the sensitivity analysis are provided in modelling report (DHI, 2010a).

A twelve month simulation was undertaken using the base case scenario to determine, over a year of continuous fines discharge, the extent of sediment movement and subsequent impacts to water quality. A twelve month simulation period was selected to coincide with the available metocean data that was used to calibrate the model. Furthermore an examination of the 12 month base case scenario model run indicates that the plume stabilises within the 12 month period and therefore this run is broadly representative of the extent of the plume for a proposed 18 month dredging campaign.

It is important to note that the figures represent the plume at a particular moment in time. It can be seen from these snapshots that the size of the plume is highly dependent on the degree of tidal movement (i.e. it is larger during spring tides and smaller during neap tides).

Results of annual simulations suggest that the plumes are likely to extend equally north and south of dredging activities (except during summer/neap conditions where the plume often extends further northward than southward; **Figure 2.3-3**). These results support the view that elliptical tidal circulation patterns in the JPP coastal region play a dominant role in water movement and sediment dispersion patterns and that an exponential decrease in turbidity can be expected with increasing distance from the source. This exponential decrease in TSS concentrations has been observed in previous dredging projects.

The spatial extent of the plume is predicted to be most extensive during spring tides in both summer and winter seasons (**Figure 2.3-2** and **Figure 2.3-4**). This is not surprising, given that tides are the dominant factor driving the dispersion of sediment particles and that water movement during spring tides is substantially greater than during neaps, especially in the macro-tidal environment of the NWMR. The more limited spatial extent of the plume during neap tides (**Figure 2.3-3** and **Figure 2.3-5**) suggests the possibility that, during dredging, some areas may experience pulses of high turbidity (during spring tides) with subsequent periods of reduced turbidity levels during neap tides. Receptors in these areas may have the potential to recover during neap periods when turbidity is lower and available light is higher (light is only a factor if the receptor is photosynthetic). However, as outlined in Section 3.1 of **Appendix C-13,** it should be noted that due to the modelling approach adopted for this strategic assessment (a continuous point source discharge) there is limited potential for 'relief' periods that would typically be associated with bunkering, maintenance, phasing of works etc.

The greatest spatial extent of plumes is predicted to occur during summer/spring conditions, where the concentrations of TSS due to dredging and spoil disposal activities are predicted to reach 10mg/l above background in an area extending from Quondong Point to just south of Coulomb Point and approximately 14 km seaward (**Figure 2.3-2**). Baseline monitoring has demonstrated that TSS concentrations frequently exceed 10mg/l in the James Price Point nearshore marine environment. In summer/spring conditions, TSS concentrations may reach 50mg/l above background in an area extending approximately 3–5km north, west and south of dredging activities. During winter/neap conditions when dispersing forces are lowest, TSS levels exceeding 750mg/l are predicted, though limited to the immediate area around dredging activities.

During these conditions, TSS concentrations may reach 50mg/l above background in an area extending approximately 3–5km north, west and south of dredging activities.

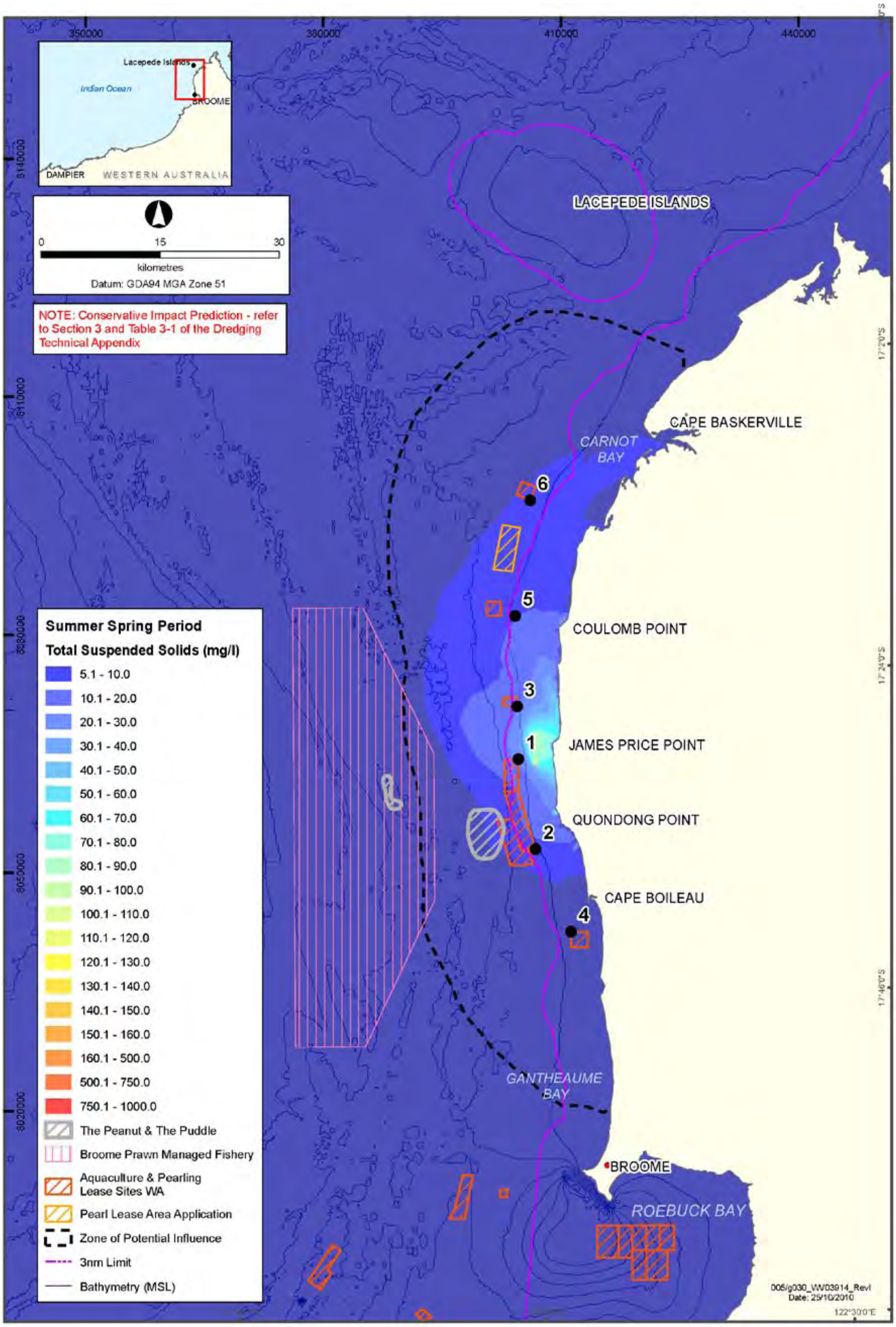
Plotted TSS time series data at six locations along a gradient within the zone of potential influence are provided in **Figure 2.3-6**, **Figure 2.3-7** and **Figure 2.3-8** in order to demonstrate the variability and intensity of turbidity with increasing range from the point source discharge. As expected, the highest TSS levels are observed at Point 1, closest to the proposed dredging location. At all points, except at Point 1 where a peak of TSS was determined in October, the highest levels of TSS were evident earlier in the year during summer (i.e. January/February). Whilst the peaks are higher during the summer period, the troughs are also lower, suggesting that the high intensity centre of the plume was physically shifted during this period. This is consistent with the dominance of abnormal metocean conditions during this period driving the plume, as outlined in Section 5.5.1 of **Appendix C-13** (BLNG Precinct Dredging and Spoil Disposal Assessment).

During operations, maintenance dredging may be required as the dredge channel, berthing pockets and turning basins infill with sediment over the lifetime of the Precinct. The requirement, frequency and extent of any maintenance dredging will be dependent on prevailing coastal and sediment transport processes. Maintenance dredging was not incorporated into the dredging and spoil disposal modelling approach, as the frequency and extent of such activities are as yet unknown. However the necessity of maintaining the seabed access channels, turning basin and berthing pockets at close to design levels means that maintenance dredge volumes will be very small compared to the capital dredging volumes. During operations, maintenance dredging may be required as the dredge channel, berthing pockets and

turning basins infill with sediment over the lifetime of the Precinct. The requirement, frequency and extent of any maintenance dredging will be dependent on prevailing coastal and sediment transport processes. Impacts associated with this activity (i.e. increase local turbidity and reduced benthic light availability) are similar in nature to those associated with the capital dredging, albeit at a much smaller scale and duration. Nevertheless, it is anticipated that the impacts associated with this activity (i.e. increase local turbidity and reduced benthic light availability) are similar in nature to those associated with the capital dredging, albeit at a much smaller scale and duration.

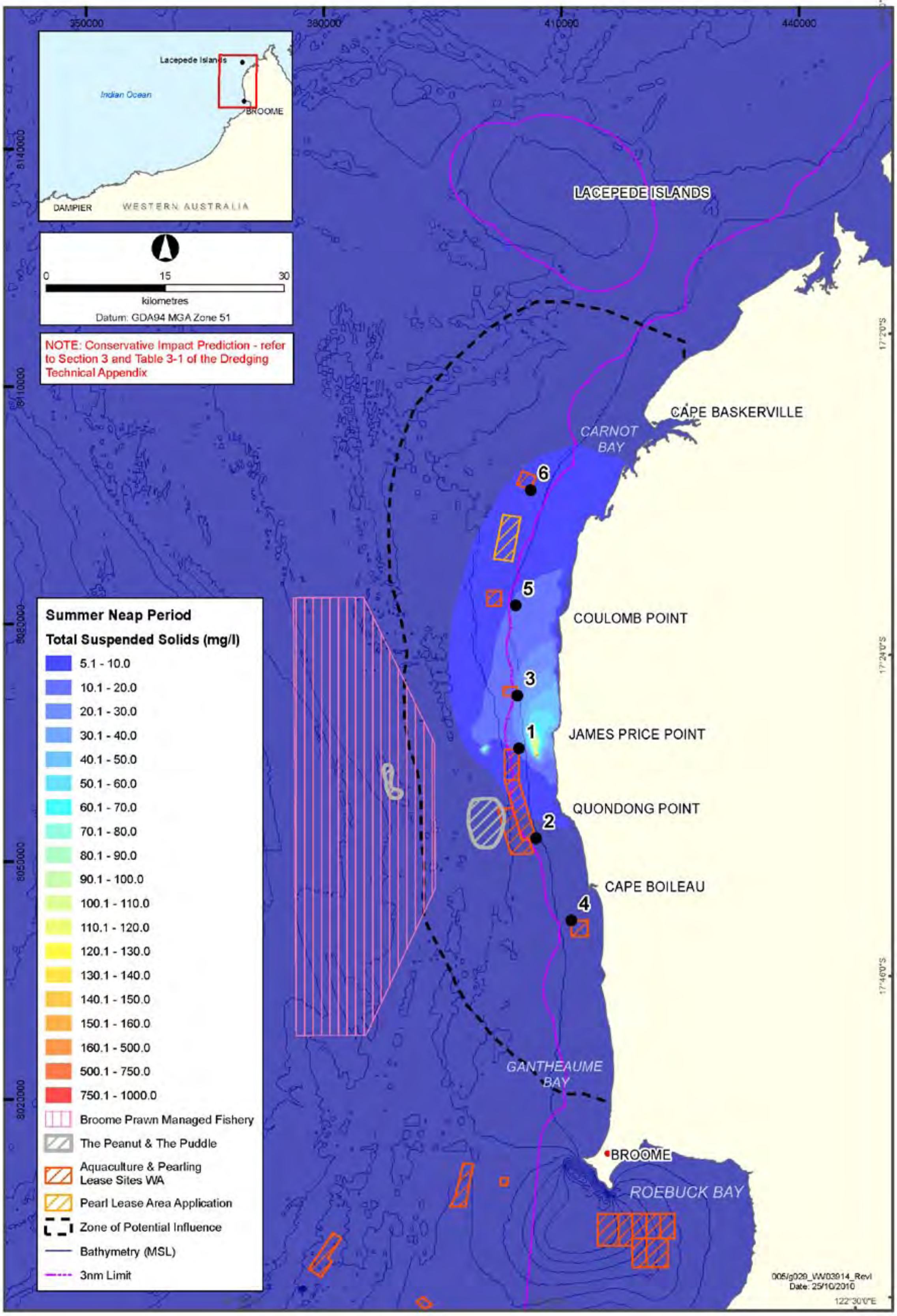
Marine site disturbance, excavation and sediment turbidity and deposition will result in an impact on marine water quality, however, changes in water quality will be localised and short-term (limited to the construction period). Preliminary plume dispersion modelling of dredging and disposal activities during construction has indicated that the greatest spatial extent of changes in turbidity would occur during summer/spring conditions, where the concentration of TSS due to dredging and spoil disposal activities could reach up to 10mg/l above background in an area extending from Quondong Point to just south of Coulomb Point and approximately 14km seaward. During these conditions, TSS concentrations may reach up to 50mg/l above background in an area extending approximately 3-5km north, west and south of dredging activities. The modelling also indicated that during dredging, some areas may experience pulses of high turbidity during spring tides and subsequent periods of reduced turbidity levels during neap tides. Receptors in these areas may have the potential to recover during neap periods when turbidity is lower and available light is higher. Recent dredging programmes on the North West Shelf have demonstrated that given appropriate management and contingency procedures, prolonged dredging campaigns can successfully mitigate water quality impacts and achieve acceptable outcomes. Prior to commencement of dredging, derived proponents would be required to prepare and implement a Dredging and Dredge Spoil Disposal Management Plan to demonstrate best practice management techniques and technologies which would be applied to minimise potential dredging impacts. A more detailed description of proposed mitigation measures is presented in **Section 2.3.5**.

The significance of residual impacts associated with the site disturbance and excavation activities associated with the BLNG Precinct are considered to be high. It is considered by the proponent that, based on industry experience, design and active management and monitoring measures, impacts can be managed to achieve acceptable outcomes.



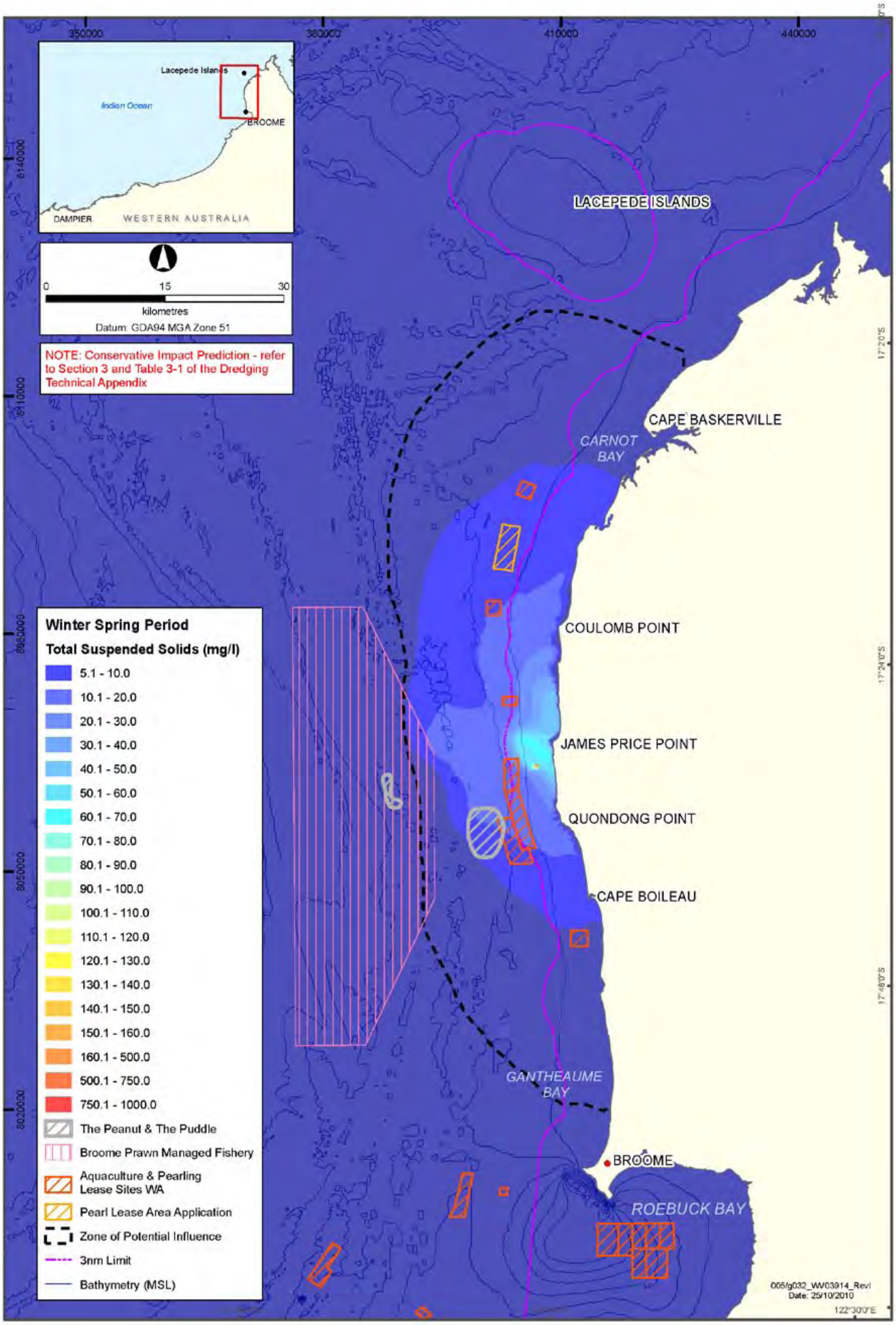

Source: DSD, 2010d; **Appendix C-13.**

- **Figure 2.3-2 Water Quality Model 'Snapshot' (i.e. a particular point in time) Showing the Contribution of Suspended Solids (i.e. above background) during Summer Spring Tide Conditions.**



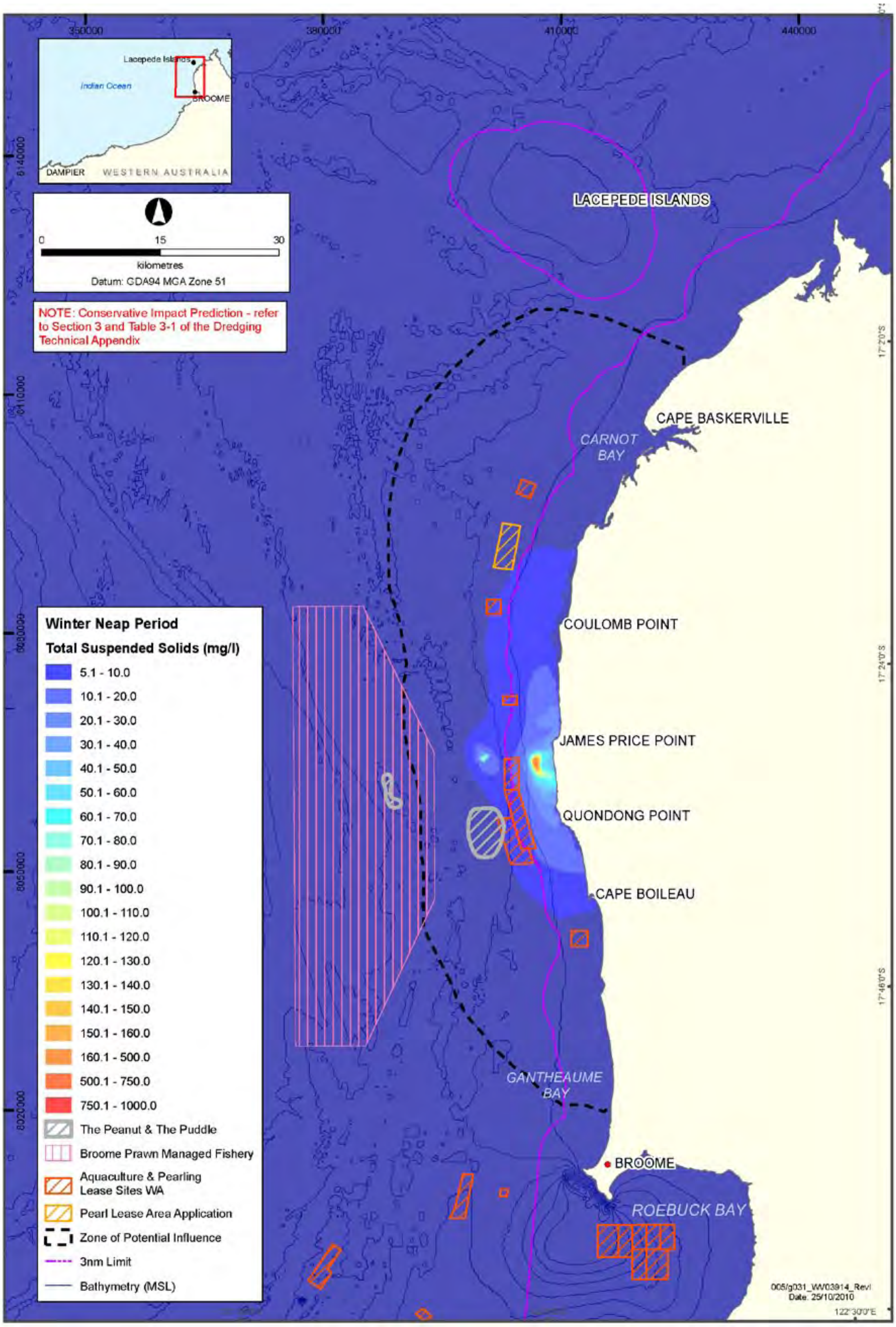

Source: DSD, 2010d; **Appendix C-13.**

- **Figure 2.3-3 Water Quality Model 'Snapshot' (i.e. a particular point in time) Showing the Contribution of Suspended Solids (i.e. above background) during Summer Neap Tide Conditions.**



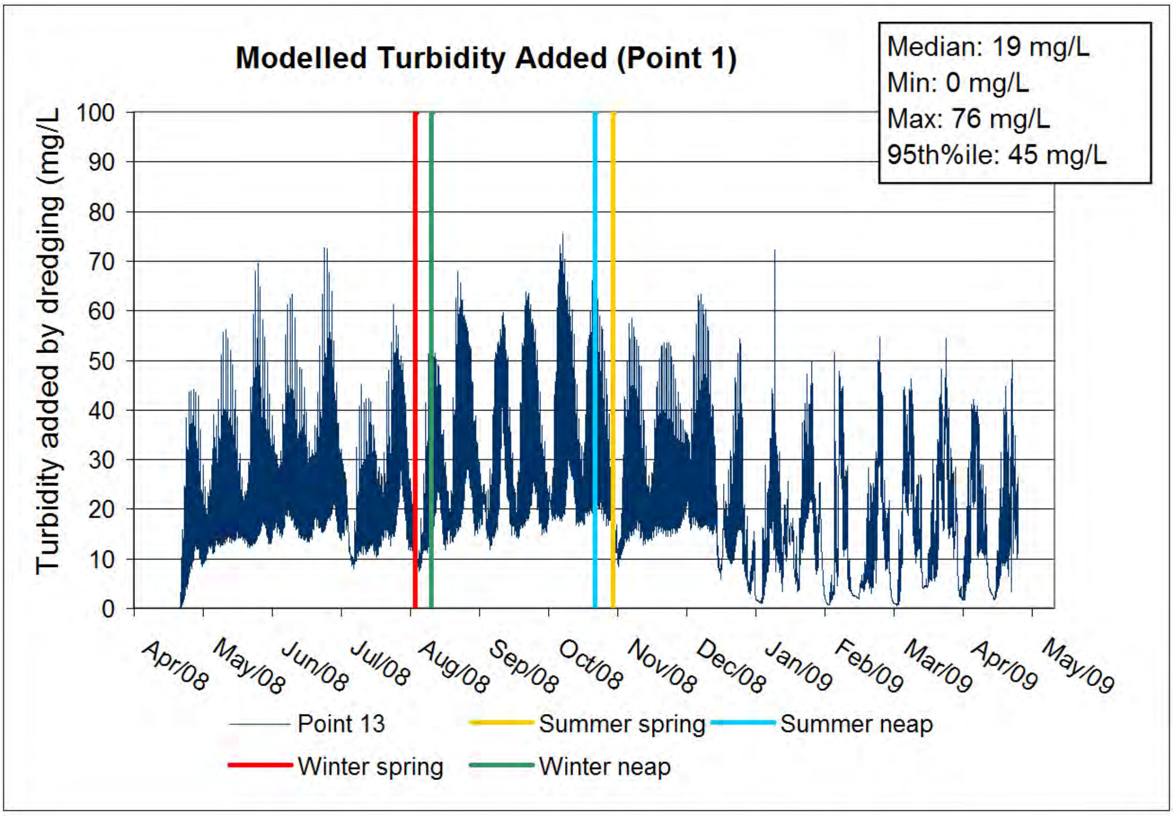

Source: DSD, 2010d; **Appendix C-13.**

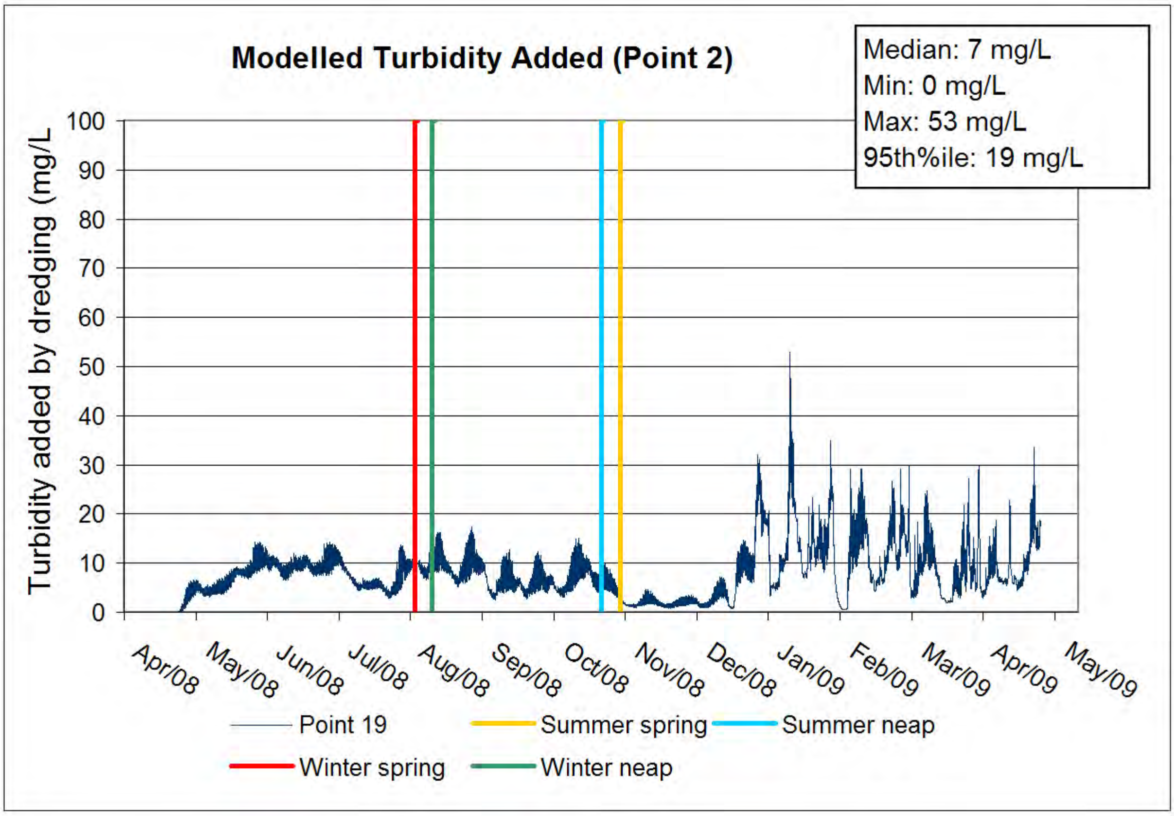
- **Figure 2.3-4 Water Quality Model 'Snapshot' (i.e. a particular point in time) showing the Contribution of Suspended Solids (i.e. above background) during Winter Spring Tide Conditions.**




Source: DSD, 2010d; **Appendix C-13.**

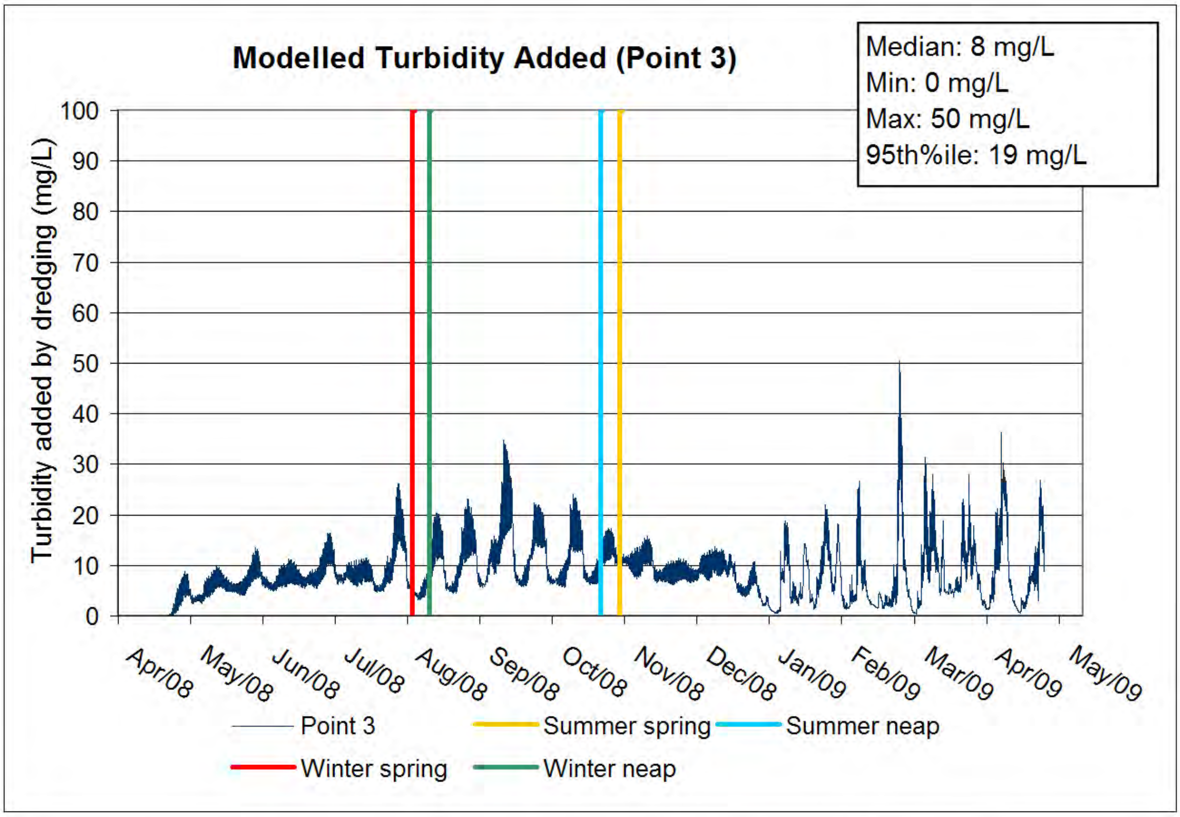
- **Figure 2.3-5 Water Quality Model 'Snapshot' (i.e. a particular point in time) Showing the Contribution of Suspended Solids (i.e. above background) during Winter Neap Tide Conditions.**

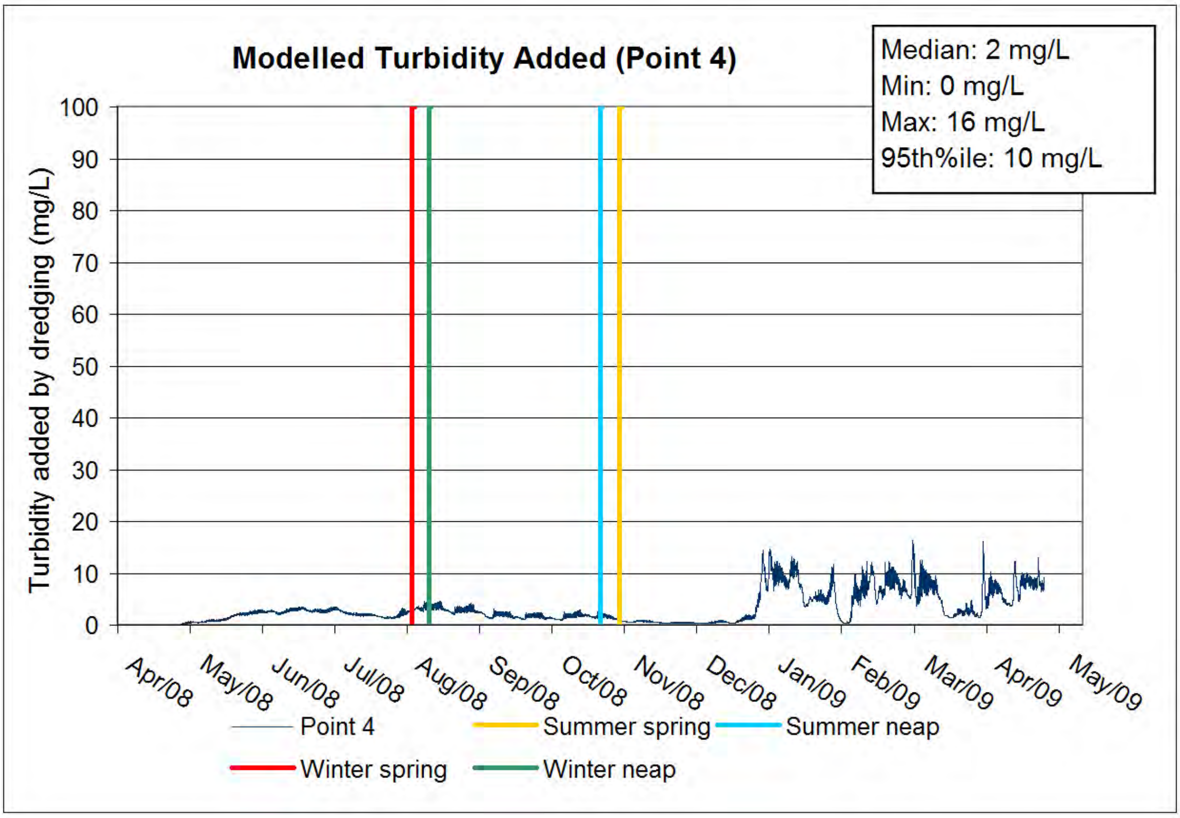



- **Figure 2.3-6 Modelled Total Suspended Sediment (TSS) Levels during the Simulated ‘Summer’ Dredging and Dumping Scenario at Points (1 and 2) Along a North-south Gradient from the Proposed Dredging Location.**

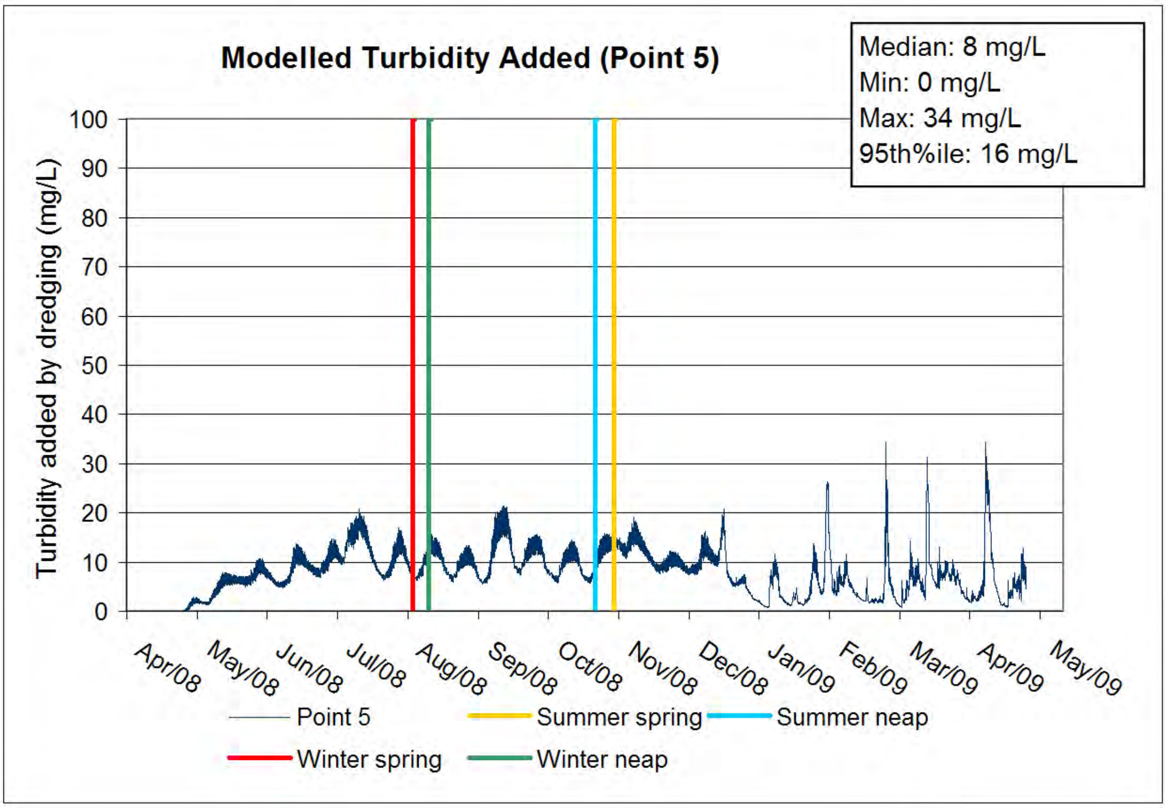
Note: See **Figure 2.3-2** and **Figure 2.3-3** for the location of points.

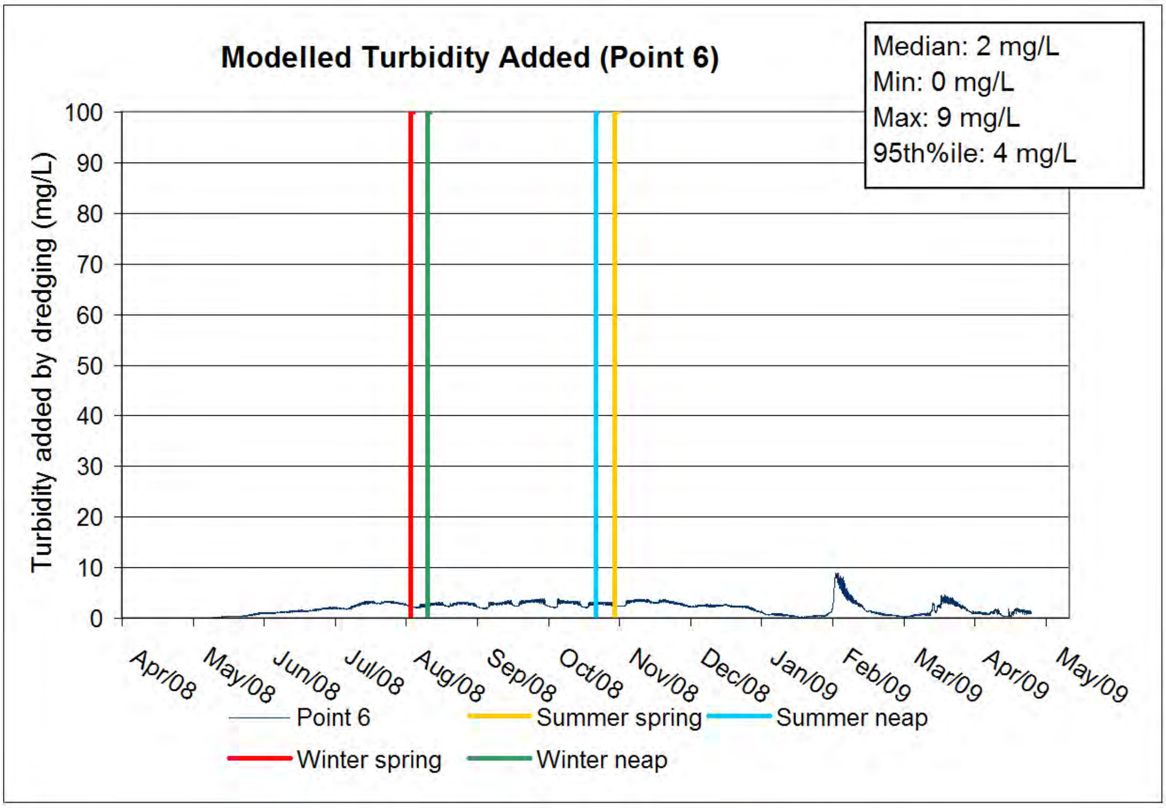



- **Figure 2.3-7 Modelled Total Suspended Sediment (TSS) Levels during the Simulated 'Summer' Dredging and Dumping Scenario at Points (3 and 4) along a North-south Gradient from the Proposed Dredging Location.**

Note: See **Figure 2.3-2** and **Figure 2.3-3** for the location of points.




- **Figure 2.3-8 Modelled Total Suspended Sediment (TSS) Levels during the Simulated Dredging and Dumping Scenario at Points (5 and 6) along a North-south Gradient from the Proposed Dredging Location.**

Note: See **Figure 2.3-2** and **Figure 2.3-3** for the location of points.

### 2.3.4.2. Impacts on Water Quality Resulting from Marine Discharges

**Routine Marine Discharges**

Some marine discharges will be routine during construction and operations. These streams will generally be treated by an onsite wastewater treatment plant prior to discharge to the sea via a common outfall. Further details on the potential impacts of such discharges are provided below.

Sewage will be gravity-fed to sanitary sumps before pumping to the wastewater treatment plant where sewage and grey water will be treated for removal of solids and debris followed by biological treatment prior to discharge to the marine environment. Treated wastewater will be further processed and where possible re-used on site prior to discharge to marine receiving waters. Therefore it is not anticipated that sewage discharge will result in a reduction in water quality outside the mixing zone.

Routine discharge of brine has the potential to produce a localised zone of marine water which is above ambient temperature, partially de-oxygenated and hypersaline. The rate of mixing of the wastewater plume discharged from the outfall will be determined by the physical characteristics of the effluent, the outfall design as well as hydrodynamic conditions of the receiving environment. Due to the brine component, it is likely that the discharge plume will be denser than surrounding waters, so it will be negatively buoyant, potentially sinking to the sea bed to form a layer of higher salinity water at the seabed. This hyper-saline plume may move slowly offshore as it flows to deeper areas under gravity.

At James Price Point, the wastewater will be discharged into a well-mixed and highly flushed environment marine. The semi-diurnal tides, with up to 8m tidal range, produce currents with high velocities and high seabed sheer stress. This dynamic environment promotes rapid mixing and is likely to accelerate dilution of any routine discharge. It is therefore likely that any contaminants entering receiving waters from the BLNG Precinct operations will be not be detectable above background levels, except within the immediate mixing zone .

Produced water, process water, hydrotest water and cooling water (if required) may contain trace levels of biocides, hydrocarbons or oxygen scavenging chemicals which may have a toxic effect on marine organisms in the vicinity of waste streams. Assessment of toxicity on the treated produced water on the Pluto LNG (WEL, 2006) development indicated that the produced water was unlikely to exhibit toxic effects at greater than 1.3 times dilution at the point of release. Following mixing with other waste streams, discharge via an outfall diffuser and subsequent dilution within the approved mixing zone, it is anticipated these wastewater streams will meet 95% level of species protection, outside the BLNG Precinct port area, according to the definitions of the ANZECC/ARMCANZ 2000 guidelines.

Stormwater runoff during construction and operations will occur during and immediately following large rainfall events. Rainfall events occur intermittently and vary in duration and intensity. The first flush of a runoff event will lift contaminants from surfaces (particularly impervious surfaces) where they have accumulated since the preceding runoff event. This water will be collected and sent to the waste water management system prior to discharge. Post ‘first flush’ stormwater will be discharged direct to sea. Therefore it is not anticipated that stormwater runoff will result in a reduction in water quality outside the mixing zone.

Deck drainage from construction, maintenance and operational vessels will routinely be discharged water to the marine environment during all phases of the BLNG Precinct Project. Contaminants which may typically be contained within the drainage include hydrocarbons, detergents and litter. In addition, there will be occasional short-term releases of bilge water from vessels into the marine environment. Although bilge water has the potential to effect the marine environment through the addition of contaminants which collect in a vessel’s bilge, the scale of impacts is likely to be minimal.

Routine discharge of sewage and greywater from dishwashing, laundering and showers will be generated on vessels commissioned for construction, maintenance and operations. These waste streams will typically add organic material, nutrients, detergents, suspended solids, biological oxygen demand, pathogens and trace levels of metals.

Routine discharges of industrial and domestic wastewater occur from a number of sites along the WA coastline with manageable environmental impacts and acceptable outcomes. Given the dynamic nature of the receiving environment at James Price Point, routine wastewater discharges will be rapidly mixed through the water column such that it is highly likely that any contaminants entering receiving waters from the BLNG Precinct operations will be not be detectable above background levels, except within the immediate mixing zone. Wastewater discharge modelling is being undertaken to confirm the predicted mixing and dilution of treated wastewater discharges beyond the outfall, and to substantiate

expected environmental outcomes associated with routine marine discharges from the proposed BLNG Precinct. Results of this modelling will be made publicly available during the public release of the SAR.

BLNG Precinct proponents will be required to demonstrate that routine wastewater discharges achieve the relevant ANZECC/ARMCANZ water quality guidelines within an agreed mixing zone, and undertake regular ecotoxicity testing and improvements to target 99% species level of protection beyond the BLNG Port Area. A Wastewater Discharge Management Plan will also be developed, including hydrodynamic modelling and environmental monitoring to ensure these water quality guidelines are achieved, minimising potential environmental impacts associated with a decline in water quality from routine discharges.

Similarly for routine brine discharges from desalination (if required), industry experience gained at Cockburn Sound (CSMC, 2010) and King Bay have demonstrated that engineering design, active management and monitoring protocols can successfully mitigate water quality impacts and achieve acceptable outcomes. Given the comparatively dynamic hydrodynamic environment at the BLNG Precinct, rapid and complete dispersal within an agreed mixing zone is anticipated to be readily achievable using standard industry practices. Details on such practices will be included in the Marine Wastewater Discharge Management Plan.

**Non-routine Marine Discharges**

There is potential for non-routine discharges of hydrocarbons to the marine environment to occur during the handling of stored hydrocarbons or in the event of a shipping accident. Spillages would occur infrequently and are short term. Hydrocarbons which may be released include condensate, marine diesels, lubrication oils and bunker fuel.

Laboratory tests on Browse gas field condensate indicates that under warm condition, light winds, high relative humidity and low light intensity 60–70% of the spilled condensate will evaporate leaving a viscous waxy residue. A condensate spill at sea is unlikely to be contained due to its low viscosity, however, rapid spread and evaporation will result in dissipation of a condensate slick (DSD, 2010d; **Appendix C-13**).

The potential for an accidental LNG spill, as well as the dynamics and dispersion of the released gas, are based on theoretical scenarios and can be clarified through specific modelling assessments. This is because the increased focus on LNG ship design and industry safety management practices for LNG transportation have reduced LNG accidents to a level such that there is little historical or empirical information on the environmental effects of spills (Hightower *et al*., 2004). Nevertheless, although the occurrence is extremely unlikely, a large scale spill of LNG within the marine environment would result in a rapid phase transition of the spilled LNG upon contact with the water. Rapid phase transitions occur when the temperature difference between a hot liquid and a cold liquid is sufficient to drive the cold liquid rapidly to its superheat limit, resulting in spontaneous and explosive boiling of the cold liquid (Hightower *et al*., 2004) (**Figure 2.3-9**). Major constituents of LNG would vaporise relatively quickly and therefore any impacts to waters would be short lived. The upper surface of the receiving water will receive cryogenic LNG heated up by the marine waters. Such an impact is likely to be short lived, given that phase transition would be rapid.

Marine diesel is a low viscosity distillate containing a high proportion of volatile light fractions with the remainder persistent hydrocarbons. If spilled, diesel would spread very rapidly with the slick elongated in the direction of prevailing wind and waves. Thicker patches of diesel would likely occur at the downwind leading edge of the slick. Some diesel fuel oils may form an unstable emulsion at the thicker, leading edges of the slick. As with condensate, the dominant process contributing to the removal of spilled diesel from the sea surface is evaporation, which can account for 60 to 80% of loss. Evaporation will be enhanced by higher wind speeds and warmer sea and air temperatures. Diesel residues usually consist of heavy compounds which may persist longer and will tend to disperse as oil droplets into the upper layers of the water column. The implementation of strict industry standards and product handling guidelines would mitigate against likely spills and restrict impact to a temporary water quality effect within the BLNG Precinct Port area and the immediate surrounds.

Collisions between vessels or vessels and the seabed may result in a spill resulting in large volumes of floating hydrocarbons (marine fuel) which would be advected great distances under tidal wind and currents of the area. The likelihood of such a spill due to the BLNG Precinct Project is low, due to stringent controls required for shipping and the response planning which will be in place in the unlikely event of its occurrence.

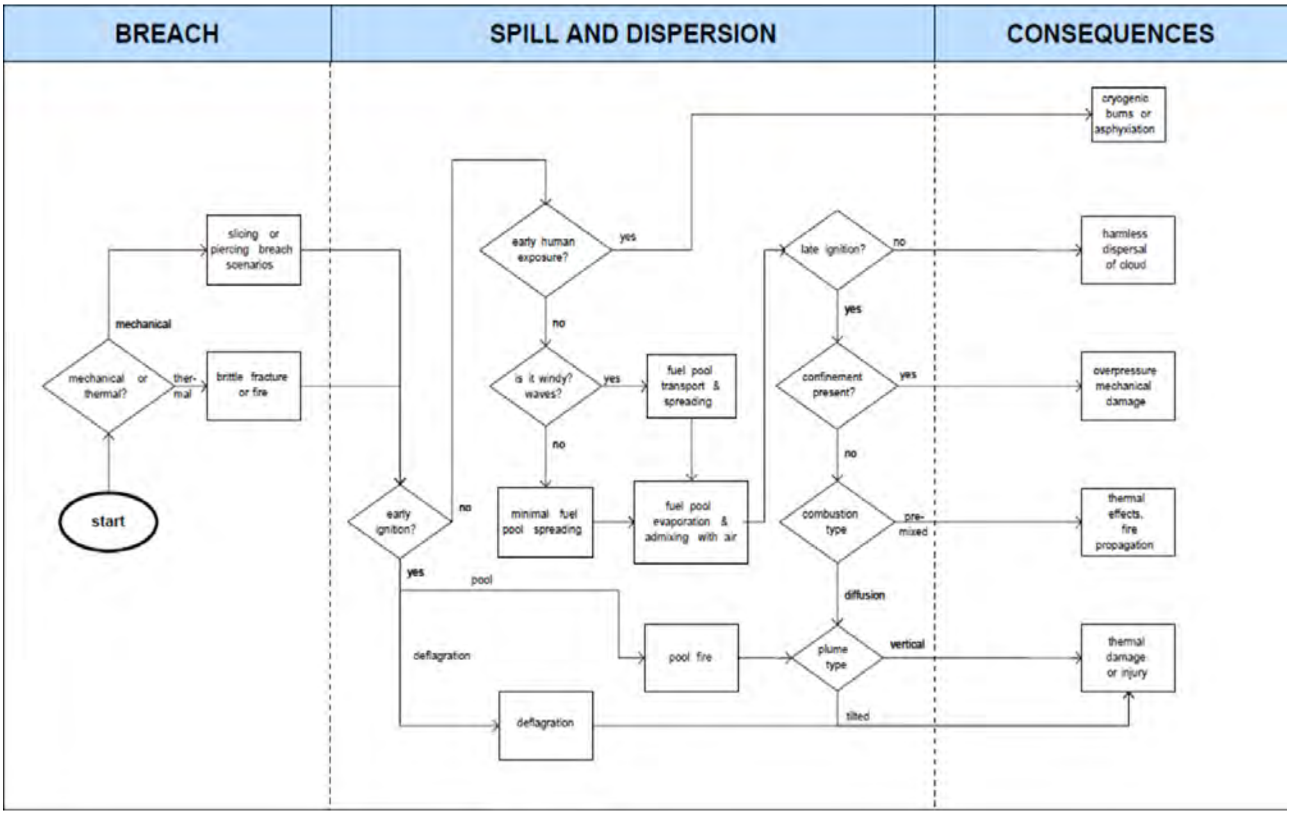
Management of non-routine discharges (i.e. spills and leaks) would largely focus on prevention and rapid response in the unlikely event that a spill does occur, as outlined in **Section 2.3.5**. Although the likelihood of a major spill or leak

occurring is very low, the impact of such an event could be significant. The potential for, and impact of, a major hydrocarbon spill will be the focus of a supplementary spill modelling exercise to be undertaken during the derived proposal stage. Such a modelling exercise would provide information concerning any significance species at risk and the actions and timeframes required to minimise potential impacts. However, it is known that LNG product is not toxic, rapidly undergoes phase transitions and evaporates following contact with warmer seawater. Such LNG spills have previously been recognised as having little impact on the marine environment generally and on water quality. Similarly, if spilled, other hydrocarbons (e.g. fuel oil, diesel or condensate) will spread from the site release point in the direction of prevailing wind and waves. The proposed implementation of measures to prevent potential loss of containment, and rapid response in the unlikely event of occurrence, are clear commitments for management by all operators within the Precinct.

Whilst the likelihood of a major hydrocarbon spill (e.g. vessel collision or pipeline rupture) is considered extremely unlikely, the consequence may be severe if appropriate response measures are not effectively implemented. The establishment of the Broome Port Authority as the statutory port authority for the BLNG Precinct will ensure supplies of oil spill response equipment are as required under the State Emergency Management Plan for Marine Oil Pollution (West Plan) to undertake an immediate oil spill response. Major hydrocarbon spills may also require deployment of additional equipment stockpiled in the Fremantle and Dampier ports, or other stockpiles under the National Plan, to minimise the extent of hydrocarbons and reduce potential impacts to sensitive environmental receptors. The oil spill modelling required by future proponents during the derived proposal process will be used to inform a Hydrocarbon and Chemical Spill Contingency Plan, which will be implemented in the event of a large hydrocarbon or chemical spill. An Emergency Response Plan will also be developed outlining emergency response procedures to be implemented by the port authority in the event of an oil spill emergency.

Impacts associated with non-routine spills are minimised as a result of strict industry standards and procedures for product handling and storage and appropriate response planning as described in **Section 2.3.5**. Furthermore, the NDT site selection process, whereby the James Price Point area was noted as the site with least environmental constraints on the Dampier Peninsula and environmental risks were likely to be manageable, has minimised the likelihood of significant environmental impacts associated with non-routine spills should they occur as a result of BLNG Precinct activities, as key sensitive receptors are distant and have been avoided.

It is therefore concluded that the significance of residual impacts to water quality from the proposed BLNG Precinct can be managed to an acceptable level. These predicted environmental outcomes from non-routine discharges will be confirmed by hydrocarbon spill modelling currently being undertaken for the BLNG Precinct and relevant activities. The results of this supplementary modelling will be made publicly available during the public consultation period for the SAR.




Source: Hightower *et al.,* 2004.

- **Figure 2.3-9 Potential Sequences of Events Following the Breach of an LNG Cargo Tank.**

### 2.3.5. Mitigation Measures

The proposed mitigation measures and safeguards applicable to management of impacts to marine water quality arising from the construction and operation of the BLNG Precinct are summarised in **Table 2.3-2**, **Table 2.3-3**, and **Table 2.3-4**.

Refer also to the Management Arrangements specifically defined for Commonwealth matters, summarised in **Part 6**, **Section 3**.

- **Table 2.3-2 State Government Measures for the Management of Impacts on Water Quality.**

| State Government Measure | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area. | Department of Transport (DoT) | On approval of BLNG Precinct |
| The Port Authority will prepare a BLNG Precinct Environmental Management Plan (BPEMP) for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• an audit of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms. | Broome Port Authority | Prior to approval of marine related derived proposals |
| Establishment of a Dredging Management Advisory Group (DMAG) comprising representatives from:<br>• Independent Chair with extensive knowledge of marine environment;<br>• Broome Port Authority;<br>• Office of EPA;<br>• DEC;<br>• DoF;<br>• SEWPAC; and<br>• Foundation or other proponent | DSD on advice of SEWPAC and EPA | Prior to referral of future major dredging proposals |
| The role of the Dredging Management Advisory Group (**DMAG**) will be to provide advice to the proponent, EPA and/or the Minister for Environment as appropriate on the following:<br>• marine investigations (including the modelling of dredge plumes);<br>• environmental risk assessments prepared for future dredging proposals;<br>• risk to key environmental values in Risk Zones;<br>• detailed water quality or impact criteria for risk-based performance standards and the final configuration of Risk Zones; and<br>• dredge management plans (including monitoring programs and adaptive response in the event that risks to key values are greater than low) prepared by proponents of future major dredging proposals | DSD | Prior to referral of future major dredging proposals |

**Table 2.3-3 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Water Quality.**

| Condition No. | Proposed Environmental Conditions for the Strategic Proposal |
|---|---|
| **Proposals involving treated wastewater discharges** | |
| M2.1 | Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95$^{th}$ percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone (i.e. outside of the port area) the proponent will ensure that the 95$^{th}$ percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels. |
| M2.2 | Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants. |
| M2.3 | Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary to ensure ongoing compliance to the General Manager of the OEPA. |
| **Proposals involving dredging** | |
| M2.4 | Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• consideration of the re-use of suitable dredge material for MOF construction, where practicable;<br>• design of the MOF including construction of bunds to isolate fill material from wind and wave action;<br>• consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives;<br>• consideration of re-use of reclaimed material to minimise ocean disposal;<br>• measures to minimise dredging impacts during sensitive ecological windows;<br>• a monitoring strategy for ecological receptors and health during marine construction (including baseline surveys);<br>• the development of trigger levels for benthic communities and water quality that define additional management responses;<br>• mechanisms to audit and assess environmental performance of proponents during construction; and<br>• a communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. |

**Table 2.3-4 Requirements to be Addressed via Development of a Management Plan to Support a Derived Proposal Potentially Affecting Water Quality.**

| Derived Proponent Requirements | Timing |
|---|---|
| Prepare and implement a Marine Wastewater Discharge Management Plan (MWDMP), to the satisfaction of the Western Australian Minister for Environment, to ensure that disposal of treated wastewater from operation of the BLNG Precinct facilities is undertaken and managed in a way that minimises the environmental impacts and is consistent with the local water quality environmental values. The plan shall include:<br>• details of the discharge including outfall location, outlet design and discharge volumes, rates and quality;<br>• construction method and management;<br>• identification of conditions used in hydrodynamic modelling which shall include any approved changes to water quality as a result of other outfall proposals; and<br>• results of hydrodynamic modelling of wastewater outfall in order to demonstrate compliance with the approval conditions, and environmental monitoring, contingencies and reporting.<br>The objective of the plan is to ensure that the discharge of wastewater is managed to achieve the ANZECC/ARMCANZ guidelines outside agreed mixing zones. These include:<br>• Maintenance of ecosystem integrity with spatially-assigned levels of protection;<br>• Ensuring that the treated discharge meets appropriate environmental protection guidelines (i.e. 95% level of species protection; Australian and New Zealand Guidelines for Fresh and Marine Water Quality, ANZECC/ARMCANZ 2000) outside the Browse LNG Port Area;<br>• Undertaking biannual ecotoxicity testing within the Browse LNG Port Area to identify discharge parameters to be improved in order to achieve a target of 99% level of species protection beyond the Browse LNG Port Area;<br>• Maintenance of aquatic life for human consumption assigned to all parts of the marine environment surrounding the ocean outlet;<br>• Maintenance of primary contact recreation values assigned to all parts of the marine environment surrounding the ocean outlet;<br>• Maintenance of secondary contact recreation values assigned to all parts of the marine environment surrounding the ocean outlet;<br>• Maintenance of aesthetic values assigned to all parts of the marine environment surrounding the ocean outlet;<br>• Maintenance of cultural and spiritual values assigned to all parts of the marine environment surrounding the ocean outlet; and<br>• Maintenance of Industrial Water Supply. To achieve the above objectives, the proposed wastewater treatment and disposal operations will be managed to minimise environmental impacts.<br>These objectives are to be achieved through the implementation of best practice techniques and technology for wastewater treatment to minimise potential impacts including: whole effluent toxicity (WET) testing to determine the toxicity of the wastewater and day to day operational environmental management. | Prior to construction of marine discharge facilities |
| Prepare and implement a Hydrotesting Procedure and a Pipeline Pre-commissioning Plan prior to such activities being carried out. Specific management measures to be considered include:<br>• chemicals to be used as hydrotest water additives and their relative;<br>• concentrations should be selected to ensure that the best environmental and technical solutions are achieved for the proponent;<br>• preference for offshore disposal of hydrotest water over nearshore disposal; and<br>• re-use of hydrotest water where possible and treatment prior to discharge.<br>Pre-commissioning systems and components offsite with appropriate hydrotest water treatment or recycling facilities will reduce the amount of testing required on site. | Prior to commissioning |
| Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment, for each activity, which addresses the following:<br>• effective and timely management of spills; | Prior to commencement of associated construction activities |

| Derived Proponent Requirements | Timing |
|---|---|
| • roles and responsibilities of response personnel;<br>• procedures for incident response;<br>• objectives, targets and associated monitoring; and<br>• alignment and compliance with the State Government Precinct Emergency Response Plan.<br>In order to address the potential impacts to marine water quality identified within this section, the Plan may include environmental management measures to address:<br>• marine vessel re-fuelling;<br>• construction, commissioning and operation of the gas trunkline;<br>• LNG and condensate export tanker loading during operations; and<br>• drilling and subsea infrastructure. | |
| All vessels will be required to have in place a SOPEP and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea. | Prior to construction and updated for ongoing operational requirements |
| Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework. | Prior to commencement of associated construction activities |

### 2.3.6. Environmental Outcome

The key aspects of the proposed BLNG Precinct that may impact marine water quality include marine site disturbance and excavation through dredging and disposal leading to increased turbidity and a reduction in benthic light availability, routine wastewater discharges giving rise to a prescribed mixing zone, and non-routine discharges of hydrocarbons.

A variable ambient environment is a feature of the James Price Point nearshore environment. However, against this natural condition, decreased water quality will result from construction activities, notably dredging. The aspects likely to impact water quality are summarised below.

#### 2.3.6.1. Direct Impacts

- Both the capital and maintenance dredge campaigns will result in sediment plumes containing elevated suspended sediments above ambient concentrations. Beyond the Precinct Area, suspended solids are likely to occur at concentrations above the usual ambient range.
- Wastewater discharge will locally decrease water quality within the defined mixing zone. This is because advection-dispersion physical processes in the marine environment will spatially constrain a reduction in water quality associated with the mixing zones. Outlets to the marine environment will be designed to achieve maximum dilutions within a prescribed mixing zone area.
- Vessel movements and operations can be sources of both turbidity and discharges to the marine environment. Shipping will be undertaken in accordance with Australian legislation which gives effect to the International Convention for the Prevention of Pollution from Ships (MARPOL). Legislation such as *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*, Protection of the Sea (Prevention of Pollution from Ships) (Orders) Regulations and Marine Orders Parts 91 to 97 all dictate the manner in which shipping is regulated to restrict water quality impacts. Therefore it is judged that increased shipping activities are expected to have little adverse impact on water quality.
- Non routine hydrocarbon spills pose a significant environmental consequence to regional water quality; however, the likelihood of a major spill associated with the BLNG Precinct is remote. An Emergency Response Plan will be developed outlining emergency response procedures to be implemented by the port authority in the event of an oil spill emergency, and operators will be required to implement a Hydrocarbon and Chemical Spill Contingency Plan.

#### 2.3.6.2. Indirect Impacts

The indirect impacts will mainly be the temporary change in faunal behaviour associated with the direct reduction in water quality. In addition, there will be further potential indirect impact to local visual amenity associated with the visible plume.

#### 2.3.6.3. Cumulative Impacts of the Proposal and Associated Activities

**Category B Activities**

The Category B activities centre around onshore actions supporting the BLNG Precinct but not subject to the current State or Commonwealth approval process. Potential activities that may directly affect water quality include: further development of Broome port and local boat ramp to accommodate more marine traffic and the increase in marine traffic associated with the Browse field and Precinct, increase in recreational vessel traffic and urban development of nearby coastal catchments.

Except for some early, pioneering activities, which would result in vessels calling at the Port of Broome and would be accommodated within the current capacity of the port, increased watercraft use would primarily be linked to increases in recreational vessel activity at the local boat ramp.

The impacts on water quality from these activities would be limited. Improvements at or expansion of the port would likely be to existing areas. Expansion or development at new areas do not appear to be required, however these would result in localised impacts with no regional impacts. Increases in recreational activities would have very limited impact on water quality.

After tropical runoff events, an increased load of sediment, potentially linked to persistent residues used in the catchment, may be carried via stormwater outfalls into the local marine environment and have a localised effect on water quality. The magnitude of this effect is likely to be very small and correlated to growth in the Broome urban area and not resulting in cumulative impacts when considered with those of the BLNG Precinct.

No dedicated additional wastewater treatment discharges are anticipated from municipal infrastructure, given current capacity planned in the existing treatment system, so no change to near coastal water quality is likely to occur.

Similar to the Category B actions, the geographic separation of the projects identified as Category C actions would also not be expected to add cumulatively to those of the BLNG Precinct.

**Category C Activities**

Category C activities which have the potential to impact on marine water quality are limited to upstream exploration and development activities and these are unlikely to present cumulative impacts, other than an accidental emission, as effects would be spatially isolated. Exploration and construction activities of the Browse Basin gas field to acquire the hydrocarbon resource and the operation of the upstream extraction of hydrocarbon will involve the discharge of drilling muds and chemicals which may cause localised changes in water quality. These effects would be localised, restricted in area to the immediate vicinity of the activity, so would not result in cumulative impacts.

Localised cumulative impacts with Category A and C are likely to evident on water quality from activities that will coincide at the same time in close proximity to the 3Nm Commonwealth Marine Area boundary. These activities include pipeline construction, dredging and dredge spoil disposal. Category C aspects which have the potential to impact water quality are limited to marine site disturbance and excavation (when pipeline and marine infrastructure construction occurs in parallel) and sediment deposition and turbidity (when dredging and spoil disposal is being undertaken near the 3Nm boundary). The upstream development activities will involve a reduction in water quality by an increase in turbidity; however, this disturbance is expected to be very localised with only a small increase in TSS and reduction in benthic light availability attributable to spoil disposal and pipeline construction activities. Circulation in areas beyond the 3Nm boundary is likely to reduce the extent of plumes from pipelines and spoil disposal.

Modelling of a cumulative dredging scenario (i.e. including category C activities) such that the cumulative impact from pipeline laying and the capital dredging activities are incorporated, will be undertaken during the derived proposal stage.

▪ **Table 2.3-5 Impact Assessment Summary for Marine Water Quality.**

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| Marine Site disturbance / excavation | Reduction in water quality due to an increase in turbidity (i.e. total suspended sediments) and a reduction in benthic light availability (i.e. increased light attenuation). | Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area.<br>The Port Authority will prepare a BPEMP for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas; | Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95th percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone the proponent will ensure that the 95th percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels.<br>Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants.<br>Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary | Prepare and implement a MWDMP, to the satisfaction of the Western Australian Minister for Environment, to ensure that disposal of treated wastewater from operation of the BLNG Precinct facilities is undertaken and managed in a way that minimises the environmental impacts and is consistent with the local water quality environmental values. The plan shall include:<br>• details of the discharge including outfall location, outlet design and discharge volumes, rates and quality;<br>• construction method and management;<br>• identification of conditions used in hydrodynamic modelling which shall include any approved changes to water quality as a result of other outfall proposals; and<br>• results of hydrodynamic modelling of wastewater outfall in order to demonstrate compliance with the approval conditions, and environmental monitoring, contingencies and reporting.<br>The objective of the plan is to ensure that the discharge of wastewater is managed to achieve the ANZECC/ARMCANZ guidelines outside agreed mixing zones. These include:<br>• Maintenance of ecosystem integrity with spatially-assigned levels of protection.<br>• Ensuring that the treated discharge meets appropriate environmental protection guidelines (i.e. 95% level of species protection; Australian and New Zealand Guidelines for Fresh and Marine Water Quality, ANZECC/ARMCANZ 2000) outside the active mixing zone.<br>• Maintenance of aquatic life for human | High |
| Marine discharges (routine) | The continuous routine discharge of treated wastewater will create a localised zone (i.e. mixing zone) of altered water quality. | | | | Low |
| Marine discharges (non- | Non-routine discharges (i.e. | | | | Low |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| routine) | spills and leaks) can result in a significant effect on water quality. | • identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• an audit of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms.<br><br>Establishment of a Dredging Management Advisory Group (DMAG) comprising representatives from:<br>• Independent Chair with extensive knowledge of marine environment;<br>• Broome Port Authority;<br>• Office of EPA;<br>• DEC;<br>• DoF;<br>• SEWPAC; and | to ensure ongoing compliance to the General Manager of the OEPA.<br><br>Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• Consideration of re-use of reclaimed material to minimise ocean disposal. | consumption assigned to all parts of the marine environment surrounding the ocean outlet.<br>• Maintenance of primary contact recreation values assigned to all parts of the marine environment surrounding the ocean outlet.<br>• Maintenance of secondary contact recreation values assigned to all parts of the marine environment surrounding the ocean outlet.<br>• Maintenance of aesthetic values assigned to all parts of the marine environment surrounding the ocean outlet.<br>• Maintenance of cultural and spiritual values assigned to all parts of the marine environment surrounding the ocean outlet.<br>• Maintenance of Industrial Water Supply.<br><br>These objectives are to be achieved through the implementation of best practice techniques and technology for wastewater treatment to minimise potential impacts including: whole effluent toxicity (WET) testing to determine the toxicity of the wastewater and day to day operational environmental management.<br><br>Prepare and implement a Hydrotesting Procedure and a Pipeline Pre-commissioning Plan prior to such activities being carried out. Specific management measures to be considered include:<br>• Chemicals to be used as hydrotest water additives and their relative concentrations should be selected to ensure that the best environmental and technical solutions are achieved for the proponent<br>• Preference for offshore disposal of hydrotest water over nearshore disposal.<br>• Re-use of hydrotest water where possible | |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | **State Government Measures** | **Proposed Environmental Conditions** | **Future Proponent Management Plans** | |
| | | • Foundation or other proponent<br><br>The role of the DMAG will be to provide advice to the proponent, EPA and/or the Minister for Environment as appropriate on the following:<br><br>• marine investigations (including the modelling of dredge plumes);<br>• environmental risk assessments prepared for future dredging proposals;<br>• risk to key environmental values in Risk Zones;<br>• detailed water quality or impact criteria for risk-based performance standards and the final configuration of Risk Zones; and<br>• dredge management plans (including monitoring programs and adaptive response in the event that risks to key values are greater than low) prepared by proponents of future major dredging proposals. | • Measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br><br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. | and treatment prior to discharge.<br><br>Pre-commissioning systems and components offsite with appropriate hydrotest water treatment or recycling facilities will reduce the amount of testing required on site.<br><br>Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment, for each activity, which addresses the following:<br><br>• effective and timely management of spills;<br>• roles and responsibilities of response personnel;<br>• procedures for incident response;<br>• objectives, targets and associated monitoring; and<br>• alignment and compliance with the State Government Precinct Emergency Response Plan.<br><br>In order to address the potential impacts to marine water quality identified within this section, the Plan may include environmental management measures to address:<br><br>• Marine vessel re-fuelling;<br>• Construction, commissioning and operation of the gas trunkline;<br>• LNG and condensate export tanker loading during operations; and<br>• Drilling and subsea infrastructure.<br><br>All vessels will be required to have in place a SOPEP and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea.<br><br>Proponents of derived proposals shall prepare | |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| | | | | and implement a Port Facilities Construction Environmental Management Plan (PFCEMP), to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework. | |

## 2.4. Key Factor: Benthos Including Benthic Primary Producers

Benthos describes a diverse range of organisms that live on the seafloor comprising infauna and epifauna, benthic primary producers (BPPs) and non-BPPs. Benthos represents a large component of marine biodiversity and ecosystem productivity. Infauna and epifauna include a range of invertebrates such as cnidarians, crustaceans, molluscs, echinoderms and polychaetes. BPP reside on the sea floor and sequester carbon and energy through photosynthesis, as such, providing one of the main bases of shallow water food chains. BPP are predominantly marine plants (e.g. seagrasses and algae) but also include invertebrates that acquire a significant proportion of energy from symbiotic microalgae (EPA, 2004a). Disturbance to the integrity of BPP communities can disrupt local marine ecosystem function.

The main groups of non-BPPs considered in this assessment are those non-photosynthetic organisms that can form significant habitat for other biota and may be at risk from development activities. These groups include non-photosynthesising sessile invertebrates such as sponges, certain soft corals, ascidians, gorgonians and sea whips.

The following section describes the potential threats and associated impacts that may reduce or cause loss of benthos, including BPP, as a result of activities, facilities and other characteristics to be implemented under the Plan for the BLNG Precinct (Category A) and the potential for cumulative impacts from activities that may indirectly arise as a result of the Precinct development (Category B) and other related resource activities (Category C).

### 2.4.1. Current Knowledge

Marine benthos can be described in terms of taxonomic details and species diversity, abundance and distribution or via the location and extent of biological communities and their substrates on a larger spatial scale. Much of the understanding of the marine ecosystem is based on this latter type of information.

Current knowledge with respect to key policy documents and regulatory requirements, as well as a summary of known existing benthos characteristics in the vicinity of the proposed precinct are presented in the section below.

#### 2.4.1.1. Key Statutory Requirements, Environmental Policy and Guidelines

The overarching EPA objective for this factor is the maintenance of:

"...*the abundance, diversity, geographic distribution and productivity of flora and fauna at ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge*" and "… *to maintain the integrity, ecological functions, and environmental values of the seabed and coast*" (EPA, 2009f).

A number of Commonwealth and State guidelines, strategies, policies and regulatory frameworks are applicable and provide the context for assessing the key issues relating to threatening process to benthos including BPP and expectations for management.

**Commonwealth Legislation, Guidance and Policies**

Commonwealth legislation, policy and guidance relevant to benthos include:

- EPBC Act;
- *Environment Protection (Sea Dumping) Act 1981;*
- Australian Ballast Water Guidelines for Shipping Australian Quarantine and Inspection Service (**AQIS**); and
- National Introduced Marine Pests Coordination Group, Marine Pests Monitoring Manual Version 2 (2006).

**State Protection, Guidance and Policies**

State legislation, guidelines and policies relevant to benthos include:

- *Environmental Protection Act 1986;* and
- Environmental Assessment Guideline (EAG) No.3. Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment (EPA, 2009a). This also includes guidance for non-BPP filter feeding communities (also referred to as sessile invertebrates).

#### 2.4.1.2. Description of Factor

For a detailed description of marine habitats and benthos including BPPs refer to **Part 3**, **Section 1** (Environmental Overview) for further information on the existing marine environment. The following section discusses the important values of benthos with respect to species diversity and abundance, community types, functional groups, and receptor sensitivity of dominant taxa in relation to predicting impacts.

The dominant subtidal habitat type within the James Price Point coastal area is bare substrate, consisting mostly of sand which occasionally supports sparse seagrass communities. Macroalgae was the most common BPPH type encountered during extensive habitat mapping surveys of the area. Sand habitat is interspersed with patches of hard substrate supporting communities of sessile invertebrates, such as sponges and occasional hard corals (Fry *et al.,* 2008; **Appendix C-4** and SKM, 2010a; **Appendix C-5**). There are areas of low relief reef along the coast from Quondong Point to James Price Point which are mostly in water less than 10m in depth (Fry *et al.,* 2008; **Appendix C-4**). In the lower littoral reefs, benthic communities are comprised of sparse hard and soft coral, macroalgae, and filter feeding invertebrates, with the highest habitat complexity found north of James Price Point and around Coulomb Point. Some high relief, rocky and rubble or stone substrates are also common in the nearshore sites along most of the coastline north from Quondong Point to Coulomb Point (Fry *et al.,* 2008; **Appendix C-4**). North of James Price Point the reef platform extends further offshore (to approximately 2km) providing a sheltered lagoon and intertidal platform with pools and crevices supporting a variety of benthic habitat types. BPPH cover and complexity is low beyond the 10m depth corridor in the area immediately adjacent to James Price Point.

The assessment has focussed on 'key receptors' that are of conservation significance or on which other conservation significant species (e.g. dugongs) rely, within the coastal waters relevant to the BLNG Precinct. These key environmental values are listed below and discussed further in their sub-sections:

- **Algae**. This includes macroalgae and sediment microalgae or MPB. Large, diverse areas of algal habitat occur in the James Price Point coastal area. These are likely to be used as foraging areas for turtles and habitat for fish and invertebrates. The presence of MPB has been assumed to be associated with bare sediment. In the James Price Point coastal area, where large tides result in constant re-suspension of the surficial sediments, MPB is likely to be highly mobile. Thus, it is difficult to determine the extent and abundance of MPB. It is assumed that MPB has a high turnover rate and will quickly re-colonise areas following a disturbance. For these reasons, MPB will not be considered further in the impact assessment process.
- **Seagrass**. Throughout the James Price Point coastal area, subtidal seagrass communities are patchily distributed and their abundance is seasonally dependent. These communities may act as possible feeding areas for transient dugongs and turtles. *Halophila* species were found to be the dominant seagrasses in the area.
- **Hard Coral**. Hard corals are scattered throughout the James Price Point coastal area in generally low densities. Colonies are typically small suggesting that natural processes periodically have an impact. Hard corals are more prevalent in nearshore areas on high relief hard substrate but also occur as single colonies mixed with other communities (e.g. filter feeders and macroalgae).
- **Filter feeders (Sessile Invertebrates)**. Filter feeding communities are a prominent component of the benthic environment within the James Price Point coastal area though strictly non-benthic primary producers (non BPPs). These organisms were observed in high abundance with a wide distribution and diverse range of species.
- **Infauna and epifauna**. Infauna refers to the organisms that occur within the sediment of the seabed, whilst epifauna are mobile and occur on the surface of the seabed. These are a diverse group of organisms that can be both macroscopic and visible to the eye or microscopic. The diversity and abundance of Infauna and epifauna communities is largely unknown within the James Price Point coastal area, compared with other benthos types.

### 2.4.2. Identification of Key Aspects

#### 2.4.2.1. Definition of Relevant Aspects

Aspects associated with the construction and operation of the BLNG Precinct (Category A activities) that have the potential to impact benthos, include:

- marine site disturbance and excavation;
- sediment deposition and turbidity;
- routine and non-routine marine discharges; and
- invasive marine species.

#### 2.4.2.2. Sources of Potential Impact

**Marine Site Disturbance and Excavation**

The BLNG Precinct marine infrastructure will include an approach channel and turning basin, LNG export jetty, breakwater and product pipelines. The construction of this infrastructure will require dredging, dredge spoil disposal, drilling and coring of boreholes, positioning of jack-up barges and other marine activities such as piling. These activities have the potential to result in the direct loss of benthic primary producer habitat.

Smothering of the seabed resulting from dumping of dredged material into the disposal grounds also has the potential to result in the direct loss of benthos.

**Sediment Deposition and Turbidity**

Impacts to marine habitats may occur as a result of the changes in water quality due to the dredging and spoil disposal activities required for the construction of the BLNG Precinct. The proposed BLNG Precinct will alter marine water quality by increasing TSS and sedimentation rates. These changes will result in reduced penetration of light through the water column (increased light attenuation), which will reduce the amount of light received by benthos (such as hard corals and macroalgae) and may affect their ability to photosynthesise. Increased sedimentation rates can abrade or smother attached or non-mobile benthic organisms and may affect the fertilisation success and survival of coral larvae.

In addition, construction of the nearshore marine infrastructure (i.e. pilling and rock dumping) may result in further disturbance to the seabed resulting in a localised increase in turbidity and sedimentation, though this will be minor in comparison with dredging and spoil disposal activities.

**Routine Marine Discharges**

Routine discharges will include cooling water, hydrotest water, process water, brine from desalination, produced formation water, stormwater, grey water and treated sewage. These waste streams will be controlled within the Precinct facilities and are likely to be discharged to the nearshore marine environment via an ocean outfall. The location of the outfall has not been determined, however, it is expected to fall within the current BLNG Precinct Port Area.

**Non-routine Marine Discharges**

A review of the proposed BLNG Precinct facilities has indicated a number of hydrocarbon fluids will be stored within the Precinct Project Area. The presence of these fluids introduces an inherent risk of spills to the area and surrounding marine environment. Hydrocarbon inventories for the BLNG Precinct facilities will likely include LNG, condensate, marine diesel, lube oil and bunker fuel. Minor spills may result from accidental releases of hydrocarbons or chemicals. Major accidents such as vessel collisions, rupture of an LNG/condensate tanker or catastrophic failure of a production pipeline could result in the rapid release of a large volume of LNG, condensate, diesel or bunker fuel. Loading and shipping activities have the potential for a large release volume. Alternatively, the rupture of the main production pipeline has the potential to release a large volume of hydrocarbons to the receiving environment. The likelihood of an event of this nature occurring is considered to be highly unlikely although the environmental consequences could be significant.

**Invasive Marine Species**

The primary pathway for IMS introductions is via vessels, either through contaminated ballast water discharge or biofouling on the vessel's hull and internal niche areas. Sources of impact include parasites, diseases and non-indigenous marine organisms.

#### 2.4.2.3. Sensitivity and Resilience

All BPPs are sensitive to removal of their habitats, as this eliminates the substrate on which they grow. Re-colonisation is only possible when the removed substrate is replaced with similar substrate in broadly comparable growing conditions. Benthic primary producers that colonise hard substrates are more sensitive to the effects of dredging as hard substrate is usually replaced with soft substrate. Hard coral species, as well as many macroalgae species, require hard substrates for settlement. In addition, non-BPP filter feeders are also reliant on hard substrate.

Of all the BPPs, hard corals are considered the most sensitive receptors both with respect to their susceptibility to impacts such as smothering and reduced light, as well as their potential to recover following disturbance. Where hard corals occur in mixed habitats with other BPPs, this is often termed mosaic BPPH and impacts are assessed against this heterogeneous habitat using the most sensitive receptor (site disturbance and excavation and sediment deposition and turbidity), hard coral, to assess such impacts.

Changes in water quality due to dredging and spoil disposal will only result in mortality when light and sedimentation levels go below and above, respectively, certain thresholds for various benthos types. For the purposes of the BLNG Precinct development, specific thresholds for sedimentation and light availability were defined based on the most sensitive benthos types. A sedimentation threshold value (**Table 2.4-1**) based on gross sedimentation was defined based on the sensitivity of hard corals and thus applied to all remaining less sensitive benthos (i.e. seagrass, algae and sponge). At and above this threshold value, impacts to benthic communities were predicted to occur. Similarly, light availability thresholds (**Table 2.4-2**) were defined for the two most sensitive BPPs: seagrass and hard coral. These threshold values were then applied to less sensitive BPPs as a proxy. For a detailed description of the justification and rationale for the development of threshold values refer to **Appendix C-13**.

The sensitivity and resilience of specific BPPs, as well as filter feeders, infauna and epifauna, to impacts specifically related to increased sedimentation and reduced light availability are discussed in greater detail below.

- **Table 2.4-1 Sedimentation Threshold used to Define the Zone of High Impact for Benthic Primary Producer Receptors.**

| Benthic Primary Producer Receptor | Gross Sedimentation |
|---|---|
| Hard Coral<br>Seagrass<br>Sponges<br>Macroalgae | Any 84 day (12 week) rolling period in which the sum of gross sedimentation throughout the period is greater than 7056mg/cm$^2$. |

- **Table 2.4-2 Light Availability Thresholds used to Define the Zone of Moderate Impact for Benthic Primary Producer Receptors.**

| Benthic Primary Producer Receptor | Light (Photosynthetically Available Radiation) |
|---|---|
| Hard Coral | Any 56 days in a 64 day rolling period where a reduction of mean daily PAR of 75%, relative to its value at the receptor without dredging. |
| Seagrass | Chronic - Mean daily PAR <12% surface irradiance for 15 consecutive days.<br>Acute - Mean daily PAR <1% surface irradiance for 3 consecutive days. |
| Sponges and Macroalgae | Seagrass thresholds are a proxy for macroalgae thresholds.<br>Coral thresholds area a proxy for sponges thresholds. |

**Algae**

Macroalgae are generally considered to be more resilient to changes in the benthic light climate, specifically reduced light availability, in comparison to seagrass. This reflects their general capacity for more rapid growth rates, greater species diversity, and tolerance for a wide range of environmental conditions. Review of literature (refer to DSD, 2010d; **Appendix C-13**) supports the fact that minimum light requirements of macroalgae are generally much lower (1–3% surface irradiance; Strickland, 1958; Luning & Dring, 1979; Sand-Jensen, 1988; Duarte, 1991; Markager & Sand-Jensen, 1992; and Dennison *et al*., 1993) than for seagrass (2–37% surface irradiance). Annual (seasonal) species will more readily adapt to periods of reduced light as one to several life histories are completed each season. During periods of low

light the distribution of these species will be restricted but rapid reproduction rates would enable them to recolonise as turbidity decreases and light levels increase.

**Seagrass**

*Halophila* spp. are known to survive in deep water environments under reduced light conditions (Kuo & den Hartog, 2006). Yet, in the case of severe light deprivation, such as prolonged light attenuation, *H. ovalis* displays very little tolerance. This is likely to be due to the fact that *H. ovalis* has low structural complexity, low root to shoot ratio and is fast growing with a low storage capacity for carbohydrates that can be used for growth during periods of low or no light (Bite *et al.,* 2007 and Terrados *et al.,* 1999). *H. ovalis* biomass declines rapidly during prolonged light deprivation making this species vulnerable to transient light deprivation events (Longstaff *et al.,* 1999). Die-off may occur after a sequence of short light deprivation events where there is limited time for the recovery between these events (Longstaff *et al.,* 1999).

The capacity of seagrass species to withstand sediment burial is largely size dependent (Cabaco *et al.,* 2008 and Duarte *et al.,* 2007). For example, small seagrass species, such as *Cymodocea* spp. and *Halophila ovalis,* which are characterised by low shoot mass, low above-ground biomass, thin rhizomes, high horizontal rhizome elongation, fewer carbohydrate stores and small leaves, are more sensitive to burial (Cabaco *et al.,* 2008 and Longstaff *et al.,* 1999). This is largely related the small amount of biomass available in roots and leaves (above and below ground) for storage of carbohydrates. The main response of seagrass species following burial from increased sedimentation appears to be shoot mortality (Cabaco *et al.,* 2008). In some species, mortality following burial can be extremely rapid (e.g. *Cymodocea* spp., *Halodule uninervis,* and *Syringodium* spp.), while other species can survive burial for prolonged periods (e.g. *Enhalus acoroides*) (Duarte *et al.,* 1997). Seagrass species with vertical shoots (e.g. *Cymodocea*, *Syringodium* and *Halodule*) can respond to increased sedimentation by relocating the leaf-producing meristems (growth centres) closer to the new sediment level. This mechanism for enhanced vertical growth appears to be triggered by a light-sensitive mechanism located in the shoot meristem (Duarte *et al.,* 1997).

**Hard Corals**

The light-dependent, photosynthetic activity of zooxanthellae controls hard coral growth and survival (Muscatine, 1990). It has been shown that hard corals require a minimum amount of light corresponding to approximately 2–8% of surface irradiance (for example Cooper *et al.,* 2007 and Titlyanov & Latypov, 1991). Although such a limit allows the maintenance of hard corals, it might be insufficient to support active reef growth (Cooper *et al.,* 2007). Reduced light, such as that induced by increased turbidity, is known to reduce photosynthesis by zooxanthellae, leading to lower carbon gains, slower calcification and thinner tissues in hard corals (Anthony & Fabricius, 2000; Fabricius, 2005; and Telesnicki & Goldberg, 1995). Reduced light is typically paralleled by a reduction in lipid production (Crossland *et al.,* 1980) which may result in a reduction of fecundity (Kojis & Quinn, 1984). Hard corals, therefore, are sensitive to increases in suspended sediment and the corresponding reduction in light penetration.

Hard corals are affected during dredging operations by the settling of suspended particles on their surfaces. Most species show some resilience by actively removing particles to avoid smothering and clogging of their feeding apparatus. The rejection mechanisms of sedimentation come at an energetic expense to the hard coral through loss of carbon from mucus release, enhanced respiration (Anthony & Fabricius, 2000) and associated reduced growth rate (Crabbe & Smith, 2005). This may vary depending on the quantity and type of deposited particles (Philip & Fabricius, 2003 and Weber *et al.,* 2006). Deposition of particles in excess of what may be actively removed by the hard coral can cause mortality on all or part of a colony (Fabricius, 2005). Furthermore, sedimentation also negatively affects rates of settlement and survival of recruiting hard coral larvae.

**Filter Feeders**

In comparison to BPPs, filter feeders are more resilient to reduced light availability since they are not reliant on photosynthesis. Thus, they are less sensitive to increased turbidity. However, filter feeders are susceptible to increased sedimentation and smothering. In severe cases filter feeders' filtering mechanisms may be blocked by sediment. Fry *et al.* (2008; **Appendix C-4**) documented the extensive occurrence of such communities at other sites on the Dampier Peninsula outside of the JPP coastal area indicating that mortality at James Price Point will not cause elimination or extinction of the functional group in the broader Canning Marine Bioregion.

**Infauna and Epifauna**

Infauna and epifauna are sensitive to habitat removal (site disturbance and excavation), sediment deposition and marine discharges. In severe cases these impacts can cause mortality. Infauna and epifauna are highly sensitive to habitat removal. The recovery potential of mobile fauna from habitat removal appears to be higher than that of sessile organisms

because avoidance and subsequent re-colonisation into adjacent areas can occur more easily. Infauna and epifauna are sensitive to burial by sediment deposition since they are generally slow moving or sessile and unable to relocate during a deposition event. Infauna and epifauna are sensitive to exposure from marine discharges, but their sensitivity and resilience varies depending on the extent and exposure type. Organisms will display less resilience and greater sensitivity to sudden changes in salinity or temperature and exposure to toxic substances.

Marine infauna is susceptible to invasive marine species which can compete with native species, replace them and change the biological community structure.

### 2.4.3. Predicted Impacts

Potential impacts on benthic habitats resulting from aspects associated with the proposed BLNG Precinct are discussed below and summarised in and presented in **Table 2.4-7**. Both direct and indirect impacts arising from aspects related to the construction and operation of the BLNG Precinct are discussed below. The impacts on benthos have been predicted through sediment dispersion modelling and threshold development as outlined in **Appendix C-13**.

#### 2.4.3.1. Potential Impacts to Benthos due to Marine Site Disturbance and Excavation

This section addresses the impacts associated with the aspects which are likely to result in physical disturbance to the seabed. These aspects, including the nearshore construction activities and infrastructure, pipelines, dredging and spoil disposal, will have an impact through the direct removal and disturbance of substrates. The main impacts will be the permanent direct removal of sub-tidal primary producers and habitats due to dredging and the smothering mortality of sub-tidal benthic producers and habitats due to dredge spoil disposal.

**BLNG Precinct Port Area Footprint**

The zone of high impact is defined as a region where a lethal affect on benthos is expected, and recovery within five years is unlikely. This zone is defined as the area beneath the dredge footprint and for approximately 1km surrounding nearshore marine infrastructure. Within this zone, mortality of benthos is predicted to occur as a direct result of removal/disturbance due to development activities and/or smothering by fine sediment resulting in permanent alteration of substrate which prevents recovery/recolonisation. The 1km buffer around the infrastructure footprint was determined from the maximum distance from the modelled discharge location to the edge of the boundary defined by the high impact sedimentation threshold (refer to **Table 2.4-1**). This level of sediment deposition is likely to result in significant BPPH mortality, and the substrate is likely to be altered to an extent where recolonisation/recovery within a period of approximately 5 years is unlikely (**Figure 2.4-1**).

As a ‘worst case’ scenario, the high impact buffer zone extends from the edge of the port boundary. It has also been assumed that the excavation and removal of substrate will directly impact the entire BLNG Precinct Port area (**Figure 2.4-2**). Whilst the final configuration and exact location of the marine facilities are not known, it should be noted that eventual area occupied by marine infrastructure is likely to only encompass a subset of the broader Precinct Port area (**Figure 2.4-2** and **Figure 2.4-3**). It is anticipated that the final port layout and subsequent impact predictions will be refined during the impact assessment process for future Derived Proposals.

The high impact buffer zone has also been extended around the centre line of the downstream portions (<3 nautical miles) of the export pipeline routes (refer to **Figure 2.4-1**, **Figure 2.4-4**, **Figure 2.4-5**, and **Figure 2.4-6**). The upstream portions (>3 nautical miles) are assessed under the Upstream Environmental Impact Assessment. It should be noted however that as outlined in **Part 2, Section 5** (Description of Activities and Facilities under the Precinct Plan), a variety of construction techniques are being considered for the shore crossing that involve varying levels of turbidity generation. Application of the high impact buffer zone (derived from the conservative point source sediment transport modelling) is considered to represent the most invasive of these techniques (i.e. conventional excavation using a Cutter Suction Dredge and/or Backhoe Dredge).

Vermaat *et al*. (1997) suggested a sedimentation threshold level of 2cm/year for *Halophila ovalis*, which equates to approximately 170mg/cm$^2$/d. This study therefore indicates that seagrass are likely to be less sensitive to sedimentation than corals. Thus, as a conservative measure, the coral ‘Zone of High Impact’ sedimentation threshold has been adopted for seagrass and other BPP to account for potential impact from sedimentation.

The dominant BPPH within the BLNG Precinct Port area footprint and James Price Point coastal area in general, are macroalgae and mixed macroalgae habitats (**Figure 2.4-5**). Their removal will permanently reduce benthic primary

production in this area. Other BPPH, such as seagrass and hard corals are not significantly represented in this zone and therefore, the impact of these habitats in proportion to their modelled extent within the James Price Point coastal area is not deemed significant.

The dominant substrate type within the impact footprint, in terms of spatial extent, is soft substrate. These habitats are colonised by infauna and epifauna. The most significant impact predicted to occur from marine site disturbance and excavation is a loss of diversity and abundance of infauna and epifauna. It is likely that the planned disturbance will result in the removal and mortality of immobile epifauna (sea pens) and some mobile epifauna (heart urchins) but since these are mobile invertebrates associated with this extensive seabed type, it is not certain how many will be in the affected area at the time of disturbance. Seapens are food sources for animals such as flatback turtles and the loss of a significant population may disturb supply to higher trophic levels. High numbers of these epifauna have been observed elsewhere in the James Price Point coastal area therefore it is likely that animals that utilise these food sources will adapt by feeding elsewhere. It is anticipated that partial re-colonisation will occur in areas of bare substrate once marine site disturbance and excavation has ceased.

**Dredge Spoil Disposal Grounds**

Given that the dredge spoil disposal ground (DSDG) locations are likely to be > 3Nm offshore, in a water depth >15m (**Figure 2.4-4**), the benthos is likely to consist primarily of bare sand with scattered non-BPP filter feeders. Benthic habitat surveys have demonstrated that beyond the 10m contour, west of James Price Point, BPPH cover is extremely low (predominantly bare sand) out to the full mapping extent (~10km offshore). Where benthic habitat is encountered, filter feeders and algae are the dominant type; however the density is typically low. Seagrass and macroalgae were generally not found beyond the 20m depth contour - predominantly to the north and south of James Price Point (Fry *et al.,* 2008; **Appendix C-4** and SKM, 2010a; **Appendix C-5**). A full discussion of the strategic review of potential offshore spoil disposal locations is provided in Section 2.2 of **Appendix C-13**.

For the purposes of this assessment, a notional spoil disposal site 7km west, and 1km north of the proposed turning basin has been selected for the base case modelling (Section 5.5 of DSD, 2010d; **Appendix C-13**). It must be noted however that a location for the spoil ground (or grounds) has not yet been fixed, and is subject to detailed studies currently underway. The implications of alternative spoil ground locations are assessed using sensitivity tests in Section 5.6 of **Appendix C-13**. The ultimate location of the spoil ground will be assessed in detail under the Commonwealth Sea Dumping Permit Process, including mapping to confirm habitat composition.

The worst case scenario is that all benthos within the spoil ground will be permanently lost, although some recolonisation of the modified substrate is likely. The area required to establish a single spoil ground is estimated to be approximately 3-6km$^2$. A 200m buffer zone to account for deposition of coarse sediments has been allowed. Given that marine site disturbance and excavation within the BLNG Precinct Port area and proposed spoil ground will result in a localised loss of BPPH, the significance of the residual impact is assessed as being medium.

It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures such as identification of key environmental values and development of water quality objectives and criteria within the Port through a BLNG Precinct Environmental Management Plan (BPEMP). A more detailed description of proposed mitigation measures is presented in **Section 2.4.4**.

### 2.4.3.2. Potential Impacts to Benthos due to Sediment Deposition and Turbidity

This section addresses the impacts associated with the deposition of sediment and increased turbidity in the water column from dredging and spoil disposal activities. Potential impacts are the permanent and temporary loss of benthic habitat (benthos and BPPs) from increased sedimentation and light depravation.

Dredging will result in both fine and coarse sediments being suspended within the water column. The most significant turbidity generating activities will be the dredging of an access channel, turning basin/s and berth pockets and associated dredge spoil disposal. Disturbance of existing marine sediments will lead to increased concentrations of suspended sediment in the water column, and a reduction in benthic light availability. Light reduction will cause an indirect effect of reduced productivity from photosynthetic BPPs in areas where levels of dredging induced suspended sediment attenuate light to below critical levels. While the effect may cause mortality to some BPPH and BPPs, it is assumed that this will be a temporary loss (for seagrass and macroalgae) or partial mortality (for coral and sponges), as the underlying conditions supporting re-colonisation and/or recovery will be present after the activity has been completed.

The likely impacts and sensitivity of benthos will depend upon the suspended sediment concentrations and the period of exposure. In order to predict these impacts, sediment dispersion modelling was carried out. It is important to note that a detailed dredging program was not simulated. Engineering studies required to accurately define the dredging activities required are currently underway as part of engineering studies. It has therefore been necessary to take a conservative approach to the sediment dispersion modelling. Conservative assumptions built into the sediment dispersion model are outlined in Section 3 of **Appendix C-13**. Interrogation of this model is therefore likely to have produced an overestimation of the scale of impact.

Thresholds for light attenuation were used to interrogate the model and define the boundaries beyond which a moderate impact is predicted to occur. Light thresholds were defined by the mean daily, minimum amount of surface irradiance in photosynthetically available radiation (PAR) required for a given time period, below which an impact was predicted to occur. These thresholds were derived from published literature and defined the area known as the zone of moderate (or temporary) impact. A threshold for sedimentation (smothering) was used to interrogate the model and define the boundaries beyond which a high (or permanent) impact is predicted to occur. This threshold was based on experiments involving exposure of relatively sensitive coral species to high levels of sedimentation, and monitoring data from previous dredging projects. This sedimentation threshold was used to depict a zone of high (or permanent) impact for all biota – i.e. coral were used as a sensitive proxy for high impact on other biota. A full discussion of the modelling approach and thresholds derived is provided in **Appendix C-13**. In addition, a summary of the modelling approach is detailed in **Part 3**, **Section 2.3** (Marine Water Quality).

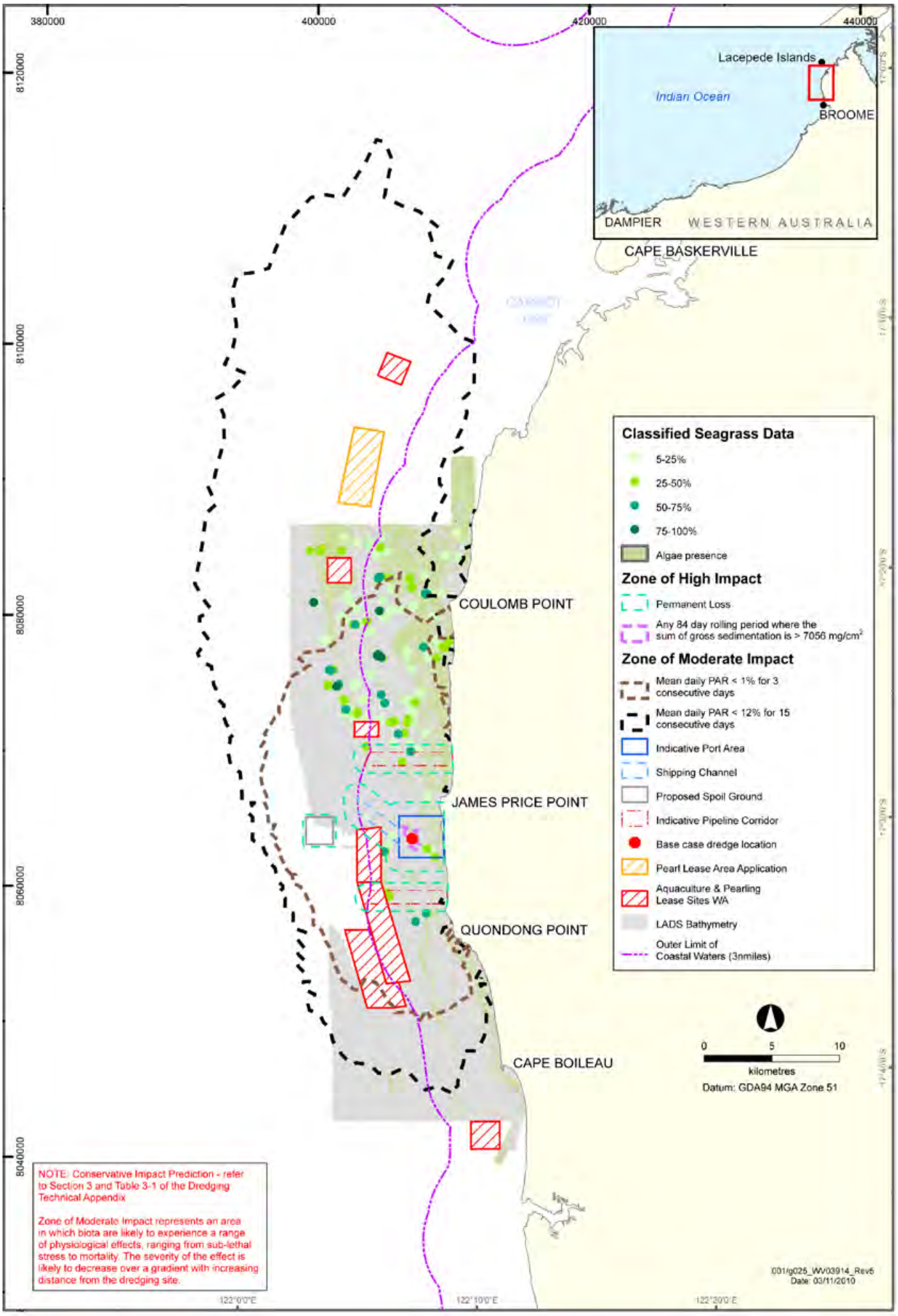
Seagrass communities have been identified as a BPPH type within the James Price Point coastal area that are considered to be at risk from the impacts associated with a reduction in benthic light availability. Therefore, for the purpose of this impact assessment section, thresholds for light availability were defined for seagrass and applied to macroalgae as a proxy. Similarly, a light availability threshold was defined for hard coral and applied to filter feeders (sessile invertebrates particularly sponges) as a proxy (**Table 2.4-2**). A justification for the use of such proxy BPPH in the impact assessment is provided in **Appendix C-13**.

### Seagrass and Macroalgae

**Figure 2.4-1** displays the extent of the Zone of Moderate Impact based on the chronic and acute light thresholds for seagrass. It is assumed that the potential impacts on macroalgae are also contained within this zone. **Figure 2.4-1** portrays the predicted temporary loss of macroalgae based on the chronic seagrass threshold (mean daily PAR <12% for 15 days). Macro and turf algae are more tolerant than seagrass to reduced light climates. Thus, these communities were predicted to experience less than or equal amounts of impact and temporary loss within seagrass threshold boundaries.

The chronic light reduction seagrass threshold (mean daily PAR <12% for 15 days) results in the most extensive area of impact (**Figure 2.4-2**). This threshold was determined to account for the potential loss of seagrass associated with long-term episodes of benthic light reduction. The literature has shown that tropical Halophila spp. demonstrated sub-lethal stress after 15 days of reduced PAR <12% surface irradiance (Longstaff *et al.,* 1999). Therefore, it assumed that within the chronic threshold boundary, there will be physiological impacts, including mortality, on seagrass during the dredging activities. Though extensive, this Zone of Moderate Impact represents an area in which seagrass communities are likely to experience a range of physiological effects, ranging from sub-lethal stress to mortality. As this impact is associated with a temporary reduction in water quality (i.e. a reduction in benthic light availability) and not a fundamental alteration in the substrate conditions; it is anticipated that such communities will recover fully within five years.

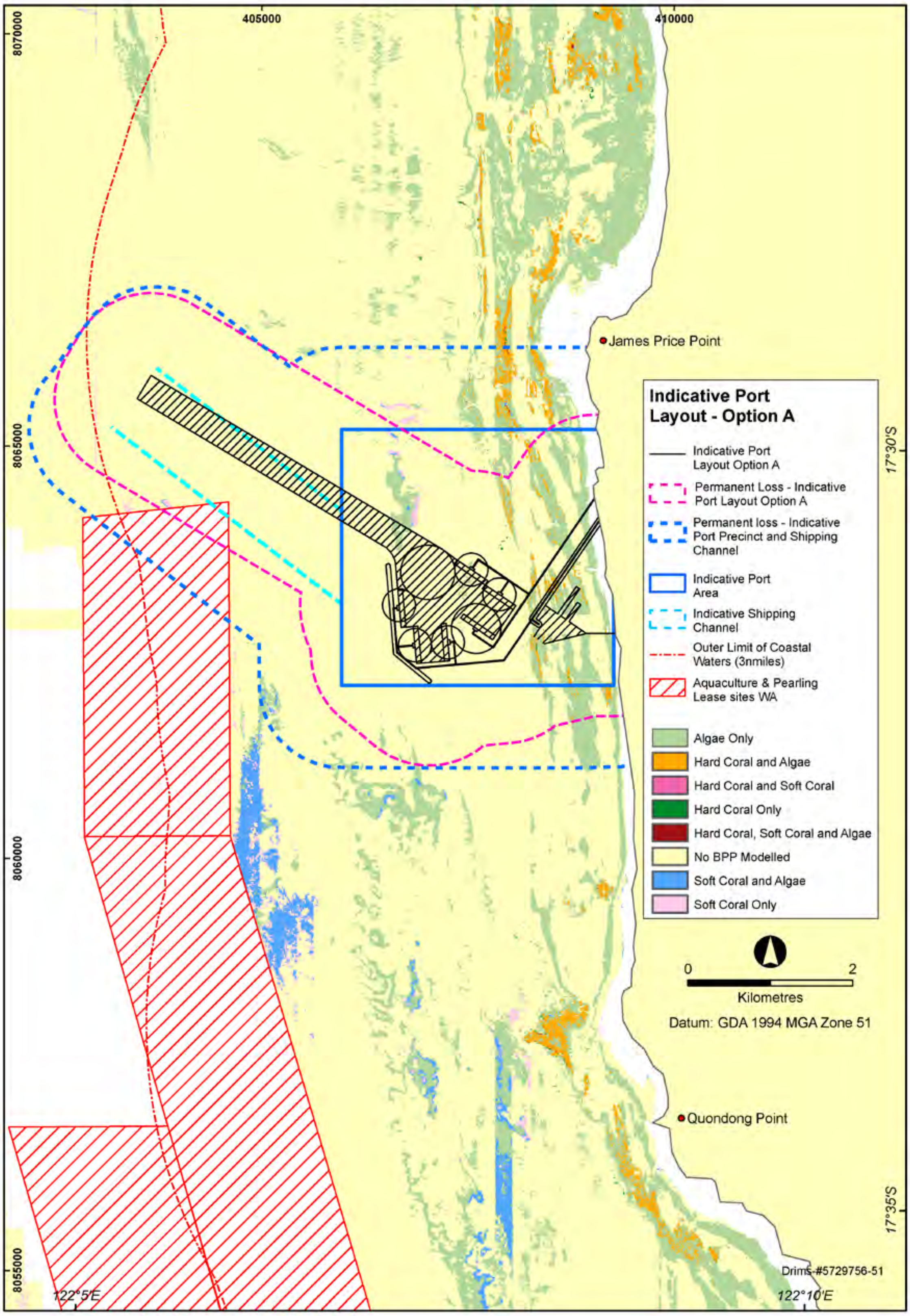
It is important to note that while the predicted impacts based on the seagrass thresholds result in the largest area of potential temporary loss, seagrass are not the most abundant BPPH within the threshold boundary and the James Price Point coastal area, therefore, the actual loss of seagrass is likely to be lower than other BPPH determined as more abundant (**Figure 2.4-3**). The majority of the benthos within the James Price Point coastal area identified from the field survey and predicted by the BPPH model, is classified as soft substrate (i.e. sand and silt). The most abundant BPP type is macroalgal habitat, primarily comprised of a mixed assemblage of brown macroalgae.




Source: DSD, 2010d; **Appendix C-13**.

- **Figure 2.4-1 Predicted Impacts to Seagrass and Macroalgae within the Zone of Moderate Impact and the Zone of High Impact.**

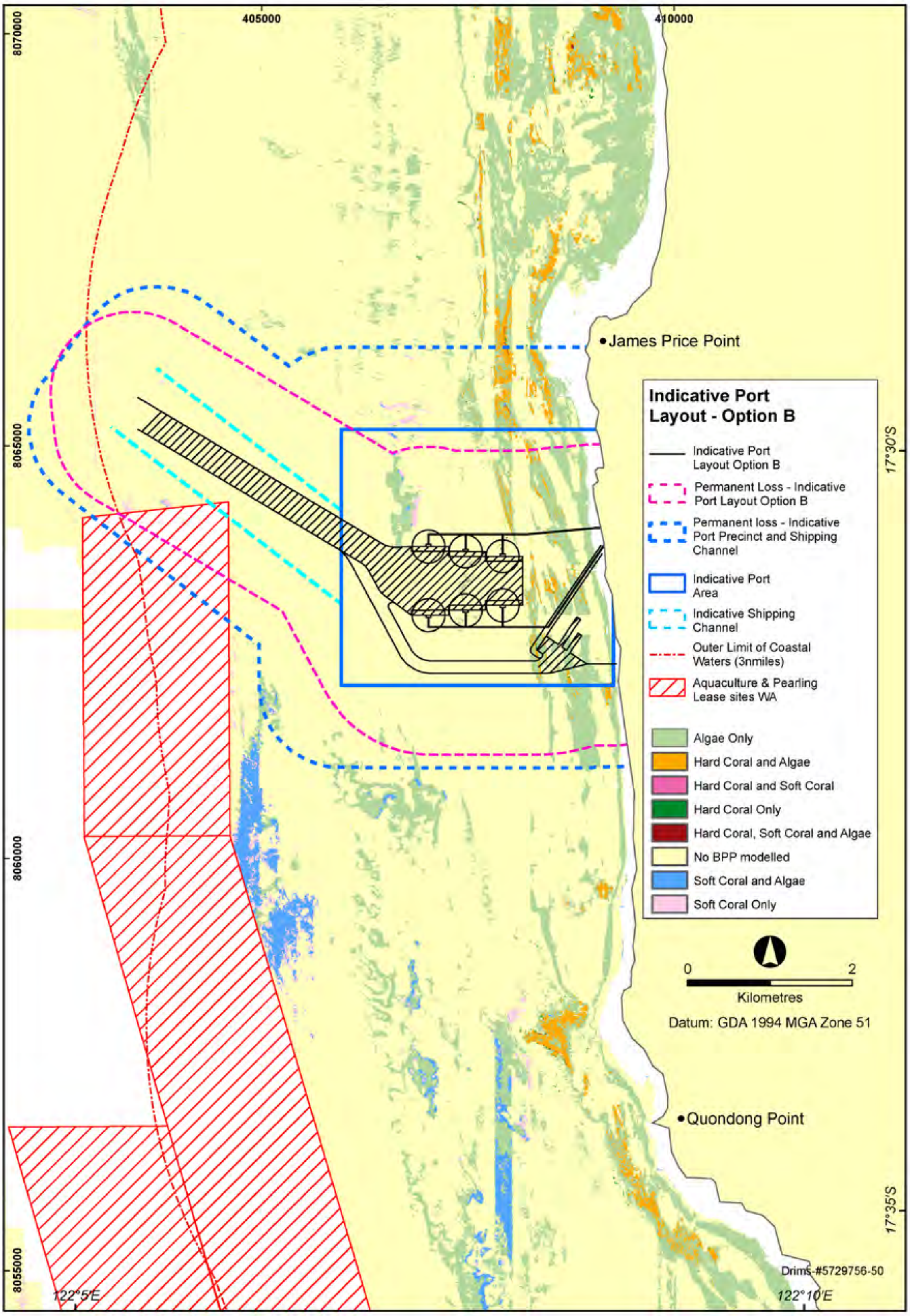
Note: Zone of Moderate Impact is based on light thresholds
Zone of High Impact is based on the BLNG Precinct Port area footprint and sedimentation thresholds.




Source: DSD, 2010d; **Appendix C-13**.

- **Figure 2.4-2 Predicted Zone of High Impact (i.e. permanent loss) for the Indicative Port Concept (Layout Option A) within the Broader Precinct Port Area.**

Note: To demonstrate potential configurations in the Precinct Port Area only, therefore export pipeline routes are not included.




Source: DSD, 2010d; **Appendix C-13**.

- **Figure 2.4-3 Predicted Zone of High Impact (i.e. permanent loss) for the Indicative Port Concept (Layout Option B) within the Broader Precinct Port Area.**

Note: To demonstrate potential configurations in the Precinct Port Area only, therefore export pipeline routes are not included.

**Hard coral and Filter Feeders (Sessile Invertebrates in particular Sponges)**

The hard coral threshold was applied to filter feeders (sessile invertebrates) since there is the possibility of photosynthetic sponges within the James Price Point coastal area (refer to DSD, 2010d; **Appendix C-13**). The actual amount of hard coral which will be lost within the Zone of Moderate Impact is predicted to be less than the total area of hard coral depicted in **Figure 2.4-4** since the actual coverage of hard coral was observed to be very low in the areas mapped (generally between 5–10% cover).

The main impacts from sediment deposition and increased turbidity would be the permanent and temporary loss of benthic habitat (benthos and BPPs) within the defined threshold boundaries, associated with the reduced availability of light reaching the substrate. This would cause an indirect effect of reduced productivity from BPPs in areas where dredged induced suspended sediment is widespread. While the effect may cause mortality to some BPPH and BPPs, it is assumed that this would be a temporary loss, as the underlying conditions for re-colonisation would be present after the activity has been completed.

The different categories of BPP/non-BPP were assessed separately due to differing conservation significance and abundance within the James Price Point coastal area. The significance of the residual impact on seagrass, algal and filter-feeding communities was determined to be medium due to the relative abundance in the area. The significance of the residual impact on corals was determined to be low due to their low abundance in the area.

**Habitat Mapping Extent vs. Predicted Impact Extent**

It has been noted that the indicative zones of moderate impact for all biota classes assessed extend beyond the spatial extent of the benthic habitat mapping (**Figure 2.4-5)**. Environmental Assessment Guideline No.3 (EPA, 2009a) advises that benthic habitat data should ideally cover the full extent of any areas likely to be impacted by development activities. However, in this strategic assessment phase of approvals, the extent of habitat data required for a full dredging assessment is not yet available. The absence of benthic habitat data at the outer boundaries of the indicative Zones of Temporary Effect are unlikely to affect the overall ability to assess impacts to BPP communities since:

- The majority of unmapped areas within the zones of moderate impact (i.e. unmapped areas to the west of the BLNG precinct) are unlikely to contain seagrass, macroalgae or sessile invertebrate communities as they generally lie beyond the depth limits (i.e. light compensation limit) of such communities.
- There is a high degree of confidence that unmapped areas within the zones of moderate impact that lie to the north and south of James Price Point can be assumed to contain BPP community types and distribution patterns that are similar to neighbouring, mapped areas. Available bathymetry data suggests that there are no anomalous features, such as shoals, reefs and underwater ridges that would indicate that unmapped areas may contain communities that are any different to those already mapped.
- The indicative zones of moderate impact include areas where there may be impacts to BPP ranging from sublethal stress to mortality. The unmapped areas occur primarily at the outer boundary of the zone of moderate impact. At this boundary, only minor changes to water quality are predicted to occur, likely resulting in sub-lethal (rather than lethal) impacts to BPP communities. In addition, the model inputs (i.e. dredge volumes and loss rates; see Section 5 of **Appendix C-13**) and thresholds used to predict impacts to BPP are highly conservative. It is, therefore, perceivable that no detectable impacts to BPP communities will occur within unmapped areas. This perception is justifiable, based on the over-prediction of impacts in areas that are far-afield from dredging and disposal activities reported in previous dredging campaigns (SKM, 2006 and MScience, 2010).

**Light Threshold Sensitivity Testing**

Light attenuation is commonly expressed as Kd, a coefficient reflecting the amount of loss as light travels through 1m of water (Kirk, 1994). The amount of light reduction experienced by a photosynthetic organism on the seabed, caused by an increase in the level of attenuation as TSS rises, will be equal to the rise in Kd times the depth in metres (z) (Light reduction = $\Delta Kd*z$).

To calculate the increase in Kd resulting from increasing TSS requires an estimate of the relationship between Kd and TSS. This relationship may be derived using a sediment sample in the laboratory or by field measurements of Kd and TSS. Ideally, such measurements might be derived from the actual sediments suspended during dredging and remaining suspended at distances out to the model cells being interrogated. However, that option is not available prior to dredging.

In any event, such relationships will depend heavily on the optical properties of the sediments suspended and will at best be indicative only of the series of relationships that may operate over space and time during dredging.

The form of the relationship derived from water samples is usually linear and may be written as: Kd = a + b*TSS.

In this case, as we are looking at a change in Kd only associated with a change in TSS levels, we are only interested in the slope of the relationship (b). The values of b used in deriving TSS levels that will cause the requisite reduction in light were based on a field study of light attenuation in waters surrounding an active dredge undertaken by In Situ Marine Optics. An estimate of b from that study was 0.033 with a standard deviation of 0.009. This estimate is consistent with a value derived from naturally occurring suspended sediments in waters off James Price Point of 0.037 +/-12.7% (IMO, 2010).

The thresholds suggested for the prediction of the zone of moderate impact on BPPH are expressed in terms of a percentage reduction in the level of light reaching these organisms while dredging is in progress. The chronic thresholds for seagrass and corals require a reduction in light of 88% and 75% respectively for a specified period of time (**Table 2.4-1** and **Table 2.4-2**). This can be restated as requiring an elevation of TSS sufficient to raise Kd*z by 2.120 or 1.386 respectively. The acute threshold for seagrass requires a 99% reduction in light, or a Kd*z or 4.605.

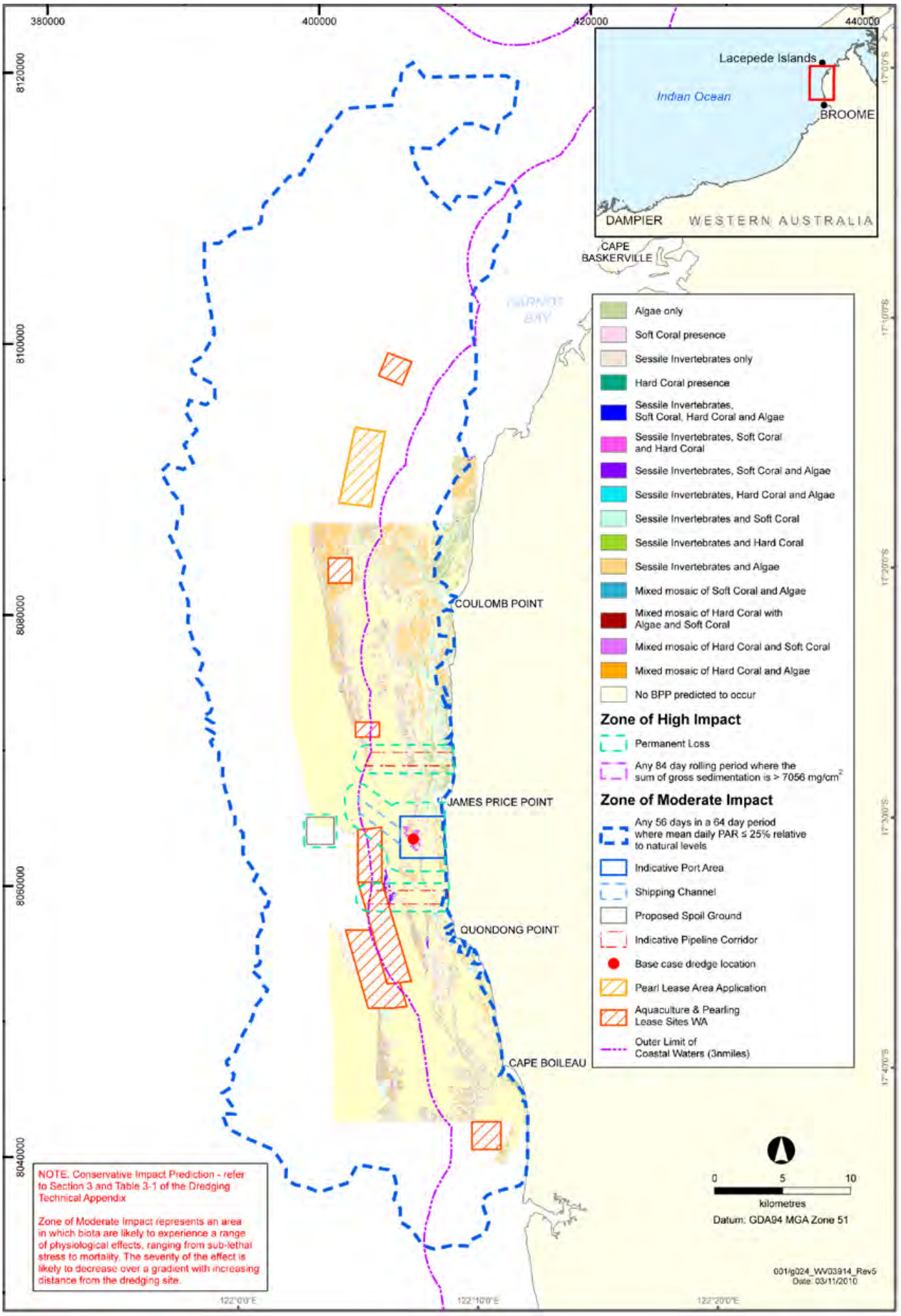
When the outputs of the sediment dispersion model are interrogated with the thresholds using the initial slope of the relationship between Kd-TSS (0.033), the zones of moderate impact on BPPH are extensive (**Figure 2.4-5**). Much of that extent is due to the relatively low levels of TSS required to elevate Kd*z to a critical level (i.e. to trigger the relative threshold) at depths. Seagrass patches were recorded up to a depth of approximately 20m (SKM, 2010a; **Appendix C-5**) which would result in a fourfold decrease in the necessary TSS level compared to that at 5m (**Table 2.4-3**).

- **Table 2.4-3 Levels of TSS Required to Reduce Light to Critical Levels for the Chronic Seagrass Threshold using the Mean Slope of the Kd~TSS line and the Mean +/-1s.d.**

| Depth | Mean + 1 s.d. (b=0.042) | Mean (b=0.033) | Mean-1 s.d. (b=0.024) |
|---|---|---|---|
| 5 | 10.1 | 12.8 | 17.7 |
| 10 | 5.0 | 6.4 | 8.8 |
| 15 | 3.4 | 4.3 | 5.9 |
| 20 | 2.5 | 3.2 | 4.4 |

Another important component of this calculation is the coefficient b, by which levels of TSS are translated into Kd. **Table 2.4-3** shows that varying b from its mean to 1 standard deviation below the mean can raise the required TSS elevation considerably. When the effects of this (i.e. using a lower value of b) on the predicted zone of moderate impact are modelled (**Figure 2.4-6**), it is evident that the extent of the moderate impact zones are highly sensitive to very small variations in the estimates of such parameters. A coefficient which used the mean + 1 standard deviation would have a correspondingly bigger footprint, although one limited seaward by the depth range of seagrass occurrence.

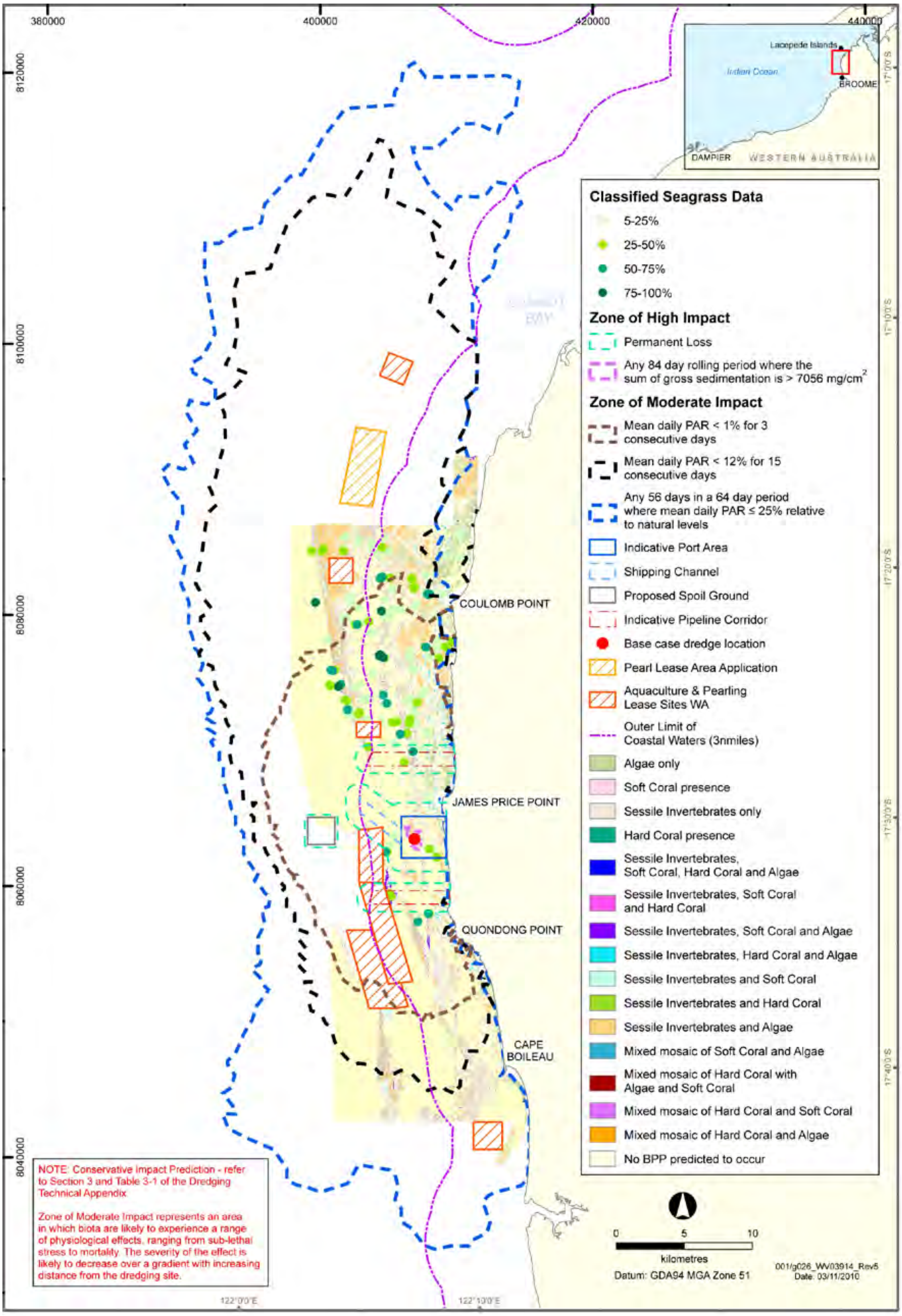
It is clear from this sensitivity analysis that an attempt to accurately predict zones of impact based on light reduction will not only include the uncertainty of the sediment dispersion model, but also the considerable variability in how light reduction is derived from the model outputs. Thus, any predicted zone should be viewed as only one of a number of potentially disparate outcomes, sensitive to the initial assumptions made and data used.




Source: DSD, 2010d; **Appendix C-13**.

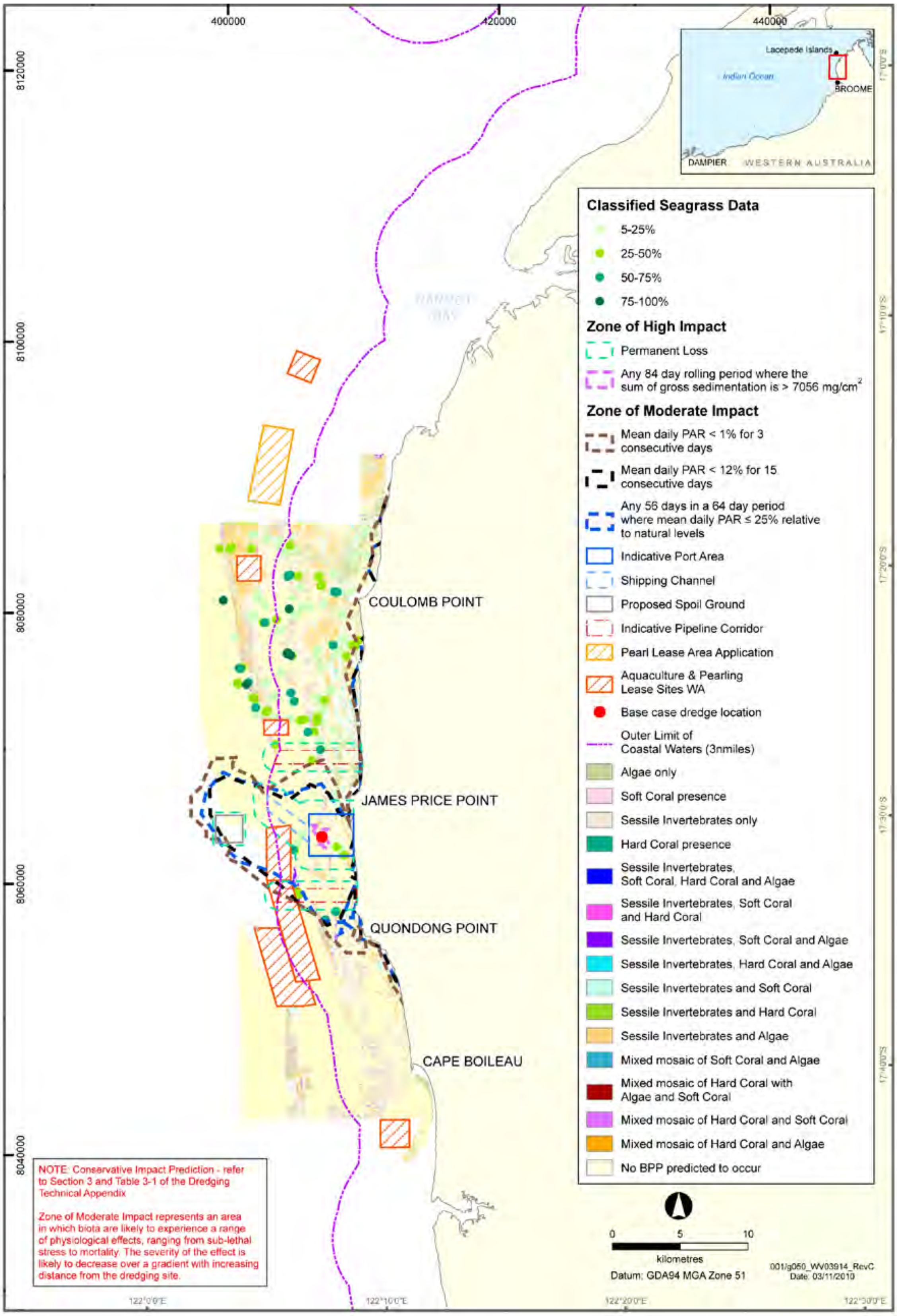
- **Figure 2.4-4 Predicted Impacts to Filter Feeders (Sessile Invertebrates) and Hard Coral within the Zone of Moderate Impact and the Zone of High Impact.**

Notes: Zone of Moderate Impact is based on light thresholds.
Zone of High Impact is based on the BLNG Precinct Port area footprint and sedimentation thresholds.




Source: DSD, 2010d; **Appendix C-13**.

- **Figure 2.4-5 Cumulative Predicted Impacts (Zone of Moderate Impact and Zone of High Impact) to BPP and non BPP.**




Source: DSD, 2010d; **Appendix C-13**.

- **Figure 2.4-6 Cumulative Predicted Zone of High Impact and Zone of Moderate Impact to BPP and non BPP Based on the Alternative Kd-TSS Relationship.**

It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures. Prior to commencement of dredging, proponents of derived proposals will be required to prepare and implement a DSDMP to demonstrate best practice management techniques and technologies which would be applied to minimise potential dredging impacts. A more detailed description of proposed mitigation measures is presented in **Section 2.4.4**. The significance of the residual impact on seagrass, algal and filter-feeding communities was determined to be medium due to the relative abundance in the area. The significance of the residual impact on corals was determined to be low due to their low abundance in the area. While the effect may cause mortality to some BPPH and BPPs, it is predicted that this would be a temporary loss, as the underlying conditions for re-colonisation would be present after the activity has been completed.

#### 2.4.3.3. Potential Impacts to Benthos due to Marine Discharges

**Routine Marine Discharges**

The main impacts associated with routine marine discharges are a decline in water quality and subsequent loss or change in the composition of benthos.

The continuous routine discharge of treated wastewater will create a localised zone (i.e. mixing zone) of altered water quality (i.e. a Low Ecological Protection Area). The outfall will be designed such that there will sufficient initial mixing to minimise the areal extent of the mixing zone. Furthermore, the discharge location will be selected to minimise potential impacts of significant benthos. Routine discharges will continue throughout the operational lifetime of the BLNG Precinct and potentially influence the fauna and flora that exist and re-colonise the substrate within the mixing zone.

Routine discharges will not affect water quality outside of the defined mixing zones. Though at this stage no wastewater modelling has been undertaken to inform the impact assessment and to delineate the extent of the BLNG Precinct mixing zone, judgements of the potential impact of the wastewater discharge have been made based on experience from similar projects (such as the Pluto LNG project with a 200m mixing zone) and on the proposed engineering design of the BLNG Precinct facilities. The dimensions of the mixing zone will be dependent on the level of effluent treatment, location and design of the discharge point and the local hydrodynamic processes.

Within the receiving waters of the BLNG Precinct Port area, where the discharge point and mixing zone is likely to be located, the seabed is dominated by bare soft substrates with macroalgae and some isolated patches of hard coral colonies. As proponents will be required to achieve the appropriate water quality guidelines, it is determined that routine wastewater discharge will not result impacts on benthic habitats or species. This assertion will have to be validated by wastewater discharge modelling, which is to be undertaken as part of the derived proposals approvals process (i.e. during the proponent derived proposals).

As proponents will be required to achieve the appropriate water quality guidelines (i.e. maintain water quality to meet the determined species protection level), it is determined that routine wastewater discharge will not result in significant impacts on benthic habitats or species. It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures, such as the outfall to be designed such that there will sufficient initial mixing to minimise the areal extent of the mixing zone. Furthermore, the discharge location will be selected to minimise potential impacts of significant benthos, and proponents will be required to achieve the appropriate water quality guidelines. The significance of the residual impact for routine discharges on benthos is assessed to be low and it is anticipated that, with the application of proposed mitigation measures, routine discharges would be confined to the BLNG Precinct.

**Non-routine Marine Discharges**

Non-routine discharges (i.e. spills and leaks) can result in a significant effect on water quality, which can have flow-on impacts such as a loss of benthos.

In the event of a LNG spill, the surface of the receiving water will receive cryogenic LNG heated up by the marine waters. This effect is likely to be short lived given that phase transition would be rapid. Similarly, if spilled, other hydrocarbons (e.g. fuel oil, diesel or condensate) will spread from the site release point in the direction of prevailing wind and waves. In general, hydrocarbon spills remain on the surface and rapidly evaporate and degrade (See **Part 3**, **Section 2.3** (Marine Water Quality)). However, dispersants spread during an oil spill response may reach benthic communities resulting in some contamination.

Non-routine discharges (i.e. spills and leaks) can result in a significant effect on water quality, which can have flow-on impacts such as a loss of benthos. Due to the fact that such events are restricted to surface waters, benthic organisms are unlikely to be exposed to discharges at the site of a spill. The proposed implementation of measures to prevent potential loss of containment, and rapid response in the unlikely event of a non-routine release, are clear commitments for management by all operators within the Precinct (refer also **Part 3, Section 2.3** (Water Quality) on proposed measures). A more detailed description of proposed mitigation measures is presented in **Section 2.4.4**. The significance of the residual impact on benthos is assessed as being very low.

#### 2.4.3.4. Potential Impacts to Benthos due to Invasive Marine Species

The introduction of invasive marine species (IMS) can potentially result in an impact to benthos via competition for space and food, change in species composition resulting in altered community structures, increased predation pressure to native species, introduction of pathogens and a reduction of biodiversity.

The nearshore marine environment in the vicinity of James Price Point coastal area is relatively undisturbed and it is considered to be currently free of IMS. This assumption is supported by the recent intertidal study (SKM, 2010b; **Appendix C-3**) which, although did not specifically target IMS, did not identify any biofouling species listed on the revised Consultative Committee for Introduced Marine Pest Emergencies (**CCIMPE**) trigger list.

The development of the BLNG Precinct and associated construction activities can be understood as a pioneering activity opening up pathways for the invasion of exotic marine species. This is primarily due to increased overseas/state vessel activity during the project construction phase (for example dredge vessels and barges) and operation phase (for example LNG export vessels). In particular, the number of international vessels entering the James Price Point coastal area will be increased. The primary pathway for IMS introductions is via vessels, either through ballast exchange or biofouling on the vessel's hull or structure.

The introduction of IMS can alter the existing balance of an ecosystem. In the event that an IMS is permanently introduced to the Canning Marine Bioregion and causes a loss of keystone native species, it could have major changes to the species composition of the area and hence it's ecological integrity. Should IMS occur, the creation of extensive areas of artificial hard substrates such as jetties and moorings may facilitate the establishment of invasive species by providing available habitat. This also provides a ready opportunity for detection monitoring systems. Once established, IMS can spread rapidly through and beyond the Canning Marine Bioregion and have the potential to permanently change marine benthic communities.

Benthos types at risk of impact from IMS include infauna and epifauna communities that will likely have to compete with IMS for food and available habitat and BPPs (seagrass and macroalgae) that could experience increased herbivory. Potential impacts are likely to be localised but result in long term changes in marine species composition. The high biodiversity and low endemism exhibited by biota within the Canning Marine Bioregion may inhibit the successful colonisation of invasive marine species through competitive exclusion by native species. There have been records (Wells *et al.,* 2009 and Huisman *et al.,* 2009) of introduced marine species into Broome (*Amphibalanus amphitrite*, *Megabalanus tintinnabulum* and *Megabalanus ajax*), although these are not listed as 'species of concern' on the Consultative Committee for Introduced Marine Pest Emergencies trigger list and are, therefore, not formally considered as 'Invasive marine species'.

To minimise the successful introduction, establishment and spread of IMS within the James Price Point Coastal Area, established management arrangements are required. These arrangements are necessary to minimise incursions, support early detection and response/eradication activities when required. This 'three step' management approach of prevention, early detection and response/eradication is vital as an overall management framework to respond to the various stages of the invasion process. The primary management strategy to minimise the potential for IMS impacts will be 'incursion prevention', as this is the most cost effective, technically feasible and practicable measure to ensure the environmental and social integrity of the local coastal area is maintained.

The introduction and establishment of invasive marine species would potentially result in an impact to benthos via competition for space and food, change in species composition resulting in altered community structures, increased predation pressure to native species, introduction of pathogens and a reduction of biodiversity. Potential impacts could result in long term changes in marine species composition within the James Price Point Coastal Area.

The impact assessment determined that the introduction and establishment of IMS, as a result of BLNG Precinct activities, to be unlikely, due to the low endemism, high biodiversity and competitive exclusion exhibited by existing biota. It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures, such as the enforcement of IMS inspection requirements to significantly reduce the risk of IMS introduction and establishment. A more detailed description of proposed mitigation measures is presented in **Section 2.4.4**. The significance of residual impact is considered to be low. It is considered by the proponent that, based on industry experience, design and management measures can be expected to be successful.

### 2.4.4. Mitigation Measures

Mitigation measures and safeguards that have been identified to manage potential impacts to benthos are outlined below in **Table 2.4-4**, **Table 2.4-5** and **Table 2.4-6**.

- **Table 2.4-4 State Government Measures for Benthos Including BPP.**

| State Government measure | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area. | Department of Transport (DoT) | On approval of BLNG Precinct |
| The Port Authority will prepare a BPEMP for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess;<br>• compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms. | Broome Port Authority | Prior to approval of marine related derived proposals |
| Establishment of a Dredging Management Advisory Group (DMAG) comprising representatives from:<br>• Independent Chair with extensive knowledge of marine environment;<br>• Broome Port Authority;<br>• Office of EPA;<br>• DEC;<br>• Fisheries Department;<br>• SEWPAC; and<br>• Foundation or other proponent. | DSD on advice of DEWHA and EPA | Prior to referral of future major dredging proposals |
| The role of the DMAG will be to provide advice to the proponent, EPA and/or the Minister for Environment as appropriate on the following:<br>• marine investigations (including the modelling of dredge plumes);<br>• environmental risk assessments prepared for future dredging proposals; and<br>• dredge management plans (including monitoring programs and adaptive response in the event that risks to key values are greater than low) prepared by proponents of future major dredging proposals. | DSD | Prior to referral of future major dredging proposals |

- **Table 2.4-5 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Benthos Including BPP.**

| Condition No. | Proposed Environmental Conditions for the Strategic Proposal |
|---|---|
| **Proposals involving marine discharge** | |
| M2.1 | Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95$^{th}$ percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone (i.e. outside of the port area) the proponent will ensure that the 95$^{th}$ percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels. |
| M2.2 | Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants. |
| M2.3 | Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary to ensure ongoing compliance to the General Manager of the OEPA. |
| **Proposals involving dredging** | |
| M2.4 | Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a DSDMP, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• consideration of the re-use of suitable dredge material for MOF construction, where practicable;<br>• design of the MOF including construction of bunds to isolate fill material from wind and wave action;<br>• consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives;<br>• consideration of re-use of reclaimed material to minimise ocean disposal;<br>• measures to minimise dredging impacts during sensitive ecological windows;<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys);<br>• the development of trigger levels for benthic communities and water quality that define additional management responses;<br>• mechanisms to audit and assess environmental performance of proponents during construction; and<br>• a communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. |
| **Invasive Marine Species** | |
| M4.1 | Proponents of derived proposals shall prepare and implement an Invasive Marine Species Management Plan, to the satisfaction of the Western Australian Minister for Environment on advice from and in consultation with the Department of Fisheries, to minimise the risk of introducing invasive marine species (IMS) into Australian waters during the life of the activity. The plan shall be developed in consultation with the AQIS and will be applied to vessels, barges and immersible equipment that plan to enter and operate within the Precinct. |
| M4.2 | The IMSMP will be consistent with the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry. |
| M4.3 | The IMSMP will adhere to the AQIS Australian Ballast Water Management Requirements under the *Quarantine Act 1908*. |
| M4.4 | Proponents shall, for the life of the activity, notify the DEC, the DoF, AQIS and the Broome Port Authority of any IMS detected in the waters of the BLNG Precinct. |

- **Table 2.4-6 Requirements to be Addressed via Development of a Management Plan to support a Derived Proposal Potentially Affecting Benthos.**

| Requirements for Derived Proponents | Timing |
|---|---|
| Proponents of derived proposals shall prepare and implement a Port Facilities Construction Environmental Management Plan (PFCEMP), to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework. | Prior to commencement of associated construction activities |
| Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to commencement of associated construction activities |
| All vessels will be required to have in place a Ship-Board Oil Pollution Emergency Plan (SOPEP) and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea. | Prior to construction and updated for ongoing operational requirements |
| Prepare and implement a Marine Wastewater Discharge Management Plan (MWDMP), to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to construction of marine discharge facilities |

### 2.4.5. Environmental Outcome of Category A Activities

All potential impacts have been assessed based on the ‘worst case’ scenario. It is likely that the actual permanent loss of benthos including BPPs will be less than that predicted during this impact assessment process. This is due to the following reasons:

- re-colonisation of benthos including BPPs at dredge spoil disposal grounds is predicted to occur where suitable substrates remain once dredge spoil disposal has ceased
- re-colonisation of benthos including BPPs within the zone of temporary loss is predicted to occur (within 5 years) once dredging has ceased
- the actual Impact on benthos including BPPs within the BLNG Precinct Port area footprint and associated 1km buffer zone is likely to be less than the defined boundary since the actual infrastructure footprint is anticipated to be well within the outer buffer zone
- the actual temporary loss of BPPs within the zone of temporary loss is predicted to be less than the area stipulated due to the low densities and sparse coverage of BPPs
- all benthos and BPPs present within the James Price Point coastal area have been documented at other locations on the Dampier Peninsula (Fry *et al*., 2008; **Appendix C-4**) so no regional loss of biodiversity is predicted to occur, and
- recruitment will occur at the cessation of dredging and spoil disposal via larvae from surrounding populations on the Dampier Peninsula.

For details surrounding the processes and predicted time until recovery by benthos including BPPs within the zones of temporary loss, refer to **Appendix C-13**.

Calculations to determine the percentage loss of each benthic habitat type within a determined Local Assessment Unit will be conducted in accordance EPA’s Environmental Assessment Guidelines. Results of these calculations will be made publicly available during the public consultation period for the SAR.

After management and mitigation measures have been applied, it is expected that the BLNG Precinct (Category A activities) will result in the following key potential direct and indirect impacts in relation to benthos including BPPs.

#### 2.4.5.1. Direct Impacts

The following direct impacts will occur as a result of the 'worst case' scenario:

- permanent loss of benthos including BPPs within the BLNG Precinct Port area footprint due to marine site disturbance and excavation (including sedimentation impacts)
- permanent loss of benthos including BPPs within the boundary of the sedimentation threshold due to marine site disturbance and excavation (including sedimentation impacts), and
- permanent loss of benthos including BPPs at the direct site of dredge spoil disposal due to marine site disturbance and excavation (including sedimentation impacts).

#### 2.4.5.2. Indirect Impacts

The following indirect impacts may occur as a result of the 'worst case' scenario:

- temporary loss of BPPs (seagrass, macroalgae and hard coral) within the outer threshold boundaries for the zone of moderate impact.
- mortality of benthos and BPPs at the discharge site and mixing zone (i.e. Low Ecological Protection Area) due to reduced water quality from routine marine discharges
- mortality of benthos including BPPs from non-routine marine discharges, and
- loss of benthos species diversity and a change in community composition from the introduction of IMS.

### 2.4.6. Cumulative Impacts of the Proposal and Associated Activities

Cumulative effects are caused by the accumulation and interaction of multiple effects on benthos in a local and regional context. While the Category A activities relate to the direct effects of the BLNG Precinct and marine infrastructure, the majority of Category B activities are related to increased population and provision of services in Broome, and Category C impacts are centred on the oil and gas exploration and development projects offshore. Category A, B and C activities will locally impact the abundance of benthos including BPPs in the areas directly affected by these activities. If these individual impacts interact and accumulate, a cumulative impact would be expected to occur.

#### 2.4.6.1. Category B Activities

The Category B activities identified centre around onshore actions supporting the BLNG Precinct but not subject to the current State or Commonwealth approval process. Three activities have the potential to directly affect marine resources, specifically benthos including BPPs. These are: further development of Broome Port to accommodate increased marine traffic; the increase in discharges from marine traffic associated with additional recreational boaters. Vessels calling at the Port of Broome may be accommodated within the current capacity of the port. Improvements at the port would likely be to existing areas. Expansion or development at new areas do not appear to be required, however, these would result in localised impacts on benthos in the vicinity of the existing BLNG Precinct Port Area with no far-field impacts through the Canning Marine Bioregion or as far away as the James Price Point coastal area. Increases in recreational activities would have minor secondary impacts to benthos due to effects upon water quality. These impacts are expected to be localised around the current location of the boat ramp and will not contribute to any cumulatively to impacts within the James Price Point coastal area.

#### 2.4.6.2. Category C Activities

The geographic separation of Category C activities means these activities are not expected to add cumulatively to those of the BLNG Precinct. Category C activities which have the potential to impact on benthos are limited to upstream exploration and development activities and these are unlikely to present cumulative impacts.

Upstream development (including explorative and construction activities) of the Browse Basin gas field to acquire the hydrocarbon resource and the operation of the upstream extraction of hydrocarbons will involve the discharge of drilling muds and chemicals which may cause localised changes in water quality, which may in turn affect the health of benthos. These effects would be localised and restricted in area to the immediate vicinity of the activity.

Localised cumulative impacts with Category A and C are likely to evident on benthos from activities that will coincide at the same time in close proximity to the 3Nm Commonwealth Marine Area boundary. These activities include pipeline construction, dredging and dredge spoil disposal. Category C aspects which have the potential to impact benthos are limited to marine site disturbance and excavation (when pipeline and marine infrastructure construction occurs in parallel) and sediment deposition and turbidity (when dredging and spoil disposal is being undertaken near the 3Nm boundary). The ups tream d evelopment activities w ill i nvolve t he d irect and indirect di sturbance a nd l oss of benthic hab itats, however, this disturbance is expected to be very localised (and typically away from shallow nearshore concentrations of BPPH). In addition, circulation in areas beyond the 3Nm boundary is likely to reduce the extent of plumes from pipelines and spoil disposal on nearshore benthos.

Upstream development activities will involve the direct disturbance of the benthos, however this disturbance is expected to be localised and as such, no cumulative impacts are predicted to occur.

Increased v essel m ovement dur ing ex ploration, c onstruction and oper ation of t he up stream r esource m ay i mpact benthos through the introduction of invasive marine species and the installation of infrastructure and moorings.

▪ **Table 2.4-7 Impact Assessment Summary for Benthos (Including BPP).**

| **Environmental Aspect** | **Potential Impacts** | **Mitigation Measures** | | | **Significance of Residual Impact** |
|---|---|---|---|---|---|
| | | **State Government Measures** | **Proposed Environmental Conditions** | **Future Proponent Management Plans** | |
| Marine Site disturbance / excavation | Direct removal of subtidal benthic habitat due to dredging<br>Smothering mortality of sub-tidal benthic primary producers and habitats due to dredge spoil disposal<br>Construction of marine facilities and pipelines resulting in the direct removal and disturbance of substrates. | Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area.<br>The Port Authority will prepare a BPEMP for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program | Prior to commencement of dredging, proponents of derived proposals prepare and implement a DSDMP, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• Consideration of re-use of reclaimed material to minimise ocean disposal.<br>• measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of times of peak | Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br>All vessels will be | Medium |
| Sediment Deposition and Turbidity | *Coral*<br>Indirect and temporary impacts from dredging and disposal activities (sedimentation and light deprivation)<br>Sub-lethal affects on reproduction success of coral spawning | | | | Low |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| | | within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms.<br>Establishment of a DMAG comprising representatives from:<br>Independent Chair with extensive knowledge of marine environment<br>• Broome Port Authority;<br>• Office of EPA;<br>• DEC;<br>• Fisheries Department; | construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation.<br>Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95th percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone the proponent will ensure that the 95th percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels.<br>Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants.<br>Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary to ensure ongoing compliance to the General Manager of the OEPA.<br>Proponents of derived proposals shall prepare and implement an Invasive Marine Species Management Plan, to the satisfaction of the Western Australian Minister for Environment, to minimise the risk of introducing invasive | required to have in place a SOPEP and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea.<br>Prepare and implement a MWDMP, to the satisfaction of the Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality).<br>Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | |
| | *Seagrass*<br>Indirect and temporary impacts from dredging and disposal activities (sedimentation and light deprivation)<br>*Algae*<br>Indirect and temporary impacts from dredging and disposal activities (sedimentation and light deprivation)<br>*Filter feeders*<br>Indirect and temporary impacts from dredging and disposal activities (sedimentation and light deprivation) | | | | Medium |
| Marine discharges (routine) | Decline in water quality and subsequent loss or change in the composition of benthos. | | | | Low |

<table>
<tr><th rowspan="2">Environmental Aspect</th><th rowspan="2">Potential Impacts</th><th colspan="3">Mitigation Measures</th><th rowspan="2">Significance of Residual Impact</th></tr>
<tr><th>State Government Measures</th><th>Proposed Environmental Conditions</th><th>Future Proponent Management Plans</th></tr>
<tr><td></td><td></td><td rowspan="3"><ul><li>SEWPAC; and</li><li>Foundation or other proponent.</li></ul>The role of the DMAG will be to provide advice to the proponent, EPA and/or the Minister for Environment as appropriate on the following:<ul><li>marine investigations (including the modelling of dredge plumes) ;</li><li>environmental risk assessments prepared for future dredging proposals; and</li><li>dredge management plans (including monitoring programs and adaptive response in the event that risks to key values are greater than low) prepared by proponents of future major dredging proposals.</li></ul></td><td rowspan="3">marine species (IMS) into Australian waters during the life of the activity. The plan shall be developed in consultation with the Australian Quarantine Inspection Service (AQIS) and will be applied to vessels, barges and immersible equipment that plan to enter and operate within the Precinct.<br><br>The IMSMP will be consistent with the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry.<br><br>The IMSMP will adhere to the AQIS Australian Ballast Water Management Requirements under the Quarantine Act 1908.<br><br>Proponents shall, for the life of the activity, notify the DEC, the DoF, AQIS and the Broome Port Authority of any IMS detected in the waters of the BLNG Precinct.</td><td rowspan="3"></td><td></td></tr>
<tr><td>Marine discharges (non-routine)</td><td>Non-routine discharges (i.e. spills and leaks) can result in a significant effect on water quality, which can have flow-on impacts such as a loss of benthos.</td><td>Very Low</td></tr>
<tr><td>Invasive Marine Species</td><td>Introduction and establishment of invasive marine species (IMS)</td><td>Low</td></tr>
</table>

## 2.5 Relevant Factor: Fish

Fish species are those contained within the classes Chondrichthyes (cartilaginous fishes including sharks and rays) and Osteichthyes (bony fish). Fish species can be either associated with the seabed community (demersal species, including both benthic and bentho-pelagic species), or the water column (pelagic species). The pelagic species include those that move locally and those that cover wide ranges throughout their life cycles that potentially pass through the James Price Point coastal area. Demersal species are generally associated with particular benthic habitat type(s) for the majority of their life cycle (habitat associations can change during different stages of the life cycle) and have a limited spatial range.

This document deals primarily with impacts to environmental values associated with fish and does not discuss any impacts to social values such as maintenance of commercial and/or recreational fisheries. These are covered in **Part 5**, **Section 4.5** (Commercial Fishing) and **Part 5**, **Section 4.8** (Sports, Recreation and Land Use (including Recreational Fishing)). The key environmental values addressed in this section are:

- diversity, abundance and richness of fish species, populations and communities;
- significant species such as migratory, vulnerable, endangered, endemic or protected species; and
- ecologically significant benthic habitat required for sustaining fish populations and communities.

### 2.5.1 Current Knowledge

Current knowledge with respect to key policy documents and regulatory requirements, as well as a summary of known existing fish characteristics in the vicinity of the proposed precinct are presented in the section below.

#### 2.5.1.1 Key Statutory Requirements, Environmental Policy and Guidance

The main objective associated with this factor (as stated by the EPA Guide to EIA Environmental Principles, Factors and Objectives) is the maintenance of:

*"...the abundance, diversity, geographic distribution and productivity of flora and fauna at ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge*" and also "*…to maintain the integrity, ecological functions, and environmental values of the seabed and coast*" (EPA, 2009f).

A number of Commonwealth and State guidelines, strategies, policies and regulatory frameworks are applicable and provide the context for assessing the key issues relating to fish and expectations for management.

There are six conservation significant fish species, and one family, that are afforded protection under either Commonwealth or State legislation, and have the potential to occur within, or migrate through, the James Price Point coastal area.

**Commonwealth Protection**

The following fish species are afforded protection under the Commonwealth EPBC Act 1999:

- whale shark *Rhincodon typus* ('vulnerable', 'migratory' and listed 'marine');
- great white shark *Carcharodon carcharias* ('vulnerable' and 'migratory');
- freshwater sawfish *Pristis microdon* ('vulnerable' and 'marine');
- green sawfish *Pristis zijron* ('vulnerable' and 'marine');
- dwarf sawfish *Pristis clavata* ('vulnerable');
- northern river shark *Glyphis garricki* ('endangered' and 'marine'); and
- pipefish, pipehorses and seahorses (family Syngnathidae).

**State Protection**

The following fish species are afforded protection under either the *Wildlife Conservation Act 1950* (WC Act 1950) or *Fish Resource Management Act 1994* (**FM Act 1994**):

- whale shark *Rhincodon typus* (FM Act 'totally protected');
- great white shark *Carcharodon carcharias* (WC Act 'Schedule 1');
- green sawfish *Pristis zijron* (FM Act 'totally protected', WC Act 'Schedule 1); and
- dwarf sawfish *Pristis clavata* (FM Act 'totally protected').

The EPBC listed whale shark was not observed during the 2009 surveys undertaken near James Price Point (Cappo *et al.,* 2010b; **Appendix C-6** and RPS, 2010d; **Appendix C-10**). Although the presence of whale sharks in the area at other times cannot be excluded because of its absence during any of the 2009 surveys, it is unlikely they occur in the area in high numbers. One individual of the great white shark was recorded during marine megafauna surveys. The northern river shark is not known to exist within the James Price Point coastal area (RPS, 2010d; **Appendix C-10**; Morgan *et al.,* 2009; **Appendix C-7** and DEWHA, 2008a). The three EPBC listed species of sawfish have been observed in greatest numbers in the Fitzroy River, north east of James Price Point. Individuals were also observed at Eighty Mile beach (approximately 197km south of James Price Point), indicating that while unlikely to support a suitable habitat, these species may pass through the James Price Point coastal area while moving between more favourable habitats.

### 2.5.2 Description of Factor

The Canning marine bioregion is known to contain a distinct assemblage of fish fauna compared to the surrounding Kimberley and Pilbara bioregions (Travers *et al.,* 2010). A large diversity of fish species are reported to occur within the Canning marine bioregion, some of which are endemic to Australia's tropical north (DEWHA, 2008a). This section summarises the extent of existing knowledge and information, including current and relevant baseline studies relating to marine fish species within the James Price Point coastal area, and key Commonwealth and State policy documents.

A recent survey in October 2009 used baited remote underwater video stations (BRUVS) to sample the nearshore (depth range of 5.9–24.3m) fish fauna from Coulomb Point (approximately 15km north of James Price Point) to Cape Boileau within the James Price Point coastal area (Cappo *et al.,* 2010b; **Appendix C-6**). A total of 114 species of fishes, sharks and rays from 154 sites were identified (Cappo *et al.,* 2010b; **Appendix C-6**).

The findings of the 2009 BRUVS survey indicated that certain habitat characteristics including epibenthic cover, depth and sediment composition had the greatest influence in defining the fish assemblages within the area surveyed. The range of habitats available to support fish populations and communities included; bare sand physically structured into ripples in shallower water and low dunes in deeper waters; mixed areas of macroalgae, filter feeders and soft corals of varying densities on low relief hard substrates; and patches of inshore sediment with seasonally abundant and sparse seagrass. Additional habitats not sampled by the BRUVS that were known to exist within the study area include high relief, hard substrate habitats with mixed communities of macroalgae and hard coral colonies in low densities (SKM, 2010a; **Appendix C-5**).

The 2009 BRUVS fish survey determined that the fish communities were both diverse and abundant, despite the relatively shallow depth, lack of topographical features on the seabed and lack of sub-tidal coral reefs. Yet, compared to the fish fauna found offshore, such as at the Rowley Shoals (Allen, 1992), the James Price Point coastal area had low fish species diversity. It is possible that fish diversity was underestimated during the 2009 BRUVS survey given that not all habitat types were sampled. Allen (1992) conducted a survey in 1991 of the fish fauna of the Kimberley islands and reefs from King George River in the east to the Lacepede Islands (approximately 65km north of James Price Point), West Island in the west and recorded a total of 311 species of marine fishes and 13 freshwater species.

No species identified during the 2009 BRUVS survey were found only off the coast of James Price Point (Cappo *et al.,* 2010b; **Appendix C-6**). The diversity of fish species observed in the James Price Point coastal area were well represented in the wider Canning marine bioregion and not considered locally unique in distribution or abundance. The species identified by Cappo *et al.* (2010b; **Appendix C-6**) were typical of the fish communities within the Canning marine bioregion as described by Newman *et al.* (2003). However, comparisons with the fauna at similar latitudes in shallow water close to shore in the vicinity of the Burrup Peninsula (Pilbara bioregion approximately 700km south east of James Price Point) and the Kimberley bioregion indicated that the study area (James Price Point coastal area) had more small pelagic planktivores and more large semi-demersal predators (Watson *et al.,* 2008 and Cappo *et al.,* 2010a).

### 2.5.3 Identification of Key Aspects

#### 2.5.3.1 Definition of Relevant Aspects

Aspects associated with the development and operation of the BLNG Precinct and associated infrastructure that may have an impact on fish were identified in the Scope of the Strategic Assessment and considered in the assessment include:

- physical presence of marine infrastructure;
- marine site disturbance and excavation;
- sediment deposition and turbidity;
- marine noise and vibration;
- marine discharges, routine and non-routine events; and
- invasive marine species (IMS).

#### 2.5.3.2 Sources of Potential Impact

**Physical Presence of Marine Infrastructure**

A range of coastal and nearshore permanent marine facilities will be constructed for the BLNG Precinct. These facilities are likely to include an export jetty facility, ship berthing pockets (with loading platforms, breasting and mooring dolphins), a breakwater, and a marine facility including a marine offloading facility, vessel all-weather harbouring facilities (for tugs and support vessels) and other facilities to support marine port operations. Pipeline infrastructure within the nearshore marine environment will include the feedstock gas pipelines and other ancillary pipelines. The physical presence of this infrastructure may result in a positive or negative impact on fish communities.

**Marine Site Disturbance and Excavation**

There is likely to be a permanent and temporary loss of fish benthic habitat as a result of dredging, dredge spoil disposal, drilling and coring of boreholes, positioning of jack-up barges and other marine activities (e.g. piling).

**Sediment Deposition and Turbidity**

The dredging and disposal of dredge spoil will result in increased sediment deposition and turbidity within the area around the marine construction activities.

**Marine Noise and Vibration**

The construction and operation of the BLNG Precinct will include activities that will emit underwater noise and vibration above background (ambient) levels. The marine activities that are considered to be the most noise intensive sources are nearshore blasting (if required) and piling works.

A variety of parameters are used in underwater acoustics to define impulsive and continuous (non-pulse) signals. Some of the important definitions are as follows:

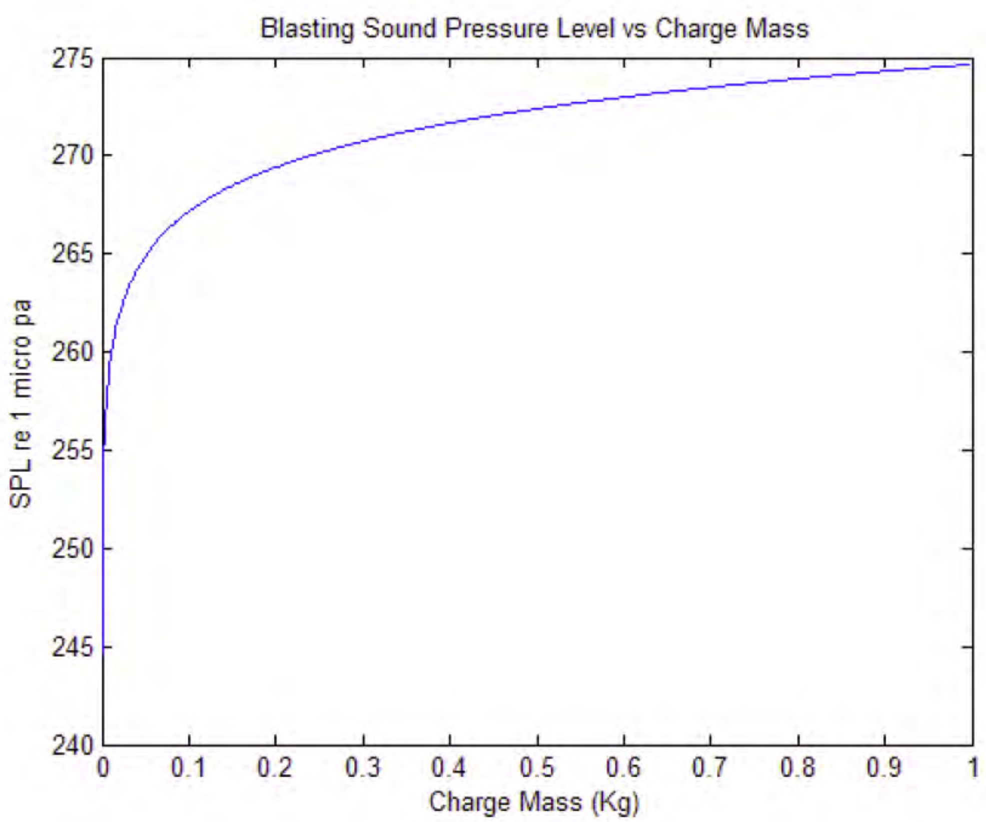
- Sound Pressure Level (**SPL**) Root Mean Square (**RMS**) units dB re 1µPa. The RMS pressure is the decibel value of the root mean of the squared pressure over a defined period of a signal.
- Sound Pressure Level Peak units dB re 1µPa (0-Pk). Peak pressure is the maximum recorded pressure and is measured from the mean of the signal to the maximum excursion from the mean.
- Sound Pressure Level Peak to Peak units dB re 1µPa (Pk-Pk). Peak to Peak sound pressure is the algebraic difference between the maximum positive and maximum negative instantaneous peak pressure.
- Sound Exposure Level (**SEL**) units dB re 1µPa2.s. The SEL is defined as the squared instantaneous sound pressure integrated over the pulse duration, and represents the total amount of energy measured during a single noise event normalized to one second. Note that SEL is not influenced by the duration of a noise event as it is a measure of the total energy of the noise event regardless of its duration.

For impulsive signals, such as pile driving noise and marine blasting noise, the averaging time is a significant consideration. Impulsive signals are better described by a measure of Sound Exposure Level (SEL) and a measure of the signal peak pressure. In particular, SEL can be a useful metric for assessing cumulative exposure because it enables sounds of differing duration to be compared in terms of total energy.

Blasting works may be required to remove hard rock encountered during dredging and jetty installation activities and may occur at any time during the dredging activities. Underwater detonations emit high intensity impulsive noise that may extend from low frequencies (less than 10Hz) to greater than 10kHz (Spence, 2007), with peak source levels as high as ~247dB re 1µPa @1m (260dB re 1µPa @1m peak-to-peak) (Nedwell and Edwards, 2004 and Wyatt, 2008).

Explosive blasts are typically broadband, non-linear effects with large peak pressures and extremely fast rise and fall times. An analytical formula can be used (if the TNT equivalent of the explosive is known) to determine the peak SPL per charge mass as shown in **Figure 2.5-1**.

For the purpose of the assessment, the blasting explosive to be used for the Browse LNG Development is expected to be an emulsion commonly used in the mining industry. This emulsion has a TNT equivalent of 0.31. Detonating 50kg of Powergel gives a peak value of 8.026766MPa at a distance of 1m using D. This translates into a value of 258dB re 1µPa @ 1m. The duration of the pulse can be calculated to be 24.5µs which gives a sound exposure level of 212dB re 1µPa²s.




- **Figure 2.5-1 Blast Sound Pressure Level Achieved per Charge Mass.**

Pile foundations will be required for the export jetty and other marine facilities. Pile driving operations involve hammering a pile into the seabed. Piling emits high intensity impulsive noise that is generated by a hammer hitting the top of the pile (Spence, 2007). Piling may generate peak source noise levels of around 200-230dB re 1µPa @1m (URS, 2005 and Wyatt, 2008). The noise emanating from a pile during a pile driving operation is a function of its material type, its size, the force applied to it and the characteristics of the substrate into which it is being driven.

It can be expected that most of the energy from the hammering action of the pile driver will transfer into the seabed. Once in the seabed, the energy will then propagate outwards as compressional and shear waves. Some of the energy may be transferred into Rayleigh waves, which are seismic waves that form on the water/seabed interface, but it is expected that this will be a small portion of the total wave energy.

Piles can be driven using various methods such as vibration, gravity and hammer. The method that is used is dependent on the size of the pile and the substrate into which the pile is being driven. It is planned that hydraulic impact hammers of up to 40 tonnes will be used for pile driving operations in this development project, and the pile will have diameters of between 900mm and 1,200mm. The noise that is generated by an impact hammer hitting the top of the pile is short in duration lasting approximately 90ms and can therefore be described as impulsive noise.

Vessels will be the primary source of continuous (non-pulse) noise from the development, and will be associated with most construction activities. Vessels will be operating in locations from the marine facilities to the end of the dredging channel. The noise energy emitted from vessels depends on a number of factors and generally increases with the size of the vessel. The fallpipe rock dumping vessels (approximately 40,000t) located about 5km offshore and the sidedump rock dumping vessels (approximately 20,000t) are expected to be the largest vessels operating during construction and they have therefore been modelled for this assessment (SVT, 2010; **Appendix C-12**). Underwater noise from dredging activities is mainly generated by the operating motors and engines of dredging vessels, and the cutter suction dredger and trailer suction hopper dredger have also been modelled for this assessment (SVT, 2010; **Appendix C-12**) (**Section 2.5.4.4**).

**Routine Marine Discharges**

Routine discharges will include cooling water, hydrotest water (during commissioning), process water, brine from desalination, produced formation water, stormwater, grey water, vessel deck drainage, bilge and treated sewage. These waste streams will be controlled within the LNG facilities and are likely to be discharged to the nearshore marine environment via an ocean outfall with a diffuser contained within the BLNG Precinct Port area boundary.

**Non-routine Marine Discharges**

A review of the proposed LNG facilities has indicated a number of hydrocarbon fluids will be stored within the BLNG Precinct area. The presence of these fluids introduces an inherent risk of spills to the area and surrounding marine environment. Hydrocarbon inventories for the BLNG Precinct facilities will likely include LNG, condensate, marine diesel, lube oil and bunker fuel. Minor spills may result from accidental releases of hydrocarbons or chemicals during refuelling and other storage and transfer operations. Major accidents such as vessel collisions, rupture of an LNG/condensate tanker or catastrophic failure of a production pipeline could result in the rapid release of a large volume of LNG, condensate, diesel or bunker fuel. Loading and shipping activities have the potential for a large release volume; however, this is limited to the volume of the tanker or transfer pipeline. Alternatively, the rupture of the main production pipeline has the potential to release a large volume of hydrocarbons into the receiving environment. The likelihood of an event of this nature occurring is considered to be highly unlikely although the environmental consequences, assuming no controls, could be significant.

**Invasive Marine Species**

The primary pathway for IMS introduction is via vessels, either through contaminated ballast water discharge or biofouling on the vessel's hull and internal niche areas. Sources of impact include parasites, diseases and marine organisms. The construction and operation of the BLNG Precinct will utilise a range of vessel types sourced from within WA, interstate and internationally. The likely vessel types that will be required include barges, dredging and dredge spoil disposal vessels, LNG and condensate tankers, mobile offshore support units, pipe laying vessels, research vessels and other construction related vessels.

#### 2.5.3.3 Sensitivity and Resilience

The sensitivity and resilience of fish species, populations and communities to threatening processes varies greatly depending on their morphological and physiological characteristics, and habitat requirements.

**Physical Presence of Marine Infrastructure**

Those species with limited home ranges (tens of kilometres) are predicted to be the most sensitive to habitat fragmentation or loss. Species with small home ranges (smaller than the area of impact) are more likely to be displaced by the presence of marine infrastructure. For example Connolly *et al*. (2002) described patterns of movement by adult

leafy sea dragons (Syngnathids) over periods of up to 14 days. All except one of the nine tagged leafy sea dragons moved within well-defined home ranges of up to 5ha, and some stayed within <1ha. Weedy sea dragons also stayed within a home range of <1ha (Sanchez-Camara and Booth, 2004). Other species more capable of ranging greater distances in search of suitable habitat will move into surrounding habitat patches and thus will be less sensitive to the physical presence of marine infrastructure.

**Site Disturbance and Excavation**

Certain species of fish that are dependent upon specific habitat requirements will be more sensitive to disturbances to and/or loss of benthic habitat. Benthic dwelling and territorial species that show high site fidelity are the most sensitive to changes in benthic habitat cover. Those species considered to be habitat generalists will be more resilient to changes in benthic habitat. The same principles apply to changes in food availability, with feeding generalists less sensitive to specific changes in the availability of different food types. Results from the 2009 BRUVS survey suggest that there were very few species that were restricted to one specific habitat type (Cappo *et al.,* 2010b). Given the mixed nature of habitats within the James Price Point coastal area, it is likely that the fish species present are not restricted to any one BPP type and will be fairly resilient to changes in the type and abundance of habitat. In addition, individual habitat types have an extensive distribution within the wider Dampier Peninsula region.

**Sedimentation and Turbidity**

The sensitivity of fish to localised changes in water quality (increased turbidity and sedimentation) will be minimal in those species which can actively avoid contact and move away. Benthic dwelling and territorial species will be more sensitive to smothering if unable to utilise suitable habitat elsewhere. Some species will be less resilient and susceptible to smothering, impaired respiration and changes to feeding and reproductive behaviours. For example, turbidity may directly interfere with cues (visual, mechanical) fish utilise to catch prey and prolonged exposure may interfere with foraging behaviours. Suspended sediment concentrations of greater than 100mg/l have shown to lead to an increase of fish egg hatching times with reduced success and decreased larval fish survival. However, Stowar (1997) questioned such effects to fish populations in Australia due to lack of studies of the effects of sedimentation and turbidity on Australian fish populations specifically (Campbell and Doeg, 1989). Within the James Price point coastal area large variations in turbidity have been documented to occur as a result of tides and weather conditions (SKM, 2010c). In general, fish fauna within the Canning marine bioregion are adapted to extremes and fluctuations in turbidity (Hutchings *et al.,* 2002) making them less sensitive and more resilient to alterations in water quality caused by anthropogenic events.

**Marine Noise and Vibration**

Noise and vibration in the underwater environment can result in a range of responses including temporary or permanent loss of hearing sensitivity, other physical injuries, and behavioural changes such as avoidance of the activity area.

Fish sensitivity and resilience varies greatly depending on the species, hearing capability, habits, proximity to the activity and if the noise occurs during a critical part of the fish lifecycle (McCauley & Salgado Kent, 2008). Most marine fish are hearing generalists (Amoser and Ladich, 2005) with relatively poor hearing. Hearing generalists are not as sensitive to noise and vibration as hearing specialists, which have developed hearing specialisations and can be particularly vulnerable to intense sound vibrations because many possess an air-filled swim bladder (Gordon *et al.,* 2004). There are a number of fish in the area with unknown noise sensitivities and these include seahorses, pipefish, sharks, skates and rays.

Syngnathids produce large click sounds during feeding, perhaps for communication, which indicates that sound is important to this group of fish (Bergert and Wainwright, 1997; Colson, 1998; and Ripley, 2006). Furthermore, Syngnathids can only hear up to approximately 1500Hz and have relatively high hearing thresholds (SVT, 2009). In contrast, elasmobranches rely on low frequency sound to locate prey (Myrberg, 1978). Elasmobranches do not have swim bladders therefore, are not typical hearing specialists (Baldridge, 1970).

**Marine Discharges**

Marine discharges can alter the surrounding water quality by increasing or decreasing salinity, dissolved oxygen, nutrients and levels of contaminants. Marine organisms have variable sensitivities and tolerances to variations in salinity. Slight increases in salinity (less than five units) have been shown to have limited effects on fish, both at adult and larval stages of their life cycles (Diaz & Rosenberg, 1995). However, large changes in salinity (greater than 10 units increase from ambient) can affect an organism’s ability to osmoregulate, leading to physiological damage and likely mortality (Diaz & Rosenberg, 1995). Low oxygen conditions can have two primary effects on benthic communities; inadequate

oxygen for aerobic respiration; and altered sediment-water fluxes resulting in contaminant release (Diaz & Rosenberg, 1995). Temporary (hours) low oxygen conditions can generally be tolerated by benthic communities, however, when very low oxygen conditions (less than 2mg/L) exist for extended periods (24 to 48 hours), physiological damage often occurs (Diaz & Rosenberg, 1995).

**Invasive Marine Species**

The marine fishes known to occur within the Canning marine bioregion are considered to be relatively resilient to invasive marine species (Hutchings *et al.,* 2002). The marine fauna that inhabit the Canning marine bioregion are adapted to the physical environment and capable of tolerating fluctuations in turbidity, seasonal changes in water temperature and cyclonic events, and these conditions may limit the establishment of invasive marine species. Within the Canning marine bioregion, biodiversity is considered to be high and endemism is low which can act to inhibit the establishment of invasive marine species through competitive exclusion. Yet, invasive marine species are generally quite tolerant to environmental extremes and often have successful reproductive strategies making them highly efficient and establishing disturbed environments.

### 2.5.4 Predicted Impacts

Potential impacts on fish resulting from aspects associated with the proposed BLNG Precinct are discussed below and summarised in **Table 2.5-4**. Both direct and indirect impacts are considered within these sections. For the purpose of this assessment it is considered that direct impacts would largely be confined to areas of direct disturbance within the BLNG Precinct, and other locations where development activities are proposed to occur.

#### 2.5.4.1 Potential Impacts to Fish due to Physical Presence of Marine Infrastructure

Impacts to fish as a result of the physical presence of marine infrastructure will be associated with loss of connectivity between habitats (fragmentation), shading of surrounding areas and the provision of additional habitat. Loss of connectivity is not predicted to have a significant impact on the populations and communities of fish within the BLNG Precinct area given that for several species of fish and invertebrates with pelagic larvae, isolation-by-distance comparisons suggest mean larval dispersal distances on the order of 25–150km (Palumbi, 2003). In addition, studies have indicated that functional ecological scales of connectivity are in the order of 20km (Underwood *et al*., 2009). Impacts associated with shading are likely to be minimal and localised to individuals that utilise the habitat within the footprint. As such, those species most likely to be affected are benthic dwelling and territorial species that display high site fidelity and have a limited home range. The provision of additional hard substrate and additional structural complexity will encourage the settlement of a variety of marine invertebrates creating potentially new habitat for fish. Likely fish species to establish will include benthic and bentho-pelagic dwelling species that will aggregate around areas of complex hard substrate. Some likely families may include Tetraodontiformes (puffers, leatherjackets, trigger fish and large communities of fish), angelfish that feed on invertebrate prey and small pelagic baitfish. There is no predicted impact to relevant EPBC listed species or pelagic, transient or migratory species.

The significance of the residual impacts is assessed as being very low given the localised nature of the marine infrastructure associated with the BLNG Precinct, and it is likely that there will be no detectable impacts to fish communities or populations.

#### 2.5.4.2 Potential Impacts to Fish due to Marine Site Disturbance and Excavation

The direct burial and/or removal of benthic habitat by construction activities, including dredging and dredge spoil disposal will result in the permanent loss of habitat occupied by fish communities, within the footprint of the BLNG Precinct. Other areas outside the footprint will only be temporally affected. The indirect impacts to marine fish from habitat loss are not likely to be significant, given that the habitats within the James Price Point coastal area are unlikely to represent unique or key fish habitats. In addition, these habitat types are found to be extensive, both locally (i.e. vicinity of James Price Point coastal area) and regionally (i.e. Dampier Peninsula) (Fry *et al.,* 2008; **Appendix C-4**). The loss of any habitat for shelter, reproduction and foraging is predicted to be localised and temporary given that representative habitats are widely distributed in the Canning marine bioregion. Pelagic fish are unlikely to be affected by loss of natural seabed relief or habitat. Bottom dwelling and territorial species inhabiting specific benthic habitats will be affected the most, but similar habitat is found in close proximity to the BLNG Precinct Port area.

Although there is the potential for fish to be affected by site disturbance and excavation activities, it is predicted that fish will avoid the area during construction, with little impact to the diversity or abundance of fish communities. As such, any impacts to fish arising from this aspect are primarily considered to be temporary and localised, however some direct disturbance may occur (i.e. permanent loss of habitat). Outside of the direct disturbance, re-colonisation of benthos and recovery in population numbers will occur over time. Therefore it is likely that there would only be local short term impact to communities and populations, which do not threaten viability of community. It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures, as detailed in a PFCEMP. A more detailed description of proposed mitigation measures is presented in **Section 2.5.5**. The significance of the residual impacts is assessed as low as the fish that occur at James Price Point are representative of the wider Canning Marine Bioregion.

#### 2.5.4.3 Potential Impacts to Fish due to Sediment Deposition and Turbidity

The impact from sediment deposition and turbidity may be both direct via changes to fish physiological and behavioural patterns and indirect through a loss of phytoplankton with flow on effects through the food chain impacting recruitment, and from a loss of, or change to, benthic habitat. These impacts will result in the movement of fish out of highly impacted areas and in severe cases, the mortality of some resident fish.

Adverse direct effects on fish from contact with increased turbidity and sedimentation range from mortality, stress and behavioural responses such as avoidance, altered feeding patterns and adverse effects on reproduction. These impacts can occur to eggs, larvae, juveniles or adult fishes. Numerous studies on the effects of suspended sediment on adult fish and larvae found the direct effects to be impaired respiration via sediment clogging gills, which can lead to death if levels are high. Levels of suspended solids (mg/l) required to cause physiological damage are generally within the range of hundreds to hundreds of thousands (Garakouei, 2009). Isono *et al*. (1998) found exposure of a range of marine fish species larvae to suspended solids ranging from 320 to 1000mg/l for 1, 3 and 12 hours resulted in over 50% mortality at 1000mg/l for 12 hours. Impacts to fish eggs are predicted to be minimal given that eggs have a tough capsule which provides protection for the developing embryo. However, the eggs of some fish species have been found to suffer loss of buoyancy and oxygen uptake as a result of suspended particles in high concentrations (greater than 320mg/l) adhering to the egg capsule (Isono *et al*., 1998), which can potentially interfere with egg development and survival. Hatching success and developmental rates of eggs of a range of marine fish species were not significantly affected by suspended solid concentrations greater than 320mg/l over a 24 hour exposure period. These levels of suspended solids are much greater than those predicted to occur as a result of the BLNG development, other than within the Port development area (i.e. immediately adjacent to the dredging location).

Turbidity also limits fish vision, which can interfere with social behaviour (Berg and Northcote, 1985), foraging (Gregory and Northcote, 1993; Vogel & Beauchamp, 1999) and predator avoidance (Miner & Stein, 1996 and Meager *et al*., 2006). Concentrations of suspended solids greater than 34mg/l have been known to induce avoidance by some fish species. Some larval fish are able to swim up to 100km in a single bout (Bellwood and Stobutzki, 1997). Thus, larvae are capable of displaying avoidance behaviour in response to increased suspended solids. Turbid water can impair feeding behaviour, particularly for species that use visual cues for foraging (ANZECC/ARMCANZ 2000). Previous experimental studies of prey consumption by piscivores (Vandenbyllaardt *et al*., 1991 and Reid *et al*., 1999) have demonstrated statistically significant decreases in prey consumption only at substantially high turbidity (52 to 140mg/l). Suspended solid concentrations, greater than these levels, are predicted to occur only for short periods in a small area directly within the BLNG Precinct port area and thus, are not predicted to have an overall impact on fish populations or communities within the region.

Fish within the James Price Point coastal area are expected to be able to withstand periodic increases in suspended sediments as high as 30mg/l, as seen during the wet season spring tides, with short peaks as high as 90mg/l. Due to the immediate effects of flight response in most fish, it is predicted that fish will move away and adopt avoidance behaviour during dredging operations.

It is unlikely that the dredging and spoil disposal activities will have a measurable impact on adult fish populations due to a reduction in phytoplankton and subsequent overall reduction in recruitment. Given the spatially variable nature of phytoplankton vertically within the water column and horizontally, localised changes to environmental conditions, i.e. reduced light availability, are not predicted to have an impact on the productivity and biomass of phytoplankton on a regional scale. Since phytoplankton can survive with a minimum light requirement of less than 1% surface irradiance, localised impacts are predicted to be very short term and spatially limited to areas within the vicinity of dredging and spoil

disposal activities. Phytoplankton is predicted to be able to cope with a certain level of turbidity exposure before mortality occurs. If changes in phytoplankton production were to occur, flow on effects to high trophic levels (adult fish) would be affected by factors such as spatial distribution of impacts, natural patchy dynamics of phytoplankton, immediate trophic level densities and their own dynamics, and behaviour and longevity of higher trophic levels. Thus impacts to adult piscivores would be virtually undetectable.

Suspended sediment and sedimentation caused by dredging and spoil disposal has the potential to adversely affect marine benthic habitats including seagrass, coral, macroalgae and filter feeding communities. The loss of light through suspended sediment in the water column or by sedimentation can limit photosynthesis and lead to mortality of benthic habitats. The increased sediment load in the water column (total suspended solids) can also clog the filter feeding mechanisms of certain immobile sessile invertebrates. The potential magnitude of impact on fish, particularly benthic dwelling and territorial species, relates to the loss or reduction of benthic habitats for food, shelter, reproduction etc. Reduced fish abundance and diversity is an indirect effect associated with the loss of habitat and can be significant.

Relevant EPBC listed protected species which potentially migrate through the James Price Point coastal area (*Pristis* spp.), may come into contact with areas of increased turbidity. These species inhabit estuarine and near coastal waters, which are typically naturally turbid, and are thus adapted to finding prey in these muddy waters and not expected to suffer any adverse affects from high turbidity.

Within the James Price Point coastal area, there will be both a permanent zone of impact and a temporary zone of effect on benthic habitats from dredging and dredge spoil disposal. Permanent impacts are associated with the area directly beneath and surrounding the nearshore marine facilities. No unique or structurally complex habitats containing a high diversity or abundance of BPPs and filter feeders were observed within the area directly offshore from James Price Point. Temporary impacts will likely encompass a much larger area, associated with a reduction in benthic light availability caused by increased suspended sediment concentration within the water column. Areas of more complex habitats observed offshore of Coulomb Point and Quondong Point, known to contain a higher diversity of fish species, are likely to be affected by the sediment plume. Such impacts would only be temporary with recovery of benthos and primary producers anticipated within five years from the cessation of dredging. Fish are predicted to return to certain areas of impact once suitable habitat has recovered.

It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures. Prior to commencement of dredging, proponents of derived proposals will be required to prepare and implement a Dredging and Dredge Spoil Disposal Management Plan to demonstrate best practice management techniques and technologies which would be applied to minimise potential dredging impacts. A more detailed description of proposed mitigation measures is presented in **Section 2.5.5**. The significance of the residual impact on fish from sediment deposition and increased turbidity is assessed as being low.

The extent of the permanent and temporary impact to benthic habitats is discussed in detail in **Section 2.4** (Benthos (Including BPPs)).

#### 2.5.4.4 Potential Impacts to Fish due to Marine Noise and Vibration

A noise modelling study of the underwater noise associated with the construction activities for the proposed precinct has been undertaken to support this assessment (SVT, 2010; **Appendix C-12**). The aim of the study was to assess the impact of underwater noise on marine fauna species (primarily on whales, dolphins and dugongs) as a result of the marine construction activities associated with the proposed Browse LNG Development.

The noise assessment focused on the following anthropogenic noise sources:

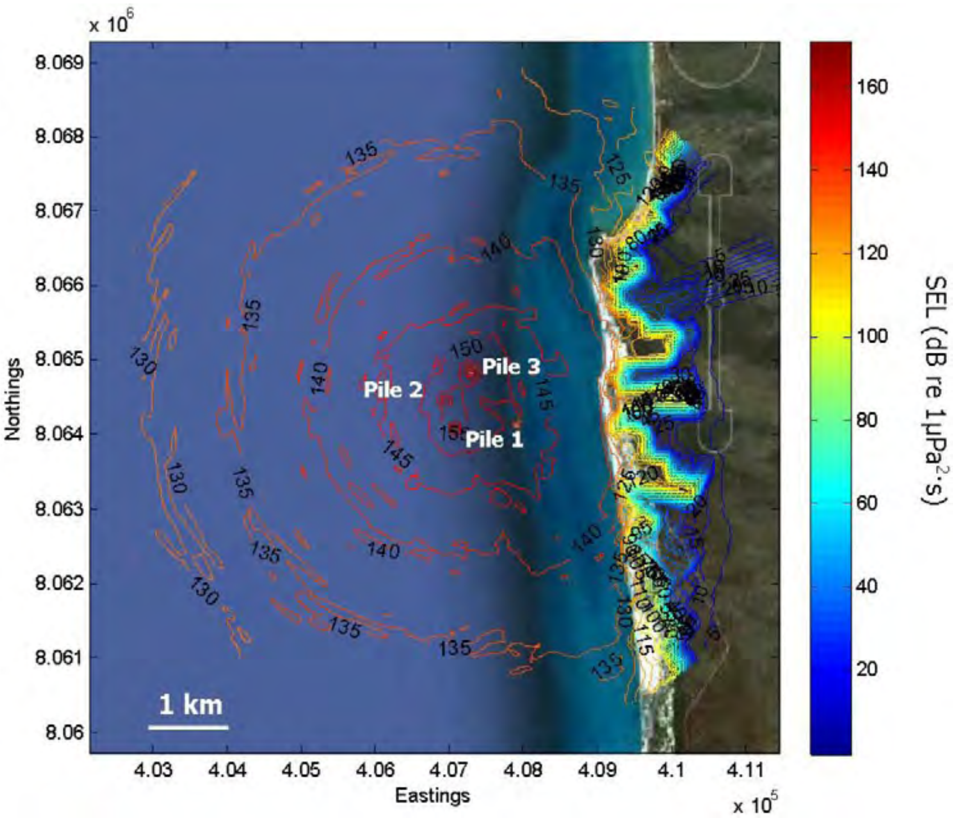
- pile driving;
- blasting;
- dredging; and
- vessel movements.

Noise sources associated with the BLNG Precinct with the highest potential to cause impacts, including physical injuries, are the high intensity impulsive noises emitted during construction activities such as blasting and piling. The need for

blasting of consolidated marine sediments has not yet been established. Nevertheless, this activity has been conservatively assumed to be required and was included in the modelling scenarios.

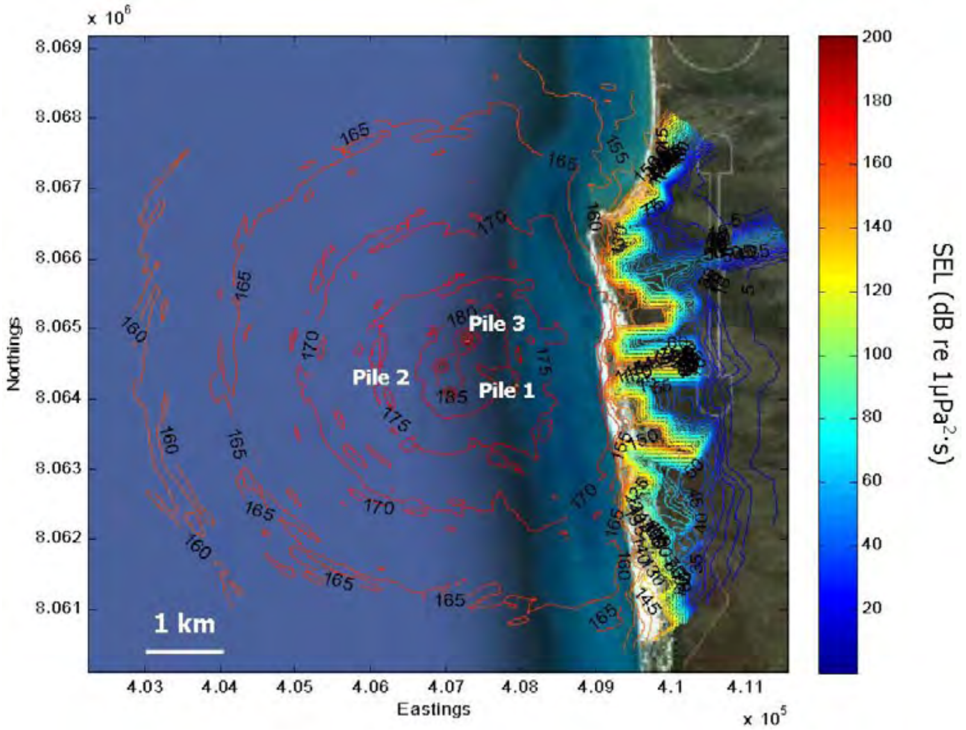
There is potential for impacts to both hearing specialist and generalist fish in proximity to construction related activities that emit intense levels of noise (blasting and piling). Vessel movement results in longer-term noise exposure which may cause temporary or permanent hearing loss and/or stress leading to physiological effects or immediate effects such as fish moving away from feeding sites.

The contour plots shown below are for a receiver depth of 2m below the sea surface. The scenarios under both MSL and Highest Astronomical Tide (**HAT**) were modelled. Only the results for of HAT are presented as it represents the worst case scenario. The plots of the piling (**Figure 2.5-2** and **Figure 2.5-3**) and blasting (**Figure 2.5-4**) activities are shown as these represent the noise emissions with most potential for physiological or behavioural impacts on fish. The plots are presented to give an indication of the sound exposure level with distance from source for these selected activities, the results of which are discussed below. Two plots are shown for pile driving, representing different time periods of exposure. **Figure 2.5-2** represents an exposure of 10 seconds to pile driving from three barges operating simultaneously, whereas **Figure 2.5-3** represents an exposure of three hours within a 24 hour period. The figures clearly demonstrate that the SEL for a given distance from source increases with length of exposure.



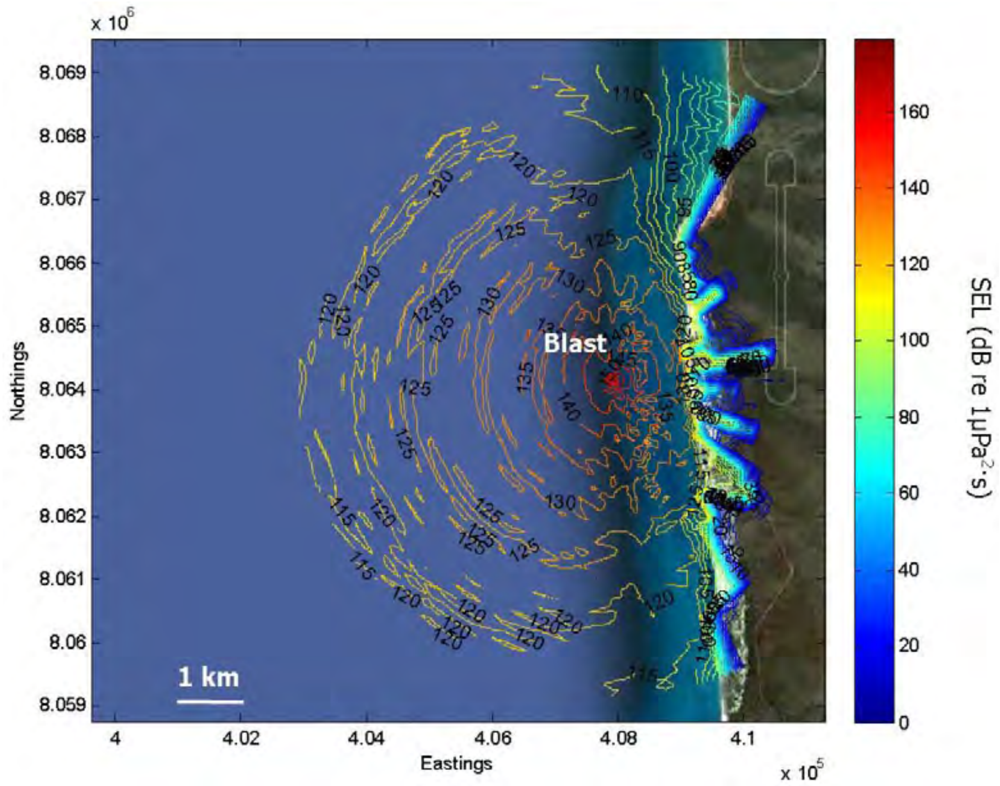

Source: SVT, 2010; **Appendix C-12**.

- **Figure 2.5-2 Plot of the Pile Driving Sound Exposure Level Noise Contour, 2m below Sea Surface, with Three Piling Barges Operating Simultaneously for a 10s period.**




Source: SVT, 2010; Appendix C-12.

- **Figure 2.5-3 Plot of the Pile Driving Sound Exposure Level Noise Contour, 2m below Sea Surface, with Three Piling Barges Operating Simultaneously for 3 Hours in a 24 Hour Period.**




Source: SVT, 2010; **Appendix C-12**.

- **Figure 2.5-4 Plot of Sound Exposure Level Contour 2m below Sea Surface for a Single Marine Blast within the Nearshore Construction Area.**

Impacts on fish from noise sources varies greatly, depending on the species, hearing capability, habits, proximity to the activity and if the noise occurs during a critical part of the fish lifecycle (McCauley & Salgado Kent, 2008). Noise disturbance will predominantly have a displacement effect.

Physiological damage to any fish species (loss of hearing sensitivity, injury to soft tissues) can result from close exposure to high intensity noise sources from pile driving or blasting (Popper *et al.,* 2006). Furthermore, intense impulsive signals produced from pile drivers are also known to kill fish, cause behavioural changes and rupture gas filled swim bladders (Yelverton *et al.,* 1975 and Nedwell *et al.,* 2004). There is potential for impacts to both hearing specialist and generalist fish in proximity to construction related activities that emit intense levels of noise (blasting and piling). McCauley and Salgado Kent (2008) proposed three impact zones for wild fish extending from pile driving:

- Zone 1 (10–20m away from source): fish within this zone can suffer serious internal injuries.
- Zone 2 (up to 300m away from source): at 20m most fish are expected to suffer some form of hearing damage or temporary threshold shifts from continual impact piling. At three hundred metres some fish, presumably stationary for long periods of time during continuous impact piling, can begin to suffer hearing damage or temporary threshold shifts.
- Zone 3 (out to 500m away from source): impacts on fish at this zone can include behavioural responses such as avoidance or startle response to increased alertness.

For pile driving, fish are unlikely to be in close proximity to the noise source since other than at start-up. Piles require multiple hammer drives at short intervals of minutes or hours within each of many consecutive days. Such activity will scare fish away prior to commencement of more intense activities.

Vessel movements cause continuous, lower intensity sounds which increase background noise levels (Popper and Hastings, 2009). Long-term noise exposure to fish could cause effects such as temporary or permanent hearing loss and/or stress leading to physiological effects or immediate effects such as fish moving away from feeding sites (Popper & Hastings, 2009). Noise and vibration arising from ships, boats, dredgers, aircraft and pipe-laying activities during the construction and operations phase appear unlikely to result in acute effects or fish mortality.

Species likely to be impacted by marine noise and vibration are inshore tropical territorial species, such as Serranids (Shpigel and Fishelson, 1989) which show high fidelity to limited areas of seabed. Low numbers of Serranids were identified during the 2009 BRUVS survey. This suggests that the habitat structure typically required to support these predators (of a high trophic level) is limited in the James Price Point coastal area. The seabed features and benthic biota within the area of predicted blasting effect are well represented elsewhere in the James Price Point coastal area and on the Dampier Peninsula (Fry *et al.,* 2008; **Appendix C-4**). Therefore, noise is likely to impact individual animals swimming through the local waters as a blast occurs and will not cause permanent, nor long term, significant impacts to populations or communities of fish over a broader area.

Population recovery from any immediate impact would occur by re-colonisation over time from areas outside any immediate zone of impact. Fish may re-inhabit seabed near to the blast zone if the period between blasts is lengthy. Given the limited spatial and temporal nature of the construction activities, any impact will be to a relatively small number of individuals and there will be no significant impact or effect at a community or population level. The worst case scenario is that marine noise and vibration from blasting deters fish fauna from habitation within the direct area of influence but, after the cessation of blast events, fish would be able to re-inhabit the area by larval recruitment or relocation.

Impacts to listed EPBC fish species from noise and vibration are not predicted to occur. There was no evidence of EPBC listed fish fauna in the BLNG Precinct area (Cappo *et al.,* 2010b) and the only possible occurrences are likely be transient (Morgan *et al.,* 2009; **Appendix C-7**) or in low numbers so the likelihood of an impact to EPBC listed species is very low. Syngnathids, although showing strong fidelity to seabed structure (such as rocky rubble), are unlikely to be present in dense population numbers, if at all, because of the patchiness of suitable habitat. If present, they would be limited to areas with macroalgae, seagrass and hard corals. Likely impacts will be limited to the general (non EPBC listed) fish populations in the nearshore waters of the BLNG Precinct area.

In summary, underwater noise and vibration generated during construction has the potential to cause physiological injuries or a behavioural response (e.g. avoidance) in fish. Peak noise levels would be associated with construction activities such as pile driving or blasting would be temporary in nature. It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures through a Port Facilities Construction

Environmental Management Plan including a range of measures such as soft-start piling, where practicable. A more detailed description of proposed mitigation measures is presented in **Section 2.5.5**. Any behavioural changes that may result would not lead to mortality of individuals. The significance of the residual impact on fish from underwater noise generation during the construction and operation of the BLNG Precinct is assessed to be low.

#### 2.5.4.5 Potential Impacts to Fish due to Marine Discharges

**Routine Marine Discharges**

Routine marine discharges have the potential to reduce water quality which can have consequential effects on marine flora and fauna within the vicinity of the discharge zone. Any impacts on benthic habitat health will reduce the production rates and availability of habitat for food and shelter for fish.

Fish experience complex physiological effects from sub-lethal toxicological levels of aquatic pollutants. The effects include reduction in exercise performance and increased metabolic rate which leads to high energetic costs (McKenzie *et al.,* 2007). Fish perform prolonged exercises to forage, migrate and move through an aquatic medium and currents (McKenzie *et al.,* 2007). Increased metabolic rates are caused by various pollutants, whereas decreased swimming speeds are caused by pollutants such as dissolved metals, ammonia and various other toxic chemicals and effluents (McKenzie *et al.,* 2007). Potential effects from trace metals and residual hydrocarbons include cellular/physiological damage that can be either temporary or permanent, depending on the concentration and duration of exposure.

Water quality is likely to be altered beyond background conditions within a small (e.g. 50m) defined mixing zone surrounding marine outfalls. Beyond this mixing zone, water quality is expected to fall within background levels. The potential for significant water quality decline is low given the dynamic nature of the marine environment, resulting in diurnal flushing of nearshore waters by the strong tidal movement. There is, however, a low probability that a limited number of individuals or schools of small demersal fish may swim through the mixing zone of the discharge area. Mobile species can move away from the affected area and are likely to avoid any deleterious effects.

It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures, such as the outfall to be designed such that there will sufficient initial mixing to minimise the areal extent of the mixing zone, and proponents will be required to achieve the appropriate water quality guidelines. BLNG Precinct proponents will be required to demonstrate that routine wastewater discharges achieve the relevant ANZECC/ARMCANZ water quality guidelines within an agreed mixing zone and undertake regular ecotoxicity testing to target 99% species level of protection beyond the BLNG Port Area. A Wastewater Discharge Management Plan will also be developed, including hydrodynamic modelling and environmental monitoring to ensure these water quality guidelines are achieved, minimising potential environmental impacts associated with a decline in water quality from routine discharges. The significance of the residual impact for routine discharges on fish is assessed to be low and it is anticipated that, with the application of proposed mitigation measures, routine discharges would be confined to the BLNG Precinct.

**Non-routine Marine Discharges**

Non-routine events, such as collisions, a rupture of an LNG/condensate tanker or catastrophic failure of a production pipeline could result in the rapid release of a large volume of hydrocarbons. Such non-routine spills and leaks can have a significant direct effect on fish fauna through toxicity of organic and hydrocarbon compounds, however, the probability of such an event is very low. Implementation of effective waste treatment/management and industry standard feedstock and product handling processes is expected to significantly reduce the potential impact (type, volume and frequency of unplanned emission) to the marine environment.

The establishment of the Broome Port Authority as the statutory port authority for the BLNG Precinct will ensure supplies of oil spill response equipment are as required under the State Emergency Management Plan for Marine Oil Pollution (West Plan) to undertake an immediate oil spill response. Major hydrocarbon spills may also require deployment of additional equipment stockpiled in the Fremantle and Dampier ports, or other stockpiles under the National Plan, to minimise the extent of hydrocarbons and reduce potential impacts to sensitive environmental receptors. The oil spill modelling required by future proponents during the derived proposal process will be used to inform a Hydrocarbon and Chemical Spill Contingency Plan, which will be implemented in the event of a large hydrocarbon or chemical spill. An Emergency Response Plan will also be develop outlining emergency response procedures to be implemented by the port authority in the event of an oil spill emergency.

Compliance with industry standards with respect to the storage and handling of hazardous liquids will minimise the likelihood of significant non-routine discharges (spills and leaks) occurring. In the unlikely event that a major spill does occur, implementation of an Emergency Response Plan and Hydrocarbon and Chemical Spill Contingency Plan, as described above, including spill contingency procedures and coordination of proponents in the event of emergency response procedures would minimise the impacts. Routine or non-routine discharges are unlikely to result in population level effects and the significance of the residual impact is assessed as being low.

#### 2.5.4.6 Potential Impacts to Fish due to Invasive Marine Species

The introduction and establishment of IMS could have an adverse impact on fish through:

- competition with indigenous species for food and habitat;
- alteration of habitat;
- predation of indigenous species; and
- introduction of parasites and diseases.

Should IMS be introduced and successfully establish viable populations, they have the potential to predate on and outcompete native marine fauna and flora. This can significantly impact on fish biodiversity through competitive exclusion or predation. The severity of potential impacts will be dependent on the introduced species characteristics. Once established, eradication of IMS populations is often impossible, limiting management options to ongoing control and/or impact minimisation (URS, 2007).

It is generally considered unlikely that an IMS would successfully establish and have an impact on fish given the resilience of the fauna within the study area (Hutchings *et al.,* 2002). The lack of IMS across northern Australia suggests that the marine ecosystem is relatively resistant to establishment of IMS. It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures, such as the enforcement of IMS inspection requirements to significantly reduce the risk of IMS introduction and establishment. A more detailed description of proposed mitigation measures is presented in **Section 2.5.5**. The significance of the residual impact of introduced marine species on fish is assessed as being very low, given the resilience of the fish fauna and the preventative measures proposed.

### 2.5.5 Management Measures

Management measures that have been identified to avoid, minimise, manage and mitigate the potential impacts to fish are outlined below in **Table 2.5-1**, **Table 2.5-2** and **Table 2.5-3**.

Refer also to **Part 5**, **Section 4.5** (Commercial Fishing) and **Part 5**, **Section 4.8** (Sports, Recreation and Land Use (including Recreational Fishing)) for proposed management measures relevant to addressing impacts on commercial and recreational fisheries.

**Table 2.5-1 State Government Management Measures for Fish.**

| State Government measures | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area. | Department of Transport (DoT) | On approval of BLNG Precinct |

| | | |
|---|---|---|
| The Port Authority will prepare a BPEMP for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference area;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms. | Broome Port Authority | Prior to approval of marine related derived proposals |
| Development of local water quality environmental values and objectives, incorporating the marine waters off James Price Point, which support the WA State WQ Management Strategy. The water quality environmental values and objectives will be consistent with the Pilbara Coastal Water Quality Objectives and used for ongoing operations within the BLNG Precinct. | DEC | On approval of the BLNG Precinct |

**Table 2.5-2 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Fish.**

| Condition No. | Proposed Environmental Conditions for the Strategic Proposal |
|---|---|
| **Proposals involving treated waste water discharges** | |
| M2.1 | Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95th percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone the proponent will ensure that the 95th percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels. |
| M2.2 | Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants. |
| M2.3 | Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary to ensure ongoing compliance to the General Manager of the OEPA. |
| **Proposals involving dredging** | |
| M2.4 | Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a DSDMP, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• consideration of the re-use of suitable dredge material for MOF construction, where practicable;<br>• design of the MOF including construction of bunds to isolate fill material from wind and wave action;<br>• consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives;<br>• consideration of re-use of reclaimed material to minimise ocean disposal;<br>• measures to minimise dredging impacts during sensitive ecological windows;<br>• a monitoring strategy for ecological receptors and health during marine construction (including baseline surveys);<br>• the development of trigger levels for benthic communities and water quality that define additional management responses;<br>• mechanisms to audit and assess environmental performance of proponents during construction; and<br>• a communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. |
| **Proposals involving quarantine management** | |
| M4.1 | Proponents of derived proposals shall prepare and implement an Invasive Marine Species Management Plan, to the satisfaction of the Western Australian Minister for Environment on advice from and in consultation with the Department of Fisheries, to minimise the risk of introducing IMS into Australian waters during the life of the activity. The plan shall be developed in consultation with the AQIS and will be applied to vessels, barges and immersible equipment that plan to enter and operate within the Precinct. |
| M4.2 | The IMSMP will be consistent with the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry. |
| M4.3 | The IMSMP will adhere to the AQIS Australian Ballast Water Management Requirements under the Quarantine Act (1908). |
| M4.4 | Proponents shall, for the life of the activity, notify the DEC, the DoF, AQIS and the Broome Port Authority of any IMS detected in the waters of the BLNG Precinct. |

- **Table 2.5-3 Requirements to be Addressed Via Development of a Management Plan to Support a Derived Proposal Potentially Affecting Fish.**

| Requirements for Derived Proponents | Timing |
|---|---|
| Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation, and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br>*In order to address the potential impacts to fish identified within this Section, the Plan may include the following environmental management measures:*<br>• *scheduling blasting for daylight hours only, avoiding dawn and dusk, to allow for effective visual monitoring and minimising health and safety concerns;*<br>• *smaller, more frequent blasts planned using sequential explosive charges to minimise cumulative impacts of the explosions, as opposed to less frequent, larger blasts;*<br>• *Warning charges used to encourage animals to move away from the construction area prior to a blast detonation;*<br>• *Shaped charges used to focus blast energy along fracture lines; and*<br>• *Reference to Listing Advice and approved Conservation Advice for Pristis spp.* | Prior to commencement of associated construction activities |
| Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to commencement of associated construction activities |
| All vessels will be required to have in place a Ship-Board Oil Pollution Emergency Plan (SOPEP) and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea. | Prior to construction and updated for ongoing operational requirements |
| Prepare and implement a MWDMP, to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to construction of marine discharge facilities |

### 2.5.6 Environmental Outcome

After management and mitigation measures have been applied, it is expected that the BLNG Precinct (Category A activities) will result in the following key potential direct and indirect impacts in relation to fish.

Certain impacts will only occur during the construction phase (high intensity noise and capital dredging) while others will be permanent and on-going during the operational life of the BLNG Precinct. The combined effect of all impacts resulting from Category A activities will not lead to any significant cumulative impacts on fish, since each impact identified operates in isolation, with the exception of the introduction of IMS. In the unlikely event that IMS are introduced, the combined effect of increased competition and predation with native fish species and the loss of benthic habitat from marine site disturbance and excavation and sediment deposition and turbidity could result in a cumulative loss of fish biodiversity.

There is the potential for provision of new habitat from the physical presence of marine infrastructure. The presence of hard surfaces to which algae and invertebrates such as barnacles, corals, and oysters attach leads to the accumulation of attached marine life and provides intricate structure and food for assemblages of fish. This could have a positive impact on fish by providing additional habitat and/or sources of food and subsequently increase populations.

#### 2.5.6.1 Direct Impacts

- displacement of individuals from certain habitats due to the presence of marine infrastructure and site disturbance and excavation;

- disruption of feeding or reproduction and direct mortality of individuals from site disturbance during the construction and operation phases;
- clogging of gills with sediment from dredging and disposal activities;
- behavioural changes, physiological effects and mortality from noise and vibration;
- physiological effects, toxicity and mortality from contact with marine discharges; and
- increased likelihood of introduction of IMS.

#### 2.5.6.2 Indirect Impacts

- modification and/or removal of benthic habitat utilised by fishes; and
- reduced water quality and subsequent loss of benthic habitat utilised by fishes.

These impacts are expected to be very limited in spatial extent. Fish species potentially affected are not of significant regional value and there are no predicted impacts to fish at a population or community scale. As such, these impacts are not predicted to compromise the environmental values and stated objective associated with this factor to maintain "...*the abundance, diversity, geographic distribution and productivity of flora and fauna at ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge" and also* "…*to maintain the integrity, ecological functions, and environmental values of the seabed and coast*" (EPA, 2009b).

### 2.5.7 Cumulative Impacts of the Proposal and Associated Activities and Projects

The Category B infrastructure and transport activities identified are centred around onshore actions supporting the BLNG Precinct, but are not subject to the current State or Commonwealth approval process. Three activities have the potential to affect marine resources. They are; further development of Broome Port to accommodate marine traffic; the increase in marine vessel traffic; and the increase in urban development and associated infrastructure resulting in increased run-off to the marine environment.

Improvements to the Broome Port would likely be to existing areas. The impacts on fish from these activities would thus be limited and only within the direct vicinity of the port.

Increased vessel activity is linked to increases in marine pollution. This is typically via the introduction of potential contaminants and waste emissions. The placement of additional moorings to cater for the increase in recreational boating activity will have a limited impact on the localised benthic habitat utilised by fish species. The greatest impact associated with increased vessel activity is an increase in recreational fishing. There is the potential for an overall cumulative impact on fish stocks (abundance) from the combined impacts of Category A and B activities. For example, a loss of localised fish habitat from Category A activities combined with increased catch rates due to Category B activities could have a cumulative impact on certain fish species. Given that the majority of fish stocks targeted by recreational fishing are in offshore waters outside the JPP coastal area and associated with habitat that is present throughout the Canning marine bioregion, the cumulative impact to fish abundance is predicted to be low. The impacts associated with recreational fishing are discussed in detail in **Part 5**, **Section 4.8** (Sports, Recreation and Land Use (including Recreational Fishing)).

Urban development will result in an increased load of contaminants and potentially persistent residues which can alter water quality in near coastal waters after runoff events. Fish can be affected by poor quality surface water inflows and groundwater migration from urban developments. However, the increase in risk is likely to be small. Landscape management and stormwater quality treatment techniques are available to reduce and capture emission loads of contaminants such as suspended sediment, hydrocarbons, pesticides and metals (from land development; vehicle emissions and other man-made chemicals). Groundwater percolation and attenuation will be addressed through regional natural resource outcomes, as interest is in the surface water quality and protection of habitat values within nearby Roebuck Bay, which is listed as an internationally significant wetland (Ramsar convention). The risk would be managed through site-based catchment management strategies, land use practices and stormwater treatment systems.

Category C activities include upstream development (explorative and construction activities) of the Browse Basin gas field (to acquire the hydrocarbon resource) and the operation of the upstream extraction of hydrocarbons. Localised cumulative impacts with Category C are likely to evident from activities that will coincide at the same time in close proximity to the 3Nm Commonwealth marine area boundary. These activities include pipeline construction, dredging and

dredge spoil disposal and vessel traffic. Category C aspects which have the potential to impact fish are limited to marine noise and vibration (particularly when piling and blasting is occurring in the port and for pipeline construction), marine site disturbance and excavation (when pipeline and marine infrastructure construction occurs in parallel) and sediment deposition and turbidity (when dredging and spoil disposal is being undertaken near the 3Nm boundary). The upstream development activities will involve the direct and indirect disturbance and loss of benthic habitats, however, this disturbance to fish food-sources and habitat is expected to be localised (and typically away from shallow nearshore concentrations of BPPH) and as such, population impacts to fish species are not anticipated.

Upstream development activities will be subject to further environmental and development approvals. The upstream exploration activities may require the use of seismic testing, however the potential impact to fish populations would be highly localised, hence cumulative impacts are not anticipated.

**Table 2.5-4 Impact Assessment Summary for Fish.**

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual impact |
|---|---|---|---|---|---|
| | | **State Government Measures** | **Proposed Environmental Conditions** | **Future Proponent Management Plans** | |
| Physical Presence | Loss of connectivity between habitats and the provision of additional habitat. | Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area.<br>The Port Authority will prepare a BPEMP for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries | Proponents of derived proposals shall ensure that within the Low Ecological Protection Area (i.e. the discharge mixing zone) the 95th percentile of bioaccumulation toxicant concentrations meets ANZECC/ARMCANZ (2000) NWQMS 80% species protection guideline levels. Beyond the boundary of the mixing zone the proponent will ensure that the 95th percentile of toxicants meets ANZECC/ARMCANZ (2000) NWQMS 95% species protection levels.<br>Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a DSDMP, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable;<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action;<br>• Consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives;<br>• Consideration of re-use of reclaimed material to minimise ocean disposal;<br>• Measures to minimise dredging impacts during sensitive ecological windows;<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys);<br>• The development of trigger levels for benthic communities and water quality that define additional management responses;<br>• Mechanisms to audit and assess environmental | Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br>In order to address the potential impacts to fish identified within this section, the Plan may include the following environmental management measures:<br>• Scheduling blasting for daylight hours only, avoiding dawn and dusk, to allow for effective visual monitoring and minimising health and safety concerns.<br>• Smaller, more frequent | Very Low |
| Marine Site disturbance / excavation | The permanent and temporary loss of benthic habitat for fish. | | | | Low |
| Sediment Deposition and Turbidity | Changes to fish physiology and behavioural patterns | | | | Low |
| Marine noise | It is anticipated | | | | Low |

<table>
<tr><th rowspan="2">Environmental Aspect</th><th rowspan="2">Potential Impacts</th><th colspan="3">Mitigation Measures</th><th rowspan="2">Significance of Residual impact</th></tr>
<tr><th>State Government Measures</th><th>Proposed Environmental Conditions</th><th>Future Proponent Management Plans</th></tr>
<tr><td>and vibration</td><td>that noise disturbance will predominantly have a displacement effect on fish.</td><td rowspan="4">and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms.<br><br>Development of local water quality environmental values and objectives, incorporating the marine waters off James Price Point, which support the WA State WQ Management Strategy. The water quality environmental values and objectives will be consistent with the Pilbara Coastal Water Quality Objectives and used for ongoing operations within</td><td rowspan="4">performance of proponents during construction;<br>• A communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br><br>The DSDMP will be subject to assessment under the Environment Protection (Sea Dumping) Act 1981 (Cwth), including appropriate stakeholder consultation.<br><br>Proponents of derived proposals shall verify the performance of outfalls in terms of achieving the required dilutions, under a range of flow rates, meteorological and sea state immediately following commissioning of wastewater plants.<br><br>Within 18 months of commissioning outfalls to the marine environment, proponents of derived proposals shall submit a report containing monitoring results and a discussion of non-conformances and the operating limitations necessary to ensure ongoing compliance to the General Manager of the OEPA.<br><br>Proponents of derived proposals shall prepare and implement an Invasive Marine Species Management Plan, to the satisfaction of the Western Australian Minister for Environment, to minimise the risk of introducing IMS into Australian waters during the life of the activity. The plan shall be developed in consultation with the Australian Quarantine Inspection Service (AQIS) and will be applied to vessels, barges and immersible equipment that plan to enter and operate within the Precinct.<br><br>The IMSMP will be consistent with the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry.<br><br>The IMSMP will adhere to the AQIS Australian Ballast Water Management Requirements under the Quarantine Act (1908).</td><td rowspan="4">blasts planned using sequential explosive charges to minimise cumulative impacts of the explosions, as opposed to less frequent, larger blasts.<br>• Warning charges used to encourage animals to move away from the construction area prior to a blast detonation.<br>• Shaped charges used to focus blast energy along fracture lines.<br>• Reference to Listing Advice and approved Conservation Advice for Pristis spp.<br><br>All vessels will be required to have in place a SOPEP and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea.<br><br>Prepare and implement a MWDMP, to the satisfaction of the Western Australian Minister for Environment. See Part 3, Section 2.3 (Marine Water Quality).<br><br>Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See Part 3, Section 2.3 (Marine Water Quality).<br><br>Refer to Proposed</td><td></td></tr>
<tr><td>Marine discharges (routine)</td><td>Physiological effects due to changes in water quality</td><td>Low</td></tr>
<tr><td>Marine discharges (non-routine)</td><td>Physiological effects due to toxicity of organic and hydrocarbon compounds</td><td>Low</td></tr>
<tr><td>Invasive Marine Species</td><td>Impacts on fish biodiversity through competitive exclusion or predation.</td><td>Very Low</td></tr>
</table>

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| | | the BLNG Precinct. | Proponents shall, for the life of the activity, notify the DEC, the DoF, AQIS and the Broome Port Authority of any IMS detected in the waters of the BLNG Precinct. | Environmental Conditions for defined Proponent Management Plans for IMS. | |

## 2.6. Key Factor: Marine Mammals

The following section describes the predicted impacts on marine mammals from activities, facilities and other components to be approved under the Plan for the BLNG Precinct (Category A) and the potential for cumulative impacts from activities that may indirectly arise as a result of the BLNG Precinct development (Category B) and other related resource activities in the region (Category C).

### 2.6.1. Current Knowledge

Current knowledge with respect to key policy documentation and regulatory requirements, as well as a summary of the key marine mammals present in the vicinity of the James Price Point coastal area, are presented in the following sections.

#### 2.6.1.1. Key Statutory Requirements, Environmental Policy and Guidance

There are a number of key statutory requirements, environmental policies and guidance documentation that apply to the Strategic Assessment in relation to marine mammal protection, including:

**State Guidance and Policy**

The Environment Protection Authority (EPA) applies the following overarching objective in its assessment of proposals, which can apply in the context of marine mammals:

"*To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge"* (EPA, 2010).

**State Protection**

The *Wildlife Conservation Act 1950* (WA) provides for the protection of native fauna, with species considered as needing special protection listed under one of four categories in the Wildlife Conservation (Specially Protected Fauna) Notice 2010, these being:

- Schedule 1 - fauna that are rare or likely to become extinct;
- Schedule 2 - fauna presumed to be extinct;
- Schedule 3 - Migratory birds protected under an International Agreement; and
- Schedule 4 - other specially protected fauna.

The following marine mammal species that have been recorded from the waters surrounding the Dampier Peninsula, are specifically protected under the *Wildlife Conservation Act 1950* (WA):

- blue whale (*Balaenoptera musculus*) - Schedule 1;
- humpback whale (*Megaptera novaeangliae*) - Schedule 1; and
- dugong (*Dugong dugon*) - Schedule 4.

In addition to those species protected under the *Wildlife Conservation Act 1950* (WA), a number of species are listed as Priority species by the Department of Conservation and Environment (WA). Although not conferred legal protection, these species have been identified as being significant. The following marine mammal species that have been recorded from the Kimberley region have been listed as Priority fauna:

- Indo-Pacific humpback dolphin (*Sousa chinensis*) - Priority 4;
- sperm whale (*Physeter macrocephalus*) - Priority 4; and
- spinner dolphin (*Stenella longirostris*) - Priority 4.

**Commonwealth Protection**

The Commonwealth EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places defined in the Act as Matters of NES.

- The humpback whale (*Megaptera novaeangliae*) and dugong (*Dugong dugon*) are classified as being Matters of NES under the EPBC Act. Both the humpback whale and dugong are listed as "Migratory" under this Act. The humpback whale is also listed as "Vulnerable" under Schedule 1 of the EPBC Act.
- The EPBC Act establishes the Australian Whale Sanctuary, the Sanctuary includes all Commonwealth waters (from the 3 Nm state waters limit) to the boundary of the Exclusive Economic Zone (i.e. out to 200Nm). Within the Sanctuary it is an offence to kill, injure, or interfere with a cetacean.

An assessment of significance criteria for fauna species that are listed under the EPBC Act is discussed in **Part 6**, **Section 2**.

**International Protection**

The Marine Environment Protection Committee of the International Maritime Organisation issued MEPC.1/CIRC.674 Guidance Document for Minimising the Risk of Ship Strikes with Cetaceans. The purpose of this document is to provide guidance to member governments in reducing and minimising the risk of ship strikes on cetaceans. This document sets forth important general principles that should be taken into account and possible actions that may be taken to reduce such risk. Though this guidance is not statutory legislation and member states (of which Australia is one) have no legal obligation to comply, there is nevertheless an implied obligation not to act contrary to the spirit and terms of such guidance.

The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range. The provisions of this convention have been incorporated into the EPBC Act.

#### 2.6.1.2. Description of Factor

This section primarily addresses impacts to humpback whales (*Megaptera novaeanglia*) and dugongs (*Dugong dugon*), reflecting the relative risks defined in the risk assessment for this project. The humpback whale is of particular significance as the Dampier Peninsula (including the James Price Point coastal area) forms an important component of the Group IV humpback whale migration route from early June to November. The Dampier Peninsula is also of regional significance for humpback whales, as they utilise areas such as Camden Sound (approximately 344km north of James Price Point), and Pender Bay (approximately 103km north east of James Price Point) as calving, staging and resting areas (**Part 3**, **Section 1** (Environmental Overview)).

Similarly, the Dampier Peninsula coastline between Cape Leveque (approximately 150km north east of James Price Point) and Cape Bossut (approximately 130km south west of James Price Point) (including James Price Point coastal area) provides important foraging habitat and supports a transient population of dugongs estimated to fluctuate between 930 and 1,774 animals (RPS, 2010c; **Appendix C-9**).

Other marine mammal species (refer to **Part 3**, **Section 1** (Environmental Overview)) such as the bottlenose (*Tursiops* spp.) and spinner (*Stenella longirostris)* dolphin, were the most commonly recorded species during both vessel and aerial surveys carried out in 2009 (RPS, 2010d; **Appendix C-10**). Both species were widespread along the Dampier Peninsula (i.e. Cape Bossut in the south to Cape Leveque in the north) and were recorded in the vicinity of James Price Point coastal area. These species, however, were not considered to utilise the marine environment in proximity to the James Price Point coastal area to a greater extent, than other areas along the Dampier Peninsula (RPS, 2010d; **Appendix C-10**). The potential for environmental impacts associated with the development of the BLNG Precinct Port area on the bottlenose and spinner dolphin is considered slight, given these species are widespread, highly mobile and are likely to exhibit behavioural and avoidance responses, such as fast flight responses, faster dive times and high speed swimming. It is assumed that mitigation measures of impacts for key marine mammal species (i.e. humpback whale and dugong), will also provide a level of impact minimisation for spinner and bottlenose dolphins. Based on this supporting information, bottlenose and spinner dolphins will not be addressed in further detail in the following sections.

Despite considerable survey effort (both aerial and vessel-based) (RPS, 2010d; **Appendix C-10**), marine mammals species such as the Indo-Pacific humpback dolphin (*Sousa chinensis)*, snubfin dolphin *(Orcaella heinsohni)* and killer whale (*Orcinus orca*) were recorded in very low numbers in inshore waters of the Canning Marine Bioregion. Other

species such as the Antarctic minke whale (*Balaenoptera bonaerensis*), Bryde's whale (*Balaenoptera edeni*), pygmy blue whale (*Balaenoptera musculus brevicauda*) and the sperm whale (*Physeter macrocephalus*) were not recorded at all throughout the duration of the surveys (RPS, 2010a; **Appendix C-8**). These marine mammal species are not known to aggregate within the James Price Point coastal area or the wider Dampier Peninsula. Similarly, those species (i.e. Indo-Pacific humpback dolphin, snubfin dolphin and killer whale) that were identified during vessel and aerial surveys (RPS, 2010d; **Appendix C-10**) were observed as occurring in very low numbers, and may transit the James Price Point coastal area occasionally. As such, it is considered that activities associated with the development and operation of the BLNG Precinct Port area, are not likely to impact these species, it is also assumed that mitigation measures of impacts for key marine mammal species (i.e. humpback whale and dugong), will also provide a level of impact minimisation for those species that have been identified as less common within the James Price Point coastal area. As such these species will not be addressed in further detail in the following sections.

The distribution of marine mammals listed under the EPBC Act, and that are considered Matters of NES are discussed in detail in **Part 6**, **Section 2** (Matters of National Environmental Significance).

In summary, this assessment of marine mammals has focussed on the 'key receptors' that are species of conservation significance that are known to occur in the coastal waters relevant to the BLNG Precinct, as outlined in **Table 2.6-1**

**Table 2.6-1 Marine Mammals and Key Receptors Considered in the Impact Assessment.**

| Key Receptor | Rationale for Selection as a key receptor |
|---|---|
| Humpback whales (*Megaptera novaeanglia*) | High conservation significance. Coastal waters of the Dampier Peninsula form part of the Group IV humpback whale migration route from early June to November. |
| Dugongs (*Dugong dugon*) | High conservation significance. Coastal waters of the Dampier Peninsula provide foraging habitat and supports a transient population of dugongs. |

**Humpback Whales**

To support the Strategic Assessment of the Browse LNG Precinct, extensive surveys were undertaken in 2008 and 2009, to understand the distribution and abundance of marine mammals, with particular focus on humpback whales and dugongs, off the Dampier Peninsula, and in particular the James Price Point coastal area. These studies included:

- Browse LNG Development Humpback Whale Distribution and Abundance in the Nearshore South-West Kimberley During Winter 2008 Using Aerial Surveys (Jenner and Jenner, 2009; **Appendix C11**).
- Whale Distribution and Abundance in the Nearshore SW Kimberley During Winter 2008 Using Vessel Surveys (Jenner and Jenner, 2009; **Appendix C11**).
- Satellite Tagging of South-Bound Female Humpback Whales in the Kimberley Region of Western Australia (Double *et al*., 2010).
- Browse LNG Development Humpback Whale Survey Report (RPS, 2010a; **Appendix C-8**).
- Browse LNG Development Nearshore regional dugong survey (RPS, 2010c; **Appendix C-9**).
- Browse LNG Development Marine Megafauna Survey (RPS, 2010d; **Appendix C-10**).

In 2008, surveys were conducted by the Centre for Whale Research (**CWR**) for Woodside and the Department of State Development (WA) (DSD) to support the Northern Development Taskforce Precinct site selection process (see **Part 2**, **Section 3**). These surveys consisted of aerial and vessel surveys to determine the seasonal and relative distribution of humpback whales and other marine megafauna (including dugongs and cetaceans).

In these surveys, higher aggregations of whale cow and calf pairs were observed north of the Lacepede Island Group (approximately 65km north of James Price Point). However, the area offshore from James Price Point coastal area did not appear to be significant for feeding, calving or socialising of whales (Jenner and Jenner, 2009; **Appendix C-11**).

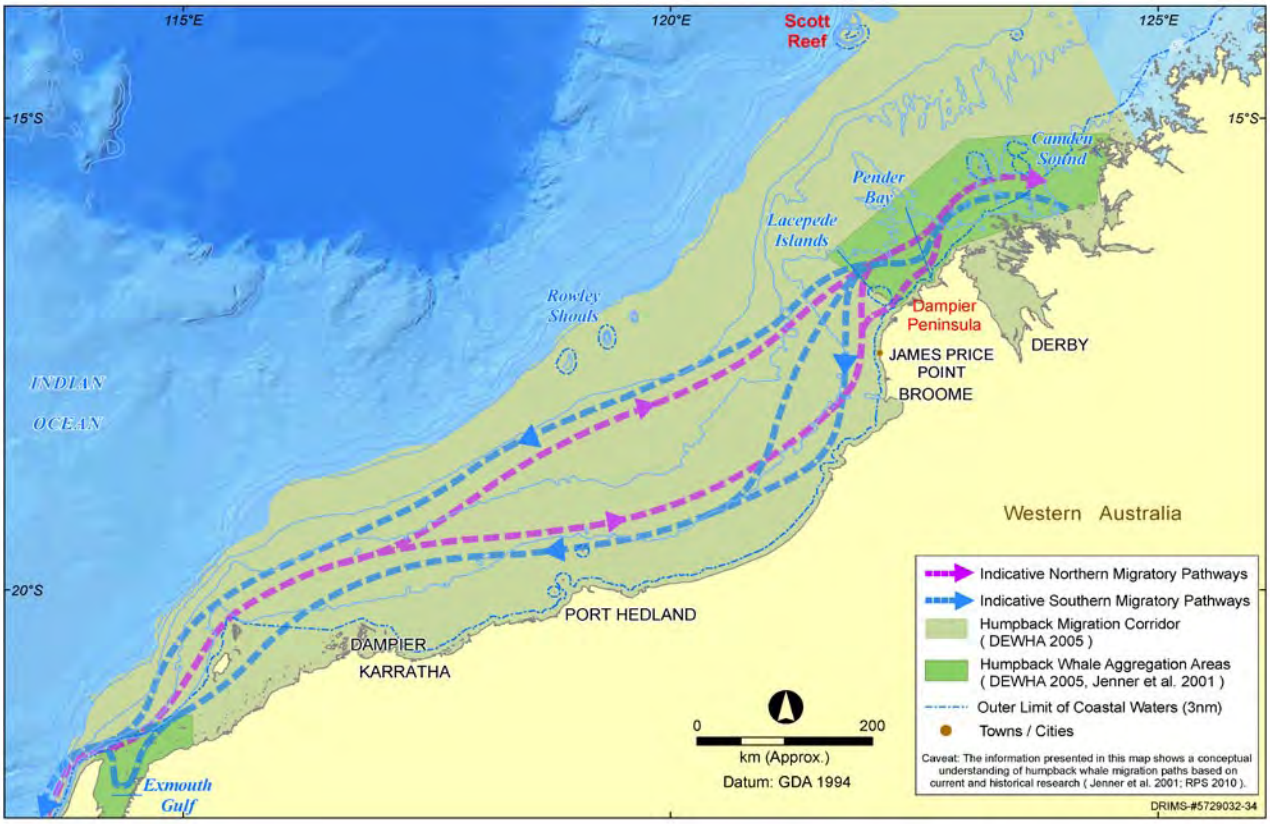
This information was used to support the site evaluation process, which led to the selection of James Price Point as a suitable location for the onshore BLNG Precinct. James Price Point was chosen as the preferred option as this area satisfied several criteria, including avoiding environmentally sensitive areas such as key humpback whale aggregation and calving areas.

During the 2009 humpback whale migration season, detailed baseline surveys were undertaken by RPS on behalf of Woodside to identify the population, behavior and distribution of humpback whales with a focus on the migration corridor offshore the Dampier Peninsula (centred offshore from James Price Point coastal area), but also including regional surveys extending along the coast of the Canning Bioregion and offshore to Scott Reef (RPS, 2010a; **Appendix C-8**). This information is detailed in this section and supporting technical reports (**Appendices C8–C10**). The surveys were also intended to establish a survey method that can be used for ongoing monitoring, if required.

The Group IV humpback whale population migrates between its feeding grounds in Antarctic waters and breeding and calving grounds between the Lacepede Islands and Camden Sound in the Kimberly region of Western Australia. The exact timing of the migration period can vary from year to year, however the northern humpback whale migration occurs generally from June to mid September with the peak of the northward migration occurring over a three week period in August (RPS, 2010a; **Appendix C-8**). The southward migration appears to be more widely dispersed and does not produce a second peak along the Dampier Peninsula coastline. However, a broad peak in numbers of humpback whales occurs at Pender Bay and north of the Lacepede Islands, when they are thought to stage their return journey south. This peak generally occurs from mid September until mid October (**Figure 2.6-1**) (RPS, 2010a; **Appendix C-8**).

During the northward migration approximately 13,000 (95% CI: 3,138–36,729) humpbacks were estimated to pass through the James Price Point migration corridor survey area. This indicates that potentially a substantial portion of the population may bypass the area, either travelling further offshore than the migration corridor survey area (further than 90km offshore) or terminating their migration further to the south.

On the basis of data collected over a 10 year period, an important area for humpback whale calving and resting exists between the Lacepede Islands and from Beagle Bay (approximately 77km north of James Price Point) in the south and Camden Sound in the north (**Figure 2.6-1**). Whilst the majority of humpback whales migrate from the feeding grounds of the Antarctic to the calving grounds of the Kimberley, some whales have been known to rest and calve before reaching the Kimberly, such as at Exmouth Gulf (Chittleborough, 1953 and Jenner *et al*., 2001).




- **Figure 2.6-1 Indicative Northern and Southern Migratory Pathways of the Humpback Whale along the North West Shelf and Kimberley Region.**

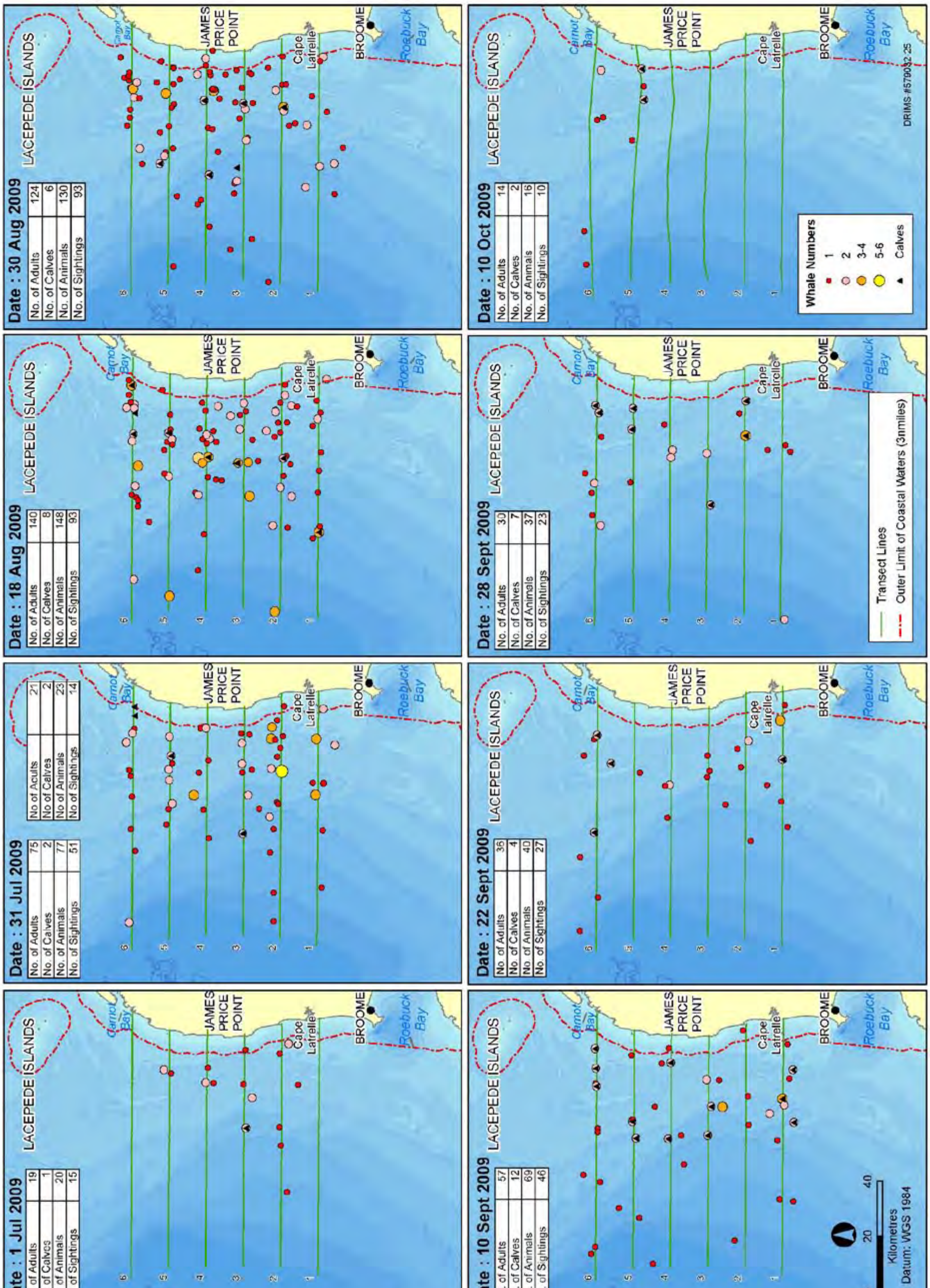
At the peak of the season (i.e. August), the total estimated number of animals that occurred within the survey boundaries of the James Price Point migration corridor survey was 499 (Pooled SE: 53.7, n=140). These were dispersed across the survey area of 6,490km$^2$. Based on the most recent estimated total Group IV stock of 21, 750 (95% CI: 17,550–43,000) whales (Hedley *et al*., 2009) this amounts to approximately 2.3% of the population present at any one time during the peak of the northbound migration. Demonstrably fewer humpback whales were seen to travel along the coastal migration corridor on the return journey southward (**Figure 2.6-2**) (RPS, 2010a; **Appendix C-8**).

As inferred by Jenner et al. (2001), the 2009 surveys (RPS, 2010a; **Appendix C-8**) also revealed significantly greater numbers of adult whales and calves at Pender Bay than in the area offshore from James Price Point, with 1.5 times the number of adult whales and three times the number of calves respectively (RPS, 2010a; **Appendix C-8**).

Results indicated that approximately 60% of the Group IV population migrate north within 90km of James Price Point coastal area, with the majority migrating along a corridor between 8 and 42km offshore (at the 10-50m depth contour) (**Figure 2.6-3**).

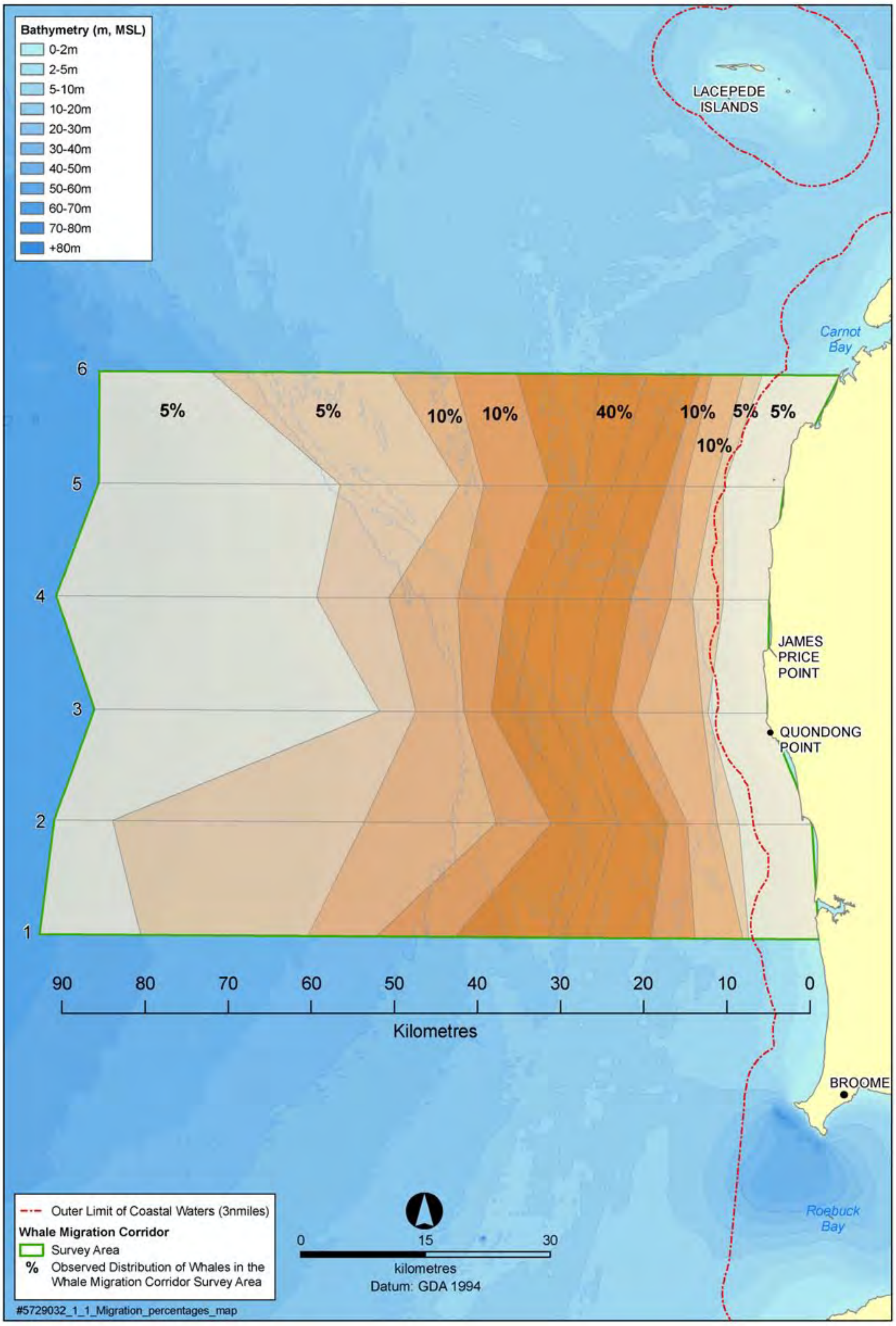
Analysis of survey data (RPS, 2010a, **Appendix C-8**) found that less than 5% of migrating humpback whales (throughout the migratory period i.e. July to October) were travelling at a distance within 8km of the coastline, with the mean distance for adults being 27km from the coastline and the mean distance for calves slightly closer to shore (24km) (**Figure 2.6-3**). In addition, satellite tagging data indicates that many southbound humpback cows and calves bypass the James Price Point migration corridor survey area, possibly travelling west from Pender Bay to deeper water, before rejoining the coastal area near Eighty Mile Beach (approximately 197km south of James Price Point) (RPS, 2010a; **Appendix C-8**).

To support aerial and vessel surveys, tagging of whales with calves was undertaken by Double *et al*. (2010). Although only a small subset of the population were tagged, the results supported the findings of the aerial surveys that concluded there was a wide migration corridor between the Lacepede Islands and Gourdon Bay (approximately 111km south of James Price Point), which appeared to narrow at Pender Bay and Eighty Mile Beach. It was also noted that none of the tagged whales were observed to rest in the vicinity of James Price Point coastal area and that most cow and calf pairs were observed resting in Pender Bay and off Eighty Mile Beach (**Figure 2.6-5**).




Source: RPS, 2010a; **Appendix C-8**.

- **Figure 2.6-2 Total Number of Whales Recorded during the James Price Point Migration Corridor Survey.**




Source: RPS, 2010a; **Appendix C-8**.

- **Figure 2.6-3 Distribution and Abundance of Humpback Whales within the James Price Point Migration Corridor Survey Area.**

Note: Data from the entire Migration Corridor Survey was used to calculate percentage bands for all groups sighted. Therefore data is not representative of any one day of surveying, but provides an indication of the location of the main migration corridor.

### Dugongs

Dugongs are marine mammals associated with tropical and sub-tropical coastal waters, in particular shallow protected areas such as sheltered bays, mangrove channels and in the lee of large inshore islands. The habitat features of greatest importance to dugongs are seagrass beds, which are important foraging areas for these animals (DEWHA, 2008a). The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Institute of Marine Science (AIMS) undertook a benthic habitat survey of various locations along the Dampier Peninsula, on behalf of the Northern Development Taskforce, in June 2008. This was further substantiated by benthic habitat modelling undertaken in November 2009 in the James Price Point coastal area (**Appendix C-5**). Results pertaining to seagrass (Fry *et al*., 2008; **Appendix C-4**) are provided in **Table 2.6-2** (refer to **Part 3**, **Section 2.4** (Benthos including BPP)).

- **Table 2.6-2 Results of Western Kimberley Benthic Habitat Surveys Pertaining to Seagrass.**

| Location | Dominant Substratum | Seagrass Presence |
|---|---|---|
| Gourdon Bay (approximately 111km south of James Price Point) | Fine sand. | Relatively wide distribution and high percentage cover of seagrass (*Halophila* sp.) in nearshore areas. |
| Quondong Point to Coulomb Point (includes James Price Point coastal area) | Fine sand (some areas of reef in the northern section). | Seasonally abundant, sparse and patchy distribution of seagrass (*Halophila* sp.) within the entire location with a greater distribution and percentage cover north of James Price Point. |
| Perpendicular Head (approximately 92km north-east of James Price Point) | Fine sand (some areas of rubble in the northern section and some reef inshore of the rubble). | Small isolated patches of seagrass (*Halophila* sp.) in nearshore areas. |
| Packer Island (approximately 126km north-east of James Price Point) | High and low reef with coarse sand in between. | Small isolated patches of seagrass (*Halophila* sp.) in nearshore areas. |

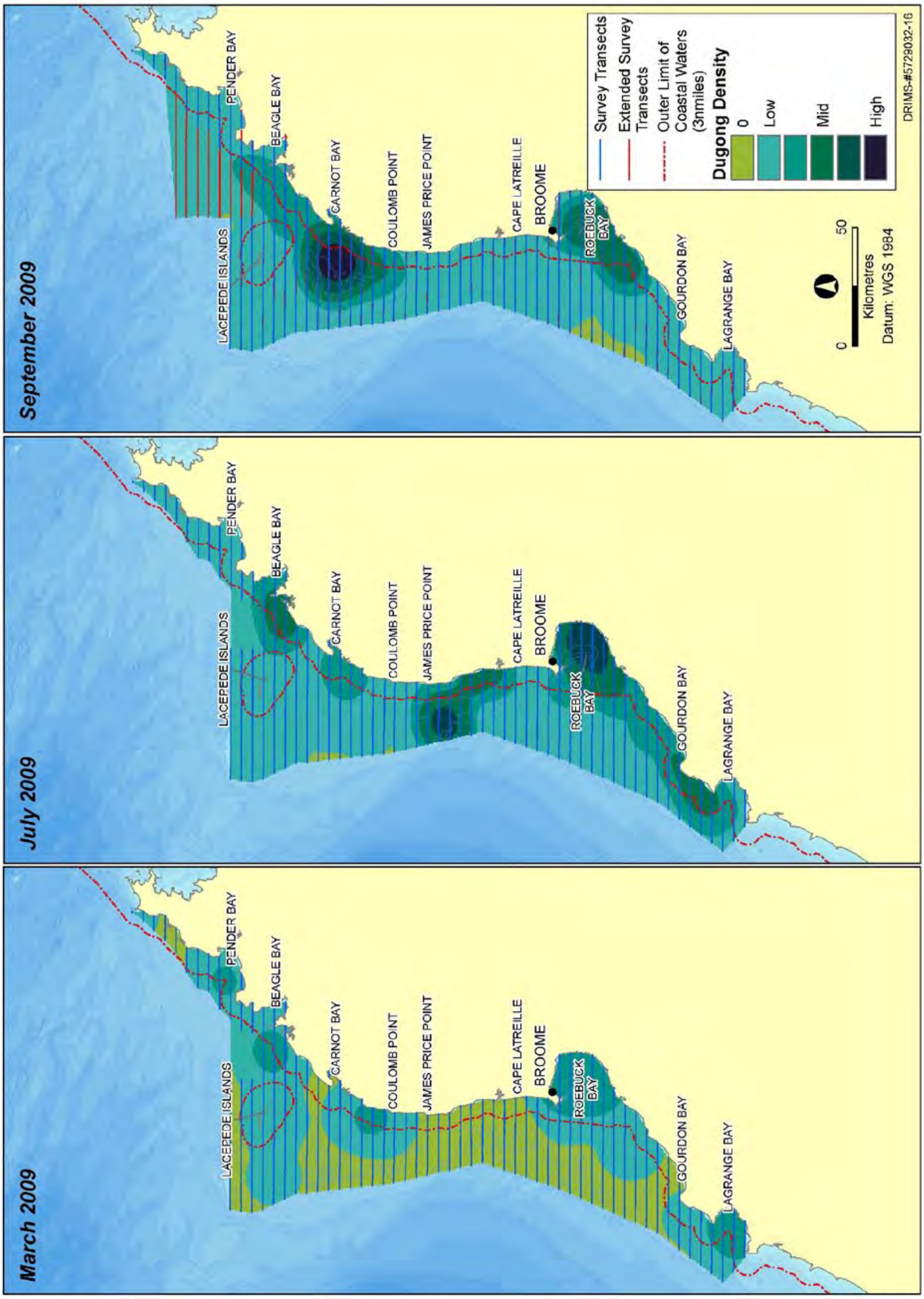
Source: Fry *et al*. 2008; **Appendix C-4** (June 2008) and SKM, 2010a; **Appendix C-5**.

The James Price Point coastal area, being within the Quondong Point to Coulomb Point location detailed in **Table 2.6-2**, has not been found to support any extensive seagrass beds. In comparison, Roebuck Bay (approximately 66km south of James Price Point) supports extensive *Halophila ovalis* and *Halodule uninervis* beds, seagrass species known to be favoured foraging habitats by dugongs (RPS, 2010c; **Appendix C-9**).

Consistent with these results, megafauna surveys (RPS, 2010d; **Appendix C-10**) found Roebuck Bay to support the most stable and highest population of dugong adults and calves within the survey region. Areas inshore of the Lacepede Islands (off Beagle Bay) and around Carnot Bay also appear to be areas important for dugongs based on relative densities (**Figure 2.6-4**) (RPS, 2010c; **Appendix C-9**).

Megafauna surveys (SKM, 2009c and RPS, 2010d; **Appendix C-10**) determined that the density of dugongs within the Dampier Peninsula nearshore survey area ranged from 0.1/km$^2$ (March survey) to 0.19/km$^2$ (July survey) (**Figure 2.6-4**). The higher densities are slightly lower than those previously recorded in Exmouth Gulf (0.24/ km$^2$) but substantially lower than those recorded in Shark Bay (0.64/km$^2$) (RPS, 2010c; **Appendix C-9**). In March, dugongs were mainly concentrated in Roebuck Bay, while during July 2009, dugongs occurred throughout the region, mostly in Roebuck Bay, offshore from James Price Point, Carnot Bay and south of Beagle Bay. Higher densities of dugongs were apparent in July, approximately 15km offshore from Quondong Point, between the 10 and 20m isobaths. It is expected that these animals were transiting the area. The September 2009 survey found dugongs concentrated in Roebuck Bay and Carnot Bay (**Figure 2.6-4**) (RPS, 2010c; **Appendix C-9**).

Past surveys have indicated that the Dampier Peninsula supports a transient population of dugongs that migrate past James Price Point coastal area, between more commonly used areas such as Beagle Bay and Montgomery Islands (approximately 283km from James Price Point) (Prince, 1984). Migratory links to other areas have also been confirmed by satellite tagging by Campbell and Holley (2010); a dugong tagged at Beagle Bay travelled almost 500km south to a location off the coast at Port Hedland. In 2009, three aerial surveys (RPS, 2010c; **Appendix C-9**) provided a dugong population estimate along the Dampier Peninsula between Cape Leveque and Lagrange Bay (134km south James Price Point) of approximately 930 to 1774 dugongs. It is evident from these surveys that a significant proportion of the Kimberley dugong population undertakes regional scale migration and tagging data suggests that dugong populations probably shift between the Dampier Peninsula (Roebuck Bay to Beagle Bay) depending on the time of year (RPS, 2010c; **Appendix C-9**).




Source: RPS, 2010c; **Appendix C-9**.

- **Figure 2.6-4 Dugong Densities along the Dampier Peninsula during March, July and September 2009.**

### 2.6.2. Identification of Key Aspects

#### 2.6.2.1. Definition of Relevant Aspects

Aspects associated with the development and operation of the BLNG Precinct and associated infrastructure that may have an environmental impact on marine mammals were identified in the Scope of the Strategic Assessment and considered in the assessment. These aspects include:

- marine noise and vibration;
- sediment deposition and turbidity;
- marine site disturbance and excavation;
- marine discharges; and
- vessel movements.

The following aspects, though listed in the Scope of Strategic Assessment as relevant to this factor, have been deemed not significant and therefore will not be addressed in the following sections:

- Light emissions- Humpback whales and dugongs predominantly utilise acoustic senses to monitor their environment rather than visual sources (Simmonds *et al.,* 2004), additionally dugongs are known to have poor eyesight (NTSC, 2010). Light is not considered to be a significant factor in humpback and dugong behaviour or survival and it is unlikely that marine mammals will be attracted or disoriented by anthropogenic lighting from the BLNG Precinct.
- Invasive marine species (IMS) - The potential introduction of IMS into the James Price Point coastal area is unlikely to significantly impact marine mammals. Impacts associated with the introduction of IMS are most likely associated with a reduction in local ecosystem integrity. The introduction of IMS is unlikely to impact the food availability of cetaceans, which feed primarily on krill and schooling fish. It is acknowledged that there is a risk of IMS impacting local seagrass communities. As the introduction and subsequent spread of the invasive marine algae, *Caulerpa taxifolia* in the Mediterranean resulted in a significant impact on *Posidonia oceanic* seagrass densities (de Villéle & Verlaque, 1995). However, the seagrass communities within the James Price Point coastal area are highly seasonally distributed and very patchy. In addition, the high biodiversity and low endemism exhibited by the biota within this region may inhibit the successful colonisation of an introduced or invasive marine species through competitive exclusion by native species. Hutchings *et al.* (2002) use the low numbers of IMS recorded within Queensland Ports in comparison to ports in southern Australia and New Zealand as justification for this hypothesis.

#### 2.6.2.2. Sources of Potential Impact

**Marine Noise and Vibration**

The construction and operation of the BLNG Precinct will include activities that will emit underwater noise and vibration above background (ambient) levels. The marine activities that are considered to be the most noise intensive sources are nearshore blasting and piling works.

Details of the source of potential impact for marine noise and vibration are provided in **Section 2.5.3.2** (Fish).

**Sediment Deposition and Turbidity**

A number of marine construction activities including dredging, dredged spoil disposal, export jetty installation, breakwater construction and pipeline shore approach installation will result in the disturbance of marine sediments, leading to increased turbidity and sediment deposition rates (see **Appendix C-13**).

The most significant sediment deposition and turbidity generating activities will be the operations required to dredge access channel/s, turning basin/s and berth pockets and associated spoil disposal, including the propeller wash that may be caused by vessels manoeuvring in shallow areas close to sensitive habitats.

**Marine Site Disturbance and Excavation**

The construction of the BLNG Precinct marine infrastructure will require the dredging of the approach channel and turning basin, LNG export jetty installation, breakwater construction and pipeline trenching. It is anticipated that the LNG export facilities within the BLNG Precinct will require approximately one berth for every 10 Mtpa of LNG production.

Consequently, export facilities will be phased in line with the precinct production capacity, with approximately six berths anticipated for a 50 Mtpa LNG Precinct. Preliminary estimates indicate that the total dredging volume for the nearshore infrastructure is in the order of 10 to $18Mm^3$ based on conceptual site layout options shown in **Part 2**, **Section 5** (Description of Activities and Facilities under the Plan). Dredged spoil material is likely to be disposed of at an offshore dredge spoil disposal site and therefore the modelling and assessment has taken this activity into account.

**Marine Discharges (including non routine discharges)**

Wastewater routinely discharged is likely to include process water, brine from desalination, produced formation water, stormwater, grey water and treated sewage. These waste streams would be controlled within the Precinct facilities and be discharged to the nearshore marine environment via an ocean outfall. In addition, there is the potential that hydrocarbons or chemicals (i.e. LNG, LPG, condensate, bunker fuel, diesel or monoethylene glycol) may be released into the marine environment through spillages from storage tanks, product pipelines or tankers.

**Vessel Movements**

Construction and operation of the BLNG Precinct would result in an increased number of vessels. During construction, vessels would be required to undertake preparatory nearshore works. Vessel activity would be distributed over the entire construction period, and at the height of construction, the number of vessels that are likely to be active could be in the order of 40 at any one time (**Table 2.6-3**). However, the majority of the construction activities would require vessels to be stationary (e.g. during piling and drilling activities) or moving at slow speeds (e.g. dredging, pipe laying). Vessel movements at higher speeds (e.g. greater than 10kn) would predominantly be limited to vessel transits between areas (e.g. between the BLNG Precinct, marine supply base, other regional ports and/or spoil disposal grounds).

During operations, the most significant vessel traffic would be the regular movements of LNG, LPG and condensate tankers and the movements of associated support vessels to aid in the berthing of the tankers in and out of the marine port facilities (**Table 2.6-4**).

- **Table 2.6-3 Approximate Number and Types of Vessels Likely During Construction of the Nearshore Marine Facilities.**

| **Construction Phase (assume all work occurring simultaneously)** | |
|---|---|
| Piling | 3 x piling barges operating at the same time.<br>1 x spud barge with tug tow used to deliver piles and materials to the jack up barges for piling (assume these are somewhere within the BLNG Precinct Port area) |
| Dredging | 1 x Cutter Suction Dredge 15% of time<br>2 x Trailer Suction Hopper Dredge 100% of time<br>Assume dredging support vessels/barges operating at same time:<br>Backhoe dredge barge (~9,000t)<br>Drill and blast barge (~9,000t)<br>2 x multicat barge (~3,000t)<br>Survey vessel (~ 500t)<br>2 x sweep barge (~1,500t)<br>2 x fuel barge (~3,000t)<br>2 x service boats (~ 100t)<br>Assume the other vessels associated with dredging are within the BLNG Precinct Port area, in the vicinity of the two dredges |
| Rock Dumping | 1 x Fallpipe rock dumping vessel (~40,000t)<br>1 x side dump rock dumping vessel (~2,0000t)<br>1 x Survey boat (~100t)<br>1 x Supply boat (~500t) |
| Heavy Lift Vessels | 1 x 12000t Roll On Roll Off (RORO) ship per<br>1 x general cargo ship (~9,000t) every 5 weeks<br>1 x chartered cargo ship (~9,000t) every 3 weeks |
| Material import barges | 1 x Barge delivering piles (~8,000t)<br>1 x Cargo barge (~9,000t)<br>1 x Landing craft (3,000t)<br>2 x Tugs (~500t)<br>1 x fuel barge/week (~3,000t) |
| Pipelay | 1 x Pipelay barge (~60,000t) – anchored<br>2 x anchor handling tugs (~500t)<br>1 x pipe barge tug (~500t)<br>1 x survey vessel (~1,000t)<br>2 x supply vessels (~1,000t)<br>1 x crew transfer vessel (~100t) |
| Tunnelling | 1 x Jackup barge<br>1 x Crane barge (~150t)<br>Anchor handling tugs (~500t) |
| Other vessels | 5 x miscellaneous small vessels (100-500t) (e.g. environmental survey vessels). |

- **Table 2.6-4 Provisional Number and Types of Vessels during Operations.**

| Operations Phase Vessels |
|---|
| 2x LNG Carriers per day (assume both loading) |
| 1x condensate tanker every 2 days |
| 4 tugs per carrier |
| 2 x supply boats |
| 1 x fuel/chemical import |

### 2.6.2.3. Sensitivity and Resilience

**Marine Noise and Vibration**

High intensity impulsive noise emitted during blasting and piling overlaps the frequency range of hearing in cetaceans and dugongs and has the potential to cause temporary threshold shift (TTS) or permanent threshold shift (PTS) in the hearing of individuals at close ranges, as well as behavioural disturbance at further distances. The continuous noise emitted from vessels and construction-related activities (such as dredging, pipe laying) would be at levels less than that considered to affect hearing, but may have the potential to cause behavioural responses (Southall *et al.,* 2007).

Cetaceans are known to have an acute acoustic sense and to be sensitive to noise variations propagating through the marine environment. Sound is a prime mechanism for communication, navigation and foraging (DEWR, 2007). Cetaceans are sub-divided into three hearing categories based on their hearing frequency ranges: low frequency (baleen whales such as humpbacks), mid and high-frequency (toothed whales such as dolphins and sperm whales) (Southall *et al.,* 2007).

Based on vocalisation frequencies, functional hearing in humpback whales has been estimated to be between 0.007kHz and 22kHz (Southall *et al.,* 2007 and Weilgart, 2007). This is advantageous because these lower frequencies travel further through water than higher frequencies, enabling cetaceans to communicate over much greater distances (Tyack, 2008). Humpback whales produce a complex set of vocalised song patterns. The spectrum of the patterns has been measured to be between 20 and 24000Hz with maximum peak to peak source level of 184dB re 1µPa @ 1m (Au *et al*., 2006). In the absence of measured audiograms for humpback whales, it can be assumed that this bandwidth and source level is indicative of the whales' auditory bandwidth and auditory sensitivities.

Sound level thresholds above which injury (PTS), TTS or behavioural disturbance may occur vary widely between species and potentially between individuals of the same species (Southall *et al.,* 2007). **Table 2.6-5** summarises available information on threshold levels of sound that may result in injury or behavioural disturbance to low frequency cetaceans such as humpback whales. The threshold for behavioural response represents the level at which a moderate behavioural response may occur, such as changes in swimming speed, direction and dive profile; localised deviations in migratory patterns; displacement from foraging or resting areas; brief to moderate shift in group distribution; short term cessation or modification of vocal behaviour, and brief separation of females and offspring (McCauley *et al.,* 2000; Southall *et al.,* 2007; Tyack, 2008; and Weilgart, 2007). For example, a decline in the number of humpback whale cows and calves present in inshore Hawaiian waters was attributed to high levels of boating activity and aircraft (Glockner-Ferrari & Ferrari, 1985).

In general, hearing capabilities of dugongs are poorly understood and are based on anecdotal observation and extrapolation from data on closely related manatee species. Data for the West Indian and Amazon manatees indicate a hearing range of approximately 0.1kHz to 40kHz. Peak sensitivity has been reported from 1.5kHz to 16kHz (Wartzok & Ketten, 1999). The hearing frequency range for Dugongs is thought to range from a few Hz up to 180kHz, with the most sensitive range between 1kHz and 8kHz.

There is a lack of scientific data specific to dugongs for determining injury and behavioural disturbance as a result of underwater noise. There is anecdotal evidence that vessel generated noise may result in displacement of dugongs from parts of their habitat (Preen, 2001). The disturbance is likely to be significant if persistent or heavy boat traffic occurs through nutritionally important seagrass habitats, as restricted food availability can ultimately reduce dugong fecundity (Preen & Marsh, 1995). Dugong herds have been seen to respond to vessels at distances from less than 50 to more than 500m and individual dugongs have been seen to stop feeding when vessels approached to within 50m of them (Hodgson, 2004).

**Sediment Deposition, Turbidity, Marine Site Disturbance and Excavation**

Information regarding direct impacts of increased turbidity on marine mammals has not been identified from a review of published literature. However, humpback whales and dugongs are not anticipated to be adversely affected by localised and short term increases in turbidity. These species predominantly utilise acoustic senses to monitor their environment rather than visual sources (Simmonds *et al*., 2004), dugongs are known to have particularly poor eyesight (NTSC, 2010). In addition, these species are migratory and are generally transiting past the James Price Point coastal area, therefore their exposure to sediment deposition and turbidity impacts will be limited.

The loss of seagrass foraging habitat has been identified as a potential threat to dugongs (Marsh *et al.,* 2002). However, studies have shown that dugongs are capable of relocating in response to temporary losses in foraging habitats following perturbations. Studies in Hervey Bay in Queensland indicated that dugongs migrated in search of suitable seagrass habitat following the loss of 1,000km$^2$ of feeding habitat caused by a cyclone (Preen & Marsh, 1995, Marsh & Lawler, 2001). Similarly, during tropical cyclone Vance in 1999, dugongs were shown to migrate south from Exmouth Gulf to Shark Bay (Gales *et al*., 2004). Despite many dugongs successfully relocating after the sudden loss of the majority of the Hervey Bay seagrass beds (Preen *et al*., 1995), numerous dugong carcasses were recovered, most having died 6–8 months after (Preen & Marsh, 1995) which may have been due, in part, to reduced food availability. However, the scale of sedimentation is not predicted to cause a loss of seagrass significant enough to displace dugongs.

**Marine Discharges**

There have been limited studies into the impact of elevated salinity, decreased dissolved oxygen or the physiological effects of pollutants such as heavy metals on marine mammals. It is thought that large (greater than ten units increase from ambient) changes in salinity can affect an organism's ability to osmoregulate, leading to physiological damage and likely mortality (Diaz and Rosenberg, 1995). Potential effects from trace metals and residual hydrocarbons include physiological damage that may be either temporary or permanent, depending on the concentration and duration of exposure. Short-term exposure may result in the ingestion of hydrocarbons while marine mammals are breathing on the surface, they may also experience eye irritations. Long-term exposure depending upon the amount and composition of the hydrocarbon ingested could range from acute, to subtle to progressive organ damage (AMSA, 2010). Long term exposure to heavy metals and hydrocarbons can potentially result in bioaccumulation of these toxins in the tissue of marine mammals. There is evidence of bioaccumulation of metals in the liver and blubber tissue in dugongs through their diets (Haynes *et al.,* 2005 and Harino *et al.,* 2007). Concerns have been raised about bioaccumulation in traditional indigenous foods such as dugongs and potential risk to the health of indigenous communities. Evidence suggests that frequent turtle (and possibly dugong) liver and kidney and wild clam consumption is linked to higher urinary cadmium levels among Torres Strait Islander women (Haswell-Elkins *et al.,* 2007).

**Vessel Movements**

Although vessels of all sizes and types have the potential to strike cetaceans, most lethal and serious injuries to large cetaceans (i.e. humpback whales) are caused by relatively large vessels (e.g. >80m in length) travelling at speeds of 13kn or more (Laist *et al*., 2001). Large whales are more vulnerable to vessel collisions, particularly those species whose behaviour includes extended surface 'milling' time (Laist *et al.,* 2001) and which demonstrate a lack of avoidance behaviour to approaching vessels (Nowaeck *et al*., 2004). Cetacean calves and juveniles also have a higher risk of impact (Stevick, 1999), possibly due to less frequent and shorter dives (Szabo and Duffus, 2007). A comprehensive review of ship strikes on large whales by Jensen and Silber (2003) revealed that humpback whales were the second highest reported species struck (44 records). It was noted that coastal species (e.g. humpback whales) may have been over represented within the database due to the likelihood of these whales (i.e. carcasses) being sighted within this zone rather than potential victims struck further from shore. Nevertheless, the database clearly depicts that humpbacks do suffer from adverse vessel interactions.

Large cetaceans including humpback whales demonstrate a variety of behaviours in response to approaching vessels (attributed to vessel noise), including longer dive times and moving away from the vessel's path with increased speed (Baker and Herman, 1989 and Scheidat *et al.,* 2004). These behavioural characteristics, in addition to the implementation of management and mitigation measures (refer to **Section 2.6.4**), will significantly reduce the likelihood of a vessel strike on humpback whales.

Slow moving species such as dugongs and in particular calving females are most at risk of adverse vessel interaction due to their lack of capacity to rapidly alter course (Vanderlaan & Taggart, 2007).

Dugongs typically spend the majority of time submerged, surfacing on average every 1-4 minutes (Anderson & Birtles, 1978; De Iongh *et al.,* 1997; and Cox, 2002) and typically spending less than 5% of the time resting on the surface (Hodgson, 2004). Because of their size, dugongs are susceptible to injury or mortality resulting from interaction with vessels, particularly when they rise to the surface to breathe rest or forage in shallow waters. One of the primary responses of dugongs to approaching vessels is to move towards deeper water (Hodgson, 2004).

Dugongs are vulnerable to shallow draft vessel impact as their specialist diet largely restricts them to shallow nearshore seagrass beds where boat traffic is often concentrated. Also, in comparison to some cetacean species, dugongs exhibit a relatively slow response to approaching boats. Mother and calf pairs are at greatest risk as calves often situate themselves above the mother's back in closest proximity to the surface (Hodgson, 2004).

The main factor to consider in the assessment of strike risk is whether dugongs can detect boats at a distance that allows them to evade collision with detection determined by hearing ability and the propagation of vessel noise. The frequency range of dugong hearing and their ability to locate the direction of sound (and thus to flee the vessel's path) is unknown, but may be determined by hearing, sight or pressure waves sensed by dorsum hairs (Anderson, 1982; Hodgson, 2004).

### 2.6.3. Predicted Impacts

The predicted impacts on marine mammals from the construction and operation of the BLNG Precinct are discussed in detail in the following sub-sections, and summarised in **Table 2.6-11**.

Both direct and indirect impacts are considered within these sections. For the purpose of this assessment it is considered that direct impacts would largely be confined to areas of direct disturbance within the BLNG Precinct Port area, and other locations where the majority of development activities are proposed to occur. The primary focus of the impact assessment is on humpback whales and dugongs due to their periodic abundance offshore from James Price Point and their conservation status.

#### 2.6.3.1. Marine Noise and Vibration

**Impact Assessment**

As detailed in **Section 2.5.4.4** a noise modelling study of the underwater noise associated with the construction activities for the proposed precinct was undertaken to support this assessment (SVT, 2010; **Appendix C-12**).

The assessment primarily uses the thresholds (or criteria) defined in Southall *et al.* (2007) for physical injury and behavioural disturbance as a guide for predicting potential impacts to marine mammals from noise related to construction activities. The injury criteria for marine mammals and signal types (i.e. single pulses, multi-pulses and non-pulses) are divided into received peak pressure level and sound exposure level (SEL). These criteria mark the expected onset of permanent threshold shift (PTS). The Southall *et al.* (2007) physical injury criteria are based on experiments conducted on mid frequency cetaceans (i.e. beluga whales and bottlenose dolphins). Due to the lack of data for low frequency cetaceans (i.e. humpback whales), the criteria for mid frequency mammals is recommended as a conservative threshold by Southall *et al.* (2007) to be also used for low frequency cetaceans.

The SEL criteria in **Table 2.6-5** for possible physical injury are weighted for the frequencies likely to be audible to low frequency cetaceans (Southall *et al.,* 2007). However, as most of the energy of the noise sources considered in this assessment are within the frequency range to which low frequency cetaceans are most sensitive, this assessment takes a conservative approach by considering the SEL criteria for possible physical injury as un-weighted.

Behavioural responses to sound are highly variable and context-specific, and the available data for marine mammals, including humpback whales and dugongs, do not converge on specific exposure conditions resulting in particular reactions, nor do they point to a common behavioural mechanism (Southall *et al*., 2007).

For impulsive noise sources, EPBC Policy Statement 2.1 recommends a threshold SEL of 160dB re 1μPa$^2$.s to minimise the risk of TTS in whales from seismic surveys. In the absence of data specific to marine blasting and pile driving, an SEL of 160dB re 1μPa$^2$.s will be used as a threshold in this assessment for minimising TTS. Seismic pulses are different both in spectrum and time to pile driving pulses, therefore the threshold for this assessment has been adjusted for the expected pulse frequency of pile driving (SVT, 2010; **Appendix C-12**).

Noise levels for impulsive noise sources at which significant behavioural disturbance may occur remain unclear. A transient behavioural response to a single pulse is unlikely to result in demonstrable effects on individual growth, survival, or reproduction. Consequently, the onset of TTS may be a suitable disturbance criterion as it can be assumed that significant behavioural disturbance might occur if noise exposure is sufficient to have a measurable transient effect on hearing (i.e. TTS-onset). This approach is expected to be precautionary because TTS at onset levels is unlikely to last a full diel cycle or to have serious biological consequences during the time TTS persists (Southall *et al*., 2007).

For all other sound types than single pulses, it is likely that significant behavioural effects will occur more commonly at levels below those involved in temporary or permanent losses of hearing sensitivity. Available information on behavioural disturbance from multiple pulse sources (such as pile driving) is based on response to seismic activity and does not converge on clear criteria for significant behavioural disturbance. For example, an aerial survey studying the response of migrating bowhead whales to seismic signals found the onset of significant behavioral disturbance to occur at received levels (RMS over pulse duration) around 120dB re 1µPa (Richardson et al., 1999). However, other studies have found this onset to occur at received levels from 140 to 160dB or above (e.g. McCauley *et al*., 1998; McCauley *et al*., 2000; Miller *et al*., 2005; and summarised in Southall *et al*., 2007).

There has been relatively extensive behavioural observation of whales and dolphins exposed to continuous (non-pulse) noise sources. The combined information generally indicates no (or very limited) responses at received levels of 90 to 120dB re 1µPa and an increasing probability of avoidance and other behavioural effects in the 120 to 160dB re 1µPa range. However, these data also indicated considerable variability in received levels associated with behavioural responses (summarized in Southall *et al*., 2007). Contextual variables (e.g. source proximity, novelty, operational features) appear to be at least as important as exposure level in predicting response type and magnitude. For the purposes of this assessment, for non-pulse signals such as vessel movements, the criteria for behavioural disturbance is taken as a SPL of 120dB re 1µPa (RMS) from the literature.

There is a lack of scientific data specific to sirenians (i.e. dugongs) for determining injury and behavioural disturbance as a result of underwater noise, therefore the criteria for cetaceans were applied to dugongs in this assessment.

- **Table 2.6-5 Received Threshold Levels for Peak Pressure, RMS Sound Pressure Level (SPL) and SEL above which there could be a Possibility of Physical Injury or Behavioural Effect for Cetaceans and Dugongs.**

| Metric | Possible Physical Injury | | Possible Behavioural Disturbance | |
|---|---|---|---|---|
| | Single/Multiple pulses | Non-pulses | Single/Multiple pulses | Non-pulses |
| Peak Pressure | 230dB re 1µPa[1] | 230dB re 1µPa[1] | 224dB re 1µPa[1] | Not applicable |
| RMS SPL | Not applicable | Not applicable | Not applicable | 120dB re 1µPa[1] |
| SEL | 198dB re 1µPa$^2$.s[1] | 215dB re 1µPa$^2$.s[1] | 160dB re 1µPa$^2$.s [2] | Not applicable |

Source: SVT, 2010; **Appendix C-12**.

**Prediction of Noise Impact**

The contour plots shown in **Section 2.5** (Fish) are for a receiver depth of 2m below the sea surface. The scenarios under both Mean Sea Level (MSL) and Highest Astronomical Tide (HAT) were modelled. Only the results for of HAT are presented as it represents the worst case scenario. The plots of the piling and blasting (**Figure 2.5-2** to **Figure 2.5-4,** in **Section 2.5**) activities are shown as these represent the noise emissions with most potential for physiological or behavioural impacts on marine mammals. The plots are presented to give an indication of the sale of the noise emission propagation for these selected activities. The results of which are discussed in the individual biota sections below. Two plots are shown for pile driving, representing different time periods of exposure. **Figure 2.5-2** represents an exposure of 10 seconds to pile driving from three barges operating simultaneously, whereas **Figure 2.5-3** represents an exposure of three hours within a 24 hour period. The figures clearly demonstrate that the sound exposure level (SEL) for a given distance from source increases with length of exposure.

[1] Southall *et al* (2007).
[2] EPBC Act Policy Statement 2.1, recommended criteria for minimising risk of TTS from impulsive noise (seismic).

Zones of possible behavioural disturbance and possible physical injury were assessed based on received threshold levels detailed in **Table 2.6-5**. Peak pressure levels for pile driving noise and marine blasting noise were estimated using an empirical formula[3].

**Table 2.6-6** and **Table 2.6-7** define the zones of possible TTS/behavioural disturbance and possible injury for whales, dolphins and dugongs for the activities modelled, based on the furthest distances from source at which the received levels are equal to the threshold level defined in **Table 2.6-5**. Both pile driving and marine blasting operations may cause physical injury and/or permanent hearing damage; temporary threshold shift; masking of biologically important sounds and/or behavioural disturbance in certain zones. While for dredging operations and vessel movements, impacts are likely to be restricted to potential masking and behavioural disturbance.

- **Table 2.6-6 Furthest Distance to Zones of Potential TTS and Potential Physical Injury at Sea Level of HAT for Impulsive Noise Sources.**

| **Modelling Scenarios** | **Furthest Distance from Source to Zone of Potential TTS (m)** | **Furthest Distance from Source to Zone of Potential Physical Injury (m)** |
|---|---|---|
| Pile Driving – Near Marine Facility | 250[4] | 60[5] |
| Marine Blasting – Near Marine Facility | 200[6] | 25[6] |

- **Table 2.6-7 Furthest Distance to Zones of Potential Behavioural Disturbance and Potential Physical Injury at Sea Level of HAT for Continuous Noise Sources.**

| **Modelling Scenarios** | **Furthest Distance from Source to Zone of Potential Behavioural Disturbance (m)** | **Furthest Distance from Source to Zone of Potential Physical Injury (m)** |
|---|---|---|
| Cutter/Trailer Suction Dredging – End of Dredging Channel | 550[11] | -[7]/ 5[8] / 15[9]/ 75[10] |
| Cutter/Trailer Suction Dredging – End of Dredging Channel near Marine Facility | 500[11] | -[7]/ -[8] / 10[9]/ 50[10] |
| Fallpipe Rock Dumping Vessel – End of Dredging Channel | 450[11] | - |
| Fallpipe Rock Dumping Vessel – End of Dredging Channel and Near Marine Facility | 400[11] | – |

### Humpback Whales

High intensity impulsive noise emitted during blasting and piling would overlap the frequency range of hearing in humpback whales and has the potential to cause physiological injuries (PTS) at close ranges (**Table 2.6-6**). The continuous noise emitted from vessels and constructed related activities (i.e. dredging, pipe laying), whilst overlapping the frequency range of hearing in humpback whales, would be at levels less than that considered to cause physiological injuries (**Table 2.6-7**), but may have the potential to cause behavioural responses.

Humpback whales would be present off the Dampier Peninsula during the northerly and southerly migration periods, with

[3] $SPL_{peak}=SEL+10*\log(T_1/T_2)+6$, where $T_1$=1s and $T_2$=duration of impulsive signal.
[4] Based on SEL of a 10 second period.
[5] Based on SEL of a single piling strike of around 90ms.
[6] Based on received peak pressure level of a single blasting pulse.
[7] Based on continuous exposure over a 30 minute period.
[8] Based on continuous exposure over an hour period.
[9] Based on continuous exposure over a 3 hour period.
[10] Based on continuous exposure over a 24 hour period.
[11] Based on SPL rms of 120 dB re 1μPa.

the majority of animals (95%) migrating at a distance of at least 8km off the coast, which is a further 1.5km from the BLNG Precinct Port area, with adults and calves travelling a mean distance of 27km and 24km from the coast line respectively. At this distance, noise emitted from blasting and piling activities would be significantly less than that considered to cause any physiological impacts (**Table 2.6-6**). Additionally, avoidance behaviour initiated as a result of the noise generated from these activities and the other lower intensity activities would minimise the potential risk of any individuals actually moving close enough for any potential physiological impacts. **Table 2.6-6** and **Table 2.6-7** summarise the maximum distances for the construction activities modelled and the zones of possible TTS/behavioural disturbance and possible injury for marine mammals.

Blasting and piling activities are likely to emit noise levels above the TTS threshold levels defined in **Table 2.6-5** for up to 200m and 250m from the BLNG Precinct respectively. The higher intensity impulsive noises emitted from these activities have the potential to cause a more significant behavioural response in humpback whales compared to vessel noise. However, these activities would be limited to the BLNG Precinct Port area. Noise emitted during these activities is likely to result in only the localised displacement of humpback whales from the BLNG Precinct Port area.

Activities that may extend outside of the BLNG Precinct Port area, include large vessel movements, which are likely to traverse the humpback whale migration path, during the migration period (i.e. June to September). These vessels emit a relatively low intensity continuous noise (source levels of 135-180dB re 1µPa @ 1m) (OSB, 2003 and Galli *et al.,* 2003) during transit. Humpback whales may demonstrate avoidance of these vessels, although no significant behavioural changes are expected. Established and busy shipping lanes and areas of significant vessel movement, along the Western Australian coastline (e.g. Dampier Port and Port Hedland), currently pass through the humpback whale migratory route, with no reported detriment to humpback whale population movements or distribution.

In summary, the high intensity impulsive noise generated from blasting and piling that may have the potential to cause physiological impacts would be restricted to the BLNG Precinct Port area. Those activities that may also occur beyond the Precinct area (i.e. vessel movements and pipeline laying) would only generate relatively low intensity noise that is considered unlikely to cause any physiological impacts to humpback whales. The data from the 2009 aerial surveys demonstrating the abundance of humpback whales within the James Price Point migration corridor survey area (i.e. incorporating the James Price Point coastal area), indicates that approximately 650 individuals (out of a total population of 21,750 (95% CI: 17,550-43,000) Group IV humpback whales (Hedley *et al*., 2009)) may migrate through the James Price Point coastal area (i.e. Coulomb Point to Quondong Point) during the migration season (**Figure 2.6-3**). Consequently, construction and operational activities are unlikely to have a significant impact on humpback whales.

**Dugongs**

Dugongs may potentially be present in the BLNG Precinct Port area and exposed to marine noise associated with construction activities. For blasting and piling, at close ranges (<25m and 60m respectively) there is a potential for individuals to be exposed to levels that could result in physical injury (based on thresholds developed for cetaceans, **Table 2.6-5**) and **Table 2.6-7**). However high intensity impulsive noise activities during construction are likely to result in the localised avoidance of individuals from the BLNG Precinct Port area, thus minimising the risk of exposure. For blasting, based on modelling results (SVT 2010), an animal would need to be within 200m of the blast origin for exposure to exceed 160dB re 1µPa @ 1m and thus have an increased risk of TTS (**Table 2.6-7**). For pile driving, the zone for potential TTS for an exposure of 10s to the modelled activity has been calculated to be 250m. The size of this zone will increase with the duration of exposure (**Figure 2.5-2** and **Figure 2.5-3** in **Section 2.5 Fish**), however it is expected that dugongs would exhibit avoidance of this wider zone before exposure results in TTS.

The BLNG Precinct Port area is not considered regionally significant for dugongs (refer to **Part 3**, **Section 1.1** (Existing Marine Environment)), and the wider Dampier Peninsula supports established populations. Therefore, it is likely that any dugongs displaced from the BLNG Precinct Port area would find suitable habitats within the wider Kimberley region during the construction period, and that this displacement would not have a significant impact on the dugong population on a local and regional level.

It is possible that marine noise and vibration arising from development activities may result in a localised behavioural response by individual marine mammals in the vicinity of the BLNG Precinct. However, no detectable decreases in abundance or lasting effects on population are likely to occur. Noise impacts due to construction activities would be managed through a Port Facilities Construction Environmental Management Plan which would include a range of measures to manage marine mammal interactions such as use of warning charges and soft-start piling, where

#### 2.6.3.2. Sediment Deposition, Turbidity, Marine Site Disturbance and Excavation

*Humpback Whales*

There is no evidence to support the idea that humpbacks navigate through the use of visual cues and thus an increase in turbidity associated with dredging is unlikely to cause behavioural responses. Humpback whales are thought to rely on acoustic senses for navigation and to monitor their environment, rather than visual sources (Simmonds *et al.*, 2004). Therefore, humpback whales are not likely to demonstrate a behavioural or physiological response to a reduction in water quality associated with increased suspended sediments or sediment deposition.

Humpback whales may be adversely affected by vessel movements associated with marine site disturbance and construction activities, vessel movement impacts are discussed in further detail below. It is not anticipated that any other impacts associated with marine site disturbance and excavation activities would affect humpback whales, as works are expected to be localised and largely contained within the BLNG Precinct Port area.

*Dugongs*

Similarly, dugongs are not likely to be impacted by a reduction in water quality associated with increased suspended sediments or sediment deposition. Such species are well adapted to low visibility turbid environments, reflected by their occurrence in Roebuck Bay, which has frequent occurrence of turbid waters.

Site disturbance and excavation would result in the direct removal of benthic habitat within the footprint of the BLNG Precinct nearshore marine facilities. This may indirectly impact dugongs through a subsequent loss of foraging habitat. In addition, the reduction in benthic light availability is predicted to result in more wide-scale temporary impacts on seagrass (refer **Part 3**, **Section 2.4** (Benthos including (BPP)). However, this temporary loss of seagrass is not expected to significantly impact on the food resource availability for dugongs given the occurrence of seagrass within the wider Canning Bioregion. As discussed earlier, dugongs have been known to relocate to adjacent areas in search of seagrass beds following losses within their home range. This ability was demonstrated through studies in Hervey Bay in Queensland, where dugongs migrated in search of suitable seagrass habitat following the loss of 1,000km$^2$ of feeding habitat caused by a cyclone (Preen & Marsh, 1995, Marsh & Lawler 2001). It is reasonable to infer that, if dugongs do sporadically forage within the James Price Point coastal area and are not dependent or restricted to seagrass patches within this area, they would readily adapt to both seasonal and abrupt changes in available habitat by relocating to nearby areas in the Canning Marine Bioregion or surrounding bioregions.

Further, the number of individuals predicted to occur at any one time within the James Price Point coastal area (i.e. Coulomb Point to Quondong Point) represents less than 1% (up to 16 individuals) of the total population estimated to occur between Cape Leveque and Lagrange Bay. Therefore, the loss of foraging habitat and the potential usage rate within the BLNG Precinct will cause a temporary impact, with no threat to overall population viability and is unlikely to have a significant impact on individual dugongs.

**Summary**

During marine site disturbance activities, there is potential for indirect impacts to marine mammals (primarily dugongs) through the removal of foraging habitat. The consequence of any impact is likely to be minor given the occurrence of seagrass within the wider Canning Bioregion. Therefore the likelihood of impact is low. During operations there will be little disturbance that would create sediment deposition and therefore no significant impact.

It is possible that sedimentation due to site disturbance and excavation activities during construction may impact on individual marine mammals in the vicinity of the BLNG Precinct. The significance of the residual impact is assessed to be low because impacts would be localised, with no detectable impacts to communities and populations.

#### 2.6.3.3. Marine Discharges (including non-routine discharges)

**Impact Assessment**

*Humpback Whales*

Routine marine discharges from the BLNG Precinct facilities and associated vessels would cause a localised reduction in water quality, predominately within the mixing zone. This area of reduced water quality could cause an impact (behavioural or physiological) on marine mammals. BLNG Precinct proponents will be required to demonstrate that

routine wastewater discharges achieve the relevant ANZECC/ARMCANZ water quality guidelines within an agreed mixing zone and undertake regular ecotoxicity testing to target 99% species level of protection beyond the BLNG Port Area. A Wastewater Discharge Management Plan will also be developed, including hydrodynamic modelling and environmental monitoring to ensure these water quality guidelines are achieved, minimising potential environmental impacts associated with a decline in water quality from routine discharges. In addition, the implementation of effective waste treatment/management and industry standard product handling processes is expected to significantly reduce the risk (from non-routine discharges) and impacts (from routine discharges) to humpback whales in the marine environment. The potential for significant water quality decline is low, given the tidal fluxes of the nearshore waters and frequent flushing by strong tidal movements. The impact from routine marine discharge relates to sub-lethal irritation or physiological dysfunction to animals swimming directly through the discharge mixing zone.

Given the low concentrations of contaminants expected in the BLNG Precinct treated wastewater, the high rates of dilution at the points of discharge and the reduced extent of the mixing zone resulting in intermittent exposure of marine mammals to this area, it is highly unlikely that controlled marine discharges will have any impact on marine mammals.

Non-routine events arising from accidental spillages could result in the release of a large volume of LNG, LPG, condensate, diesel or fuel oil. In the event of an LNG spill, there would be a large phase transition as LNG vaporises upon contact with marine waters. Rapid phase transitions occur when the temperature difference between a hot liquid and a cold liquid is sufficient to drive the cold liquid rapidly to its superheat limit, resulting in spontaneous and explosive boiling of the cold liquid (Hightower *et al.,* 2004). Major constituents of LNG will vaporise relatively quickly and therefore any impacts to waters would be short lived.

Whales surface to breathe, at which point they may inhale hydrocarbon fumes that have the potential to cause lung injuries (USEPA, 1999). They may also inhale hydrocarbons directly; resulting in toxicity effects, particularly from the lighter fractions, and may experience eye irritations.

However, the likelihood of such an event is very low, considering the industry standard risk and operations management measures to be implemented. Nevertheless, although the occurrence is unlikely, a large scale spill of LNG within the marine environment would result in temporary reduction in water quality, which may result in physiological impacts or avoidance of the area by humpback whales.

The establishment of the Broome Port Authority as the statutory port authority for the BLNG Precinct will ensure supplies of oil spill response equipment are as required under the State Emergency Management Plan for Marine Oil Pollution (West Plan) to undertake an immediate oil spill response. Major hydrocarbon spills may also require deployment of additional equipment stockpiled in the Fremantle and Dampier ports, or other stockpiles under the National Plan, to minimise the extent of hydrocarbons and reduce potential impacts to sensitive environmental receptors. The oil spill modelling required by future proponents during the derived proposal process will be used to inform a Hydrocarbon and Chemical Spill Contingency Plan, which will be implemented in the event of a large hydrocarbon or chemical spill. An Emergency Response Plan will also be develop outlining emergency response procedures to be implemented by the port authority in the event of an oil spill emergency.

Impacts associated with non-routine spills are minimised as a result of strict industry standards and procedures for product handling and storage and appropriate response planning.

*Dugongs*

Currently there is no information that documents the susceptibility or sensitivity of dugongs to routine and non-routine hydrocarbon spills. It is likely that dugongs may display similar behavioural and physiological characteristics to humpback whales when exposed to marine discharges (including non-routine discharges).

Dugongs may be affected by ingestion of hydrocarbons while they are breathing on the surface and through irritation of the eyes. As with most animals, juveniles are most at risk. Longer term chronic effects may also be experienced when migrating through hydrocarbon contaminated waters. In addition, dugongs are likely to suffer secondary effects from the hydrocarbon spill through habitat disturbance and damage particularly to seagrass habitats.

Given the low concentrations of contaminants expected in the BLNG Precinct treated wastewater, the high rates of dilution at the points of discharge and the reduced extent of the mixing zone resulting in intermittent exposure of marine mammals to this area, it is highly unlikely that controlled marine discharges will have any impact on marine mammals. It

is expected that potential impacts from routine discharges can be successfully mitigated through application of management and mitigation measures such as including appropriate design and location of the discharge infrastructure. A more detailed description of proposed mitigation measures is presented in **Section 2.6.4**. The significance of the residual impact on marine mammals from routine discharges from the BLNG Precinct is assessed as being very low.

Accidental spillages could result in the release of LNG, LPG, condensate, diesel or fuel oil. Large spills are highly unlikely however small spills during construction are possible. In the event of a spill, mammals are expected to only have minimal exposure prior to moving away from the area. It is expected that potential impacts can be successfully mitigated through implementation of an Emergency Response Plan and Hydrocarbon and Chemical Spill Contingency Plan including spill contingency procedures and coordination of proponents in the event of emergency response procedures. A more detailed description of proposed mitigation measures is presented in **Section 2.6.4**. The significance of the residual impact is assessed to be very low.

#### 2.6.3.4. Vessel Movement

*Humpback Whales*

Vessel movement during the construction and operational phases of the BLNG Precinct have the potential to cause injury or mortality to humpback whales as a result of vessel collisions. Vessel collision and vessel disturbance are most likely to occur when vessel activity is highest (during construction) and this coincides with periods of increased marine mammal presence. Although vessels of all sizes and types have the potential to collide with cetaceans, most lethal and serious injuries to large cetaceans (i.e. humpback whales) are caused by relatively large vessels (e.g. >80m in length) travelling at speeds of 13kn or more (Laist *et al*., 2001).

The James Price Point coastal area is not recognised as a humpback aggregation area, however, it does host whales transiting through the offshore area during the migration period. The movement of vessels through whale migratory routes does create a potential risk of vessel collision. During the migration period (approximately June to October each year), there may be an overlap between high densities of humpback whales (peak abundances occur between August to September) and vessels operating in and transiting across the main migration corridor (e.g. vessels associated with pipelay, dredging, rock supply, rock dumping and module delivery).

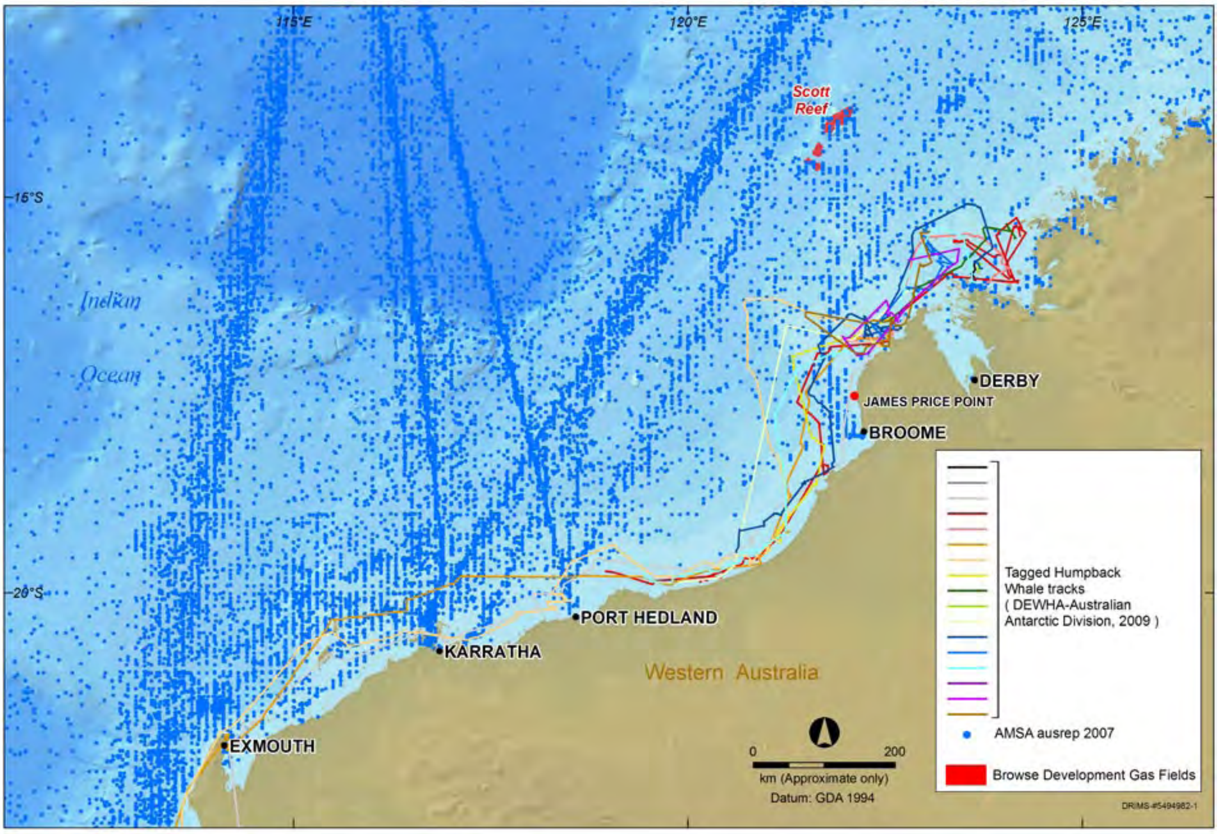
Aerial surveys (RPS, 2010a; **Appendix C-8**) showed that the distribution of migrating adult humpback whales is predominantly offshore from James Price Point (average distance of 27.5km from the coastline). The risk of vessel interaction is therefore primarily from large vessels approaching or departing from the BLNG Precinct Port area during construction and operations. However, it should be noted that when approaching or departing from the Precinct Port area, larger vessels will be typically moving at reduced speeds for navigational reasons, thus reducing the potential for collision with humpback whales.

Vessel collision poses a greater risk to humpback whales in areas used by nursing or juvenile animals, where they generally have longer or more frequent surface intervals (Laist *et al.,* 2001). Aerial surveys (RPS, 2010a; **Appendix C-8**) showed that pairs of female-calf humpback whales occur offshore from James Price Point from July to October (RPS, 2010a; **Appendix C-8**). The majority of calf sightings during the migration corridor survey (i.e. an area of approximately 6,500km$^2$ bounded by Carnot Bay (approximately 41km north of James Price Point) and Cape Latreille to the south (approximately 40km south of James Price Point) and out to the 80m depth contour were recorded further than 8.6km off the shore and no calves were recorded within 5km of the shore near James Price Point.

Although there is the potential to impact individual animals given the large numbers of humpback whales that migrate through the James Price Point coastal area, there have only been five reported vessel collisions in Western Australian waters between 2006 and 2008. Of these only one incident involved a humpback whale (IWC, 2008). However, the reporting of whale strikes is not required in Western Australia, and most incidents of vessel strikes of whales remain undocumented (Laist *et al*., 2001).

Experience at other ports along the north-west WA coast where humpback whales seasonally migrate is considered in the context of this assessment. Woodside operates a large LNG facility within the Dampier Port. This port has had over 920 supply vessel movements and 320 tug boat movements in the last year, as well as LNG, LPG and/or condensate tanker movements on a daily basis. Since 2007, Dampier Port has had approximately 11 vessel (supply vessels, tankers, bulk carriers and tugs) arrivals per day. There have been no reported encounters with whales during these operations. **Figure 2.6-5** shows historical shipping movements (AMSA, 2007) and the tracks of tagged female whales with calves

during the southern migration. It is evident that humpback whales successfully cross major shipping corridors (i.e. Port Hedland and Dampier Ports) and continue their migration south, with little evidence of vessel strike incidents.



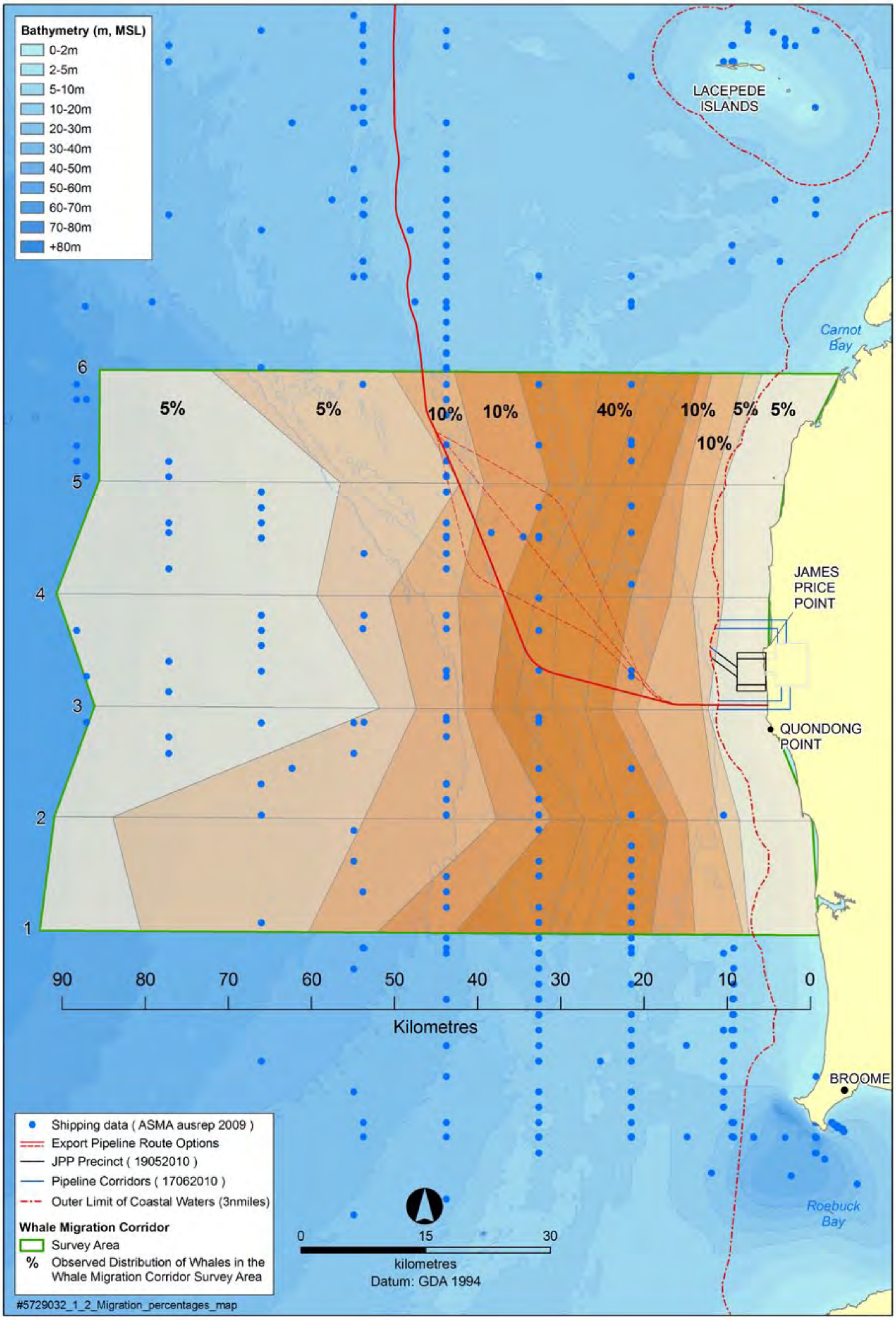

Source: AMSA, 2007 and Double *et al*., 2010.

- **Figure 2.6-5 Tracks from Satellite-tagged Female Humpback Whales with Calves during the Southern Migration in 2009 Coincident with Vessel Movements from Western Australian Ports.**

Note: Blue dots show individual shipping movements.

The number of vessels movements (approximately 1,300 during operations) to and from the BLNG Precinct represents a small increase in the current vessel movements to and from Western Australian ports. Considering this relatively small increase in vessel movements, it is considered unlikely that the additional vessel traffic would have a significant impact on humpback whale populations. Although the risk of vessel strikes on individual humpbacks is proportionally increased, the mitigation measures implemented through the vessel management plan (**Section 2.6.4**), in addition to those management arrangements defined in The Plan (**Part 6**) would reduce the potential for collisions (**Figure 2.6-6**). Data collected over recent years has demonstrated that humpback whale population is steadily increasing (Hedley *et al.,* 2009) despite the significant presence of shipping activities along the Western Australian coastline.

Nearshore and offshore construction activities on the Pluto LNG Project involved construction activities such as dredging, pipelay, and module delivery through the migration pathways as shown in **Figure 2.6-3**. Whilst humpback whales were regularly sighted, no vessel strikes were recorded.

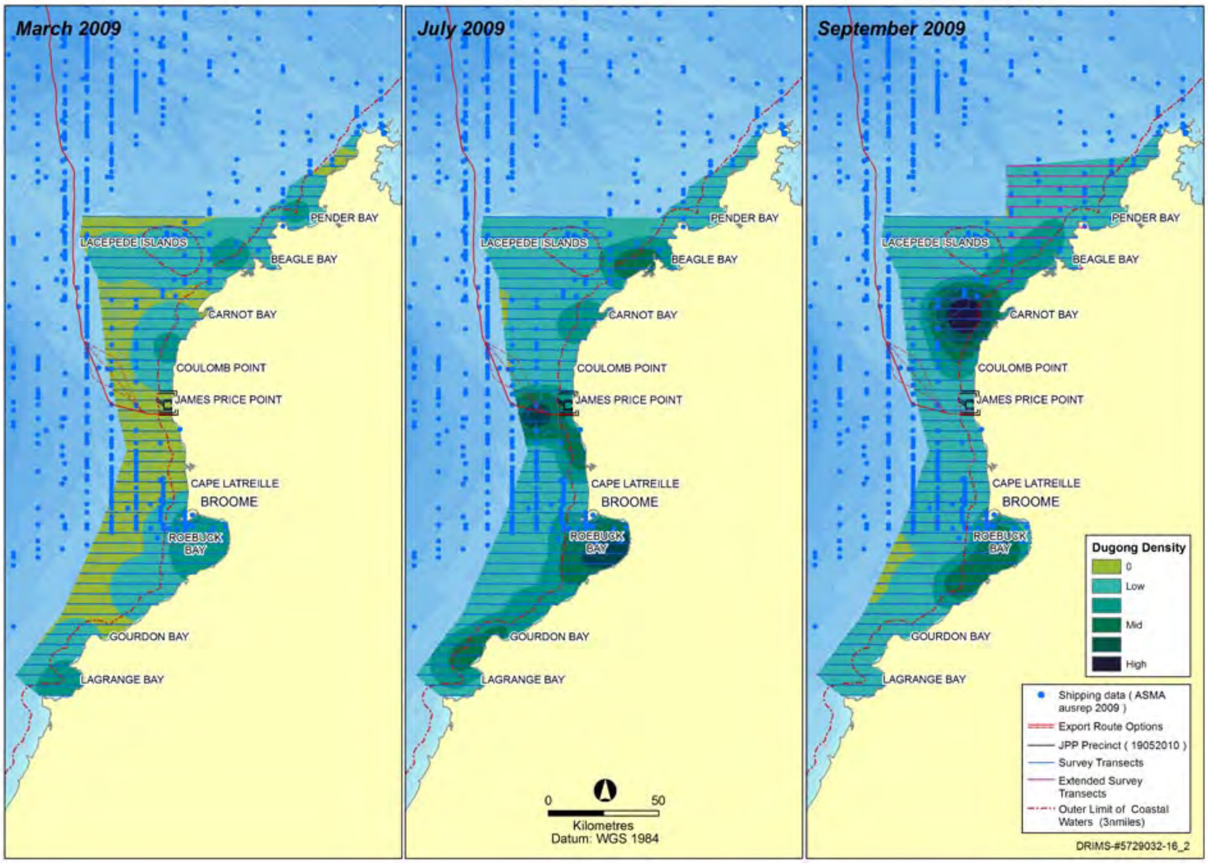



Source: RPS, 2010a; **Appendix C-8** and AMSA, 2007.

- **Figure 2.6-6 Shipping Movements through the James Price Point Humpback Whale Migration Corridor.**

*Dugongs*

Dugongs are susceptible to injury or mortality resulting from interaction with vessels, particularly when they rise to the surface to breathe, rest or forage in shallow waters. Due to their delayed flight response, dugongs would be at the most significant risk of vessel strikes during construction, when vessel activity is highest and faster vessels (e.g. supply vessels) are common. Dugongs are known to occur along James Price Point coastal area and throughout the wider Dampier Peninsula. However, aerial surveys (SKM, 2009c; RPS; 2010d; **Appendix C-10**) and historical records of dugong distribution between Roebuck Bay and Cape Leveque (Holley and Prince, 2008) indicate that the James Price Point coastal area is not a regionally significant foraging or aggregation area. During the nearshore regional survey (i.e. Cape Bossut near Lagrange Bay in the south to Cape Leveque in the north), the highest number of individual dugongs sighted within the James Price Point coastal area (i.e. Coulomb Point to Quondong Point) was 16 recorded during July 2009 (RPS; 2010c; **Appendix C-9**). This represents less than 1% of the total population (approximately 1,774 animals) estimated to occur between Cape Leveque and Cape Bossut. Therefore, it is likely that a small number of individuals may be affected by vessel activity associated with the BLNG Precinct Port area (**Figure 2.6-7**). However, no significant impact to population viability is anticipated.




Source: RPS, 2010c; **Appendix C-9** and AMSA, 2007.

- **Figure 2.6-7 Historical Shipping Movements and Proposed BLNG Shipping Infrastructure Coincident with Dugong Densities Sampled Along the Dampier Peninsula.**

It is possible that vessel movements during construction and operation may result in a localised impact on individual marine mammals in the vicinity of the BLNG Precinct. It is expected that potential impacts on marine mammals from vessel movements can be successfully mitigated through application of management and mitigation measures such as implementation of a marine fauna and vessel interaction management and monitoring strategy, and vessel speed restrictions within the Marine Precinct Port area. A more detailed description of proposed mitigation measures is presented in **Section 2.6.4**. The significance of the residual impact was assessed as low, and no significant impact to population viability is anticipated.

### 2.6.4. Management Measures

Management measures and safeguards that have been identified to manage potential impacts to marine mammals are outlined in **Table 2.6-8**, **Table 2.6-9** and **Table 2.6-10**.

Refer also to the Management Arrangements specifically defined for Commonwealth matters, summarised in **Part 6**, **Section 3**.

**Table 2.6-8 State Government Measures for Marine Mammals.**

| State Government measure | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory BLNG Precinct Port Authority, and an associated port area, which would have functions including regulation of:<br>• marine construction within the Port Area;<br>• long term dredging and spoil disposal program and management strategy to service the Port Area;<br>• vessel navigation, operations and movements within the Port Area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the Port Area. | Department of Transport (DoT) | Prior to approval of marine related derived proposals |
| The Port Authority will prepare a BLNG Precinct Environmental Management Plan (BPEMP) for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation;<br>• reporting and review mechanisms; and<br>• management of interaction of vessels and aircraft with cetaceans will be in accordance with the measures for cetacean interactions specified under the EPBC Regulations 2000. | Broome Port Authority | Prior to approval of marine related derived proposals |

- **Table 2.6-9 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Marine Mammals.**

| Condition No. | Proposed Environmental Conditions for the Strategic Proposal |
|---|---|
| M6.1 | Proponents of derived proposals shall report to the Broome Port Authority, DEC and SEWPAC a mortality resulting from BLNG Precinct activities, including vessel movements or dredging, of any specially protected and/or EPBC listed marine mega fauna. |
| M6.2 | Proponents of derived proposals shall prepare and implement a marine fauna and vessel interaction management and monitoring strategy, to the satisfaction of the Western Australian Minister for Environment, prior to the commencement of marine construction activities. |
| **Proposals involving dredging** | |
| M2.4 | Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• Consideration of re-use of reclaimed material to minimise ocean disposal.<br>• Measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. |

**Table 2.6-10 Requirements to be Addressed via Development of a Management Plan to Support a Derived Proposal Potentially Affecting Marine Mammals.**

| Derived Proponent Requirements | Timing |
|---|---|
| Proponents of derived proposals shall prepare and implement a Port Facilities Construction Environmental Management Plan (PFCEMP), to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br><br>In order to address the potential impacts to marine mammals identified within this section, the Plan may include the following environmental management measures:<br>• scheduling blasting for daylight hours only, avoiding dawn and dusk, to allow for effective visual monitoring and minimising health and safety concerns;<br>• smaller, more frequent blasts planned using sequential explosive charges to minimise cumulative impacts of the explosions, as opposed to less frequent, larger blasts;<br>• warning charges used to encourage animals to move away from the construction area prior to a blast detonation; and<br>• shaped charges used to focus blast energy along fracture lines. | Prior to commencement of associated construction activities |
| Prepare and implement a Vessel Management Plan (VMP), which may include the following measures:<br>• vessel speed restrictions within the Marine Precinct Port area;<br>• training for selected vessel crew to sight and manage interactions with marine mammals; and<br>• vessel contractor(s) to be provided with a map showing sensitive environmental features, including humpback whale aggregation areas and foraging areas for dugongs. These areas will be avoided as far as practicable. | Prior to construction and updated for ongoing operational requirements |

The implementation of the aforementioned mitigation measures and safeguards will be effective in mitigating the impact of the BLNG Precinct Port area. All management plans will be developed in consultation with DEC and SEWPAC (DEWHA).

### 2.6.5. Environmental Outcome

A precautionary approach has been incorporated due to the degree of uncertainty in the construction method and timeframes, the extent of the marine footprint and the sensitivities of marine mammals to potential impacts.

#### 2.6.5.1. Direct Impacts

Cumulative impacts from all Category A activities indicate that the potential impact to marine mammals will predominantly occur during construction, when noise emissions and vessel activity will be highest.

After management and mitigation measures have been applied, it is expected that the BLNG Precinct Port area will result in the following direct impacts in relation to marine mammals:

- Vessel strike: the risk of vessel strike on marine mammals is likely to be during the construction phase when vessel activity is highest. Humpback whales are most at risk as vessel activity during both construction and operations will coincide with periods of peak humpback whale activity.
- Marine noise and vibration: elevated marine noise and vibration levels generated during construction (i.e. blasting and piling) and operational (i.e. vessel movements) phases of the BLNG Precinct, may interfere with the acoustic perception and communication of marine mammals in the vicinity of the Precinct Port area. Whilst the level of noise at which response is elicited varies between species and even between individuals within a species (Richardson *et al.*, 1999), impacts to marine mammals may occur if individuals are exposed to noise and vibration levels above background within the BLNG Precinct Port area.

Taking into account mitigation measures as outlined in **Section 2.6.4**, the proposed development activities are not anticipated to result in adverse impact on marine mammals at a population or species level.

#### 2.6.5.2. Indirect Impacts

Indirect impacts, associated with marine site disturbance and excavation, is likely to include the removal and loss of foraging habitat (i.e. seagrass) for dugongs. This may have an impact on dugong foraging success and result in displacement of individuals. Whilst dugongs may occur within the BLNG Precinct Port area the widespread availability of food along the Dampier Peninsula (i.e. Roebuck Bay, Carnot Bay) is likely to offset any temporary loss of feeding within the BLNG Precinct Port area.

Consistent with the EPA objectives, the abundance, species diversity, geographic distribution and productivity of fauna at species and ecosystem levels will be maintained, thereby conserving regional biological diversity.

### 2.6.6. Cumulative Impacts of the Proposal and Associated Activities

#### 2.6.6.1. Category B Activities

The following Category B cumulative impacts may apply to marine mammals:

- further development of Broome Port to accommodate an increase in marine vessel traffic associated with regional development; and
- additional recreational traffic associated with increased population base.

An increase in boating activity through Broome Port may impact marine mammals feeding and/or migrating through coastal waters adjacent to James Price Point coastal area. Direct impact may occur via increased small vessel movement, increasing the risk of vessel strike on marine mammals. The increased use of recreational vessels from the Shire of Broome may pose a risk particularly to dugongs inhabiting areas such as Roebuck Bay. Small recreational vessels are swift and highly manoeuvrable meaning that they may strike animals breathing at the surface with little advanced warning of approach. The incremental level of effect on marine mammals from additional boat movements and port operations is likely to be small and localised. However, the successive growth in activity in the area should be monitored and long-term effects evaluated. Campaigns to educate boaters to the presence of local marine mammals and appropriate actions to take to minimise impacts will be implemented.

Increased boating activity out of Broome may result in localised impacts which would not be cumulative to those of Category A. Impacts on marine mammals from these potentially impacting Category B activities will be limited.

#### 2.6.6.2. Category C Activities

Upstream development (including explorative and construction activities) of the Browse Basin gas field to acquire natural gas and the operation of the upstream facilities will involve the discharge of drilling muds and chemicals which may cause localised changes in water quality, this in turn may affect marine mammal health. These effects would be localised, restricted in area to the immediate vicinity of the activity.

Increased vessel movement during exploration, construction and operation of the gas fields may impact humpback whales through vessel-strike, limited to the seasonal period of their annual migrations.

The upstream exploration activities may also involve seismic data acquisition, however, the potential risk or impact to marine mammal populations would be highly localised, hence cumulative impacts are not anticipated. Further, the upstream development activities will involve the disturbance of benthic environment, however this disturbance to marine mammal food-sources and habitat is expected to be localised and as such population impacts to marine mammal species are not anticipated.

- **Table 2.6-11 Impact Assessment Summary for Marine Mammals.**

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | **State Government Measures** | **Proposed Environmental Conditions** | **Future Proponent Management Plans** | |
| Noise and vibration | Disturbance of conservation significant fauna individuals | Establish the Broome Port Authority as the statutory BLNG Precinct Port Authority, and an associated port area, which would have functions including regulation of:<br>• marine construction within the Port Area;<br>• long term dredging and spoil disposal program and management strategy to service the Port Area;<br>• vessel navigation, operations and movements within the Port Area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the Port Area.<br>The Port Authority will prepare a BLNG Precinct Environmental Management Plan (BPEMP) for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine | Proponents of derived proposals shall report to the Broome Port Authority, DEC and SEWPAC a mortality resulting from BLNG Precinct activities, including vessel movements or dredging, of any specially protected and/or EPBC listed marine mega fauna.<br>Proponents of derived proposals shall prepare and implement a marine fauna and vessel interaction management and monitoring strategy, to the satisfaction of the Western Australian Minister for Environment, prior to the commencement of marine construction activities.<br>Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and | Proponents of derived proposals shall prepare and implement a Port Facilities Construction Environmental Management Plan (PFCEMP), to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation ; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br>In order to address the potential impacts to marine mammals identified within this section, the Plan may include the following environmental management measures:<br>• scheduling blasting for daylight hours only, avoiding dawn and dusk, to allow for effective visual monitoring and minimising health and safety concerns; | Low |
| Sediment Deposition and Turbidity | Disturbance of conservation significant fauna individuals | | | | Low |
| Site disturbance / excavation | Loss of habitat | | | | Low |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| | | facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms.<br><br>Management of interaction of vessels and aircraft with cetaceans will be in accordance with the measures for cetacean interactions specified under the EPBC Regulations 2000. | technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• Consideration of re-use of reclaimed material to minimise ocean disposal.<br>• Measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br><br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. | • smaller, more frequent blasts planned using sequential explosive charges to minimise cumulative impacts of the explosions, as opposed to less frequent, larger blasts.<br>• warning charges used to encourage animals to move away from the construction area prior to a blast detonation; and<br>• shaped charges used to focus blast energy along fracture lines.<br><br>Prepare and implement a Vessel Management Plan (VMP), which may include the following measures:<br>• vessel speed restrictions within the Marine Precinct Port area;<br>• training for selected vessel crew to sight and manage interactions with marine mammals; and<br>• vessel contractor(s) will be provided with a map showing sensitive environmental features, including humpback whale aggregation areas and foraging areas for dugongs. These areas will be avoided as far as practicable. | |
| Routine marine discharges | Disturbance of conservation significant fauna individuals | | | | Very low |
| Non-routine discharges (spills and leaks) | Disturbance of conservation significant fauna individuals | | | | Very low |
| Vessel movements | Injury or death of conservation significant fauna | | | | Low |

## 2.7. Key Factor: Marine Reptiles

The following section describes the predicted impacts on marine reptiles from activities, facilities and other components to be approved under the Plan for the BLNG Precinct (Category A) and the potential for cumulative impacts from activities that may indirectly arise as a result of the BLNG Precinct development (Category B) and other related resource activities in the region (Category C).

### 2.7.1. Current Knowledge

Current knowledge with respect to key policy documentation and regulatory requirements, as well as a summary of marine reptiles present in the vicinity of James Price Point coastal area, are presented in the following sections.

#### 2.7.1.1. Key Statutory Requirements, Environmental Policy and Guidance

There are a number of key statutory requirements, environmental policies and guidance documentation that apply to the Strategic Assessment in relation to marine reptile protection, including:

**State Guidance and Policy**

The Environment Protection Authority (EPA) applies the following overarching objective in its assessment of proposals which can apply in the context of marine reptiles:

"*To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge"* (EPA, 2009f).

**State Protection**

The *Wildlife Conservation Act 1950* (WA) provides for the protection of native fauna, with species considered as needing special protection listed under one of four categories in the Wildlife Conservation (Specially Protected Fauna) Notice 2010, these being:

- Schedule 1- fauna that are rare or likely to become extinct;
- Schedule 2- fauna presumed to be extinct;
- Schedule 3- which relates to the protection of migratory birds and birds in danger of extinction; and
- Schedule 4- other specially protected fauna.

The following marine reptile species which have been recorded from the Kimberley region, are specifically protected under the *Wildlife Conservation Act 1950* (WA):

- green turtle (*Chelonia mydas*) - Schedule 1;
- loggerhead turtle (*Caretta caretta*) - Schedule 1;
- leatherback turtle (*Dermochelys coriacea*) - Schedule 1;
- olive Ridley turtle (*Lepidochelys olivacea*) - Schedule 1;
- hawksbill (*Eretmochelys imbricata*) - Schedule 1;
- flatback turtle (*Natator depressus*) - Schedule 1; and
- saltwater crocodile (*Crocodylus porosus*)- Schedule 4.

**Commonwealth Protection**

The Commonwealth EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the Act as Matters of NES.

All six species of marine turtles (green, flatback, hawksbill, loggerhead, leatherback, and olive Ridley), are classified as being matters of NES under the EPBC Act. All marine turtle species are listed as "Migratory" under this Act. The green, hawksbill, leatherback and flatback turtles are listed as "Vulnerable", and the loggerhead and olive ridley turtles are listed as "Endangered" under the EPBC Act.

Thirty-one species of sea snakes are listed under the *EPBC Act*, seventeen of which may occur within the James Price Point coastal area.

**International Protection**

Under the Red List of Threatened Species, the IUCN have assigned "Critically Endangered" status to hawksbill and leatherback turtles, "Endangered" status to green and loggerhead turtles and "Vulnerable" status to the olive Ridley turtle. Flatback turtles are listed as "Data Deficient" on the Red List. Loggerhead, green and flatback turtles occur at Roebuck Bay, which also is a listed Wetland of International Importance under the Ramsar Convention.

Australia is party to the *Convention on the Conservation of Migratory Species of Wild Animals 1979* (commonly referred to as CMS or the Bonn Convention). All six species of marine turtles are listed under this Convention. Australia as a result is required to protect endangered species of migratory animals and also migratory animals that have an unfavourable conservation status due to habitat depletion or reduction in range. This listing is administered through relevant State legislation.

#### 2.7.1.2. Description of Factor

A full discussion on the geographical distribution, abundance and life history of marine reptiles is presented in **Part 3**, **Section 1** (Environmental Overview). Therefore, only brief discussions of marine reptiles (turtles and sea snakes) relevant to this factor impact assessment are presented below.

The following information on marine reptiles is largely based on extensive aerial, vessel and beach surveys undertaken in 2008 and 2009. These studies were undertaken to support the Strategic Assessment of the BLNG Precinct and to also understand the distribution, abundance and seasonality of marine reptiles, with a particular focus on the James Price Point coastal area. These studies included:

- Browse LNG Development Turtle Technical Report, Ecology of Marine Turtles of the Dampier Peninsula and the Lacepede Island Group (RPS, 2010b; **Appendix C-2**); and
- Browse LNG Development Marine Megafauna Survey - Other Marine Megafauna (RPS, 2010d; **Appendix C-10**).

The key findings from these studies are summarised below.

**Marine Turtles**

- Turtles that migrate along the Dampier Peninsula are likely to be inter-nesting, post-nesting and/or foraging animals.
- The James Price Point coastal area does not support consistently high densities of turtles. The area is largely considered to be used by post nesting turtles migrating north or south to foraging areas.
- No significant green or flatback turtle nesting areas were identified on the mainland coast within the James Price Point coastal area. Track count data from 2009-2010 indicates that the James Price Point coastal area supports only very low levels of nesting (three tracks and one potential nest over 2009/2010 nesting season). In comparison, the Lacepede Island Group supports significant green and flatback turtle rookeries.
- Many of the characteristics of James Price Point coastal area are considered unsuitable for nesting, largely as a result of periods of inundation during spring high tides, incline of the beach, rocky substrate around the coastal zone and limited space for nesting between the aeolian sands and the intertidal platform.
- Probable turtle foraging habitats have been identified off Carnot Bay (approximately 41km north of James Price Point), Cape Latreille (approximately 39km south of James Price Point), Roebuck Bay (approximately 66km south of James Price Point) and Lagrange Bay (approximately 134km south of James Price Point), based on high turtle densities in these areas during the non-breeding period (July-October 2009).
- Satellite tracking identified that the majority of post-nesting turtles (green and flatback turtles) nesting at the Lacepede Island Group migrated in a north-easterly direction to foraging grounds as far as Coburg Peninsula in the Northern Territory (approximately 1,280km north-east of James Price Point).

**Sea Snakes**

- Sea snakes were widely distributed and abundant along the Dampier Peninsula coastline (including Lagrange Bay, Broome, Pender Bay and Scott Reef), however they were not as common along the James Price Point coastal area.
- The majority of sea snake sightings were in waters between 10 to 50m deep. The highest relative densities of sea snakes were recorded in July and September approximately 30km west of Broome outside of the 10m isobath.

### 2.7.2. Identification of Key Aspects

#### 2.7.2.1. Definition of Relevant Aspects

Aspects associated with the development and operation of the BLNG Precinct and associated infrastructure that may have an environmental impact on marine reptiles were identified in the Scope of the Strategic Assessment and considered in the assessment include:

- marine noise and vibration;
- sediment deposition and turbidity;
- marine site disturbance and excavation;
- marine discharges (including non routine discharges);
- light emissions; and
- vessel movements.

#### 2.7.2.2. Sources of Potential Impact

**Marine Noise and Vibration**

The construction and operation of the BLNG Precinct will include activities that will emit underwater noise and vibration above background (ambient) levels. The marine activities that are considered to be the most noise intensive sources are nearshore blasting and piling works.

Details of the source of potential impact for marine noise and vibration are provided in **Section 2.5.3.2** (Fish).

**Sediment Deposition and Turbidity**

The marine construction activities associated with the construction and operation of the BLNG Precinct include, but are not limited to, dredging and dredge spoil disposal, export jetty installation, breakwater construction and pipeline shore approach installation. These activities will result in the disturbance of marine sediments, leading to increased turbidity and sediment deposition rates.

The most significant sediment deposition and turbidity generating activities will be the operations required to dredge access channel/s, turning basin/s and berth pockets and associated spoil disposal, including the propeller wash caused by vessels manoeuvring in shallow areas. Further details on the dredging are given below.

**Marine Site Disturbance and Excavation**

It is anticipated that the LNG export facilities within the BLNG Precinct will require approximately one berth for every 10Mtpa of LNG production. Consequently, export facilities will be phased in line with the precinct production capacity, with approximately six berths anticipated for a 50Mtpa LNG Precinct. Altering the seabed level, through dredging and spoil disposal for such infrastructure, may impact the local hydrodynamic regime. Preliminary estimates of the total dredged volume for the nearshore infrastructure based on conceptual site layout options shown in **Part 2, Section 5** (Description of Activities and Facilities under the Plan) are of the order of 21Mm$^3$. Dredged spoil material is likely to be disposed of at an offshore dredge spoil disposal site and therefore the modelling and assessment has taken this activity into account.

Maintenance dredging during operations including disposal Maintenance dredging may be required depending on prevailing sediment transport and deposition processes. The method and effect of dredging and disposal of maintenance dredge material is similar to capital dredging, however the volume of material to be dredged during a single maintenance campaign would be significantly less than that removed during capital dredging.

Dredge spoil is likely to be disposed of at a designated offshore spoil ground. Similar to the actual dredging activities, spoil disposal is likely to increase suspended sediment concentrations and reduce benthic light availability. Spoil disposal at a location approximately 7km off James Price Point (see DSD, 2010d; **Appendix C-13** for rationale into the location of the spoil ground) has been incorporated into the modelling approach and therefore the impact on water quality portrayed and discussed in proceeding sections takes this activity into account.

There is the potential that some dredge spoil, if it is of adequate quality for construction, may be reclaimed onshore for the construction of the nearshore Marine Facility. If used or selected as an option, it is likely that sedimentation and turbidity will be increased in the immediate vicinity of reclamation works.

**Marine Discharges (including Non-routine Discharges)**

Routine wastewater discharge is likely to include process water, brine from desalination, produced formation water, stormwater, grey water and treated sewage. These waste streams will be controlled within the Precinct facilities and are likely to be discharged to the nearshore marine environment via an ocean outfall. Hydrocarbons or chemicals (e.g. LNG, LPG, condensate, bunker fuel, diesel or monoethylene glycol) may be released into the marine environment through spillages from storage tanks, product pipelines or tankers.

**Light Emissions**

Light emissions are likely to be generated by a number of sources including vessels and land-based sources during construction and operations of the BLNG Precinct. During operations LNG processing facilities and Marine Precinct Port facilities will operate to maintain industrial safety standards and permit safe navigation and departure of tankers and support vessels. Light emissions that are considered to represent the greatest risk of impact are land-based sources (such as flaring) (refer to **Part 2**, **Section 5** (Description of Activities and Facilities under the Plan)).

Flare systems are required for the safe and effective operation of an LNG facility. The main flaring systems proposed for the BLNG Precinct may include a marine low pressure flare, low pressure flow flare; and emergency high pressure flare. The low pressure flow flare is used to manage smaller quantities of gas typically related to operations and smaller maintenance related events. The low pressure flow flare is smaller and is expected to represent only a short term and less intense source of lighting. The emergency high pressure flare system is anticipated to be either mounted on a stack (approximately 100 to 180m in height) or be a ground type flare and located in a designated area within the BLNG Precinct.

**Vessel Movements**

Construction and operation of the BLNG Precinct will result in an increased number of vessels. During construction, vessels will be required to undertake preparatory nearshore works in the BLNG Port Precinct area. Vessel activity will be distributed over the entire construction period, and at the height of construction, the number of vessels that are likely to be active in the BLNG Precinct area could be in the order of 20 at any one time (in addition to existing vessel traffic). However, while a number of vessels will be operating within the BLNG Precinct area, the majority of the construction activities will require vessels to be stationary (e.g. during piling and drilling activities) or moving at very slow speeds (e.g. dredging, pipe laying). Vessel movements at higher speeds (e.g. greater than 10kn) would predominantly be limited to vessel transits between areas (i.e. between the BLNG Precinct and marine supply base or other regional ports).

During operations, the most significant vessel traffic will be the regular movements of LNG, LPG and condensate tankers and the movements of associated support vessels to aid in the berthing of the tankers in and out of the marine port facilities. The number of LNG and condensate tankers will be dependent on vessel size and the capacity of the installed facilities.

### 2.7.2.3. Sensitivity and Resilience

**Marine Noise and Vibration**

Turtle auditory perception probably occurs through a combination of bone and water conduction (Lenhardt, 1982; Lenhardt *et al.,* 1983; Lenhardt and Harkins 1983; and Bartol *et al.,* 1999). Sea turtle hearing is believed to be limited to low frequencies, between 0.25 – 0.75kHz (Bartol *et al.,* 1999) Ridgway *et al.* (1969) measured hearing in the green turtle and found sensitivity from 0.2 – 0.7kHz, with most sensitive hearing between 0.3 and 0.5kHz.

There is limited information available on hearing in sea snakes, but they are known to be capable of detecting pressure changes (Mick Guinea, pers. comm.). However, it is likely that sea snakes rely more heavily on vision and olfaction than on hearing (Hibbard, 1975).

Noise and vibration in the underwater environment can result in a range of responses including temporary or permanent loss of hearing sensitivity, other physical injuries, and behavioural changes such as avoidance of the activity area. Thresholds above which temporary or permanent loss of hearing sensitivity (temporary threshold shift (**TTS**) and permanent threshold shift (**PTS**) respectively), or behavioural disturbance may occur for marine reptiles are uncertain and have not been defined in the literature.

**Sediment Deposition, Turbidity, Marine Site Disturbance and Excavation**

Turtles are not deemed to be physiologically affected by an increase in suspended sediments associated with dredging activities. However, the direct permanent and indirect temporary loss of permanent seagrass and macroalgae foraging habitat has been identified as a potential threat to marine turtles. Construction and operational activities will increase the turbidity and sediment deposition, which may potentially reduce foraging success or negatively impact on food supply in the vicinity of the dredge area. It is acknowledged that some turtles visit the nearshore areas adjacent to the BLNG Precinct area to feed on the available benthic habitats, however foraging habitat is extensive along the Dampier Peninsula and any loss of foraging habitat within the James Price Point coastal area is likely to cause turtles to move to other foraging grounds within the wider Dampier Peninsula region. A study undertaken by Senko *et al*., 2010 on the fine scale daily movements and habitat use of East Pacific green turtles (*Chelonia mydas*), reported that the spatial use of green turtles along coastal areas is highly variable, with some turtles travelling large distances (>100km) and traversing multiple habitats over short temporal scales. In addition, turtles are considered not to be especially sensitive to the proposed site disturbance and excavation activities, taking into account the results of surveys that indicate the individuals predicted to be within the immediate development zone are unlikely to be resident to the area.

**Marine Discharges**

There have been limited studies into the impact of elevated salinity, decreased dissolved oxygen or the physiological effects of pollutants such as heavy metals on marine turtles or other marine reptiles. It is thought that large (greater than ten units increase from ambient) changes in salinity can affect an organism's ability to osmoregulate, leading to physiological damage and likely mortality (Diaz and Rosenberg, 1995). Exposure to heavy metals and other pollutants can potentially result in bioaccumulation in turtle species. Bioaccumulation of heavy metals and organic pollutants has been recorded in turtle populations (Gardner *et al.,* 2006; Gordon *et al.,* 1998; and Maio *et al.,* 2001). Concerns have been raised about bioaccumulation in traditional indigenous foods such as turtles and potential risk to the health of indigenous communities. There is evidence that frequent turtle liver, kidney and wild clam consumption is linked to higher urinary cadmium levels among Torres Strait Islander women (Haswell-Elkins *et al.,* 2007).

**Light Emissions**

Marine turtles typically respond to artificial light emissions (light spill) through avoidance of nesting beaches by fecund adult females or disorientation of hatchling turtles (Witherington and Martin, 1996).

The wavelength at which adult and hatchling turtles can sense light is important in determining their corresponding attraction and sensitivity to light emissions. Studies on hatchling orientation, relative to spectrally controlled light sources, indicate that although the wavelength at which hatchlings can sense light varies between species, all turtle species are more sensitive to light in the blue and ultraviolet (**UV**) end of the spectrum. The most disruptive wavelengths to hatchlings are in the 300 to 500Nm range (Witherington, 1997 and Witherington, 2000). Light spill effects are not known to vary for different turtle species; however, loggerhead turtle hatchlings may be influenced by lower wavelengths towards the middle of the visible spectra.

No information is available in the published literature that suggests adult turtles are affected by light during foraging activity (K. Pendoley pers. comm. 2009).

- **Table 2.7-1 Range of Visible Light to Turtle Species and Wavelength Causing Disturbance.**

| Common Name | Visual Range Wavelength (nm) | Limited Influence Wavelength (nm) | Most Disruptive Wavelengths (nm) |
|---|---|---|---|
| Green turtle | 400 – 600 | 680 | 300 to 500 |
| Hawksbill turtle | 400 – 600 | 650 | 300 to 500 |
| Olive Ridley turtle | 400 – 600 | 600 | 300 to 500 |
| Loggerhead turtle | 400 – 600 | 500 | 300 to 500 |
| Flatback turtle | 400 – 600 (assumed) | Not known | 300 to 500 (assumed) |
| Light transmission through water | 425 – 600 | – | – |
| Comparative human eyesight range | 380 – 750 | – | – |

Source: Witherington and Martin, 2000 and Pendoley, 2004.

**Nesting Cues**

There is evidence that indicates artificial lighting on or near nesting beaches may disrupt adult female turtle nesting behaviour (Salmon, 2005 and Salmon *et al.,* 1995). Although lighting may not be the primary cause of altered behaviour, nesting densities are typically lower at beaches exposed to artificial light while higher nesting densities have been found in the shadows of buildings and trees (Salmon *et al.,* 1995 and Salmon, 2005). Artificial lighting may affect the location that turtles emerge to the beach, the success of nest construction, whether nesting is abandoned, and even the seaward return of adults (Salmon *et al.,* 1995 and Salmon, 2005). It was found that turtles deterred from typical nesting beaches due to artificial lighting, re-emerged onto alternate beaches outside of their typical range at increasingly distant and inappropriate nesting locations (Witherington and Martin, 1996; 2000). The selection of suboptimal nesting habitat may contribute to a reduction in the success of egg deposition and hatchling production (Witherington and Martin, 1996; 2000). There is no indication whether, under natural conditions, the full moon affects rates of female adults landing onto a beach to nest.

**Hatching Juvenile Turtles**

The risk of an undue effect on turtle hatchling disorientation is based on the use of a beach for egg laying. This is known not to be the case for the beaches near James Price Point. The potential for artificial light to interfere with hatchling orientation is greatest during the dark period (new moon) and lowest during the full moon, because natural moon light, is typically brighter than artificial light. Turtle hatchlings use natural lighting glow as an orientation cue to help direct them from the nest towards the ocean. Hatchlings have a strong tendency to orient themselves to the brightest light source, which under natural conditions is the seaward horizon (in natural circumstances derived from the moon for most of the month) rather than the darker silhouetted landward horizon. This viewshed angle (V) is influenced by a hatchling’s ability to receive light in the vertical dimension. The light glow created by artificial lighting inland may therefore cause hatchlings to be attracted to this light source rather than to the water (Witherington and Martin, 1996; 2000). Hatchlings which are disoriented or mis-oriented by artificial lights often do not find the sea promptly, this may lead to predation or exhaustion. Hatchlings may also use part of their limited energy supply in the yolk, thereby reducing their capacity to swim offshore away from coastal predators (EPA, 2010). Hatchlings swimming out to sea from the beach may also be attracted to light emissions from offshore structures or vessels, again making them susceptible to predation or vessel strike after they enter the water.

**Vessel Movement**

Marine turtles are typically found in shallow, nearshore waters, especially those areas containing seagrass, algae or other benthic habitats utilised for foraging (Davenport and Davenport, 2006). While turtles spend most of the time beneath the surface, they return to the surface periodically to breathe. The dive behaviour may vary considerably between turtle species and between individuals of the same species, reflecting differences in foraging/resting behaviour, predatory pressures, environmental conditions (e.g. sea temperatures, wave conditions, water depth) and breeding behaviour (Hazel *et al.,* 2007). Typically periods of heightened activity (i.e. foraging) requires a greater frequency of ascents for respiration, thus these periods may be considered as periods of greater risk from vessel strike (Hazel *et al.,* 2007).

Marine turtles on the sea surface or in shallow coastal waters are observed to avoid approaching vessels by typically moving away from the vessels track (Hazel *et al.,* 2007). Hazel *et al.* (2007) suggests this observed avoidance behaviour is based primarily on visual cues (although these authors acknowledge that vessel noise is within range of turtle hearing) and the success of this behaviour in avoiding a vessel strike is largely dependent on the speed of the approaching vessel (rather than vessel type) and the prevailing water clarity. While the potential for vessel strikes at various speeds has not been quantified, the success of avoidance behaviour is a factor of the response time available (i.e. visual observation distance/vessel speed). Thus, there is less opportunity for turtles to avoid vessels travelling at higher speeds in turbid waters. While vessel speed is a significant factor, vessel draft may also contribute to the risk of vessel strikes, with vessels with less draft providing a greater clearance distance between the turtle and the extremities of the vessel. In the event of a collision, the turtle's carapace provides a level of protection from serious injury, although the type and severity of the injuries would be dependent on the force of the collision and the structure of the vessel (hull or propellers).

Although few studies have been conducted to accurately determine the level of risk, turtles are also known to be susceptible to entrainment in dredging equipment. The occurrence of marine turtle entrainment is relatively common (refer to Greenland *et al.,* 2002) and is likely to result in mortality (Dickerson *et al.,* 1991), although differences in dredges types and turtle species are an influencing factor and the risk is significantly reduced by use of standard mitigations and protection devices (Felger *et al*., 1976).

### 2.7.3. Predicted Impacts

The predicted impacts on marine reptiles from the construction and operation of the BLNG Precinct are discussed in detail in the following sub-sections, and summarised in **Table 2.7-6**. Both direct and indirect impacts are considered within these sections. For the purpose of this assessment it is considered that direct impacts would largely be confined to areas of direct disturbance within the BLNG Precinct Port area, and other locations where the majority of development activities are proposed to occur. Of the protected marine reptiles likely to occur within the James Price Point region, green and flatback turtles are considered the most sensitive and will therefore form the focus of the impact assessment for marine reptiles.

This section primarily addresses impacts to the green turtle (*Chelonia mydas*) and flatback turtle (*Natator depressus*). Both the green and flatback turtle commonly occur along the Dampier Peninsula coastline and are known to nest in significant numbers in areas such as the Lacepede Island Group (approximately 65km north of James Price Point).

Other marine turtle species including hawksbill, loggerhead, leatherback and olive Ridley turtles are not present in significant numbers in the vicinity of the James Price Point coastal area and do not commonly use the area for foraging or breeding (RPS, 2010b; **Appendix C-2**). This was supported by vessel surveys undertaken in 2009, where low numbers of hawksbill and loggerhead turtles were recorded along the James Price Point coastal area. No sightings of leatherback or olive Ridley turtles were recorded (RPS, 2010b; **Appendix C-2**). These marine turtle species are also not known to nest along the James Price Point coastal area. Beach surveys undertaken along potential nesting beaches within the area did not record any evidence of nesting activity of these turtle species, however it is acknowledged that some of these species may nest outside of the beach survey period (November to March) (Biota, 2009a; and RPS, 2010b; **Appendix C-2**).

Sea snakes, though widely distributed and abundant along the Dampier Peninsula including James Price Point, are unlikely to be adversely affected by construction and operational activities associated with the BLNG Precinct. These animals are likely to exhibit behavioural and avoidance responses to impacts such as noise/vibration, light emissions and increased turbidity. It is however, acknowledged, that sea snakes will be susceptible to entrainment in dredging equipment. Although, differences in dredge types and sea snake species are an influencing factor and the risk is significantly reduced by the use of standard mitigation measures and protection devices. Given the low inherent risk of construction and operational activities associated with the BLNG Precinct Port area to sea snakes, they will not be addressed in further detail in the following sections.

Other reptile species such as the saltwater crocodile (*Crocodulus porous*), freshwater crocodile (*Crocodulus johnstoni*), hawksbill turtle (*Eremochelys imbricata*), loggerhead turtle (*Caretta caretta*), leatherback turtle (*Dermochelys coriacea*) and olive Ridley turtle (*Lepidochelys olivacea*), are known to occur in low numbers along the Dampier Peninsula coastline, and are not considered to be common within the James Price Point coastal area.

The James Price Point coastal area does not support estuarine or mangrove environments, therefore the area is unlikely to provide suitable permanent crocodile habitat. Whilst crocodiles were not recorded during 2009 aerial surveys (RPS,

2010d; **Appendix C-10** and SKM, 2009c), one individual and evidence of another were observed during a turtle survey on the Lacepede Islands (RPS, 2010b; **Appendix C-2**). The limited number of crocodile sightings throughout the surveys indicates that none of the areas surveyed, including onshore and offshore areas of the James Price Point coastal area, provide important or permanent habitat for these animals (RPS, 2010d; **Appendix C-10**). Should individuals occur, they are likely to be transiting through the area to more favourable estuarine habitats.

Due to the low occurrence of the saltwater crocodile, freshwater crocodile, hawksbill turtle, loggerhead turtle, leatherback turtle and olive Ridley turtle along the James Price Point coastal area (i.e. Coulomb Point to Quondong Point), as observed during vessel, aerial and beach surveys (RPS, 2010a; **Appendix C-8**; RPS, 2010b; **Appendix C-2**; RPS, 2010c; **Appendix C-9**; and RPS, 2010 d; **Appendix C-10**). It is considered that these species are unlikely to be significantly impacted by the BLNG Precinct and will therefore not be assessed in the following sections. However, it is anticipated that minimisation of impacts on the key marine reptile species will also minimise potential impacts on these other non-key species.

In summary, this assessment of marine reptiles has focussed on the 'key receptors' that are species of conservation significance that are known to occur in the coastal waters relevant to the BLNG Precinct, as outlined in **Table 2.7-2**.

- **Table 2.7-2 Marine Reptiles and Key Receptors Considered in the Impact Assessment.**

| Key Receptors | Rationale for Selection as a Key Receptor |
|---|---|
| Green Turtle (*Chelonia mydas*)<br>Flatback Turtle (*Natator depressus*) | High conservation significance. Commonly occur along the Dampier Peninsula coastline and are known to nest in significant numbers in areas such as the Lacepede Island Group (approximately 65km north of James Price Point). |

#### 2.7.3.1. Potential Impacts to Marine Reptiles due to Marine Noise and Vibration

As discussed in **Part 3, Section 2.5** (Fish) a noise modelling study of the underwater noise associated with the construction activities for the proposed precinct was undertaken to support this assessment (SVT, 2010; **Appendix C-12**).

The contour plots shown in **Section 2.5** (Fish) are for a receiver depth of 2m below the sea surface. The scenarios under both MSL and HAT were modelled. Only the results for of HAT are presented as it represents the worst case scenario. The plots of the piling (**Figure 2.5-2** and **Figure 2.5-3**) and blasting (**Figure 2.5-4**) activities are shown as these represent the noise emissions with most potential for physiological or behavioural impacts on marine reptiles. The plots are presented to give an indication of the sound exposure level with distance from source for these selected activities, the results of which are discussed below. Two plots are shown for pile driving, representing different time periods of exposure. **Figure 2.5-2** represents an exposure of 10 seconds to pile driving from three barges operating simultaneously, whereas **Figure 2.5-3** represents an exposure of three hours within a 24 hour period. The figures clearly demonstrate that the SEL for a given distance from source increases with length of exposure.

There have been no studies to date which have determined physiological injury or behavioural noise threshold levels for marine reptiles, including turtles. Therefore, it is uncertain what effects the high intensity construction activities (blasting and piling) will have on individuals that occur close to such activities. Samuel *et al*. (2005) demonstrated that anthropogenic noise may increase surface time of turtles, as they may rise to the surface as a 'startle' response to noise stimuli.

Underwater noise and vibration generated during construction has the potential to cause physiological injuries or a behavioural response (e.g. avoidance) in marine reptiles. Peak noise levels would be associated with construction and would be temporary in nature. Given the lack of physiological or behavioural noise thresholds, it is assumed that within the areas of highest SEL (**Figure 2.5-2**, **Figure 2.5-3** and **Figure 2.5-4**), the high intensity impulsive noise emitted during blasting and piling will overlap the frequency range of hearing in marine reptiles and will have the potential to cause physiological injuries or a behavioural response (e.g. avoidance).

Altered behaviour due to construction noise will be temporary and restricted to the construction phase of the BLNG Precinct. The primary impact on marine reptiles from blasting, piling and vessel activities will be focused nearshore with sound exposure levels for a given time period of exposure decreasing with distance from the source. Therefore, it is unlikely that noise emissions will affect turtles transiting through and/or foraging within the wider James Price Point coastal area. Post-construction, it is likely that displaced individuals will resume use of the area.

During port operations, the noise sources would consist primarily of continuous and lower intensity noise emitted from LNG vessels, with a considerably reduced potential to cause behavioural changes. Behavioural impacts resulting from marine noises are likely to include displacement from foraging. Numerous sources of anecdotal evidence suggest that turtles exhibit a 'startle' response to sudden increase noise levels, particularly moving vessels (MMS, 2007). Likely affected taxa would be predominantly green and flatback turtles, as they are the most common within the James Price Point coastal area.

It is expected that potential impacts on marine reptiles from marine noise and vibration can be successfully mitigated through application of management and mitigation measures such as a Port Facilities Construction Environmental Management Plan which would include a range of measures to manage turtle interactions such as soft-start piling, where practicable. A more detailed description of proposed mitigation measures is presented in **Section 2.7.4**. Given that the James Price Point coastal area does not support consistently high densities of turtles, noise associated with vessel activity is unlikely to result in turtle population level effects. Any behavioural changes that may result would not lead to mortality of individuals. The significance of the residual impact on marine reptiles from underwater noise generation during the construction and operation of the BLNG Precinct is assessed to be very low.

#### 2.7.3.2. Potential Impacts to Marine Reptiles due to Sediment Deposition, Turbidity, Marine Site Disturbance and Excavation

A review of published literature revealed no evidence that marine turtles are adversely affected by localised and short term increases in turbidity. These species are known to occur in areas of variable turbidity (e.g. Roebuck Bay).

There will be an indirect impact on reptiles associated with the loss of benthos (see **Part 3**, **Section 2.4** (Benthos including BPP)), resulting in a reduction in foraging habitat. This loss in benthic habitat may temporarily alter the usage of the area by marine reptiles; however, the majority of habitat loss has been determined to be temporary, with recovery anticipated within 5 years. In addition, it is anticipated that the loss of foraging habitat will not significantly impact food resource availability for marine reptiles, given the other extensive foraging areas throughout the adjacent Dampier Peninsula coastal region. The proportion of the permanent loss of foraging habitat, on total available turtle foraging area within the Dampier Peninsula is very small (see **Part 3**, **Section 2.4** (Benthos (including BPP)).

As discussed in **Part 3**, **Section 2.1** (Tidal regimes, wave climate, currents and hydrodynamics) the nearshore marine infrastructure is unlikely to result in any significant change to the coastal morphology (i.e. beach erosion or accretion) which may potentially impact nesting turtles. Additionally, it has been demonstrated that the beaches adjacent to the proposed BLNG Precinct are not recognised turtle nesting beaches, with only a very low frequency or opportunistic nesting noted during surveys (RPS, 2010b; **Appendix C-2**).

It is unlikely that increased turbidity generated during dredging and dredged spoil disposal activities would have a direct impact on marine reptiles. There could be a temporary, localised, indirect impact on reptiles associated with the loss of benthos, resulting in a reduction in foraging habitat. It is expected that potential impacts on marine reptiles can be successfully mitigated through application of management and mitigation measures such as controls for minimising impacts on marine reptiles detailed in a PFCEMP. A more detailed description of proposed mitigation measures is presented in **Section 2.7.4**. The significance of the residual impact was assessed as being low, given that the James Price Point coastal area does not support consistently high densities of turtles, and direct and indirect impacts are unlikely to result in turtle population level effects.

#### 2.7.3.3. Potential Impacts to Marine Reptiles due to Marine Discharges (including Non-routine Discharges)

Marine discharges, including both routine and non-routine (accidental spills or leaks) from the BLNG Precinct facilities and associated vessels will cause a localised reduction in water quality. This, in turn, represents a potential for indirect effects on marine reptiles that swim through the vicinity of those discharge zones. The implementation of effective waste treatment/management and industry standard product handling processes is expected to significantly reduce the impact from non-routine and routine discharges to reptiles in the marine environment. The potential for significant water quality decline is low, given the tidal fluxes of the nearshore waters and frequent flushing by strong tidal movements. The impact from routine marine discharge relates to sub-lethal irritation or physiological dysfunction to animals swimming directly through the discharge mixing zone.

Given the low concentrations of contaminants expected in the BLNG Precinct treated waste water, the high rates of dilution at the points of discharge and the reduced extent of the mixing zone resulting in intermittent exposure of marine reptiles to this area, it is highly unlikely marine discharges will have any impact on marine reptiles.

Non-routine events arising from accidental spillages could result in the release of a large volume of LNG, LPG condensate, diesel or fuel oil. In the event of an LNG spill, there would be a large phase transition as LNG vaporises upon contact with marine waters. Rapid phase transitions occur when the temperature difference between a hot liquid and a cold liquid is sufficient to drive the cold liquid rapidly to its superheat limit, resulting in spontaneous and explosive boiling of the cold liquid (Hightower *et al.,* 2004). Major constituents of LNG will vaporise relatively quickly and therefore any impacts to waters would be short lived.

However, the likelihood of such an event is very remote, considering the industry standard risk and operations management measures to be implemented. Nevertheless, although the occurrence is extremely unlikely, a large scale spill of LNG within the marine environment would result in temporary reduction in water quality, which may result in avoidance of the area by marine reptiles.

Routine marine discharges would result in a localised sub-lethal irritation or physiological dysfunction to individual marine reptiles swimming directly through the discharge mixing zone. The aerial extent of the reduction in water quality would be minimised through the design of the waste water infrastructure and the frequent flushing by strong tidal movements. Compliance with industry standards with respect to the storage and handling of hazardous liquids will minimise the likelihood of significant non-routine discharges (spills and leaks) occurring. In the unlikely event that a major spill does occur, implementation of an Emergency Response Plan including spill contingency procedures and coordination of proponents in the event of emergency response procedures would minimise the impacts. A more detailed description of proposed mitigation measures is presented in **Section 2.7.4**. The significance of the residual impact is assessed as being very low and it is considered by the proponent that, with the application of proposed preventative and mitigation measures, impacts can be managed to achieve acceptable outcomes.

#### 2.7.3.4. Potential Impacts to Marine Reptiles due to Light Emissions

Artificial lighting associated with the construction and operation of the BLNG Precinct has the potential to impact marine turtles by decreasing nesting attempts on the beach, disorientating hatchlings emerging from nests and increasing hatchling exposure to predation.

Indicative modelling from a similar LNG project (Gorgon LNG Project – Revised PER, Chevron Australia, 2008) has shown that lighting levels at a beach approximately 400m from the facility were predicted to be 0.04 to 0.08lux, less than natural moonlight levels (0.2lux) (Chevron Australia, 2008). Therefore, lighting states and subsequent impacts are not expected to be significantly altered more than 400m from the BLNG Precinct.

The BLNG Precinct is expected to be set back from the beach by at least 1km, with the jetty extending as much as 3km offshore. The degree to which direct light/light spill from the BLNG Precinct terrestrial and marine infrastructure may be visible, as well as the expected lux levels at various distances from infrastructure is shown in **Figure 2.7-1** and **Figure 2.7-2**, respectively.

Direct lighting and light spill (potentially + 1lux), largely emanating from taller elements of terrestrial infrastructure , such as fin fans and storage tanks (columns and turbine exhausts are not likely to be lit) and marine infrastructure, may potentially be visible from sections of James Price Point beach. This beach has had very low level nesting use (two tracks and one potential nest) recorded in previous surveys (RPS, 2010b; **Appendix C-2**). Potential disruption to this nesting activity is considered to be insignificant in the context of more suitable regionally significant nesting grounds such as the Lacepede Islands.

Murdudun Beach, south of the Precinct area towards Quondong Point, may be impacted by direct lighting and light spill (<+1lux at Murdudun Beach) emanating from the emergency high pressure flare system and marine infrastructure, however, no previous nesting has been recorded on this beach (refer **Figure 2.7-1** and **Figure 2.7-2**) (RPS, 2010b; **Appendix C-2**).

Lux levels at Quondong Beach are likely to be 0lux (i.e. less than natural moonlight levels). Parts of this beach (south) were considered suitable for nesting, however, direct light and light spill levels are considered to be less than natural moonlight levels and no nesting has been recorded here in previous surveys (refer **Figure 2.7-1** and **Figure 2.7-2**) (RPS, 2010b; **Appendix C-2**).

No other potentially suitable nesting beaches are likely to be affected by the BLNG Precinct.

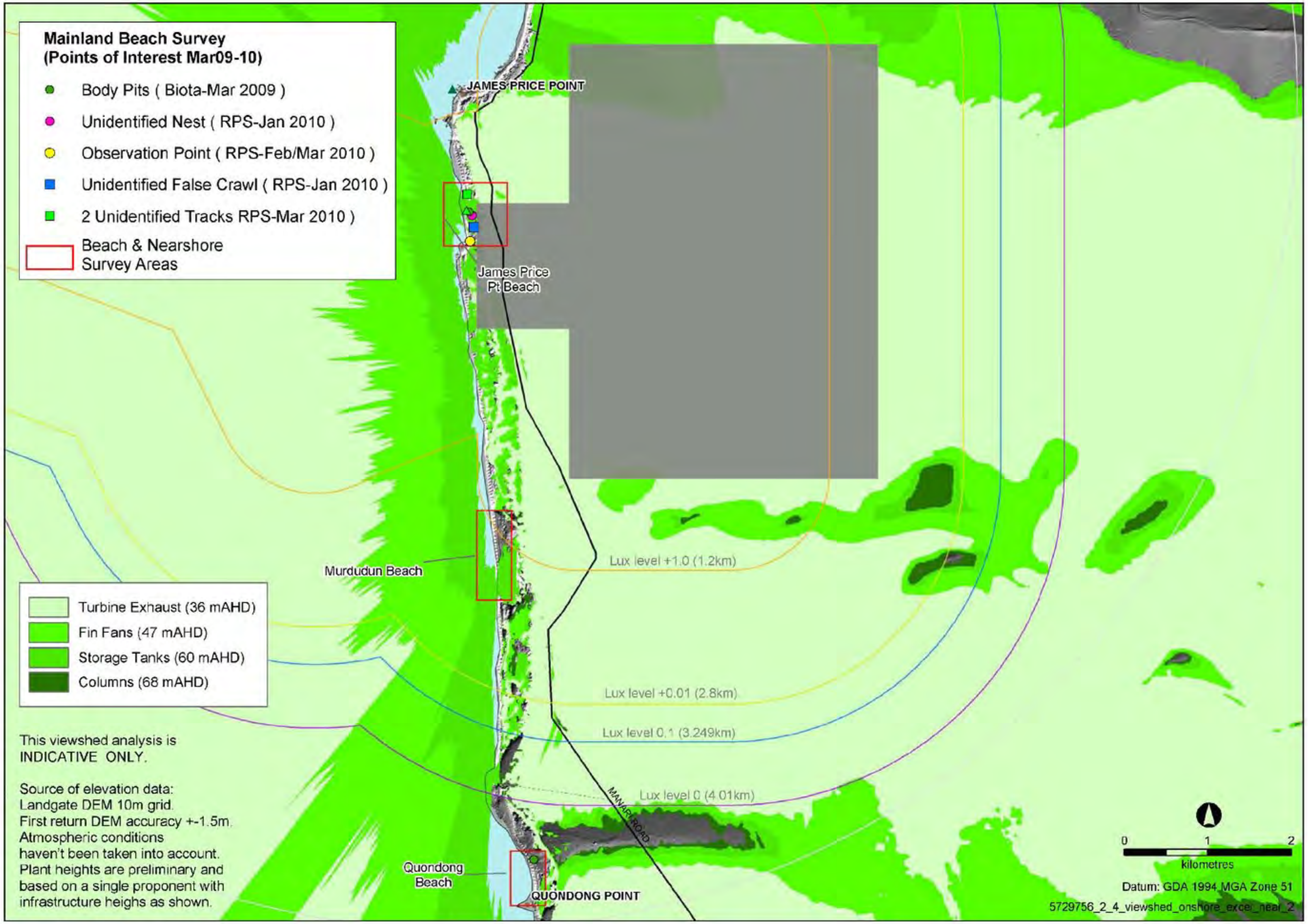
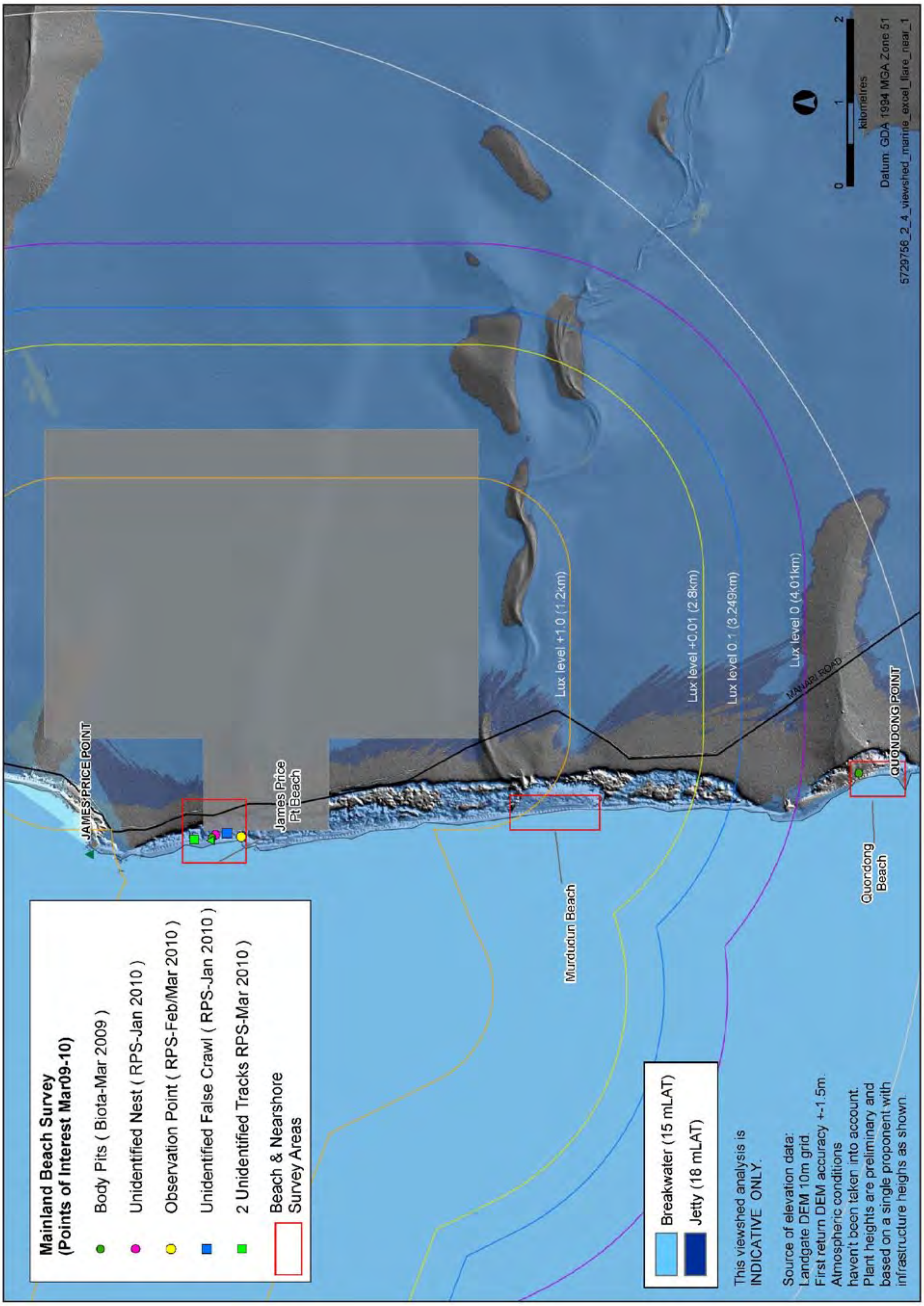



**Figure 2.7-1 Indicative Viewshed of Terrestrial Infrastructure and Predicted Lux Level Contours.**




■ **Figure 2.7-2 Indicative Viewshed of Marine Infrastructure and Predicted Lux Level Contours.**

As indicated, possible nesting beaches at Quondong Beach and Coulomb Point are located outside the area of predicted impact of light overspill. Lighting visible at these beaches is only likely to be a distant sky glow. The coastal topography including the sand dunes at the top of the beach creates a shading effect over the low-lying beach such that point sources of light are unlikely to be visible to turtles or hatchlings at beach level. As such, there is not expected to be any significant impact to nesting turtles from lights associated with the construction and operation of the BLNG Precinct, as surveys have indicated that nesting is opportunistic and very limited on beaches along the James Price Point coastal area (RPS, 2010b; **Appendix C-2**).

Significant turtle nesting habitat has been identified at the Lacepede Islands (approximately 65km north-west of James Price Point) and Eighty Mile Beach (approximately 197km south of James Price Point) for green and flatback turtles, respectively. Given the distance of these sites from the BLNG Precinct location and the localised nature of lighting emissions, there are no predicted impacts on these rookeries.

Hatchlings swimming out to sea from the beach may be attracted to light emissions from marine infrastructure or vessels, making them more prone to predation or vessel strike. This effect can be addressed by lowering the level of light spill onto the water, although noting the limited amount of turtle nesting/hatching activity in the immediate area. Vessels passing the Lacepede Islands at night, particularly LNG/condensate tankers moving to or from the BLNG Precinct Port area will be a distant moving source of light not in close proximity to the Lacepede Islands and are subsequently highly unlikely to attract hatchlings as they swim offshore.

Any significant nesting beaches are well removed from proposed light sources associated with the BLNG Precinct, therefore any residual impact is expected to be relevant to a small proportion of the regional turtle population. Impacts will be highly localised, and minimal and not at the population level. The significance of the residual impact on marine turtles due to light emission is assessed to be very low given the absence of any significant turtle nesting beaches in the immediate James Price Point coastal area.

#### 2.7.3.5. Potential Impacts to Marine Reptiles due to Vessel Movements

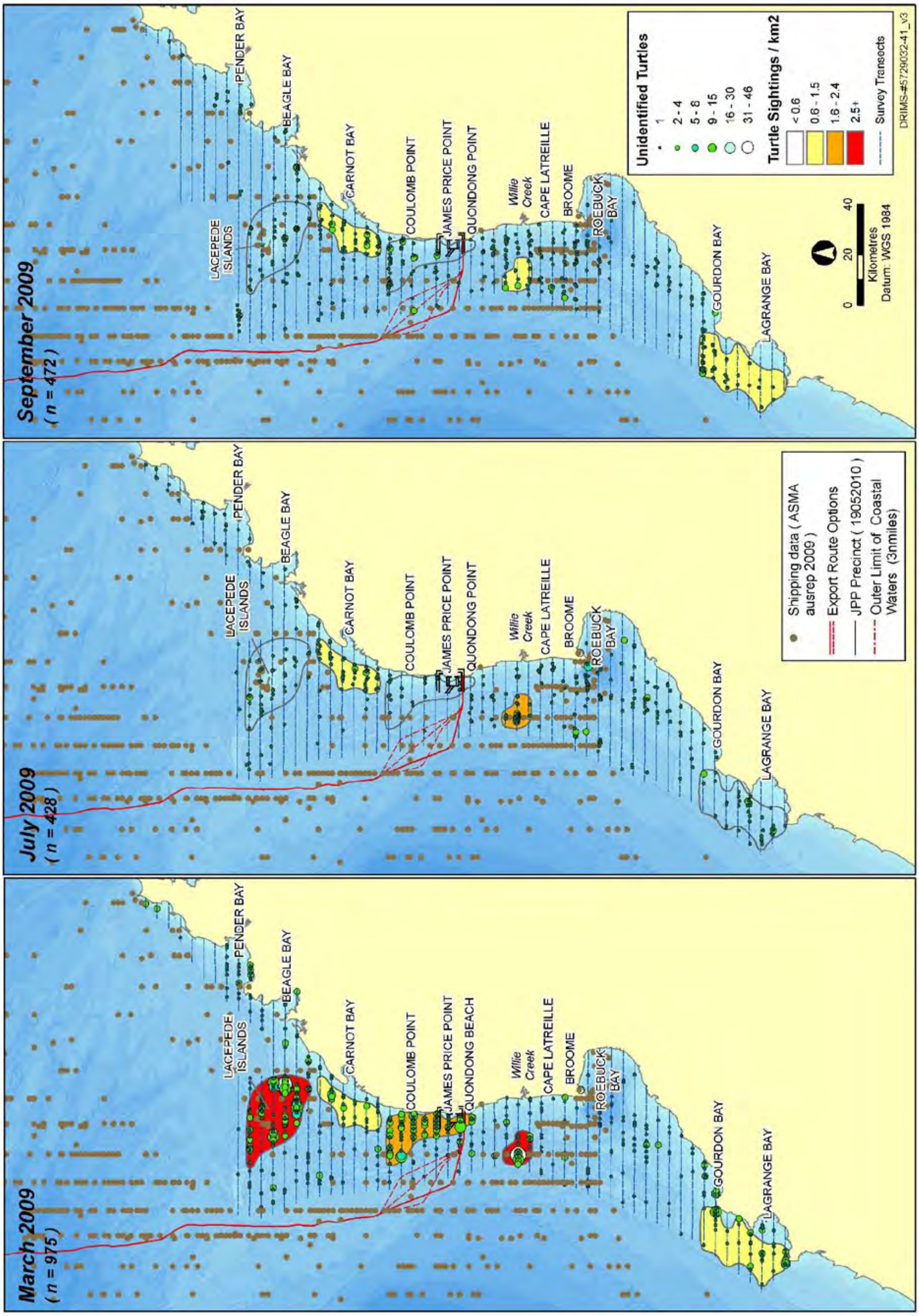
Turtles are susceptible to injury or mortality resulting from interaction with construction equipment. Given that marine turtles are known to occur in the Kimberley region and in the vicinity of James Price Point, there is the potential for direct contact and entrainment as a result of vessel operations during the development and operation of the BLNG Precinct Port area.

Generally, animals are most susceptible to vessel strike in shallow waters due to their proximity to the vessel (hull, propeller or equipment) and their limited ability to avoid vessels by diving due to shallow waters. Fast moving (smaller) vessels would tend to surprise or confuse an animal and therefore would pose the greatest risk of collision. The highest likelihood of vessel strike is during construction when vessel activity is highest and during periods of increased marine turtle activity (i.e. between dawn and dusk) at which time turtles may have a higher frequency of ascents.

There is also the potential for marine turtle entrainment within dredging equipment that may result in injuries and potentially mortality. However, this potential would be significantly reduced by the use of standard mitigation and protection measures (refer to **Section 2.7.4**).

While there is a potential for individuals to be affected, it is anticipated the potential exposure of turtles to vessel collision and entrainment is considered to be low, due to their relatively low density and occurrence in the James Price Point coastal area (**Figure 2.7-3**). Marine turtles observed in 2009 surveys off James Price Point coastal area, were largely concentrated in waters along the 10-20m isobaths, some 5 to 30km offshore (RPS, 2010b; **Appendix C-2**). Turtle densities off the James Price Point coastal area in particular, were low in comparison to other areas such as Lacepede Island Group, Carnot Bay and Cape Latreille. It is not expected that there will be an increase in vessel movements at important turtle nesting sites such as the Lacepede Island Group (approximately 65km north of James Price Point).

Marine reptiles are likely to forage over benthic habitat within the James Price Point coastal area during transit of the area . However no unique or abundant foraging habitats have been identified offshore from James Price Point, relative to other regional benthic habitats that have been identified along the Dampier Peninsula (i.e. Roebuck Bay, Lagrange Bay and Carnot Bay). Green and flatback turtles are known to feed on seagrass, algae and soft invertebrates, however it is evident that while there are such habitats available for grazing, such habitats are not limited or particularly abundant, within the BLNG Precinct Port area.




■ **Figure 2.7-3 Historical Shipping Movements and Proposed BLNG Shipping Infrastructure Coincident with Turtle Densities Sampled Along the Dampier Peninsula.**

There is the potential that marine reptiles, in particular, marine turtles, could be impacted by vessel movements, or entrainment within construction machinery. It is expected that potential impacts on marine reptiles can be successfully mitigated through application of management and mitigation measures such as briefing to vessel contractors of sensitive environmental features, and vessel speed restrictions. A more detailed description of proposed mitigation measures is presented in **Section 2.7.4**. The significance of the residual impacts on marine reptiles is assessed to be very low, given their relatively low density and occurrence in the James Price Point coastal area and it is likely that there would be no detectable impact to communities and populations.

### 2.7.4. Management Measures

Mitigation measures and safeguards that have been identified to manage potential impacts to marine reptiles are outlined below **Table 2.7-3**, **Table 2.7-4** and **Table 2.7-5**.

Refer also to the Management Arrangements specifically defined for Commonwealth matters, summarised in **Part 6**, **Section 3**.

- **Table 2.7-3 State Government Measures for Marine Reptiles.**

| State Government measure | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area. | Department of Transport (DoT) | On approval of BLNG Precinct |
| The Port Authority will prepare a BLNG Precinct Environmental Management Plan (BPEMP) for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management<br>• stakeholder consultation;<br>• reporting and review mechanisms; and<br>• management of turtle interactions will be in accordance with the measures for turtles specified under Part 8 of the *EPBC Regulations 2000.* | Broome Port Authority | Prior to approval of marine related derived proposals |

- **Table 2.7-4 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Marine Reptiles.**

| Condition No. | Proposed Environmental Conditions |
|---|---|
| M7.1 | Proponents of derived proposals shall report to the Broome Port Authority, DEC and SEWPAC a mortality resulting from BLNG Precinct activities, including vessel movements or dredging, of any specially protected and/or EPBC listed marine mega fauna. |
| **Proposals involving dredging** | |
| M7.2 | Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• consideration of the re-use of suitable dredge material for MOF construction, where practicable;<br>• design of the MOF including construction of bunds to isolate fill material from wind and wave action;<br>• consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives;<br>• consideration of re-use of reclaimed material to minimise ocean disposal;<br>• measures to minimise dredging impacts during sensitive ecological windows;<br>• a monitoring strategy for ecological receptors and health during marine construction (including baseline surveys);<br>• the development of trigger levels for benthic communities and water quality that define additional management responses;<br>• mechanisms to audit and assess environmental performance of proponents during construction; and<br>• a communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. |

- **Table 2.7-5 Requirements to be Addressed via Development of a Management Plan to Support a Derived Proposal Potentially Affecting Marine Reptiles.**

| Derived Proponent Requirements | Timing |
|---|---|
| Proponents of derived proposals shall prepare and implement a Port Facilities Construction Environmental Management Plan (PFCEMP), to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br>*In order to address the potential impacts to marine reptiles identified within this section, the Plan may include the following environmental management measures:*<br>• *scheduling blasting for daylight hours only, avoiding dawn and dusk, to allow for effective visual monitoring and minimising health and safety concerns;*<br>• *smaller, more frequent blasts planned using sequential explosive charges to minimise cumulative impacts of the explosions, as opposed to less frequent, larger blasts.*<br>• *warning charges used to encourage animals to move away from the construction area prior to a blast detonation; and*<br>• *shaped charges used to focus blast energy along fracture lines.* | Prior to commencement of associated construction activities |

| Derived Proponent Requirements | Timing |
|---|---|
| Prepare and implement a Vessel Management Plan (VMP), which may include the following measures:<br>• vessel speed restrictions within the Marine Precinct Port area;<br>• training for selected vessel crew to sight and manage interactions with marine mammals; and<br>• vessel contractor(s) to be provided with a map showing sensitive environmental features, including key turtle nesting areas. These areas will be avoided as far as practicable. | Prior to construction and updated for ongoing operational requirements |

### 2.7.5. Environmental Outcome

#### 2.7.5.1. Direct Impacts

Cumulative impacts from all Category A activities indicate that the potential impact to marine reptiles will be greatest during construction, when noise emissions and vessel activity will be highest.

After management and mitigation measures have been applied, it is expected that the BLNG Precinct Port area will result in the following direct impacts in relation to marine reptiles:

- Marine noise and vibration: Blasting and piling activities may cause behavioural and physiological impacts to turtles that are within close proximity (i.e. within several hundred metres) of these construction activities. It is expected that only a few to dozens of animals would typically be exposed and only a small proportion of those would be permanently affected. The level and extent of impact will depend on the actual number of energetic blasts conducted and preliminary indications are that these would be limited in number, if required at all. Noise impacts during operations from routine port operational sources, such as vessel propeller noise, will be minimal. These activities may cause behavioural change in swimming and foraging activity of marine turtles within the immediate BLNG Precinct Port area. Implementation of noise management strategies to minimise impacts are important during on-water construction.
- Light Emissions: The light emissions from proposed construction and operational activities will be localised (estimated at 400m from the infrastructure boundary within the BLNG Precinct Port area). However, such emissions are not in close proximity to any sensitive or critical turtle nesting or feeding habitat, so there is little risk of disorientation that may occur to hatchlings. No adverse effects to marine turtles are anticipated to arise from infrastructure presence, or likely to dissuade opportunistic nesting visits, so will not cause a significant impact or reduction on any turtle populations.
- Vessel strike: The risk of vessel strike on marine turtles will be greater during construction than operation due to the inclusion of dredge vessels (with an entrainment risk) and the presence of smaller, more manoeuvrable supply and service vessels. Additionally, there is less opportunity for turtles to avoid vessels travelling in turbid waters, which is also likely to be exacerbated during construction dredging. The effect of noise on marine turtles will dissuade foraging turtles from milling in the direct construction area, which is likely to limit the risk of vessel strike. During port operations, vessels will observe port channels and movements will be according to operating conditions.

#### 2.7.5.2. Indirect Impacts

Minor indirect effects on marine turtles may result from disturbance to seabed foraging habitats. Reduced productivity levels are unlikely to have an impact on the turtle populations during construction phase and will do so for only for a limited period of time until benthos outside of the excavation area recovers. This is likely to be less than five years.

Consistent with the EPA objectives, the abundance, species diversity, geographic distribution and productivity of fauna at species and ecosystem levels will be maintained, thereby conserving regional biological diversity.

**Cumulative Impacts of the Proposal and Associated Activities**

**Category B Activities**

The Category B activities centre around onshore actions supporting the BLNG Precinct, however they may potentially not be subject to the Strategic Assessment approval process. Activities that have the potential to affect marine reptiles in the wider Kimberley region include:

- further development of Broome Port to accommodate an increase in marine vessel traffic associated with regional development; and
- additional recreational traffic associated with increased population base.

The further development of Broome Port may have a minor impact on marine reptiles via direct disturbance to the seabed (if any), additional lighting requirements, limited areas of effect on the natural benthic habitat of the port environs through increased vessel anchoring and moorings, and reduction in water quality through potential spills and leaks from vessels and port infrastructure into the marine environment. Related infrastructure, such as a regional marine supply base, would typically have a similar effect, subject to final location of its infrastructure in relation to turtle nesting and foraging grounds.

The increased use of recreational vessels from the Broome district may pose a risk to turtles inhabiting areas such as Roebuck Bay, and adjacent waters. Small recreational vessels are swift and highly manoeuvrable meaning that they may impact turtles breathing at the surface with little advanced warning of approach. The incremental level of effect on marine reptiles from additional boat movements and port operations is likely to be small and localised, with no expected increase in vessel movements at important turtle nesting sites such as the Lacepede Island Group (approximately 65km north of James Price Point).

**Category C Activities**

Similar to the Category B actions, the geographic separation of the projects identified as Category C actions would not be expected to cumulatively add to those resulting from the BLNG Precinct development and operation. Category C activities which have the potential to impact on marine reptiles are limited to upstream exploration and development activities and, for turtles, these are unlikely to present major impacts.

Upstream development (including explorative and construction activities) of the Browse Basin gas field to acquire the natural gas resource and the operation of the upstream extraction of the gas will involve the discharge of drilling mud and chemicals that may cause localised changes in water quality, which may in turn affect marine reptile health. These effects would be localised, restricted in area to the immediate vicinity of the activity and typically well offshore away from the high turtle abundances which were recorded within 18km of the coast in up to 20m of water.

Increased vessel movement during exploration, construction (including pipelay operations) and operation of upstream resources may impact marine reptiles though vessel strikes. These are expected to be infrequent and are not expected collectively to impact numbers or viability of marine reptile populations.

▪ **Table 2.7-6 Impact Assessment Summary for Marine Reptiles.**

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | **State Government Measures** | **Proposed Environmental Conditions** | **Future Proponent Management Plans** | |
| Marine Noise and Vibration | Disturbance of conservation significant fauna individuals | Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area.<br>The Port Authority will prepare a BLNG Precinct Environmental Management Plan (BPEMP) for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water | Proponents of derived proposals shall report to the Broome Port Authority, DEC and SEWPAC a mortality resulting from BLNG Precinct activities, including vessel movements or dredging, of any specially protected and/or EPBC listed marine mega fauna.<br>Derived proponents shall prepare and implement a marine fauna and vessel interaction management and monitoring strategy, to the satisfaction of the Minister for Environment, prior to the commencement of marine construction activities.<br>Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredge Spoil Disposal Management Plan (DSDMP) to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts to. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and | Proponents of derived proposals shall prepare and implement a Port Facilities Construction Environmental Management Plan (PFCEMP), to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework<br>In order to address the potential impacts to marine mammals identified within this section, the Plan may include the following environmental management measures:<br>• scheduling blasting for daylight hours only, avoiding dawn and dusk, to allow for effective visual monitoring and minimising health and safety concerns;<br>• smaller, more frequent blasts planned using sequential explosive charges to minimise | Very low |
| Sediment Deposition and Turbidity | Disturbance of conservation significant fauna individuals<br>Loss of habitat | | | | Low |
| Site Disturbance/ Excavation | Loss of habitat | | | | Low |
| Marine Discharges | Disturbance of conservation significant fauna individuals | | | | Very Low |
| Non-routine Discharges (spills and leaks) | Disturbance of conservation significant fauna individuals | | | | Very Low |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| | | quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• an audit of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management<br>• stakeholder consultation; and<br>• reporting and review mechanisms. | technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• Consideration of re-use of reclaimed material to minimise ocean disposal.<br>• Measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br><br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. | cumulative impacts of the explosions, as opposed to less frequent, larger blasts;<br>• warning charges used to encourage animals to move away from the construction area prior to a blast detonation; and<br>• Shaped charges used to focus blast energy along fracture lines.<br><br>Prepare and implement a Vessel Management Plan (VMP), which may include the following measures:<br>• vessel speed restrictions within the Marine Precinct Port area;<br>• training for selected vessel crew to sight and manage interactions with marine mammals; and<br>• vessel contractor(s) will be provided with a map showing sensitive environmental features, including key turtle nesting areas. These areas will be avoided as far as practicable.<br><br>All vessels will be required to have in place a Ship-Board Oil Pollution Emergency Plan (SOPEP) and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea. | |
| Light Emissions | Disturbance of conservation significant fauna individuals | | | | Very Low |
| Vessel Movements | Injury or death of conservation significant fauna individuals | | | | Very Low |

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## 2.8. Relevant Factor: Marine Ecosystem Integrity

The health of an ecosystem is determined by its ability to maintain its 'integrity' for continued self-organisation (Kay and Regier, 2000). Thus, 'ecosystem integrity' describes an ecosystem's critical range of variability in biodiversity, ecological processes and structures enabling it to recover to a healthy state after a disturbance. Ecological integrity includes:

- diversity of genes, species, populations, communities and habitats;
- species abundance, richness and productivity;
- functional processes and structures including chemical, physical and biological processes;
- intactness (historical state);
- connectivity (links between habitats, communities and species); and
- resilience (ability to recover from or withstand disturbances).

Ecosystem integrity is compromised if an activity "reduces the capability of an ecosystem to support and maintain key ecological processes and organisms so that the species composition, diversity and functional organisations it supports are as comparable as possible to those occurring in natural habitats within the region" (Government of WA, 2004). Ecosystem integrity can be weakened when habitats degrade, the distribution and abundance of species alter or natural ecological processes are sub-optimal. Ecosystems can, however, show resilience in that they can resist or recover from certain disturbances. This resilience depends on site-specific factors and processes, which buffer against disturbances and promote ecological stability and productivity.

The following section describes the potential threats and associated impacts that may reduce or cause loss of marine ecosystem integrity (at the bioregional level) as a result of activities, facilities and other characteristics to be implemented under the Plan for the BLNG Precinct (Category A) and the potential for cumulative impacts from activities that may indirectly arise as a result of the Precinct development (Category B) and other related resource activities (Category C).

### 2.8.1. Current Knowledge

The following sub sections present the extent of knowledge and information from current and relevant studies, including key Commonwealth and State policy documents, relating to marine ecosystem integrity, potentially sensitive receptors and the current threats within the Canning Marine Bioregion.

#### 2.8.1.1. Key Statutory Requirements, Environmental Policy and Guidance

The main objective associated with this factor (as stated by the EPA) is the maintenance of

"*...the abundance, diversity, geographic distribution and productivity of flora and fauna at ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge*" and also "*…to maintain the integrity, ecological functions, and environmental values of the seabed and coast*" (EPA, 2009f).

Given the holistic nature of ecosystem integrity, a number of Federal and State guidelines, strategies, policies and regulatory frameworks are applicable and provide the context for assessing the key issues relating to threatening process to marine ecosystem integrity and expectations for management.

**International Conventions**

- United Nations Convention on the Law of the Sea (UNCLOS) 1982.
- Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties 1969 and the 1973 Protocol to the Convention.
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) 1972 and the 1996 Protocol to the Convention.
- International Convention on Oil Pollution Preparedness, Response and Cooperation 1990, as amended by the Protocol on Preparedness, Response and Cooperation to Pollution Incidents by Hazardous and Noxious Substances 2000.
- Convention for the Prevention of Pollution from Ships 1973 (MARPOL) through the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983.*
- International Convention for the Control and Management of Ship's Ballast Water and Sediments.
- International Convention on the Control of Harmful Anti-Fouling Systems on Ships.
- Convention on Biological Diversity 1992.

**Commonwealth Protection**

Marine ecosystem integrity is managed under the federal *EPBC Act* (1999) by affording protection to threatened species, communities and matters of National Environmental Significance. Additional commonwealth legislation, policy and guidance include:

- *Offshore Petroleum and Greenhouse Gas Storage Act 2006.*
- Petroleum (Submerged Lands) (Management of Environment) Regulations 1999.
- *Sea Installations Act 1987.*
- *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006.*
- *Environment Protection (Sea Dumping) Act 1981.*
- *Quarantine Act 1908.*
- The Australian Quarantine and Inspection Services (AQIS) ballast water guidelines.
- Australian Government National System Guidance Documents (Shipping and Ports, Petroleum and Non-trading vessels).
- National Introduced Marine Pest Identification System.
- National Assessment Guidelines for Dredging 2009 (NAGD) (DEWHA, 2009e).
- Revised Consultative Committee for Introduced Marine Pest Emergencies Trigger List.

**State Guidance and Policies**

- *Environmental Protection Act 1986.*
- Draft Environment Protection (State Marine Waters) Policy 1998.
- *Conservation and Land Management Act 1984.*
- *Marine Act 1982.*
- Environmental Assessment Guidelines (EAG) No.3 for Protection of Benthic Primary Producer Habitat in WA's Marine Environment (EPA, 2009a).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000).
- *Wildlife Conservation Act 1950* (WC Act).
- *Fish Resource Management Act 1994* (FM Act).

An Environmental Quality Management Framework is available for certain WA state waters. In the absence of a Kimberley specific framework, the WA Department of Environment and Conservation (2006) "*Pilbara Coastal Water Quality Consultation Outcomes. Environmental Values and Environmental Quality Objectives*" will be used for guidance. Accordingly, this document cites the following key elements that should not be affected in order to maintain ecological integrity:

- ecosystem processes (for example, primary production, nutrient cycles, food chains);
- biodiversity (for example, variety and types of naturally occurring marine life);
- abundances and biomass of marine life (for example, number or density of individual animals, the total biomass of plants); and
- quality of water biota and sediment (for example, types and levels of contaminants such as heavy metals, dissolved oxygen content, water clarity).

Four levels of protection and associated acceptable levels of change have been specified under the management framework and are presented in **Table 2.8-1**. As stated in the management framework (DEC, 2006), one or other of these levels of protection is applied to each part of the ecosystem in such a way that the general integrity of the ecosystem is maintained. This allows for management of conservation values and multiple uses (some with localised effects) while still maintaining the broad structure and function of the ecosystem.

**Table 2.8-1 The Level of Protection and Associated Limit of Acceptable Change Applied to Manage Ecological Integrity.**

| Level of protection | Relative protection | Limit of acceptable change | |
|---|---|---|---|
| | | Contaminant concentration indicators | Biological indicators |
| Level 1 | Total protection | No contaminants- pristine | No detectable changes from natural variation |
| Level 2 | High protection | Very low levels of contaminants | Some small changes from natural variation |
| Level 3 | Moderate protection | Elevated levels of contaminants | Moderate changes from natural variation |
| Level 4 | Low protection | High levels of contaminants | Large changes from natural variation |

Source: DEC, 2006.

### 2.8.1.2. Description of Factor

Relative to elsewhere in WA, there have been few scientific studies looking at the ecological linkages, processes and features that describe the ecosystem integrity of the Canning Marine Bioregion. Little is known about the susceptibility of its biological communities and marine ecosystem processes to anthropogenic pressures. However, there have been a few key studies conducted within the Canning Marine Bioregion that describe the existing marine environment including benthic habitats, substrate types, fish, the presence of marine mammals and reptiles and some studies that have investigated the effects of natural disturbances such as cyclonic events on the marine environment.

#### Marine Diversity and Abundance

The Canning Marine Bioregion contains unique and complex habitats that support a high level of biological diversity at all trophic levels (DEWHA, 2008a). Filter feeding communities containing sponges and gorgonians, as well as infaunal organisms, were prominent components of the benthic environment (Masini *et al.,* 2009). These organisms were observed in high abundances with a wide distribution and diverse range of species. Coral communities in the Canning Marine Bioregion were not well developed, although there were some localised examples off the Dampier Peninsula coast and a biogenic reef structure at the Lacepede Islands (approximately 65km north of James Price Point) (Fry *et al.,* 2008; **Appendix C-4**; Masini *et al.,* 2009; and SKM, 2010a; **Appendix C-5**). Within the James Price Point coastal area, hard coral communities were typically sparse, patchily distributed and usually consisted of only a few single colonies. Some medium to dense patches of *Turbinaria* sp. were observed at Perpendicular Head (approximately 92km north of James Price Point) and Packer Island (approximately 126km north east James Price Point) (Fry *et al.,* 2008; **Appendix C-4**). Seagrass communities within the James Price Point coastal area were sparse, patchily distributed, seasonally abundant and dominated by *Halophila* spp. (Prince, 1986; Masini *et al.,* 2009; and SKM, 2010a; **Appendix C-5**). Macroalgae communities were diverse, seasonally abundant and known to occur throughout the James Price Point coastal area associated with hard substrate (Fry *et al.,* 2008; **Appendix C-4**; Masini *et al.,* 2009; and SKM, 2010a;

**Appendix C-5**). All habitats observed within the James Price Point coastal area were represented elsewhere in the Canning Marine Bioregion (Gourdon Bay, Perpendicular Head and Parker Island).

The subtidal benthic habitats of the Canning Marine Bioregion supported fish communities that were both diverse and abundant, including a range of commercial and recreational fisheries (Fletcher and Santoro, 2007; Travers *et al*., 2010; Cappo *et al*., 2010b; **Appendix C-6**). A wide variety of larger marine organisms, such as sea turtles, whales, dugong and dolphins were known to occur either transiently or permanently (Masini *et al.,* 2009; and RPS, 2010a; **Appendix C-8**; RPC, 2010b; **Appendix C-2**; RPC, 2010c; **Appendix C-9**; and RPC, 2010d; **Appendix C-10**).

**Marine Functions and Processes**

Connectivity is used to describe the links between habitats, communities, species and processes at multiple spatial and temporal scales (Noss, 1991). It is the linkages across distances and areas (spatial) and in time (temporal) that have consequences on the growth, survival, and distribution of marine species.

Understanding connectivity is important when assessing the potential for ecosystems to recover from disturbances. For example, a marine community that does not receive a regular and large supply of recruits from other systems (is poorly connected) will recover slowly from a cyclone, and potentially undergo a dramatic transition from the historically dominant community, if the disturbance is prolonged or occurs repeatedly.

The degree of connectivity among populations also governs genetic divergence. Genetic divergence is the process by which two or more populations of an ancestral species go through independent genetic changes (mutations) through time. Recent data suggested that genetic divergence among offshore and onshore corals in the Kimberley Region can occur within species that are separated only by a few kilometres (Underwood *et al.,* 2007). This means that, depending on connectivity, species can recover from disturbances, or, if they have substantially diverged and can no longer reproduce, suffer localised extinction. This isolation presents a risk to ecosystem integrity as remote flora and fauna populations can be isolated from potential biological source areas, and low population sizes can increase the risk of extinction (Harris, 1984 and Soule, 1987).

The James Price Point coastal area has been described as a hotspot for sponge biodiversity (Hooper & Ekins, 2004). Irvine & Keesing (2009) collected and identified 52 species of tropical marine sponge in the vicinity of JPP (Coulomb Point to Quondong Point). Of these, 36 species belong to the class Demospongiae which were identified to species level where possible, remaining species were assigned to the broad Porifera group. Irvine and Keesing (2009) found twice the species diversity between Coulomb Point and Quondong Point than any site along the Dampier Peninsula and Gourdon Bay.

**Current Threats to Marine Ecosystem Integrity**

A threatening process in natural ecosystems is a process that detrimentally affects the conservation of native species or ecological communities (Lindenmayer and Burgman, 2005). Currently there are 19 Key Threatening Processes listed under the EPBC Act. It should be noted that the Commonwealth list is not definitive and that local threats identified by state conservation agencies must be understood. Existing threats to marine ecosystem integrity which are currently managed accordingly within the Canning Marine Bioregion include:

- commercial and recreational fishing;
- illegal, unreported and unregulated fishing;
- biosecurity breaches;
- pearling and aquaculture;
- tourisms and urban development;
- marine pollution and debris;
- boating and shipping; and
- climate change.

Due to its former relatively low level of human usage, the Canning bioregion has likely retained its historical composition and a high degree of intactness compared with other tropical marine ecosystems of the world (Wood and Mills, 2008 and Masini *et al.,* 2009). Yet, the above threats have to some degree influenced the intactness of the marine ecosystem.

### 2.8.2. Identification of Key Aspects

#### 2.8.2.1. Definition of Relevant Aspects

Aspects associated with the development and operations of the BLNG Precinct (Category A activities) that could have an impact on marine ecosystem integrity include:

- physical presence of marine infrastructure;
- marine site disturbance and excavation;
- sediment deposition and turbidity;
- marine noise and vibration;
- marine discharges, routine and non-routine events; and
- invasive marine species.

#### 2.8.2.2. Sources of Potential Impact

**Physical Presence of Marine Infrastructure**

A range of coastal and nearshore marine facilities will be constructed for the BLNG Precinct. These facilities are likely to include an export jetty facility, ship berthing pockets (with loading platforms, breasting and mooring dolphins), a breakwater (if required), and a Marine Facility including a marine offloading facility, vessel all-weather harbouring facilities (for tugs and support vessels) and other facilities to support marine port operations. Pipeline infrastructure within the marine and nearshore environment will include the feedstock gas pipelines and other ancillary pipelines.

**Marine Site Disturbance and Excavation**

The construction of the BLNG Precinct marine infrastructure will require dredging, dredge spoil disposal, drilling and coring of boreholes, positioning of jack-up barges and other marine activities (e.g. piling). These activities are associated with the dredging of the approach channel and turning basin, LNG export jetty installation, breakwater construction and pipeline trenching.

**Sediment Deposition and Turbidity**

The construction of the BLNG Precinct will require a capital dredging and dredge spoil disposal program to develop the shipping channel, turning basin(s) and berth pockets. The dredging and disposal of dredge spoil will result in increased sediment deposition and turbidity within the area around the marine construction activities.

**Marine Noise and Vibration**

The key potential sources of marine noise are vessels (engines and propellers), drilling and blasting if required, and piling activities. Other, less significant noise sources are dredging, pipeline installation, breakwater construction and aircraft movements.

**Routine Marine Discharges**

Routine discharges will include cooling water, hydrotest water, process water, brine from desalination, produced formation water, stormwater, grey water and treated sewage. These waste streams will be controlled within the Precinct facilities and are likely to be discharged to the nearshore marine environment via an ocean outfall.

**Non-routine Marine Discharges**

A review of the proposed BLNG Precinct facilities has indicated a number of hydrocarbon fluids will be stored within the Precinct Project Area. The presence of these fluids introduces an inherent risk of spills to the area and surrounding marine environment. Hydrocarbon inventories for the BLNG Precinct facilities will likely include LNG, condensate, marine diesel, lube oil and bunker fuel. Minor spills may result from accidental releases of hydrocarbons or chemicals. Major accidents such as vessel collisions, rupture of an LNG/condensate tanker or catastrophic failure of a production pipeline could result in the rapid release of a large volume of LNG, condensate, diesel or bunker fuel. Loading and shipping activities have the potential for a large release volume. Alternatively, the rupture of the main production pipeline has the

potential to release a large volume of LNG within the pipeline section. The likelihood of an event of this nature occurring is considered to be 'highly unlikely' although the environmental consequences could be significant.

**Invasive Marine Species**

The primary pathway for IMS introductions is via vessels, either through contaminated ballast water discharge or biofouling on the vessel's hull and internal niche areas. Sources of impact include parasites, diseases and marine organisms.

#### 2.8.2.3. Sensitivity and Resilience

The concept of ecosystem resilience can be defined as the ability of a system to resist, reorganise and recover from a disturbance (Nystrom *et al.,* 2000). Resilience depends on biological or ecological characteristics that promote resistance or restoration after disturbances. Resilience also depends on characteristics of the physical environment such as bathymetry and currents. These characteristics affect processes such as settlement through availability of optimal substrata and rates of recruitment, or aid flushing of pollutants and/or toxicants (for water quality related impacts). Some systems are inherently more diverse than others and may have greater functional redundancy allowing for species replacement rather than loss. Alternatively, some habitats such as seagrass meadows may comprise communities reliant upon a few, specific foundation species (or ecosystem engineers) and hence be potentially more vulnerable to habitat collapse.

Existing exposure to disturbances within the Canning Marine Bioregion appear to be dominated by natural features of the environment including high insolation, tidal currents, large tides (over 10 metres), extreme and sudden variations in salinity and cyclonic events. Therefore, it has been suggested that the intertidal and subtidal biota of the Canning bioregion have evolved to withstand the physical stresses and disturbances associated with Australia's northern nearshore marine habitats (Hutchings *et al.,* 2002). For example, there is evidence that nearshore benthic primary producers (BPPs) can withstand episodic acute turbidity events (Cooper *et al.,* 2008). In addition, hard coral communities at Scott Reef 470km north-west of James Price Point have been observed to recover following a mass bleaching event in 1998 and subsequent impacts from two cyclones (Gilmour *et al.,* 2009). An alternative theory is that naturally disturbed communities already exist at the limit of their environmental tolerance and may be vulnerable to further disturbances (Perry *et al.,* 2008).

Currently no large scale development activities occur or have occurred within the James Price Point coastal area. Without evidence of the added affect of additional anthropogenic stress upon the marine ecosystem, it is difficult to generalise as to whether it will display a high degree of resilience or not. The response of the marine ecosystem to anthropogenic stress (resilient or otherwise) is typically predicted based upon known information to current stresses. Specific details on the sensitivity and resilience of specific factors are discussed in each of the Marine Impact Assessment Sections (**Part 3**, **Section 2**).

### 2.8.3. Predicted Impacts

The presence of the BLNG Precinct has the potential to alter the long-term ecosystem integrity of the local marine environment through the aspects summarised below. However, marine ecosystem integrity is generally affected by a combination of aspects and their complex interaction with various marine factors, which are addressed in further detail in the associated sections of this report (refer preceding sections of **Part 3**). Subsequently the impact assessment process for marine ecosystem integrity focussed on IMS, which is deemed to have particular relevance to this factor, specifically the potential degradation or loss of habitat and benthic productivity. This approach is consistent with the Scope of Strategic Assessment (DSD, 2010b; **Appendix A-2**), which also identified IMS as the main aspect with the greatest potential to cause impact to marine ecosystem integrity.

#### 2.8.3.1. Potential Impacts to Marine Ecosystem Integrity due to Physical Presence of Marine Infrastructure

The physical presence of marine infrastructure will result in permanent loss of benthic habitat, although this is not considered to result in a reduction in diversity. The permanent loss of benthic habitat will be localised and restricted to approximately 40–50% of the BLNG Precinct Port area (500ha). Potential impacts from the permanent loss of benthic habitat include behavioural responses in marine fauna, a reduction in abundance of benthic flora and fauna (mostly immobile organisms), potential habitat fragmentation, changes to intactness and possible effects to community resilience due to the loss of species abundance.

The presence of marine infrastructure can provide additional habitat which would otherwise not be able to exist within that particular area. For example, the construction of a jetty would provide additional habitat for settling and recruitment of pelagic larvae of organisms including bivalves, ascidians and barnacles. This can potentially create new communities and alter the localised ecosystem structure, which may provide habitat for IMS recruitment and result in an increase in biodiversity.

As the impacts associated with the physical presence of the marine infrastructure have been demonstrated to be localised to the BLNG Precinct project area, they are not expected to affect ecosystem integrity at a bioregional scale. Marine infrastructure associated with the BLNG Precinct will result in some localised loss of benthic habitat whilst creating new habitat structures, potentially increasing species diversity and abundance. This resulting change to ecosystem structure would be localised to the BLNG Precinct area and would not affect marine ecosystem integrity at a bioregional scale.

It is expected that potential impacts from physical presence of infrastructure can be successfully mitigated by the application of best practice management and mitigation measures such as the requirement for derived proponents to demonstrate the minimisation of impacts on coastal processes from onshore and nearshore marine infrastructure. A more detailed description of proposed mitigation measures is presented in **Section 2.8.4,** and also in **Part 3**, **Section 2.1** and **Part 3**, **Section 2.4**. The significance of the residual impact on marine ecosystem integrity is assessed as low as impacts will be localised and it is considered by the proponent that, based on industry experience, proposed management measures can be expected to be successful.

For further detail of the impacts associated with the physical presence of marine infrastructure, refer to **Part 3**, **Section 2.1** (Tidal Regimes, Wave climate, Currents and Hydrodynamics) and **Section 2.4** (Benthos (including BPP)).

#### 2.8.3.2. Potential Impacts to Marine Ecosystem Integrity due to Marine Site Disturbance and Excavation

Site disturbance and excavation will result in some temporary and permanent loss of benthic habitat. Aside from those areas directly affected by the physical presence of marine infrastructure, the recovery of local ecosystem stability and productivity is predicted to occur within the short-term (<5 years).

Certain activities will cause habitat loss through the removal or disturbance of benthic habitat. This will cause a limited reduction in localised species numbers, richness and abundance. These changes present a risk to ecosystem stability and function within the immediate vicinity of the BLNG Precinct.

There is also the potential impact of nutrient and contaminant release from sediments during maintenance dredging activities. This release can potentially change nutrient cycles and water quality. Reduced water quality can affect the stability and function of an ecosystem through changes to the physical environment (for example, light reduction) or change to the relative abundance of different algae. This, in turn, can lead to changes in community structure, diversity and function. The sediments and nearshore waters of the James Price Point area are naturally nutrient poor, so this effect is unlikely to occur. A potential release of contaminants would be very localised to within the direct vicinity of the dredging activity and would not impact on surrounding waters due to rapid dilution.

It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures such as identification of key environmental values and development of water quality objectives and criteria within the Port through a BLNG Precinct Environmental Management Plan (BPEMP). A more detailed description of proposed mitigation measures is presented in **Section 2.8.4** and also in **Part 3**, **Section 2.4.** The significance of the residual impact on marine ecosystem integrity is assessed as low.

For further detail of the impacts associated with marine site disturbance and excavation, refer to **Part 3**, **Section 2.4** (Benthos including BPP).

#### 2.8.3.3. Potential Impacts to Marine Ecosystem Integrity due to Sediment Deposition and Turbidity

Both direct and indirect impacts are potentially associated with sediment deposition and turbidity. The most significant impacts will be from reduced water quality, increased turbidity and sedimentation, habitat loss and a subsequent reduction in diversity and abundance of marine flora and fauna. Given the changes to the benthic environment that are predicted to occur as a result of dredging and spoil disposal activities, as well as the estimated localised individual loss

and indirect impacts to populations and communities, there is a potential for sedimentation and turbidity to adversely impact on marine ecosystem stability.

Sediment deposition and turbidity from dredging and disposal activities are physical stressors that can have a direct impact on ecosystem function via habitat loss, a reduction in light availability and smothering. This can affect the structural complexity and primary production of benthic habitats. Habitat loss and smothering can cause a reduction in populations of immobile benthic flora and fauna. This can have a cumulative effect via bottom-up population control on consumers. There is evidence to suggest that benthic habitats within the BLNG Precinct area are, to some degree, resilient to fluctuations in turbidity and sedimentation. This is due to the naturally variable conditions under which indigenous organisms are exposed.

There is evidence that microbial communities can flourish during sediment deposition (Hallegraef & Jeffrey, 1984 and Kline *et al.,* 2006). Conversely, microbial species can become pathogenic at critical densities, hence, risk of infection for susceptible organisms at higher trophic levels becomes greater causing changes to ecosystem balance and function.

Sediment deposition and turbidity may result in reduced water quality, increased turbidity and sedimentation, habitat loss and a subsequent reduction in diversity and abundance of marine flora and fauna. Dredge activities, which are the main cause of sediment deposition and turbidity, will occur predominantly during the construction phase of the BLNG Precinct, with the recovery of ecosystem stability and productivity predicted to occur in the short term.

It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures such as demonstration of best practice management techniques and technologies which would be applied to minimise potential dredging impacts. A more detailed description of proposed mitigation measures is presented in **Section 2.8.4** and also in **Part 3**, **Section 2.3**. The significance of the residual impact to marine ecosystem integrity is assessed as low. For further detail of the impacts associated with sediment deposition and turbidity, refer to **Part 3**, **Section 2.3** (Marine Water Quality).

#### 2.8.3.4. Potential Impacts to Marine Ecosystem Integrity due to Marine Noise and Vibration

Noise and vibration, predominantly during construction of the BLNG Precinct, have the potential to affect individual fish and benthic biota within the vicinity of the port construction activities.

Noise and vibration can deter mobile fauna from entering an affected area. If the fauna are top-down ecosystem regulators (predators and consumers), the effects include reduction of ecosystem stability and function through changed competition/predation for food or habitat of functional groups or species that were otherwise balanced. For example, the proliferation of macroalgae due to a lack of herbivory can cause a loss of habitat for recruitment of other functional groups. High intensity noise sources (drilling and piling) can potentially cause physiological and/or behavioural changes in fish and marine mammals and in extreme cases, mortality. However, given the mainly localised and intermittent nature of this aspect, it is likely to only affect individual fish and benthic biota with minimal threat to ecosystem stability and function. Therefore, it is unlikely that noise and vibration from planned BLNG Precinct activities would detrimentally affect marine biota at the population, community or ecosystem level.

It is expected that potential impacts from marine noise and vibration can be successfully mitigated through application of management and mitigation measures such as a Port Facilities Construction Environmental Management Plan which would include a range of measures to manage marine fauna interactions such as soft-start piling, where practicable. A more detailed description of proposed mitigation measures is presented in **Section 2.8.4** and also in **Part 3**, **Sections 2.5**, **Section 2.6** and **Section 2.7**. The significance of the residual impact to marine ecosystem integrity is assessed to be low as, with the application of proposed mitigation measures, impacts are expected to be localised and intermittent and therefore not predicted to result in ecosystem level effects.

For further detail of the impacts associated with marine noise and vibration, refer to **Part 3**, **Section 2.5** (Fish), **Section 2.6** (Marine Mammals) and **Section 2.7** (Marine Reptiles).

#### 2.8.3.5. Potential Impacts to Marine Ecosystem Integrity due to Marine Discharges

**Routine Discharges**

Routine marine discharges are a potential source of pollution that can reduce water quality within the vicinity of the mixing zone. This mixing zone will be localised within the BLNG Precinct Port Area. Discharges can act as toxins to biota or change the water quality causing mortality. Reductions in the diversity and abundance of marine flora and fauna can cause changes to community structure and abundance of different trophic assemblages.

Elevated nutrient discharges are commonly associated with the construction of marine infrastructure. These nutrients can trigger changes to nutrient cycles and subsequently promote localised declines in water quality. Changes in water quality can affect the stability and function of an ecosystem through changes to the physical environment (for example, light reduction) or changes in the relative abundance of different trophic assemblages, which in turn leads to changes in community structure, diversity and function.

Given the low concentrations of contaminants expected in the BLNG Precinct treated waste water, the high rates of dilution at the point of discharge and the reduced extent of the mixing zone, the impacts from routine marine discharges would be localised (i.e. within the mixing zone) and are unlikely to have effects on the broader marine ecosystem. Wastewater discharge modelling is being undertaken to confirm the predicted mixing and dilution of treated wastewater discharges beyond the outfall, and to substantiate expected environmental outcomes associated with routine marine discharges from the proposed BLNG Precinct. Results of this modelling will be made publicly available during the public release of the SAR.

**Non-routine Marine Discharges**

Non-routine events arising from accidental spillages could result in the release of a large volume of LNG, LPG condensate, diesel or fuel oil. In the event of an LNG spill, there would be a large phase transition as LNG vaporises upon contact with marine waters. Rapid phase transitions occur when the temperature difference between a hot liquid and a cold liquid is sufficient to drive the cold liquid rapidly to its superheat limit, resulting in spontaneous and explosive boiling of the cold liquid (Hightower et *al.,* 2004). Major constituents of LNG will vaporise relatively quickly and therefore any impacts to waters would be short lived.

Non-routine impacts, such as hydrocarbon spills and leaks present an ongoing risk to marine ecosystem integrity, although industry standard practices and management measures ensure the likelihood of such events is extremely low. The overall effect on the marine environment due to spills is difficult to predict and depends on the severity of the spill or leak. Potential impacts can be widespread and permanent. They include a reduction in water quality, a reduction in sediment quality, mortality of marine flora and fauna, cumulative effects to ecosystem processes and functions, loss of biodiversity and abundance, reduced resilience, reduced intactness and bioaccumulation.

Compliance with industry standards with respect to the storage and handling of hazardous liquids will minimise the likelihood of significant non-routine discharges (spills and leaks) occurring. In the unlikely event that a major spill does occur, implementation of an Emergency Response Plan including spill contingency procedures and coordination of proponents in the event of emergency response procedures would minimise the impacts. A more detailed description of proposed mitigation measures is presented in **Section 2.8.4** and also in **Part 3**, **Section 2.3**. The significance of the residual impact to marine ecosystem integrity was assessed as medium and it is considered by the proponent that, with the application of proposed preventative and mitigation measures, impacts can be managed to achieve acceptable outcomes. These predicted environmental outcomes from non-routine discharges will be confirmed by hydrocarbon spill modelling currently being undertaken for the BLNG Precinct and relevant activities. The results of this supplementary modelling will be made publicly available during the public consultation period for the SAR.

For further detail of the impacts associated with marine discharges, refer to **Part 3**, **Section 2.3** (Marine Water Quality).

#### 2.8.3.6. Potential Impacts to Marine Ecosystem Integrity due to Invasive Marine Species

The potential impact from IMS is the introduction and establishment of non-indigenous species, diseases and parasites. Flow on impacts include changes to nutrient and energy cycles, changes to ecosystem stability, loss of biodiversity and abundance from predation and/or competition, competitive exclusion of native species and mortality from infection.

The key risk pathways for introduction of IMS are via contaminated (biofouling) vessels, immersed equipment and ballast water discharge during construction and operation (Hallegraef, 1998). Successful establishment depends upon the introduction, colonisation and establishment and further dispersal (Sakai *et al.,* 2001).

The introduction of IMS could alter the existing marine ecosystem balance in the Canning Marine Bioregion if successful establishment occurs. In the event that an IMS is permanently introduced to the Canning Marine Bioregion and causes a loss of keystone native species, it would have major changes to the species composition of the area and hence it's ecological integrity. Consequential impacts may include changes to nutrient and energy cycles, changes to ecosystem stability, loss of biodiversity and abundance.

The high biodiversity and low endemism exhibited by biota within the Canning Marine Bioregion may inhibit the successful colonisation of invasive marine species through competitive exclusion by native species. There have been records (Wells *et al.,* 2009 and Huisman *et al.,* 2009) of introduced marine species into Broome (*Amphibalanus amphitrite*, *Megabalanus tintinnabulum* and *Megabalanus ajax*), although these are not listed as 'species of concern' on the Consultative Committee for Introduced Marine Pest Emergencies trigger list, and are therefore not formally considered as 'invasive marine species'.

The impact assessment determined that the introduction and establishment of IMS, as a result of BLNG Precinct activities, to be unlikely, due to the low endemism, high biodiversity and competitive exclusion exhibited by existing biota. It is expected that potential impacts can be successfully mitigated by application of management and mitigation measures, such as the enforcement of IMS inspection requirements to significantly reduce the risk of IMS introduction and establishment. A more detailed description of proposed mitigation measures is presented in **Section 2.8.4**. The significance of residual impact is considered to be low.

### 2.8.4. Management Measures

Management measures and safeguards that have been identified to avoid, minimise, manage and mitigate potential impacts to ecological integrity are outlined below in **Table 2.8-2**, **Table 2.8-3**, **Table 2.8-4** and **Part 6**, **Section 3** of the Plan.

- **Table 2.8-2 State Government Measures for Marine Ecosystem Integrity.**

| State Government measure | Responsibility | Timing |
|---|---|---|
| Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area. | Department of Transport (DoT) | On approval of BLNG Precinct |
| The Port Authority will prepare a BLNG Precinct Environmental Management Plan (BPEMP) for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port;<br>• auditing of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management<br>• stakeholder consultation; and<br>• reporting and review mechanisms. | Broome Port Authority | Prior to approval of marine related derived proposals |
| Establishment of a DMAG comprising representatives from:<br>• Independent Chair with extensive knowledge of marine environment;<br>• Broome Port Authority;<br>• office of EPA;<br>• DEC;<br>• DoF;<br>• SEWPAC; and<br>• Foundation or other proponent. | DSD on advice of SEWPAC and EPA | Prior to referral of future major dredging proposals |
| The role of the DMAG will be to provide advice to the proponent, EPA and/or the Minister for Environment as appropriate on the following:<br>• marine investigations (including the modelling of dredge plumes);<br>• environmental risk assessments prepared for future dredging proposals;<br>• risk to key environmental values in risk zones;<br>• detailed water quality or impact criteria for risk-based performance standards and the final configuration of risk zones; and<br>• dredge management plans (including monitoring programs and adaptive response in the event that risks to key values are greater than low) prepared by proponents of future major dredging proposals | DSD | Prior to referral of future major dredging proposals |

- **Table 2.8-3 Proposed Environmental Conditions for the Strategic Proposal Potentially Affecting Marine Ecosystem Integrity.**

| Condition No. | Proposed Environmental Conditions for the Strategic Proposal |
|---|---|
| **Proposals involving quarantine management** | |
| M4.1 | Proponents of derived proposals shall prepare and implement an Invasive Marine Species Management Plan, to the satisfaction of the Western Australian Minister for Environment on advice from and in consultation with the Department of Fisheries, to minimise the risk of introducing IMS into Australian waters during the life of the activity. The plan shall be developed in consultation with the AQIS and will be applied to vessels, barges and immersible equipment that plan to enter and operate within the Precinct. |
| M4.2 | The IMSMP will be consistent with the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry. |
| M4.3 | The IMSMP will adhere to the AQIS Australian Ballast Water Management Requirements under the Quarantine Act (1908). |
| M4.4 | Proponents shall, for the life of the activity, notify the DEC, the DoF, AQIS and the Broome Port Authority of any IMS detected in the waters of the BLNG Precinct. |
| **Proposals involving dredging** | |
| M2.4 | Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• consideration of re-use of reclaimed material to minimise ocean disposal.<br>• Measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of times of peak construction activity that may influence non-construction related activities within the area.<br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. |

- **Table 2.8-4 Requirements to be Addressed via Development of a Management Plan to Support a Derived Proposal Potentially Affecting Marine Ecosystem Integrity.**

| Derived Proponent Requirements | Timing |
|---|---|
| Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework. | Prior to commencement of associated construction activities |
| Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to commencement of associated construction activities |
| All vessels will be required to have in place a SOPEP and will be required to comply with MARPOL 73/78 regulations with regards to discharges at sea. | Prior to construction and updated for ongoing operational requirements |
| Prepare and implement a Marine Wastewater Discharge Management Plan (MWDMP), to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | Prior to construction of marine discharge facilities |

### 2.8.5. Environmental Outcome

After management and mitigation measures have been applied, it is expected that the BLNG Precinct (Category A activities) will result in the following key potential direct and indirect impacts in relation to marine ecosystem integrity.

#### 2.8.5.1. Direct Impacts

Potential direct impacts on marine ecosystem integrity include:

- changes in community structure, diversity and functional processes;
- changes in the relative abundance of different trophic assemblages; and
- reduction in resilience due to the restriction of connectivity and habitat fragmentation.

#### 2.8.5.2. Indirect Impacts

The key potential indirect impacts, in relation to marine ecosystem integrity, predicted to occur as a result of the BLNG Precinct (Category A activities) after management and mitigation measures have been applied are mainly through the localised permanent loss, and or reduction, to ecosystem stability and function. Ecosystem stability and function is indirectly affected by the removal or addition of habitats, species and communities which causes flow-on effects to other trophic levels and can alter the processes operating within an ecosystem.

Overall, the predicted impacts are not expected to compromise the main objective associated with this factor (as stated by the EPA) to maintain "*...the abundance, diversity, geographic distribution and productivity of flora and fauna at ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge" and also "…to maintain the integrity, ecological functions, and environmental values of the seabed and coast*" (EPA, 2009f).

### 2.8.6. Cumulative Impacts of the Proposal and Associated Activities

Cumulative effects to ecosystem integrity result from the addition and interaction of multiple stresses affecting the stability and the functions of ecosystems. Cumulative effects are of particular concern as ecological systems can sometimes change abruptly and unexpectedly in response to apparently small disturbances when exposed to additional sources of stress. From a precautionary point of view, it is therefore necessary to assume that multiple stresses increase the risk of decline to ecosystem integrity.

#### 2.8.6.1. Category B Activities

The Category B activities are centred around onshore actions supporting the BLNG Precinct but are not subject to the current State or Commonwealth approval process. A number of Category B activities have the potential to affect marine ecosystem integrity. These include further development of Broome Port to accommodate offshore shipping activity, the additional recreational boating attributable to regional population growth, and the associated urban development of the near coastal catchment of Broome and environs. However, these impacts are expected to be localised and of limited extent. Ecosystem integrity attributes such as connectivity of habitat and functional processes are not compromised by spatially limited and/or small effects arising from Category B activities. These localised impacts are not foreseen to interact through the broader Canning Marine Bioregion with BLNG Precinct (Category A) activities. For these reasons, there are no significant expected cumulative impacts to marine ecosystem integrity arising from Category B activities.

#### 2.8.6.2. Category C Activities

Category C activities include upstream development (explorative and construction activities) of the Browse Basin gas field (to acquire the hydrocarbon resource) and the operation of the upstream extraction of hydrocarbons. Key Category C activities that have the potential to impact on ecosystem integrity involve the introduction of invasive marine species, non-routine discharges and vessel movements. There is the potential for the introduction of IMS to occur as vessels and rigs will be arriving in the area regularly during the lifespan of the development. The main controllable factor affecting the degree of environmental impact associated with the introduction of IMS is the 'probability of introduction'. Therefore, once suitable management and mitigation measures have been put in place, the impact to ecosystem integrity from the introduction of IMS from Category C activities is considered to be unlikely.

The upstream development activities will involve the direct and indirect disturbance and loss of benthic habitats, and partial fragmentation of these habitats, however, this disturbance is expected to be localised (and typically away from more biodiverse shallow nearshore environments).

The geographic separation of the activities identified as Category C means that all other impacts would not be expected to add cumulatively to those of the BLNG Precinct across the Canning Marine Bioregion. In addition, the localised nature of most impacts from Category C activities minimises the overall impact to ecosystem integrity.

■ **Table 2.8-5 Impact Assessment Summary for Marine Ecosystem Integrity.**

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | **State Government Measures** | **Proposed Environmental Conditions** | **Future Proponent Management Plans** | |
| Physical Presence | Loss or change in ecosystem integrity | Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct, and an associated port area, which would have functions including regulation of:<br>• marine construction within the port area;<br>• long term dredging and spoil disposal program and management strategy to service the port area;<br>• vessel navigation, operations and movements within the port area;<br>• establishment and management of exclusion zones; and<br>• environmental and risk management within the port area.<br><br>The Port Authority will prepare a BPEMP for the port area in consultation with DEC and other relevant agencies, which addresses the following:<br>• collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally;<br>• an ecological and water quality monitoring program within the port boundaries and appropriate reference areas;<br>• identification of key environmental values and development of water quality objectives and criteria for waters within the Port<br>• auditing of operational marine | Proponents of derived proposals shall prepare and implement an Invasive Marine Species Management Plan, to the satisfaction of the Western Australian Minister for Environment, to minimise the risk of introducing invasive marine species (IMS) into Australian waters during the life of the activity. The plan shall be developed in consultation with the AQIS and will be applied to vessels, barges and immersible equipment that plan to enter and operate within the Precinct.<br><br>The IMSMP will be consistent with the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry.<br><br>The IMSMP will adhere to the AQIS Australian Ballast Water Management Requirements under the Quarantine Act (1908).<br><br>Proponents shall, for the life of the activity, notify the DEC, the DoF, AQIS and the Broome Port Authority of any IMS detected in the waters of the BLNG Precinct.<br><br>Prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan, to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice | Proponents of derived proposals shall prepare and implement a PFCEMP, to the satisfaction of the Western Australian Minister for Environment, which addresses the following:<br>• schedule of construction activities;<br>• details of the construction methods to be used;<br>• environmental training and inductions;<br>• environmental monitoring, management, contingencies and reporting;<br>• stakeholder consultation; and<br>• consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.<br><br>Prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality).<br><br>All vessels will be required to have in place a Ship-Board Oil Pollution Emergency Plan (SOPEP) and will be required to comply with MARPOL 73/78 regulations with | Low |
| Marine Site Disturbance and Excavation | Temporary and permanent loss of benthic habitat | | | | Low |
| Sediment | Changes to | | | | Low |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | State Government Measures | Proposed Environmental Conditions | Future Proponent Management Plans | |
| Deposition and Turbidity | ecosystem function via habitat loss, a reduction in light availability and smothering | facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP;<br>• an Emergency Response Plan including an oil spill contingency procedures and coordination of proponents in the event of emergency response procedures;<br>• preparation and enforcement of vessel operating requirements including invasive marine species management;<br>• stakeholder consultation; and<br>• reporting and review mechanisms.<br>Establishment of a DMAG comprising representatives from:<br>• Independent Chair with extensive knowledge of marine environment;<br>• Broome Port Authority;<br>• office of EPA;<br>• DEC;<br>• DoF;<br>• SEWPAC; and<br>• Foundation or other proponent<br>The role of the DMAG will be to provide advice to the proponent, EPA and/or the Minister for Environment as appropriate on the following:<br>• marine investigations (including the modelling of dredge plumes);<br>• environmental risk assessments prepared for future dredging proposals; | management techniques and technologies to minimise potential dredging impacts. The Plan shall include:<br>• Consideration of the re-use of suitable dredge material for MOF construction, where practicable.<br>• Design of the MOF including construction of bunds to isolate fill material from wind and wave action.<br>• Consideration of applicability of management techniques and technology in meeting location specific WQ environmental values and environmental quality objectives.<br>• Consideration of re-use of reclaimed material to minimise ocean disposal.<br>• Measures to minimise dredging impacts during sensitive ecological windows.<br>• A monitoring strategy for ecological receptors and health during marine construction (including baseline surveys).<br>• The development of trigger levels for benthic communities and water quality that define additional management responses.<br>• Mechanisms to audit and assess environmental performance of proponents during construction.<br>• A communications strategy to inform other local marine users of | regards to discharges at sea.<br>Prepare and implement a Marine Wastewater Discharge Management Plan (MWDMP), to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality). | |
| Marine Noise and Vibration | Reduction of ecosystem stability and function through changed competition/predation for food or habitat of functional groups or species that were otherwise balanced | | | | Low |
| Marine Discharges | Reduction in water quality, a reduction in sediment quality, | | | | Medium |

| Environmental Aspect | Potential Impacts | Mitigation Measures | | | Significance of Residual Impact |
|---|---|---|---|---|---|
| | | **State Government Measures** | **Proposed Environmental Conditions** | **Future Proponent Management Plans** | |
| | mortality of marine flora and fauna, cumulative effects to ecosystem processes and functions, loss of biodiversity and abundance, reduced resilience, reduced intactness and bioaccumulation. | • risk to key environmental values in risk zones ;<br>• detailed water quality or impact criteria for risk-based performance standards and the final configuration of risk zones; and<br>• dredge management plans (including monitoring programs and adaptive response in the event that risks to key values are greater than low) prepared by proponents of future major dredging proposals | times of peak construction activity that may influence non-construction related activities within the area.<br><br>The DSDMP will be subject to assessment under the *Environment Protection (Sea Dumping) Act* 1981 (Cwth), including appropriate stakeholder consultation. | | |
| Invasive Marine Species | Loss or change in biodiversity / alteration of habitat integrity | | | | Low |

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