# Mardie Project - Subtidal Benthic Communities and Habitats

Mardie Minerals Ltd

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## Version Register

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# Acronyms and Abbreviations

| Acronyms/Abbreviation | Description |
|---|---|
| ADCP | Acoustic Doppler Current Profiler |
| BC | Biodiversity Conservation |
| BCH | Benthic Communities and Habitats |
| CALM | Conservation and Land Management |
| CATAMI | Collaborative and automated tools for analysis |
| Dom | Domestic gas |
| DSN | Dredging Science Node |
| EIA | Environmental Impact Assessment |
| EPBC | Environmental Protection and Biodiversity Conservation |
| EP | Environmental Protection |
| EPA | Environmental Protection Authority |
| ESD | Environmental Scoping Document |
| FRM | Fish Resources Management |
| GLpa | Gigalitre per annum |
| GIS | Geographic information system |
| ha | Hectares |
| HAT | Highest Astronomical Tide |
| ISLW | Indian Spring Low Water |
| km | kilometers |
| Ktpa | Tonnes per annum |
| LAT | Lowest Astronomical Tide |
| LAU | Local assessment unit |
| m | Meter |
| $m^3$ | Cubic Meter |
| MBES | Multibeam echo sounder |
| MHWS | Mean High Water Springs |
| MHWN | Mean High Water Neaps |
| MLWS | Mean Low Water Springs |
| MLWN | Mean Low Water Neaps |
| MSL | Mean Sea Level |
| Mtpa | Million tonnes per annum |
| NaCl | Salt |
| NTC | National Tide Centre |
| Pty Ltd | Proprietary Limited |

| | |
|---|---|
| SOP | Sulphate of Potash |
| TC | Tropical Cyclone |
| WA | Western Australia |
| WAMSI | Western Australian Marine Science Institution |
| ZoI | Zone of Influence |

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# 1.1. Project Description

## 1.1.1. Short Summary of the Proposal

**Table 1 Short Summary of the Proposal**

| Proposal Title | Mardie Project |
|---|---|
| **Proponent Name** | Mardie Minerals Pty Ltd |
| **Short Description** | Mardie Minerals Pty Ltd is seeking to develop a greenfields high quality salt and sulphate of potash (SOP) project and associated export facility at Mardie, approximately 80 km south west of Karratha, in the Pilbara region of WA. The proposal will utilise seawater to produce a high purity salt product, SOP and other products derived from sea water.<br><br>The proposal includes the development of a seawater intake, concentrator and crystalliser ponds, processing facilities and stockpile areas, bitterns disposal pipeline and diffuser, trestle jetty export facility, transhipment channel, drainage channels, access / haul roads, desalination (reverse osmosis) plant, borrow pits, pipelines, and associated infrastructure (power supply, communications equipment, offices, workshops, accommodation village, laydown areas, sewage treatment plant, landfill facility, etc.). |

## 1.1.2. Proposal Description

Mardie Minerals Pty Ltd (Mardie Minerals) seeks to develop the Mardie Project (the proposal), a greenfields high-quality salt project in the Pilbara region of Western Australia (Figure 1) Mardie Minerals is a wholly-owned subsidiary of BCI Minerals Limited.

The proposal is a solar salt project that utilises seawater and evaporation to produce raw salts as a feedstock for dedicated processing facilities that will produce a high purity salt, industrial grade fertiliser products, and other commercial by-products. Production rates of 4.0 Million tonnes per annum (Mtpa) of salt (NaCl), 100 kilo tonnes per annum (ktpa) of Sulphate of Potash (SoP), and up to 300 ktpa of other salt products are being targeted, sourced from a 150 Gigalitre per annum (GLpa) seawater intake. To meet this production, the following infrastructure will be developed:

- Seawater intake, pump station and pipeline;
- Concentrator ponds;
- Drainage channels;
- Crystalliser ponds;
- Trestle jetty and transhipment berth/channel;
- Bitterns disposal pipeline and diffuser;
- Processing facilities and stockpiles;
- Administration buildings;
- Accommodation village,
- Access / haul roads;
- Desalination plant for freshwater production, with brine discharged to the evaporation ponds; and

> Associated infrastructure such as power supply, communications, workshop, laydown, landfill facility, sewage treatment plant, etc.

Seawater for the process will be pumped from a large tidal creek into the concentrator ponds. All pumps will be screened and operated accordingly to minimise entrapment of marine fauna and any reductions in water levels in the tidal creek.

Concentrator and crystalliser ponds will be developed behind low permeability walls engineered from local clays and soils and rock armoured to protect against erosion. The height of the walls varies across the project and is matched to the flood risk for the area.

Potable water will be required for the production plants and the village. The water supply will be sourced from desalination plants which will provide the water required to support the Project. The high salinity output from the plants will be directed to a concentrator pond with the corresponding salinity, or managed through the project bitterns stream.

A 3.4 km long trestle jetty will be constructed to convey salt (NaCl) from the salt production stockpile to the transhipment berth pocket. The jetty will not impede coastal water or sediment movement, thus ensuring coastal processes are maintained.

Dredging of up to 800,000 $m^3$ will be required to ensure sufficient depth for the transhipper berth pocket at the end of the trestle jetty, as well as along a 4 km long channel out to deeper water. The average depth of dredging is approximately 1 m below the current sea floor. The dredge spoil is inert and will be transported to shore for use within the development.

The production process will produce a high-salinity bittern that, prior to its discharge through a diffuser at the far end of the trestle jetty, will be diluted with seawater to bring its salinity closer to that of the receiving environment.

Access to the project from North West Coastal Highway will be based on an existing public road alignment that services the Mardie Station homestead and will require upgrading (i.e. widening and sealing).

The majority of the power required for the project (i.e. approximately 95%) is provided by the sun and the wind, which drives the evaporation and crystallisation processes. In addition, the Project will require diesel and gas to provide additional energy for infrastructure, support services and processing plant requirements.

The proposal will be developed within three separate development envelopes. The boundaries of these development envelopes are shown in **Figure 1** and described in **Figure 2**.

**Table 2 Location and proposed extent of physical and operational elements**

| Element | Ref. | Proposed Extent |
|---|---|---|
| **Physical Elements** | | |
| Ponds & Terrestrial Infrastructure Development Envelope – evaporation and crystalliser ponds, processing facilities, access / haul road, desalination plant, administration, accommodation village, quarry, laydown, other infrastructure. | Fig. 2 | Disturbance of no more than 11,142 ha within the 15,667 ha Ponds & Terrestrial Infrastructure Development Envelope. |
| Marine and Dredge Channel Development Envelopes – trestle jetty, seawater intake and pipeline, bitterns pipeline. | Fig. 2 | Disturbance of no more than 7 ha within the 53 ha Marine and Dredge Channel Development Envelopes. |
| Dredge Channel Development Envelope – berth pocket, channel to allow access for transhipment vessels, bitterns outfall diffuser, bitterns dilution seawater intake. | Fig. 2 | Disturbance of no more than 55 ha within the 304 ha Dredge Channel Development Envelope. |
| **Operational Elements** | | |
| Desalination Plant discharge | Fig. 2 | Discharge to concentrator ponds or to bitterns stream. |
| Dredge volume | Fig. 2 | Dredging is only to occur within the Dredge Channel Development Envelope.<br><br>Dredging of no more than 800,000 m$^3$ of material from the berth pocket and high points within the transhipment channel, with the material to be deposited within the Ponds & Infrastructure Development Envelope. |
| Bitterns discharge | Fig. 2 | Discharge of up to 3.6 gigalitres per annum (GLpa) of bitterns within a dedicated offshore mixing zone. |

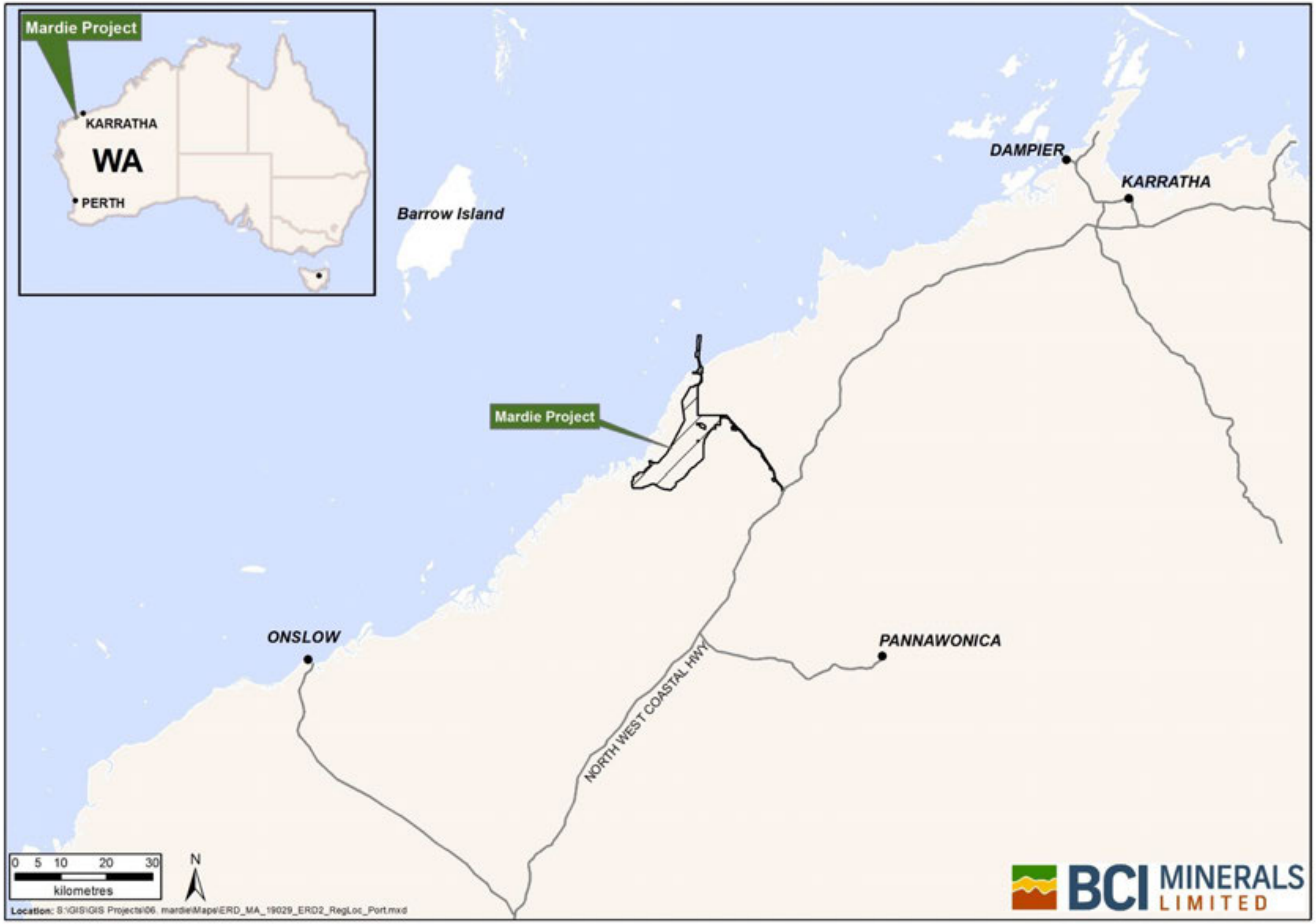



**Figure 1 Mardie Project Regional Location**

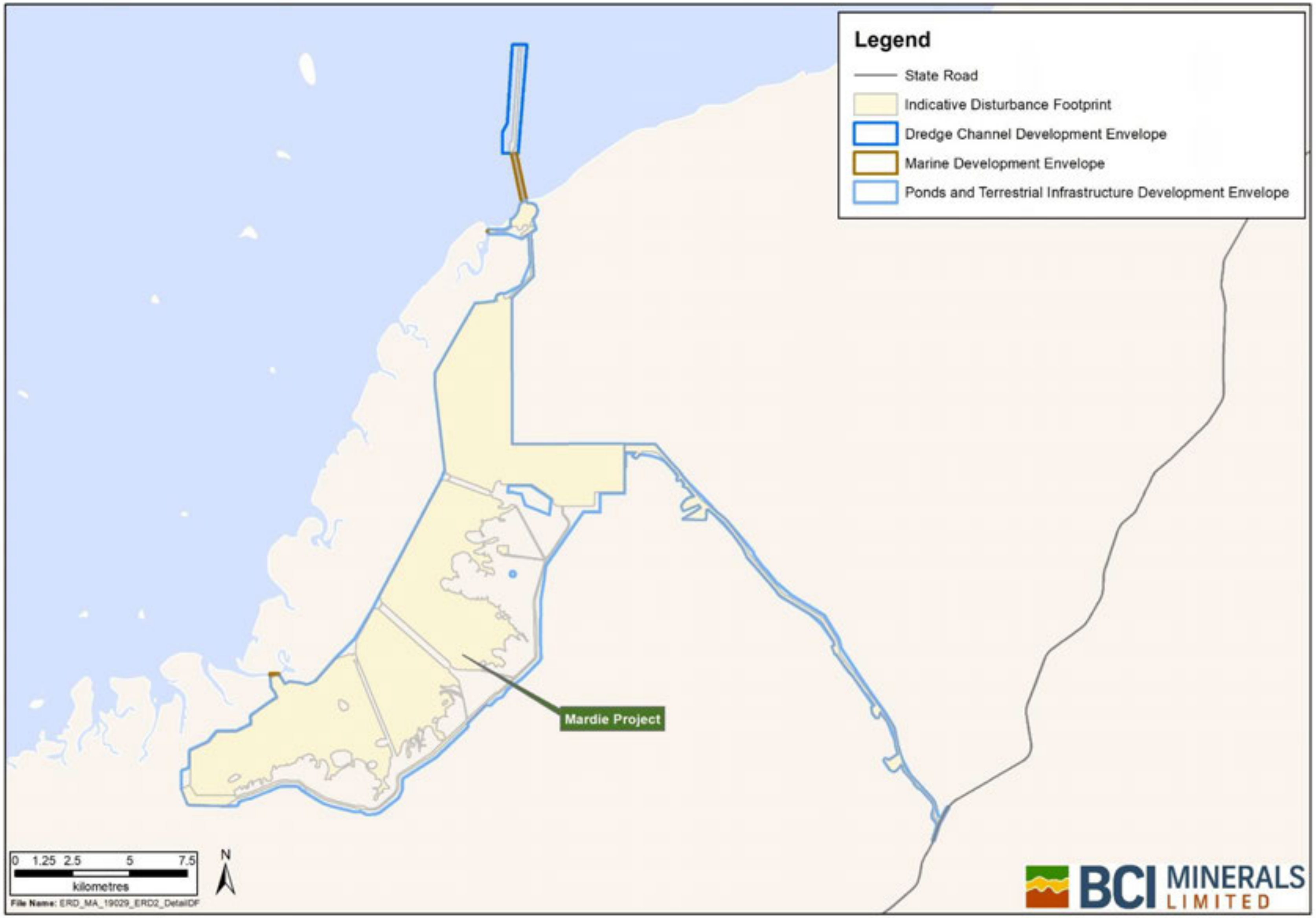



**Figure 2 Mardie Project Development Envelopes: Marine, Ponds and Terrestrial Infrastructure and Transhipment Corridor.**

## 1.2. Scope and Objectives

The scope of this report is to address the relevant work requirements outlined by in the Mardie Project - Environmental Scoping Document (ESD) (Preston 2018). **Table 3** outlines the specific requirements from the ESD that are required to be addressed this Subtidal BCH report.

This document provides an account of the Subtidal BCH of the Project area using desktop investigations and site-specific surveys. The Report will provide a basis for an EIA of the Subtidal BCH, with reference to a range of project related information such as historical loss of BCH, coastal stability, hydrodynamic, groundwater and surface water modelling and engineering design.

Specific application of the desktop and survey data presented in this Report includes:

- Description of the current understanding of the ecological role and value of the Subtidal BCH in the Project area;
- Preparation of detailed Subtidal BCH maps and description of the effort in the field to ground-truth and validate the predicted distributions; and
- Review of any tenure, conservation, ecological or social values of the BCH that should be considered.

The specific objectives of this Report are to address the ESD Items outlined with **Table 3.**

**Table 3 Benthic Communities and Habitat Objectives from the Environmental Scoping Document – Mardie Project 2018**

| ESD Item | Requirement | Report Section | Comment |
|---|---|---|---|
| **ESD Item 3.** | Undertake subtidal habitat field surveys within the LAUs to produce local and regional scale maps of BCH and bare areas, as well as a list of species found. The survey will include: | | |
| | a. Broadscale mapping of subtidal BCH within LAU's | Section 4.2 | |
| | b. Detailed mapping of the boundary of key BCH such as corals and seagrass (if present) within predicted impact area; | Section 4.2 | |
| | c. Assessment of the functional ecological value and regional significance of key habitat such as coral and seagrass communities that may be impacted by the Proposal; | Section 5 | |
| | d. Assessment of seasonal variation in presence/absence of seagrass; | Section 6 | |
| | e. Health assessment to determine the current status of the BCH; and | Section 5 | |
| | f. Expert advice on the significance of the BCH impacted by the Proposal from a local and regional perspective. | | Peer review of BCH impacts undertaken by DR John Russell Hanley. |

| | | | |
|---|---|---|---|
| **ESD Item 5.** | Assessment of spatial and temporal variability of BCH types within the potential impact area and associated influence on predicted impacts. | Section 4<br>Section 5 | Potential impacts and influence to be assessed during the Cumulative Loss Assessment Report. |
| **ESD Item 16.** | Characterise the biodiversity and functional ecological values and significance of BCH, particularly in relation to arid-tropical mangrove communities (Guidance Statement 1 – Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline (EPA, 2001)). | Section 5 | Significance of intertidal BCH are discussed in the Intertidal BCH Report. (O2 Marine 2020a) |

## 1.3. Legislation and Regulatory Guidance

This study has been aligned with relevant state and federal legislation and technical guidance that will be applicable to BCH in the Project area. The relevant legislation specific to BCH, includes:

- Commonwealth *Environmental Protection and Biodiversity Act 1999* (EPBC Act);
- West Australian *Environmental Protection Act 1986* (EP Act);
- West Australian *Biodiversity Conservation Act 2016* (BC Act); and
- West Australian *Conservation and Land Management Act 1982* (CALM Act).

The EPA provides guidance on how an EIA will be evaluated when determining whether or not an assessed proposal may be implemented. The EPA uses environmental principles, factors and associated objectives as defined within the Statement of Environmental Principles, Factors and Objectives (EPA 2018) as the basis for assessing whether a proposal's impact on the environment is acceptable. These principles, factors and objectives therefore underpin the EIA process.

### 1.3.1. Environmental Principles

The object of the EP Act is to protect the environment of the State and identifies five environmental principles. The third principle of the conservation of biological diversity and ecological integrity is directly relevant to subtidal BCH and is therefore a fundamental consideration for an EIA.

### 1.3.2. Environmental Factors and Objectives

The EPA list 13 environmental factors, which are organised into five themes: Sea, Land, Water, Air and People. The environmental factors are those parts of the environment that may be impacted by an aspect of a proposal. An environmental objective has been established for each environmental factor. The EPA will then make judgements against these objectives on whether the environmental impact of a proposal may be significant. The BCH was identified by the EPA as one of the key environmental factors for the Project. The objective for BCH is *'to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained'*.

The EPA provides the following guidelines to explain how impacts on BCH are considered during EIA and to set out the type and form of the information that should be presented to facilitate the assessment of impacts on BCH in Western Australia's marine environment:

- Technical Guidance – Protection of Benthic Communities and Habitats (EPA 2016a);
- Environmental Factor Guideline – Benthic Communities and Habitats (EPA 2016b); and
- Technical Guidance – Environmental Impact Assessment of Marine Dredging Proposals (EPA 2016c).

# 2. Methodology

## 2.1. Study Area

The assessment of subtidal Benthic Communities and Habitats (BCH) primarily focused on the subtidal nearshore coastal zone surrounding the Proposed Marine Development Envelope (**Figure 2**). However, the assessment also draws conclusions on subtidal BCH of the Project area based on wider regional surveys undertaken during pre-feasibility stages of the Mardie Project and for other nearby (within 100 km) Projects.

For the purpose of this assessment, the subtidal nearshore coastal zone extends from the intertidal area of the Mardie Coast to approximately the 10 m isobath and includes several small coastal islands. The majority of seabed substrate is comprised of bare sand/silt, with patches of sand and limestone veneer which support sparse (<5%) to moderate (10-25%) cover of filter feeders, macroalgae, seagrass and coral BCH. Many of the coastal islands also support large expanses of macroalgal dominated limestone reef, with isolated areas of dense hard coral occurring on the reef slope.

Although the surveys included the coastal islands and the broader region, the survey results are presented and discussed in the context of the proposed Local Assessment Unit (LAU) 7, which has been established for the subtidal BCH areas surrounding the proposed Marine and Dredge Channel Development Envelopes. Rationale for the selection of proposed LAUs is provided in the BCH Cumulative Loss Assessment Report (O2 Marine 2020a).

An overview of the survey effort, together with proposed LAUs and Marine and Dredge Channel Development Envelopes is presented in **Figure 3**.

## 2.2. Desktop Assessment

O2 Marine undertook a comprehensive desktop assessment of the subtidal BCH in the Project area as a preliminary component of this report. The review focussed on surveys undertaken for previous coastal development projects in the Pilbara and relevant scientific journal literature on subtidal BCH in the Pilbara region.

Data from other studies being completed as part of the development of the Mardie Project were also utilised in the preparation of this report. The most directly relevant documents included:

- Baird (2020) Mardie Project Hydrodynamic Modelling. Report prepared for Mardie Minerals Ltd;
- O2 Marine (2020a) Mardie Project Intertidal Benthic Communities & Habitat. Report prepared for Mardie Minerals Ltd;
- O2 Marine (2020b) Mardie Project Baseline Water Quality Monitoring. Report prepared for Mardie Minerals Ltd;
- O2 Marine (2019a) Mardie Project Baseline Sediment Characterisation. Report prepared for Mardie Minerals Ltd.

The desktop review had the following aims:

- Identify existing subtidal BCH mapping of the Project area and adjacent areas to spatially characterise the known distribution of subtidal BCH;

- Identify and describe the factors that may affect distribution and condition of subtidal BCH;
- Identify if the subtidal BCH has any particular tenure or conservation, ecological or social values that should be considered; and
- Inform evaluation of the functional ecological value and regional significance of subtidal BCH of the Project area.

## 2.3. Field Survey

### 2.3.1. Survey Effort

Consistent with the commitments provided in the ESD, O2 Marine was commissioned to characterise and map the subtidal BCH within the proposed LAU7. Limited information existed regarding the extent and distribution of subtidal BCH within LAU7, therefore extensive field surveys were undertaken to characterise, map and describe the subtidal BCH in this area. All surveys were conducted by qualified and experienced marine scientists from O2 Marine. The field survey effort is summarised in **Table 4** and presented in **Figure 3,** survey locations are discussed in section 2.3.2.

Surveys of the Project area were constrained by a number of key factors, most notably being:

- Access to the remote location was restricted at certain tides and during wet weather conditions when the nearest boat ramp (i.e. Fortescue River mouth) was inaccessible;
- Water visibility was often very poor due to the naturally turbid water conditions;
- Vessel access in the survey area was often constrained due to water depth in shallow intertidal areas and across shoals and sand bars; and
- Adverse weather conditions were experienced on most surveys.

**Table 4 Subtidal BCH field survey effort**

| BCH Survey | Survey Date | Sampling Locations | Survey Objective |
|---|---|---|---|
| **Initial Survey** | 8th – 14th March 2018 | 50 | > Undertake 'snapshot' survey to broadly characterise the subtidal BCH at three potential outfall locations.<br>> Identify the discharge location which poses the lowest risk of significant impact on subtidal BCH. |
| **Second Survey** | 12th – 15th December 2018 | 64 | > Undertake targeted survey at the proposed port location and broader regional area. |
| **Third Survey** | 14th – 18th January 2019 | 18 | > Undertake targeted survey at the proposed port location, focussing on dredging footprint. |
| **Fourth Survey** | 6th – 8th February 2019 | 8 | > Undertake opportunistic survey of dredging footprint (Conducted during sediment sampling survey). |

| | | | | |
|---|---|---|---|---|
| **Final Survey** | 16th – 18th March 2019 | 66 | > | Undertake targeted survey of modelled worst-case dredging Zone of Influence (ZoI) and any other areas not surveyed within LAU7. |

### 2.3.2. Survey Locations

Surveys were conducted at a total of 206 locations (**Figure 3**) using a combination of drop camera/towed video at all locations, combined with diving/snorkelling to verify habitat in low visibility conditions at suspected seagrass and coral BCH locations. To ensure accurate BCH characterisation within potential impact areas, survey locations were generally targeted within and adjacent to the proposed Marine and Dredge Channel Development Envelopes. Additional targeted survey locations were identified based on review and analysis of the available multibeam (i.e. acoustic backscatter) echosounder (MBES) bathymetry data and aerial imagery to achieve broad spatial coverage of BCH across LAU7.

Survey locations also extended beyond the LAU7 boundary to include the Passage Islands group, Angle Island in the south and Mardie Island in the North.

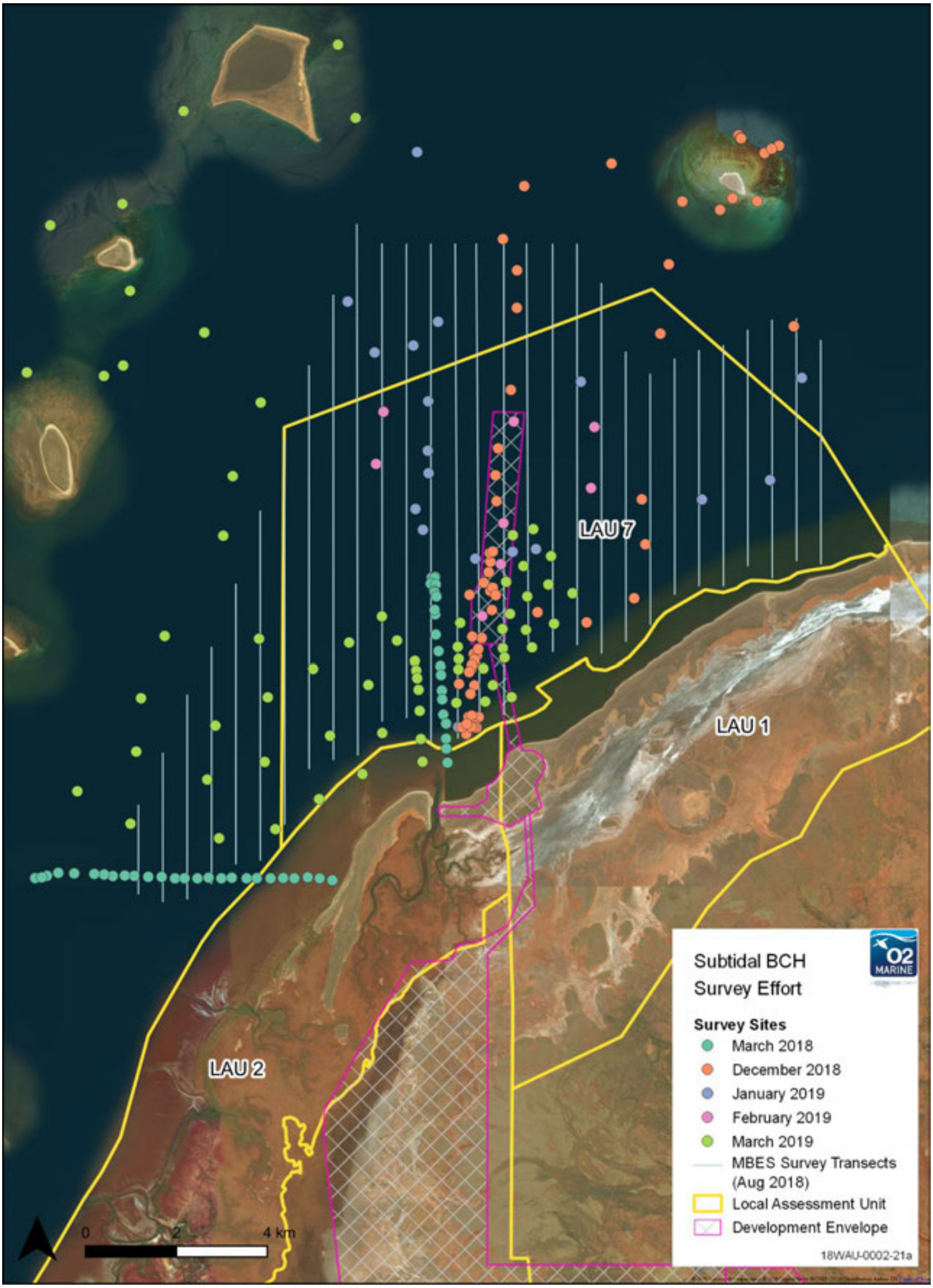



**Figure 3 Subtidal BCH survey effort.**

### 2.3.3. Video Survey

At each survey location, a Spot X Underwater Vision Pro Squid, which utilises a GoPro4 camera was used to record real-time, high definition (1080p 50fp) video footage which is streamed to the surface and viewed on-board the vessel via a monitor. The camera system was deployed from the survey vessel at each target location. To maintain an appropriate speed for capture of good quality video, a sea anchor was often deployed to slow the drift rate of the vessel.

Footage (video and stills) were recorded, reviewed and both a substrate classification and a benthic habitat classification were assigned using the GIS software Global Mapper V12. The preliminary BCH classification was made in accordance with the Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) standard classification scheme for scoring marine biota and physical characteristics from underwater imagery. The following information was also manually recorded during video survey at each location:

- Date/time;
- GPS coordinates (start and finish);
- Water depth;
- Relief;
- Substrate;
- Bedforms;
- Visual estimate of cover of benthic flora and fauna;
- The dominant and sub-dominant taxa; and
- Incidental observations of mobile marine fauna (i.e. Turtle, dugongs, dolphin sightings etc).

To address recommendations made by Western Australian Marine Science Institution (WAMSI) (Lavery *et al.* 2018) regarding applicability of towed/drop camera survey techniques to detect seagrass, where seagrass was suspected in low visibility conditions, habitat verification was undertaken via spot dive/snorkelling to confirm seagrass presence/absence and identify seagrass species. The same information was recorded at these locations as for the video survey.

## 2.4. Data Analysis

The preliminary classification was reviewed for each survey location and BCH at each location was assigned a simplified classification based on the BCH types present within LAU7 and the level of benthic cover associated with each BCH type. These ground-truth locations were then used in conjunction with bathymetry data to delineate and map the BCH boundaries using QGIS V3.4. Aerial imagery was also reviewed, but the turbidity of the nearshore waters was found to be too high to effectively inform mapping within LAU7.

# 3. Mardie Coastal Setting

## 3.1. Overview

Regional factors that shape the coast include the coastal setting, climate and tidal range. The coastal setting describes factors such as the coastal geomorphology and geology, Quaternary geological history, the relationship of the coast to the differing types of hinterland and oceanographic setting. These factors determine the coastal processes, the sediments and stratigraphy. Important aspects of the climate are rainfall, evaporation, cyclonic activity and wind. Tidal range determines the extent of tidal habitat and coastal processes.

## 3.2. Mardie Coastline

The Pilbara coast is noted to be a region of extremes (Elliot *et al* 2013), an arid environment where sediment is delivered periodically to the coast through networks of rivers and streams and where significant events such as tropical cyclones bring episodic flooding and inundation impacts that drive geomorphic changes along its coastal landforms. Tides along the Pilbara are relatively large and tidal processes are dominate drivers in coastal processes and ecology at many locations, including the project site where the spring tide range exceeds 3.5 m.

The coastal area of the Pilbara is composed of an ancient hard-rock terrain over which the deposition of sediment from sources including coral reefs, flood plains and river deltas has occurred for 2 million years. The shoreline at the project site is generally northwest facing with the inter-tidal region around the project site generally described as quaternary mudflat deposits, clay, salt and sand (Elliot *et al* 2013).

The inner shelf region is very wide along this section of the coast, and consequently the near shore bathymetry is very shallow, with water depth of approximately 5m (below LAT) at a distance of 10km offshore. A series of offshore islands and reefs are located immediately offshore which provide natural protection for the coastline during extreme events (e.g. Tropical Cyclones). Further offshore the Montebello Islands, Barrow Island and the Barrow shoals provide significant protection against extreme waves associated with the passage of a tropical cyclone.

A series of major tidal creeks lined by mangroves and salt marsh extend from the shoreline through the intertidal area, with branches that convey tidal flows across the tidal flats. Beyond the mangrove areas, large areas of clay pan are present across expansive tidal flat areas which extend 10km or more inland from the coast. During neap tides the high tide water level is generally contained within the creeks through the intertidal areas and there is little to no inundation of the tidal flats. During spring tides, a large proportion of the intertidal area becomes completely inundated and based on aerial imagery and anecdotal reports the surface water can remain on the surface for days after. The Fortescue river mouth is located approximately 20km east of the project site and under extreme flooding scenarios breakout flows have the potential to extend across the project site (RPS 2018).

Analysis of satellite images from the Mardie site over the period 2004 - 2017 reported in RPS 2018 noted the dynamic nature of the mangroves and tidal creek areas. The flat terrain of the intertidal areas results in the tidal watersheds being highly sensitive to small changes in the landform. The analysis examined the tidal branches over time noting evidence of increased colonisation of many of the creeks by mangroves along with increased branching of the creeks over the approximately 13-year period. Behind the mangrove zone the analysis indicated a clay pan area which is colonised by algae and cyanobacteria that form extensive crusting mats. The tidal creek systems through the intertidal area provide the mechanism by which seawater is moved in and out of this area under the general tidal regime.

## 3.3. Climatology and Oceanography

The southern Pilbara region has a tropical monsoon climate with distinct wet and dry seasons. The dry season extends from May to October, and is characterised by warm to hot temperatures, easterly to south-easterly winds from the continental landmass, clear and stable conditions as the subtropical high-pressure ridge migrates over this area. In the afternoon, the wind direction shifts to north-westerly, particularly later in the dry season, associated with the onset of the land sea breeze as the temperature difference between the continent and the ocean increases throughout the day. In the wet season the wind climate is dominated by westerly and north-westerly winds. Wind rose plots for the Dry Season months (May to October) and Wet Season months (November to April) are presented in **Figure 4** based on analysis of the measured wind records from Mardie Airport over the period 2011 - 2018.

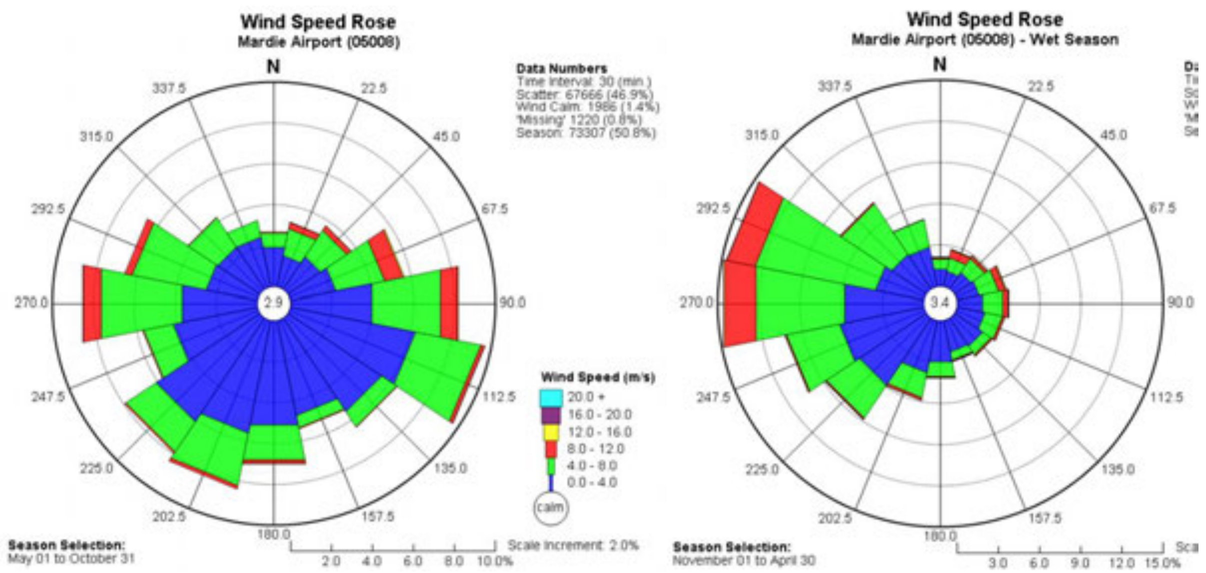



**Figure 4 Wind Rose plots for Dry Season (left) and Wet Season Months (right) based on analysis of the measured data from Mardie airport**

Climate statistics for the town of Mardie are presented in **Figure 5** from the BoM site which is approximately 16 km inland. Maximum daily temperatures at Mardie average 33.9 °C throughout the year, peaking at 38.0 °C in January and falling to 27.7 °C in July. The Pilbara is influenced by northern rainfall systems of tropical origin. These systems are responsible for heavy falls during the summer months, while the southern low-pressure systems sometimes bring limited winter rains. The annual average rainfall is only 128 mm, and the mean monthly rainfall has a bimodal distribution, peaking in January to March and also May to June, with very little rainfall from July to December (**Figure 5**). Daily rainfall can reach over 300 mm during extreme events that may occur one to two times per decade. Evaporation rates in the region are high, estimated to exceed by ten times the annual rainfall.

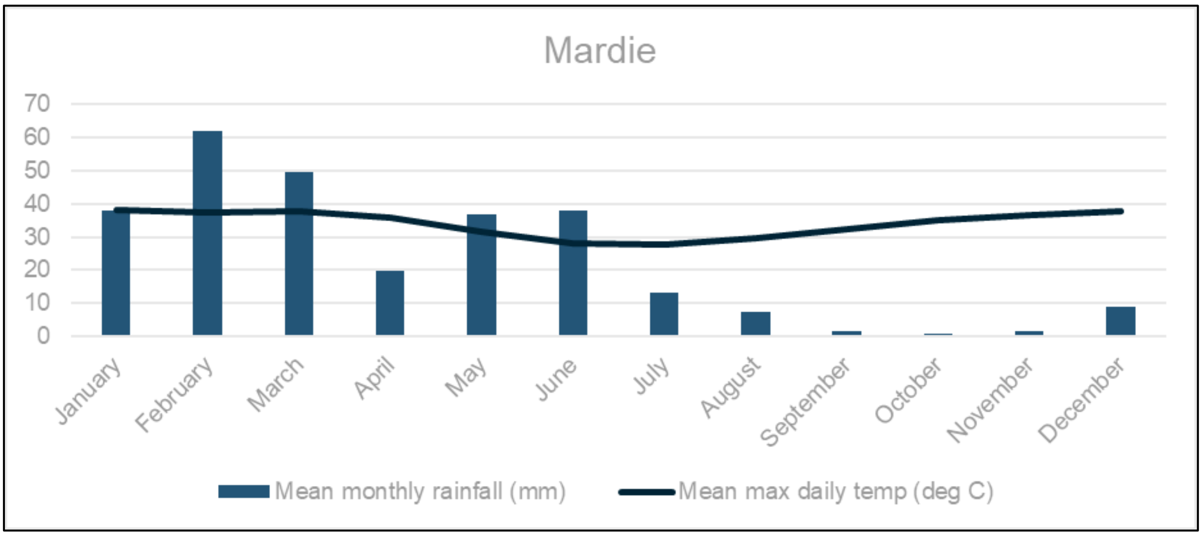



**Figure 5 Climate Statistics for Mardie (BOM 2019).**

The Australian cyclone season extends from November through to April with an average of 10 cyclones per year, although not all make landfall. Tropical cyclone winds can generate extreme coastal water levels through storm surge and these systems are frequently associated with heavy rainfall that can cause significant flooding. The Pilbara region of Western Australia has a high exposure to tropical cyclone events, with a typical cyclone track recurving and making landfall in the coastline between Broome and Exmouth. The season typically runs from mid-December to April, peaking in February and March. The Karratha to Onslow coastline is the most-cyclone prone of the Australian coast, typically experiencing one landfalling event every two years. The north western coastline of Western Australia is highly vulnerable to the occurrence of storm surge. This is due to the frequency of tropical cyclones, the wide continental shelf and relatively shallow ocean floor over the North West Shelf, as well as the low-lying nature of much of the coastline. In addition, tropical cyclone events are strongly associated with flooding due to widespread heavy rainfall.

Historical events of significance impacting between Karratha and Onslow include: Trixie 1975, Chloe 1984, Orson 1989, Olivia 1996, John 1999, Monty 2004, Clare 2006 and Glenda 2006 (**Figure 6**). In late March 2019 the passage of TC Veronica tracked west over the region from offshore of Karratha losing intensity as it continued west offshore of Mardie as a tropical low system.

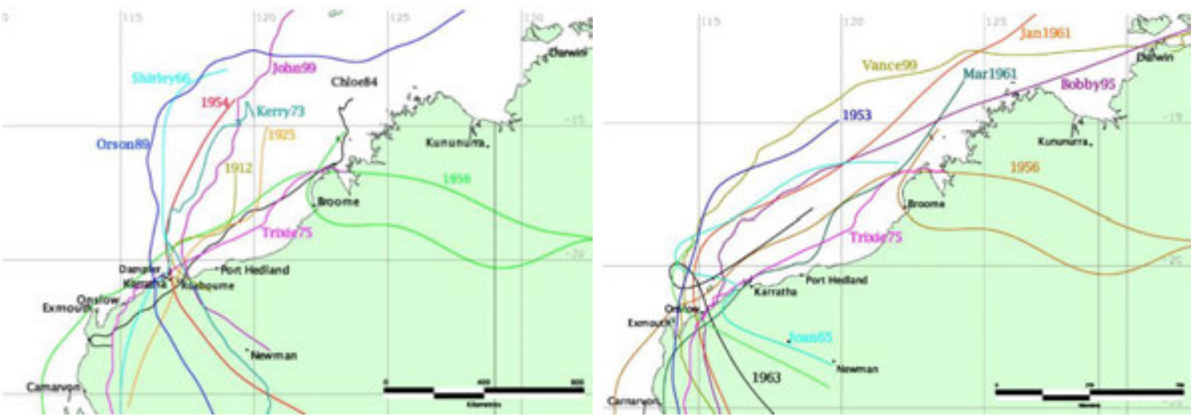



**Figure 6 Tracks of notable cyclones impacting Karratha (left) and Onslow (right)**

The astronomical tide is the periodic rise and fall of the sea surface caused by the combination of the gravitational force exerted by the moon and the Sun upon the Earth and the centrifugal force due to rotations of the Earth and moon, and the Earth and the Sun around their common centre of gravity. Tides are subject to spatial variability due to hydrodynamic, hydrographic and topographic influences. At the study area, the tides are characterised by amplification of tidal range due to the shallow bathymetry over the North West Shelf and complex hydrographic and topographic features. The tide levels recently analysed from data near the project site indicates that the mean spring tide range exceeds 3.5 m and the maximum tide range is ≈ 5.1 m.

The northwest shelf of Western Australia experiences waves generated from three primary sources: Indian Ocean swell, locally generated wind-waves and tropical cyclone waves. Along the shoreline the ambient (non-cyclonic) wave climate is generally mild. In dry season months low amplitude swell originating in the Indian Ocean propagates to the site and occurs in conjunction with locally generated sea waves of short period (<5s). In the wet season the wave climate is locally generated sea waves from the southwest. In general, the significant wave height is dominated by locally generated sea conditions within the range of 0.5m to 1m at short wave periods (Tp< 5 s). Measured data from an ADCP instrument deployed approximately 15km offshore for the project has been analysed to characterise the wave conditions in the wet and dry seasons as shown in **Figure 7**.

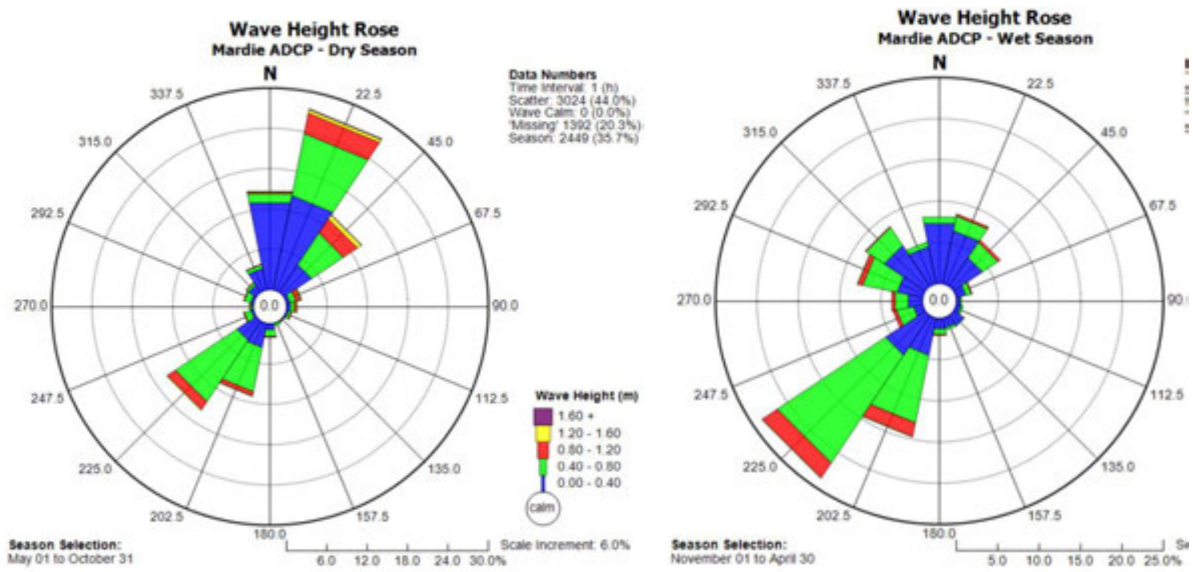



**Figure 7 Wave conditions offshore of the Mardie project location for Dry Season months (left) and Wet Season Months (right) based on measured data April 2018 – January 2019.**

Whilst the non-cyclonic ambient wave conditions are generally mild, in contrast the strong winds in a tropical cyclone can generate extreme wave conditions. It is noted that the offshore island features would provide some natural protection form extreme wave conditions depending on the direction of propagation. Extreme cyclonic waves contribute to the total water level through wave run-up which is the maximum vertical extent of wave uprush on a beach and is comprised both wave set-up and swash. The impact of cyclonic waves on the study site is dependent on the prevailing water level conditions and direction of cyclone approach. If coincident with a spring tide and storm surge, waves could propagate beyond the typical position of the beach and induce erosion of the shoreline as well as sediment transport.

Tropical cyclones are typically associated with heavy rainfall prior to, during and after the landfall of the system, which can lead to catchment flooding. The elevation in coastal water levels caused by the storm tide and wave processes can also propagate into estuarine waterways. The peak flood levels within the waterways will be influenced by the combination of fluvial and ocean, and coastal based processes, the interaction of which is highly dependent on the timing of peak of each process and the specific bathymetry and topography of the catchment and the inlet.

## 3.4. Geomorphology

In the Pilbara the coastal zone incorporates coastal waters out to 30m depth contour and associated coastal islands. The seafloor in this zone is virtually flat with the exception of small nearshore islands. Further offshore the substrate become steeper and therefore influences the type of benthic communities that exist here. The coastal platform generally slopes seaward with turbid waters (particularly to 10m and deeper in the north) and increasing tidal influence from south to north. Shallow sandbars, platforms, reefs and ridges are common in the Pilbara and constitute the substrate types found at Mardie.

The Mardie coastline is characterised by tidal creeks which have generally evolved in response to the ongoing tidal current forcing. Rainfall in this environment is highly intermittent and it is likely that rainfall runoff occurs as sheet flow over the local drainage catchments that have relatively small catchment areas towards the tidal creek drainage network. Sediment is delivered periodically to the coast through networks of rivers and streams. Extreme water levels and waves and associated rainfall and runoff under cyclonic conditions would be a significant driver of geomorphic changes along the coast, leading to erosion and enhanced sediment transport processes (Elliot *et al* 2013).

The primary mechanism for sediment transport in nearshore areas appears to be the tidal flows. The measured data from inshore shows a marginally stronger flood magnitude compared with the ebb, likely due to the shallow water and complex bathymetry which funnels water in on the flood tide between the reefs and islands. Based on measured data from inshore, the depth averaged velocity in spring tides is in the range of 0.3m/s to 0.5 m/s, whilst on the neaps the current speed is 0.2m/s to 0.3 m/s. Whilst the site is generally protected by swells, the sea waves and swell will contribute to nearshore and shoreline sediment transport processes

Sediment samples from the nearshore areas around the project site collected in 2018 and 2019 confirm the seabed composition is made up of predominantly sand fractions with varying degrees of fines (O2 Marine 2019a). The samples collected from the seabed in the proposed berth pocket and entrance channel showed fine fractions (silt and clay) of 20% to 30%. Further offshore (approximately 5km) the sediment sampling indicated the fine fractions reduced to less than 5% of the sample with the composition of the seabed sediment dominated by sand fractions.

## 3.5. Tides

The Mardie project location experiences a semi-diurnal tide (two highs and two lows a day) and the tidal planes have been defined by the National Tide Centre (NTC) based on field measurements completed for the project in late 2018 (O2 Marine 2019b). The Mardi Gauge (MardiLAT18) datum definition completed by the NTC shows that the offset between LAT and MSL is 2.75 m and the total tidal range is 5.185 m with tidal planes shown in **Table 5**. The mean tide range is 3.6m in springs and 1 m in neaps.

It is noted that the calculated tidal planes for Mardie are larger than for the nearest stations at Steamboat Island, Barrow Island Tanker Mooring and North Sandy Island likely as a result of the closer inshore location (O2 Marine 2019b).

Table 5 Mardie Tidal Planes (location 21.03572 S, 115.92766 E, National Tide Centre).

| Tidal Planes | Elevation (m LAT) |
|---|---|
| HAT | 5.185 |
| MHWS | 4.557 |
| MHWN | 3.226 |
| MSL | 2.75 |
| MLWN | 2.275 |
| MLWS | 0.943 |
| ISLW | 0.528 |
| LAT | 0 |

Measured data from an inshore Aquadopp in November 2018 is shown in **Figure 8** illustrating the water level time series through the spring and neap cycles.

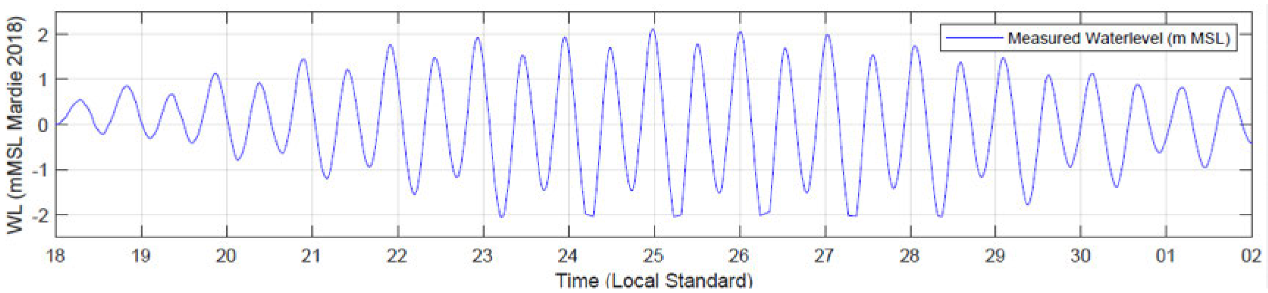



Figure 8 Measured water level data from inshore Aquadopp location November 2018

## 3.6. Marine Water Quality

Consistent with other nearshore Pilbara environments (GHD 2018; MScience 2009; Pearce *et al.* 2003), the coastal waters of the Mardie project area are characterised by high turbidity in the inshore waters (i.e. Mean 14 NTU in the vicinity of the proposed outfall location), which decreases with increasing distance from shore (i.e. Mean 1.5 NTU in the vicinity of the Passage islands) (O2 Marine 2019b). Turbidity levels were generally found to be higher during spring tides and associated with significant rainfall events. The highest turbidity levels were reported in conjunction with Tropical Cyclone Riley, with maximum turbidity levels of 250 NTU and 100 NTU reported inshore and offshore areas respectively.

O2 Marine (2020b) compared the turbidity and associated suspended sediment concentrations (SSC) reported for the Mardie inshore and offshore waters against recently published (Jones *et al.* 2019; Fisher *et al.* 2019) WAMSI thresholds for coral. The analysis determined that the naturally turbid conditions frequently exceeded the thresholds for possible and probable effects on coral, and as such, represented conditions which would be unlikely to support diverse coral communities typical of clearer water Pilbara environments. Conversely, turbidity and SSC levels reported for the Mardie offshore waters only exceeded the Jones *et al.* (2019) thresholds during passing of TC Riley, thus indicating that the Mardie offshore waters surrounding the nearshore islands are more likely to support a diverse coral community that than the inshore waters.

O2 Marine (2020b) found that salinity levels were high (Median of 37.5 ppt) in the inshore Mardie waters and appeared to be indicative of a sheltered bay. These high salinity conditions were thought to be due to the influence of the Passage Islands which act as a natural barrier and appear to restrict mixing with lower salinity oceanic waters, which combined with high evaporation rates and limited freshwater runoff has contributed to higher salinity values than are typically reported for coastal Pilbara waters.

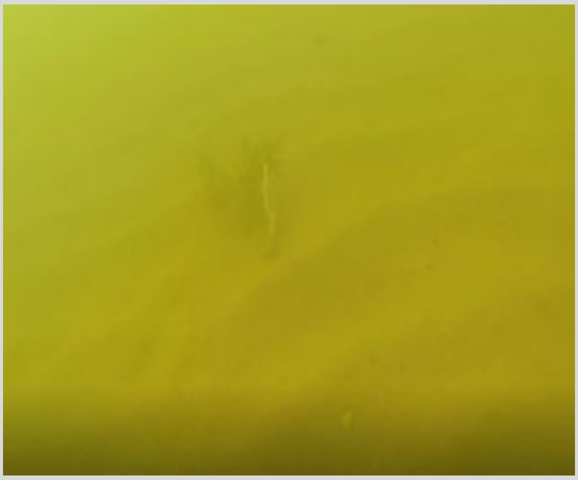
Laboratory analysis of marine water samples collected by O2 Marine (2020b) showed no evidence of contamination in the marine waters of the Project area and the current allocation of maximum and high levels of ecological protection were considered to be appropriate for the marine waters of the Mardie Project area.

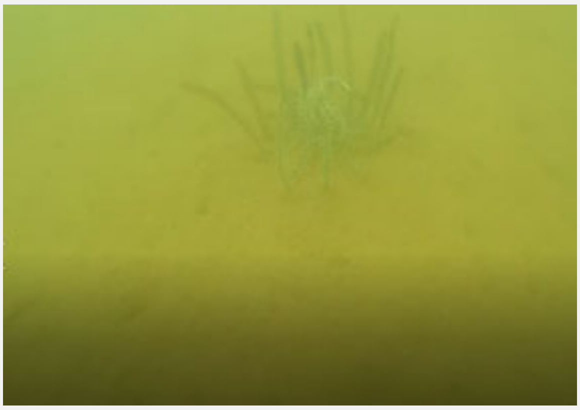
# 4. Results

## 4.1. Subtidal Benthic Communities and Habitat Classes

Within LAU7, the subtidal BCH surveys identified three broad BCH classes, with eight BCH subclasses distinguished based on varying levels of benthic cover and dominant taxa. These classes and subclasses are described in **Table 6** and the locations of where they were recorded are shown on **Figure 10**.

**Table 6 Description of broad subtidal BCH classes mapped within LAU7**

| BCH Class | Sub-class & Description | Example Image |
|---|---|---|
| **Bare Sand** | **Bare Sand**<br>Typically comprises of silt or sand with no or occasional very sparse macroalgae. Silt areas often comprised of bioturbation (burrows formed by living organisms). Sand areas often contain traces of shell grit.<br>This habitat comprises 89% of the subtidal BCH within LAU7 and is also widely dispersed across the region. |  |
| | **Sand / Very Sparse (<1%) Cover (Macroalgae)**<br>Fine silt/sand and bioturbated bedform with a very patchy distribution of macroalgae and invertebrates. Macroalgae (Phaeophyta) was the dominant cover, but was very sparse, generally comprising <1% of the overall cover. Class was differentiated from the other macroalgal classes due to the very sparse nature of the cover and the much finer grained, and often bioturbated sediments.<br>This habitat comprises 1% of the subtidal BCH within LAU7. Outside of LAU7, it was also observed on the eastern fringing waters of Round Island, whilst the largest contiguous area was observed closer to the mainland in the shallow waters between Angle Island and the mainland. |  |

| BCH Class | Sub-class & Description | Example Image |
|---|---|---|
| **Filter Feeder/ Macroalgae/ Seagrass** | **Sand / Sparse (<5%) Cover**<br>Sparse filter feeder habitat occurs where the relief is flat and is associated with fine to coarse sands. Although only present in sparse densities (<5% Cover), hydroids are most common where there is no bedform, whilst sponges occur where there is some bioturbation.<br>This habitat comprises 2% of the subtidal BCH within LAU7 and is widely dispersed throughout the region. |  |
| | **Low (5-10%) Cover**<br>Flat to low relief constituting either fine to coarse sands, including shell grit on occasions. Macroalgae, hydrozoan and sponge species are equally dispersed throughout this habitat although benthic cover is low (3-10%). Occasional very sparse (<1%) cover of *Halophila sp*. seagrass was also observed at some locations.<br>This habitat comprises 6% of the subtidal BCH within LAU7 and follows a patchy distribution throughout the region.<br>Outside of LAU7, this habitat was also observed in small patches fringing the shallow waters of Long Island, Mardie Island and close to the mainland. |  |
| **Coral / Macroalgae** | **Low (5-10%) Cover**<br>Flat to low relief rock and rubble with coarse sand. Low (3-10%) cover of soft and hard corals, including *Faviidae, Dendrophyllidae, Mussidae and Octocroals*. Sparse macroalgae was also present.<br>This habitat comprises 1% of the subtidal BCH within LAU7. Outside of LAU7 this habitat was also found fringing Mardie Island and in small isolated patches between Angle Island and the mainland. It was generally recorded in waters between 1-3 m depth. |  |

| BCH Class | Sub-class & Description | Example Image |
|---|---|---|
| | **Moderate (10-25%) Cover**<br>Low to moderate relief rock and rubble/coarse sand. Low to moderate cover (3 – 25%) of soft and hard corals with macroalgae. Corals largely consisted of *Faviidae, Poritidae*, and Octocorals, while *Phaeophyceae* dominated the macroalgae communities.<br>This habitat class comprises only 1% of the subtidal BCH within LAU7. However, outside of LAU7, it was recorded in larger areas in fringing shallow waters south of Mardie Island and adjacent to the mainland coast. |  |
| | **Dense (>25%) Cover (Macroalgae Dominated)**<br>This habitat class occurs on low relief substrate with fine to coarse sands and areas of exposed limestone reef. Dense assemblages (>75%) of macroalgae and hydrozoan species predominately in waters at depths of 2.2m-4.0m. This habitat also supported sparse juvenile corals (*Faviidae, Dendrophyllidae, Mussidae)* with occasional larger coral (*Poritidae*) bommies (1-2m diameter).<br>This habitat class comprised <1% of the subtidal BCH in LAU7. It was also identified outside of LAU7 in the waters fringing the eastern outer edge of Long Island, Round Island and Sholl Island. |  |
| | **Dense (>25%) Cover (Coral Dominated)**<br>Low relief limestone reef and rubble substrate which supports high coral cover (25%-75%) of diverse coral species, including *Faviidae, Dendrophyllidae, Mussidae, Portitidae*, and Octocoral species.<br>This habitat class was only recorded at one location in LAU7 and, as such, comprises only <1% of the subtidal BCH within LAU7. However, it was also recorded outside of LAU7, in a much larger area, fringing the Northern edge of Mardie Island. |  |

In addition to the BCH classes presented in **Table 6**, a standalone Seagrass BCH class was also identified approximately 5 km to the south of LAU7, which supported densities of *Halophila ovalis* seagrass up to ~25% (**Figure 9**). However, this BCH type was entirely avoided through site selection during the Project pre-feasibility stage.

**Figure 9 Seagrass (*Halophila sp.*) BCH detected outside of LAU7**

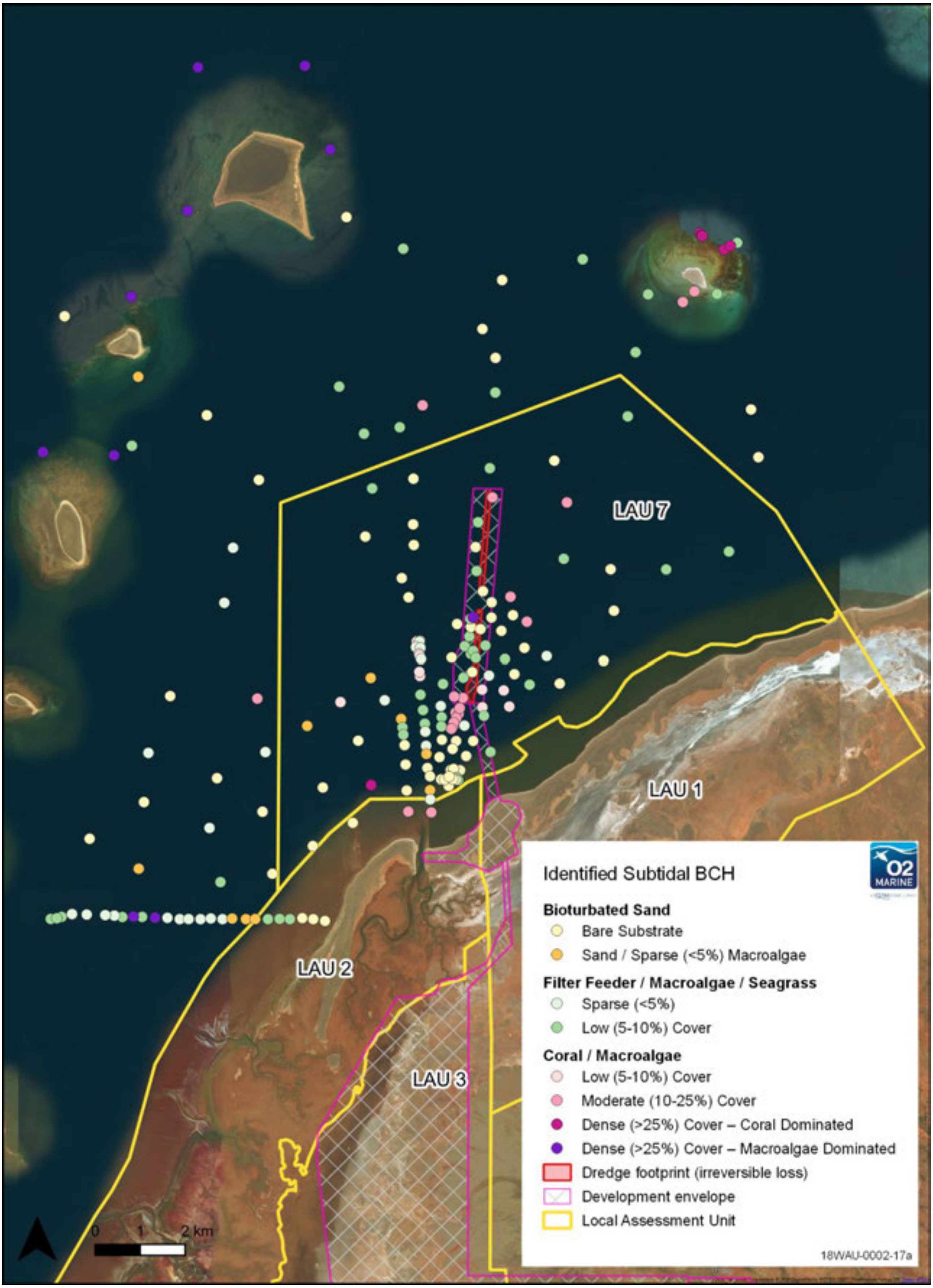



**Figure 10 Subtidal BCH Identified within Study area**

## 4.2. Habitat Mapping

Mapping of subtidal BCH has been generated through a review of bathymetry data, aerial imagery and extensive field survey. Although subtidal BCH surveys extended beyond LAU7, mapping of the subtidal BCH was restricted to only within LAU7 to facilitate impact assessment in accordance with EPA guidance.

A broad map of the three primary BCH classes is presented in **Figure 11**, while a more detailed map showing the benthic cover of each class is presenting **Figure 12**. The assumptions for generating the broad classification BCH mapping presented in **Figure 11** are based on technical guidance provided in EPA (2016a, 2016b) and recommendations within documents published by the Western Australian Marine Science Institution Dredging Science Node (WAMSI DSN). These key recommendations together with how they have been adopted for mapping subtidal BCH of the Project area is provided in **Table 7**.

**Table 7 Recommended BCH Mapping Assumptions and Application to the Mardie subtidal BCH Mapping**

| Recommended Assumption | Application to Project |
|---|---|
| Mapping the area of habitat that supports, or has the potential to support, benthic communities (EPA 2016a). | Areas which support or have the potential to support different BCH types were primarily distinguished based on substrate type, e.g. 'Coral / Macroalgae' BCH was always associated with hard moderate relief substrate such as rock or exposed limestone veneer. |
| Consideration of the uniformity (or heterogeneity) of biological communities (EPA 2016b). | The heterogeneity of BCH has been considered by grouping the community types which form the major components of the habitat. |
| Identification of where different BCH types can be distinguished and mapped separately (EPA 2016a). | Areas supporting hard corals (i.e. 'Coral / Macroalgae' BCH) as the dominant or potentially dominant taxa have been distinguished and mapped separately from areas of 'Filter Feeder / Macroalgae / Seagrass' BCH. However, due to significant variation and complex mosaic of dominant and sub-dominant taxa within the 'Filter Feeder / Macroalgae / Seagrass' BCH, map accuracy would be compromised to achieve any further separation. |
| The map should be produced with little regard for the relative quality of the benthic community (i.e. at the time of preparing the map), although should consider the functional ecological value of the BCH (EPA 2016a). | The three broad BCH classes mapped in **Figure 11** are a combination of eight subclasses (shown in **Figure 12**) which consider the relative benthic cover of each BCH class. In the case of the 'Coral / Macroalgae' BCH, the relative dominance of the taxa is considered in the subclass, but not in the primary class to account for the fact that the BCH may have been at varying stages of recovery from natural effects at the time or preparing the map. |
| Identification of BCH that are not well locally and regionally represented (EPA 2016a). | All BCH classes identified during field surveys were considered to be well represented on both local and regional scales. |
| Differentiate between areas of habitat that are 'vegetated' or 'inhabited' by benthic communities and areas of habitat that are not (i.e. 'bare' or 'unvegetated' substrate) (EPA 2016a). | 'Bare' areas were designated where benthic cover was absent or very sparse (<1%). Within LAU7, 'bare' areas were always associated with low relief, fine sand/silt bedform, often with evidence of bioturbation. |

| Recommended Assumption | Application to Project |
|---|---|
| Consideration of how uncertainty associated with mapping BCH can be reduced (EPA 2016a). | Given the absence of any regionally significant BCH within the mapped area survey effort was focused on reducing uncertainty in areas where direct and indirect impacts are most likely to occur. This will enable accurate loss assessment of subtidal BCH in the context of BCH types which are known to be well represented both locally and regionally. |
| Characterise historical seagrass distribution as potential seagrass habitat by overlaying all seagrass observations to produce a layer which defines the potential habitat in which low biomass seagrass can grow (McMahon *et al.* 2017). | Only low biomass seagrass was observed within the mapped area of LAU7. Seagrass was always observed in sparse to low densities as a sub-dominant taxa to either macroalgae or filter feeder species. Therefore, all areas mapped as the 'Filter Feeder / Macroalgae / Seagrass BCH were considered possible to support Seagrass regardless of whether it was observed during the survey. Distribution of seagrass habitats in the region are discussed further in Section 5.3. |

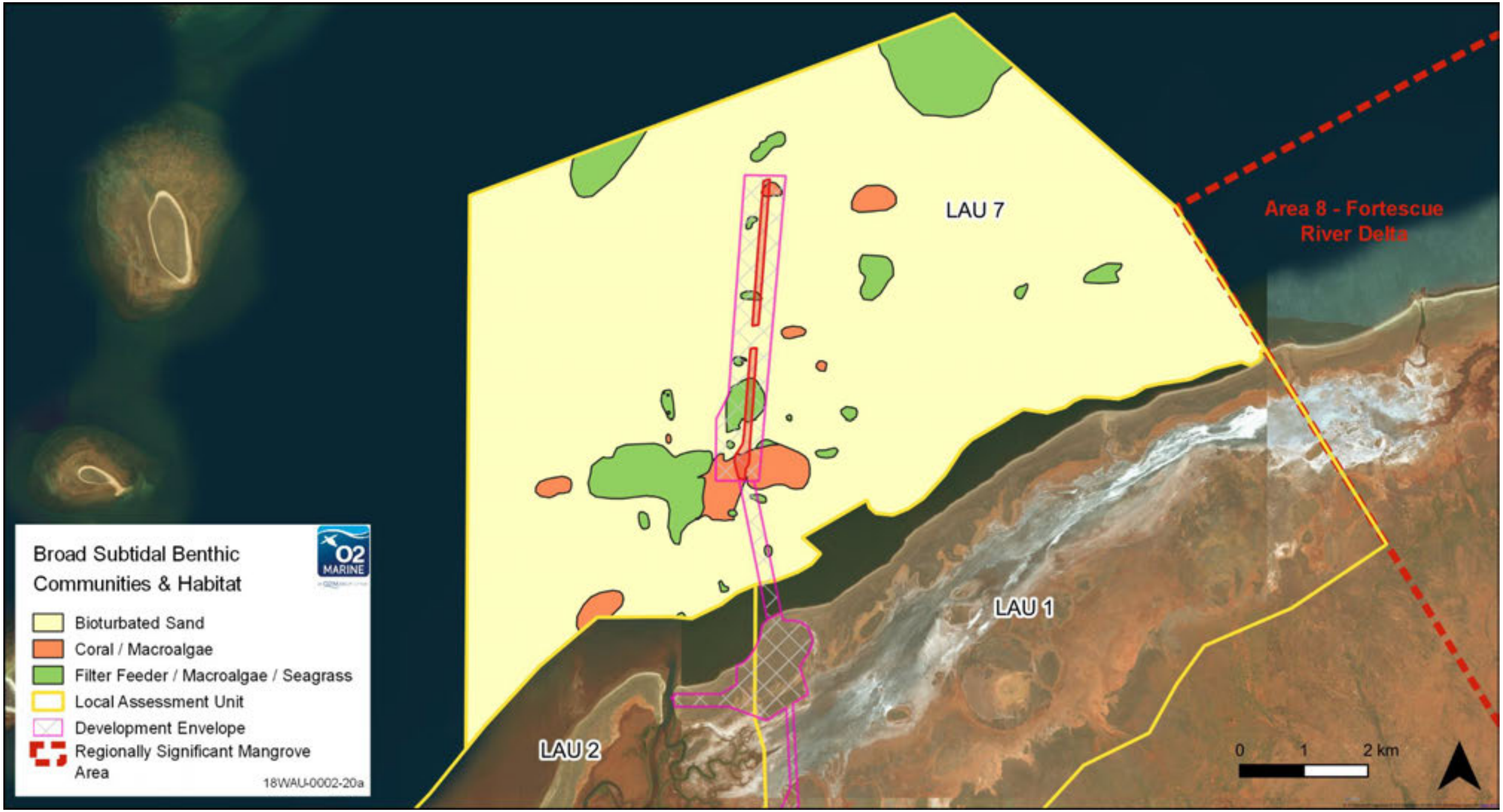



**Figure 11** **Broad Subtidal Benthic Communities and Habitat Mapping within LAU7**

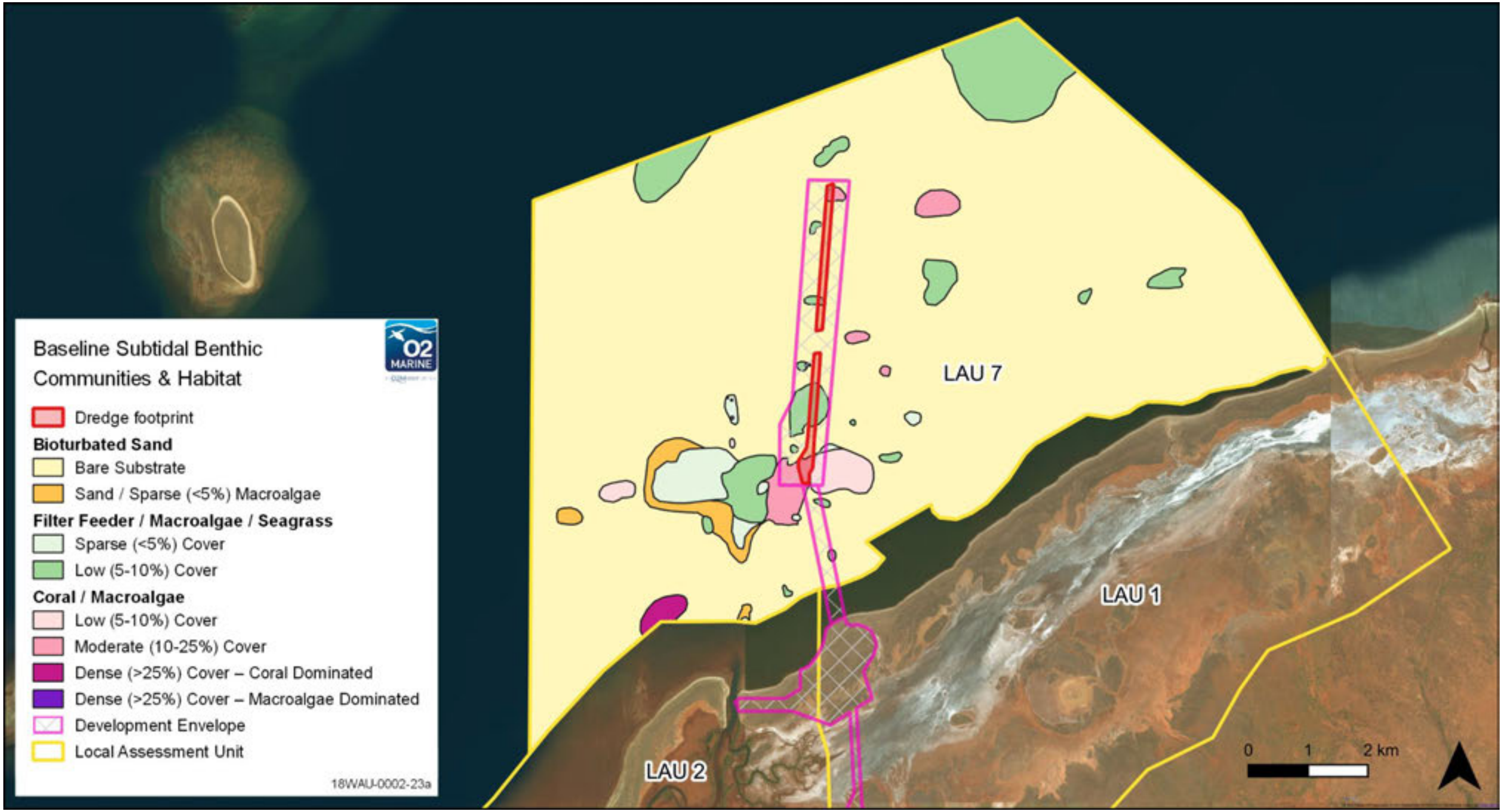



**Figure 12 Subtidal Benthic Communities and Habitat Mapping within LAU7, including subclasses**

# 5. Subtidal Benthic Habitats of the Mardie Coastline

In general, the complex topography of the coastal Pilbara marine environment is known to provide habitat for a variety of benthic biota including seagrasses, corals, filter feeders and macroalgae. However, in the vicinity of the Mardie Project area, the low relief, flat topography provides limited variation and complexity in habitat. The substrate of the Project area is predominantly characterised by gently sloping, bare silt / sand substrate with areas of low relief, sand veneer over limestone pavement, which typically supports sparse to moderate cover of filter feeders, macroalgae, seagrass and coral species. In the Mardie Project area, species diversity within these BCH types is low and generally limited to sediment tolerant species which have adapted to the, shallow, naturally turbid nearshore conditions.

All habitats identified in the Mardie Project area are widely distributed across the Pilbara region. Scott *et al.* (2006) described the subtidal BCH along entire nearshore coastline from the Fortescue rivermouth in the north to the southern end of the Exmouth Gulf as similar habitat, being "*Sand; Limestone Pavement; Macroalgae; Seagrass*" (**Figure 13**), which is a reasonably accurate representation of the BCH observed by O2 Marine in the area. However, a study by Chevron (2014) described the nearshore BCH habitats adjacent to the Mardie Coastline as "*Unvegetated*" (**Figure 14**), which although is an accurate characterisation of 80% of the BCH in the area, does not account for the patchy distribution of sparse to moderate cover of filter feeders, macroalgae, seagrass and coral BCH in this nearshore area. This description also does not account for the seasonal variation and constantly changing substrate in response to physical disturbance from cyclones, wave mobilisation of sediments during the wet season and potential flash flooding and attendant sediment loads during heavy rainfall events, which can seasonally expose and cover hard substrates which could support more complex BCH at different times.

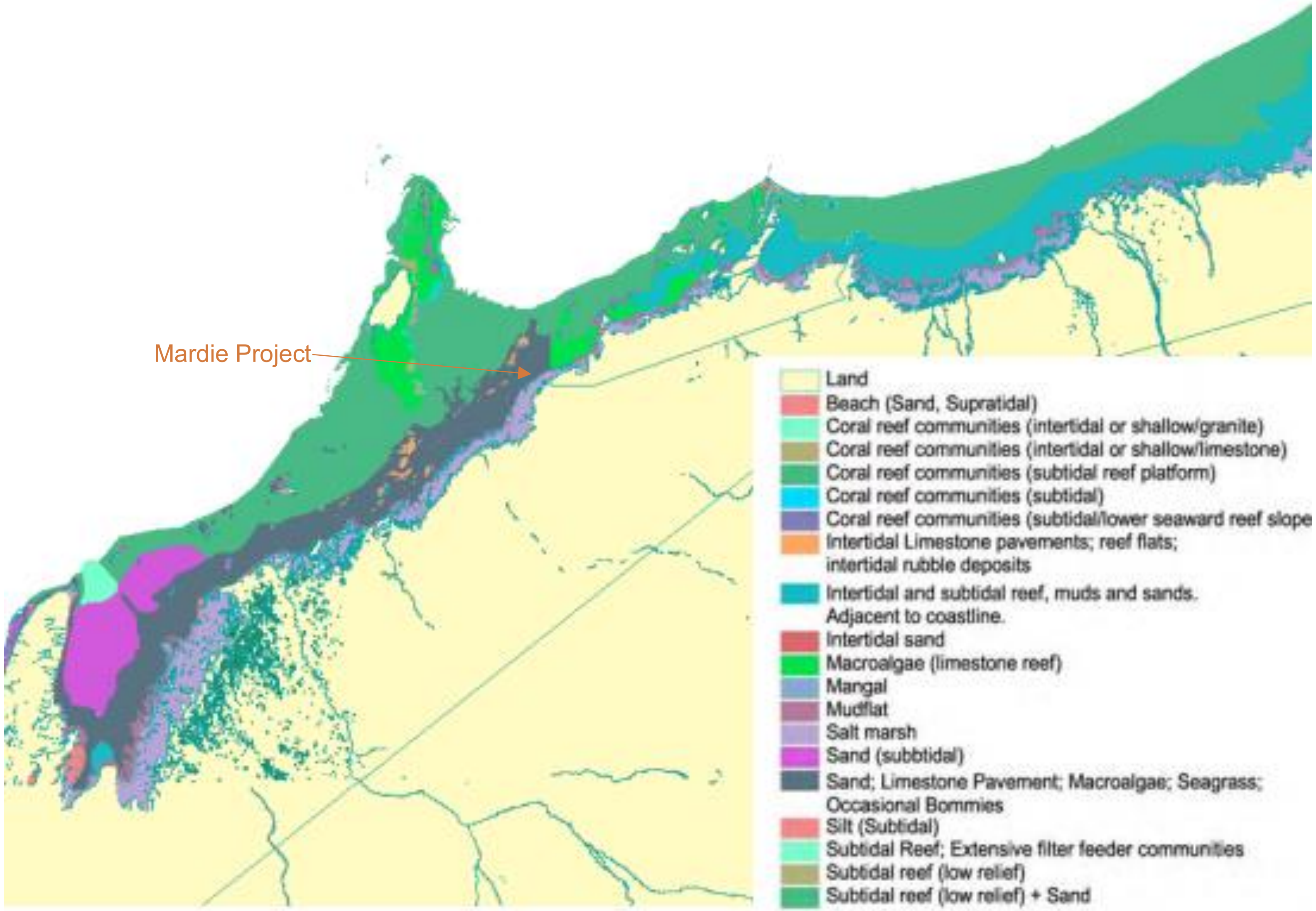



**Figure 13 Map of habitats derived for the NWSJEMS region, with location of Mardie Project shown. Source: (Scott *et al.* 2006)**

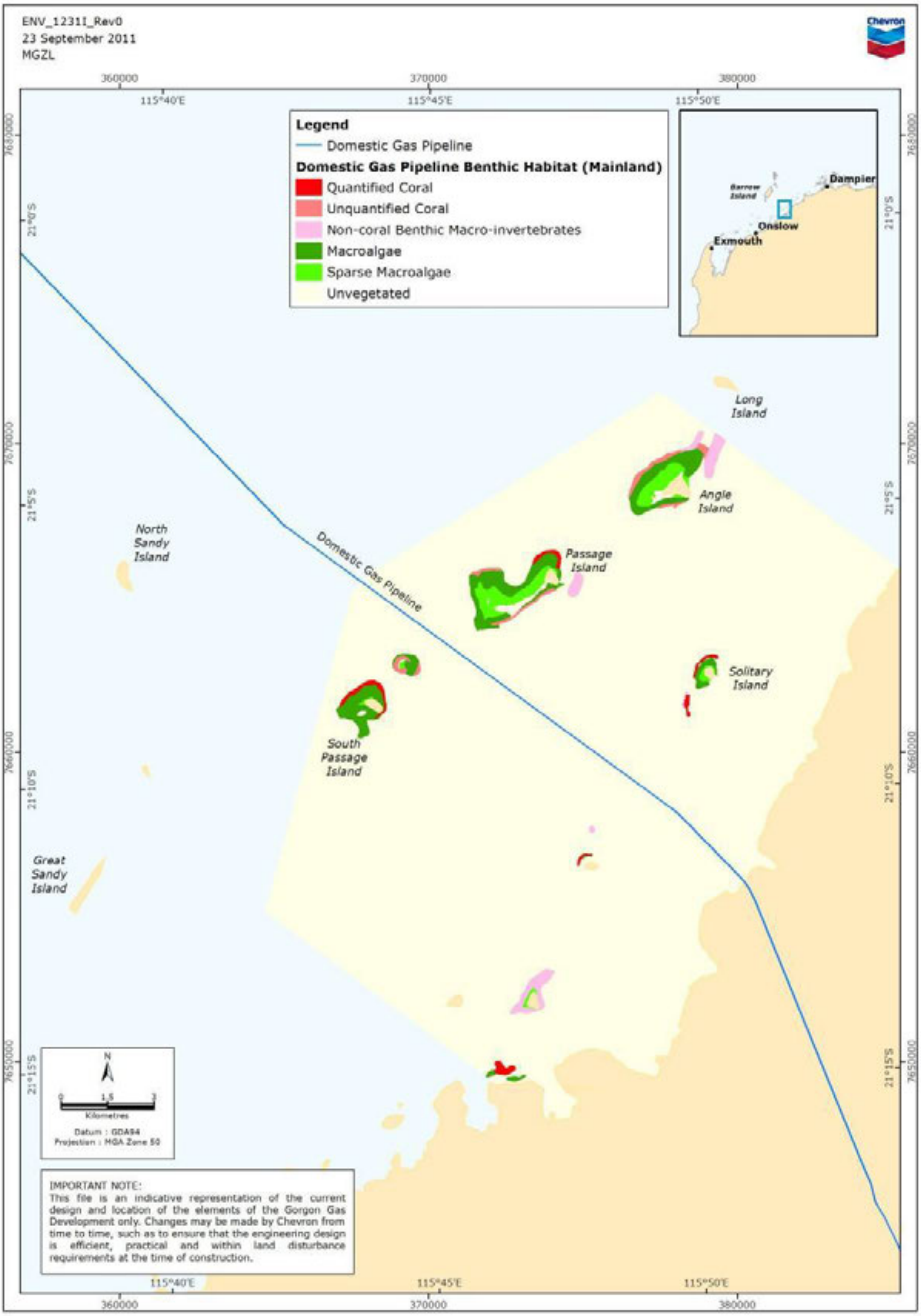



**Figure 14 Benthic Habitat Mapping for the DomGas Pipeline near the Mainland Shore Crossing (Chevron 2014). Mardie Project area located on the western boundary of the map.**

## 5.1. Bare Substrate/Soft Sediments

### 5.1.1. Distribution

The dominant BCH that occurs extensively in the nearshore subtidal zone of the Pilbara is bare sand substrate comprising of fine silty to coarse sands (**Figure 11** and **Figure 12**). This habitat has been identified as the most dominant habitat type found throughout the study area at Mardie which is similar to studies completed at Cape Preston (~70% sand) and for the DomGas Pipeline, 10 km south-west of LAU7 (Chevron 2014), which mapped the entire nearshore zone as 'unvegetated' (**Figure 14**).

For this study, bare, fine, coarse and bioturbated sands have been classed as Bare Sand and sub-classed as either completely bare substrate or Sand substrate that supports very sparse (1-3%) cover of macroalgae. There is a general gradation of silty sands from inshore to the 10m isobath to sandy gravels seaward of the 10m isobath. Silty sands closer to shore were generally found to support a lower density of sessile invertebrates compared to the coarse sands offshore, which is consistent with the nearshore sediments around Onslow (URS 2010a). The silty sands however, showed greater bioturbated activity compared to the coarser sands further from shore. This seems to be common throughout the Pilbara, as species of infauna are likely to dominate softer sediments, whereas epifaunal species are likely to inhabit harder substrates (Chevron 2015).

### 5.1.2. Functional Ecological Value

Bare or unvegetated substrate is afforded the lowest level of protection given the limited contribution to primary production and low relative value as marine fauna habitat. However, this BCH class does support microphytobenthic algal communities and benthic infauna. It is also likely that some areas of bare or unvegetated substrate will support more complex BCH at different times, particularly in shallow areas of the Pilbara nearshore environment, where the benthos is constantly changing in response to physical disturbance from cyclones, wave mobilisation of sediments during the wet season and potential flash flooding and attendant sediment loads during heavy rainfall events.

## 5.2. Macroalgae

Macroalgae are locally and regionally widespread within the Pilbara region (**Figure 15**) with as many as 187 different algal species found in the region by the Pilbara Marine Conservation Partnership (Kendrick and Olsen 2017). Macroalgae are generally restricted to hard substratum in subtidal and lower intertidal areas and appear to be most dominant on shallow hard pavement, platforms and flats that surround islands (Chevron 2015a and O2 Marine 2017).

### 5.2.1. Species Diversity

Macroalgal assemblages surveyed within LAU7 were dominated by Phaeophytes (e.g. *Padina sp.*, *Glossophora sp. and Spatoglossum sp.*), with a smaller component of chlorophytes (e.g. *Halimeda sp. and Caulerpa sp.*) and a low abundance of rhodophytes (e.g. *Laurencia sp.*, *Amphiroa sp and*, *Asparagopsis sp.)* The greatest diversity was typically related to the limestone reef and limestone pavement whilst sand and limestone veneer substrates supported much lower diversity and abundance macroalgae. The species observed in the Mardie Project area are typical of the turbid nearshore Pilbara environment and have been observed in in similar areas including Cape Preston, Onslow and Dampier (O2 Marine 2017; O2 Marine 2018; Chevron 2015; GHD 2013; and URS 2011).

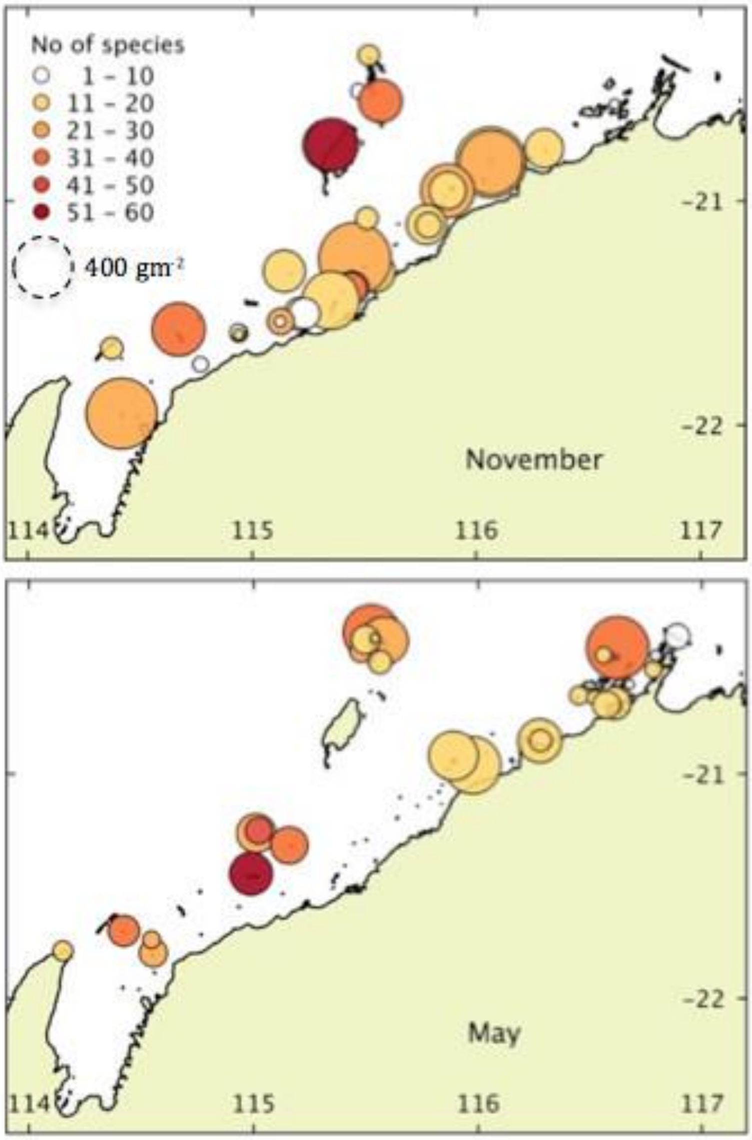



**Figure 15** **Species richness and biomass of macroalgal at each site sampled in November 2013 and May 2014. The size of the circle corresponds to relative abundance of macroalgae. Source: (Kendrick & Olsen 2017).**

### 5.2.2. Distribution and Condition

Macroalgal assemblages represent the most extensive ecological element in the subtidal portion of the Project area. Percentage cover of macroalgae assemblages within mapped areas within LAU7 were spatially variable, both between and within sites. Percentage cover was generally highest on the areas of low to medium relief, such as limestone reefs and platforms, whilst sparse cover (<5%) was present on areas of mainly coarse sands to fine sands either attached to small rocks or shell fragments which permitted colonisation in a typically soft substratum habitat. Similar fine sand bioturbated habitat at Onslow have also been found to support benthic macroalgae (0.05m to 0.4m) and other benthic species (O2 Marine 2017).

Low cover (5-10%) of macroalgae found on low relief limestone pavement covered with coarse sand was generally found in association with filter feeders. Denser (>25%) assemblages of macroalgae found in the study area occurred in association with coral species on moderate relief limestone reef and pavement, where macroalgae were either dominant or intermixed with low cover (5-10%) or moderate (10-25%) cover in mainly dominant coral communities. This association is consistent with results found at Onslow, where coral, filter feeders (sponges) and macroalgae associations (phaeophytes) were found to commonly occur on larger low-profile rocky outcrops (1m wide).

Tropical macroalgae such as that found at Mardie are typically less dense and rarely form obvious beds when compared to temperate areas in WA, except for ephemeral species which are known to increase in abundance during summer in the southwest Pilbara such as *Sporochnus* sp. and *Sargassum sp.* (Kendrick & Olsen 2017). Seasonal trends in macroalgal abundance are commonly observed on tropical shallow reef systems and have been recorded elsewhere in north western Australia (Chevron 2015).

### 5.2.3. Functional Ecological Value

Macroalgae are an important component of tropical reef ecosystems as they contribute to the productivity of a system as a food source, provide habitat for a range of economically and ecologically important species, contribute to local sediments and play an important role in the nutrient cycle from decomposition (Kendrick & Olsen 2017). Some algae such as crustose coralline algae are also crucial in terms of their contribution to the formation and maintenance of coral reefs, as they lay down calcium carbonate as calcite, cementing and binding reef materials which in turn affect the settlement and establishment of corals (Kenrick & Olsen 2017).

## 5.3. Seagrasses

### 5.3.1. Species Diversity

Two species of seagrass were identified from the Mardie Project area being, *Halophila ovalis* and *Halodule uninervis*. These species are consistently recorded from across Pilbara region, particularly in shallow nearshore environments, and are known to be the most widespread seagrass species in the Pilbara (Vanderkilft *et al.* 2017; and McMahon *et al.* 2017).

Whilst seagrass species diversity at Mardie is low, there are only seven species of seagrass, known to occur in the Pilbara region, and the highest species diversity (i.e. five) recorded in recent years was at Exmouth Gulf (Vanderkilft *et al.* 2017). The low diversity recorded at Mardie is also consistent with other locations in the Pilbara (i.e. South Murion Island, Bundegi and Thevenard Island), which were also found to support only two seagrass species (Vanderkilft *et al.* 2017).

### 5.3.2. Distribution and Condition

Seagrass were identified in the shallow (< 5 m LAT) nearshore water of LAU7, generally in areas dominated by Filter Feeder and Macroalgal BCH. However, targeted multi-season surveys failed to identify any locations within LAU7 that recorded benthic cover of seagrass >1%. However, seagrass (i.e. *H. ovalis and H. uninervis*) was identified in densities up to 25% approximately 5km south of LAU7.

The seagrass species (i.e. *H. ovalis and H. uninervis*) that were observed in the Mardie area are common and widely distributed across the Pilbara (Vanderkilft *et al.* 2017; and McMahon *et al.* 2017). They are known to be rapid colonisers of bare substrates, which reflect life-history traits of short individual turnover times (<2months), fluctuating total biomass, a high level of reproductive effort producing seeds and an ability to build up a seed bank (McMahon *et al.* 2017). In Western Australia, the genus *Halophila* is one of the most widespread of the tropical seagrass species, can colonise the widest range of habitat types and appears to be genetically diverse (McMahon *et al.* 2017). For both species of seagrass, spatial and temporal fluctuations are likely to be influenced by naturally limiting processes in the area, such as the resuspension of sediments in nearshore waters, elevated warm temperatures and cyclones during summer months. Biomass or cover is likely to be highest late in the year (i.e. November/December) as water temperatures are within the seagrasses optimal growth range (Lee *et al.* 2007). However, the seasonal growth and reproductive pattern for these seagrasses is spatially and temporally variable and no clear and generally applicable environmental window can be specified.

Whilst *Halophila sp.* have previously been observed in turbid nearshore environments to the South and North of the Project area (i.e. near Onslow and Cape Preston respectively) (O2 Marine 2017; O2 Marine 2018; Chevron 2015 and GHD 2013), McMahon *et al.* (2017) identified that the silty substrates which dominate the Project area are the least preferred habitat for seagrasses. Additionally, a study by Bertolino (2006) indicated that most seagrass species typically prefer the coarser, more compact sediments, where resuspension is less likely to occur; the water column is less likely to be turbid, and where sufficient light can reach the seabed. In the Mardie area, seagrass assemblages were recorded in or adjacent to soft sediment substrates, with veneers of sand overlying limestone pavement, generally as small sparse (<1% cover) patches rather than distinct, dense (i.e. meadow-forming) beds.

### 5.3.3. Functional Ecological Value

Seagrasses are known to provide valuable ecosystem services such as carbon storage, filtering nutrients and particles from the water column, stabilising sediments and providing high primary productivity (McKenzie *et al.* 2006). However, the limited distribution and low cover of seagrasses in the Project area suggests that their contribution to ecosystem services in a regional context is limited.

The nearest known seagrass 'meadows' to the Project area are located in the North, near to Cape Preston (O2 Marine 2018; and GHD 2013) and in the South, near Coolgra Point (Chevron 2014), with densities up to 50% recorded at both locations. Seagrass meadows provide an important source of foraging habitat for Dugong, Turtles and commercially fisheries, such as prawns. Whilst it is well documented that seagrass habitats in the Pilbara vary greatly between seasons and years, unrelated surveys by O2 Marine at nearby Cape Preston (50 km north of Mardie) in March 2018, identified extensive *Halophila sp.* seagrass meadows, indicating that local (i.e. <50km from the Project area), seasonal conditions were appropriate to support meadow formation at the time of surveys undertaken in the Mardie Project area (i.e. February & March 2018). Therefore, it is unlikely that the Project area constitutes ideal habitat to support the quality of the regionally important seagrass meadows that are regularly observed at Cape Preston to the north and Coolgra Point to the South.

Similarly, BCH surveys of the Cape Preston region in March 2018, recorded high Dugong activity in the vicinity of dense seagrass meadows, with four individual observations recorded over two days. However, no Dugong were observed in over 700 hours of vessel-based observations around the Mardie project area. This suggests that the very low, patchy cover of seagrass in the Project area is unlikely to represent regionally significant habitat for Dugong.

## 5.4. Filter feeders

### 5.4.1. Species Diversity

Filter feeder communities include bivalves, hard and soft corals, sea squirts and sponges (Abdul *et al.* 2019). Filter feeder communities found in the Pilbara dominate the seafloor where waters are turbid or deep and sunlight penetration is low (Abdul *et al.* 2019). Sponges comprise the highest abundance and diversity of filter feeders in the Pilbara and at Mardie with 1233 species identified in the Pilbara (Abdul *et al.* 2019). At Mardie, sessile filter feeder communities included hydroids, bryozoans, ascidians, gorgonians and soft corals, which is typical of the filter feeder communities found in the nearshore Pilbara environments (Abdul *et al.* 2019).

### 5.4.2. Distribution and Condition

Most areas identified to support filter feeders were found in association with either algae, coral, seagrass or sponge in habitats with low to dense cover. For this study these species were therefore classified in the subtidal BCH class Filter Feeder/ Macroalgae/ Seagrass. Filter feeder/macroalgae/seagrass associations at Mardie were also found in Onslow, common on the sand veneered pavement and dominated the inner shelf. At Mardie this BCH was identified as one of the largest BCH units present throughout the study area.

At some sites, filter feeders such as hydroids were found in isolation with sparse (<5%) to low (5-10%) cover occurring in soft substratum such as fine bioturbated sands. This same cover of filter feeders was identified at Cape Preston for sponges but not for hydroids (~1%) (GHD 2013). Similarly, at Onslow and south of Mardie filter feeder communities were rarely described as homogenous and were characterised by patches of different community types with sponges forming a significant component of this community like at Mardie (O2 Marine 2017 & Chevron 2014).

### 5.4.3. Functional Ecological Value

Filter feeders are considered keystone species with a major influence on the dynamics of aquatic ecosystems. They are key elements in food webs, controlling primary production, phytoplankton community structure and nutrient cycling (Sanchez *et al.* 2016 & Abdul *et al.* 2019). Benthic filter feeders (secondary production) can also be important both in terms of ecological connectivity and in providing food for pelagic, demersal and even for commercially important species.

## 5.5. Corals

### 5.5.1. Species Diversity

Coral diversity in Western Australia is high, with 361 species from 17 families and 83 genera of hard corals recorded (Jones 2016). The species richness of coral taxa in the Mardie Project area is considerably lower, however, it is characteristic of inshore Pilbara environments which are generally low in diversity and abundance and often dominated by sediment-tolerant Faviid, Dendrophylliid and Poritid species (GHD 2013; SKM 2011; Worley Parsons 2009; and URS 2008).

In the vicinity of the Project area, the highest diversity of coral taxa was observed on the fringing reef and limestone platform surrounding the nearby islands with species observed from the families Faviidae, Acroporidae, Merulinidae, Poritidae, Dendrophyliidae. However, these islands were located outside of the mapped LAUs. Within LAU7, diversity and abundance of coral was much lower, and the communities were generally dominated by octocoral species, *Turbinaria sp.* and corals from the Faviidae family (*Favites, Favia, Cyphastrea spp.*) with occasional larger >1m diameter Poritid bommies.

### 5.5.2. Distribution and Condition

For most coral species that are found at Mardie and in the inshore Pilbara waters, their composition and spatial distribution are likely due to natural disturbance events that have found to be associated with anomalous water temperatures and cyclones (O2 Marine 2017). As well as natural disturbance events, natural physiochemical parameters such as depth and turbidity (light availability), affect where corals are likely to be found and the extent of their cover. The corals that inhabit the coastal waters of Mardie experience turbid waters for most of the year, particularly in the summer months, due to stronger winds and the generation of wind waves resulting in the uplift of fine sediment in the water column (O2 Marine 2020b).

The fringing reefs and shoals in the vicinity of the Mardie Project area lacked evidence of true coral reef formation (a reef formed on layers of dead coral), rather the reefs found were formed by a thin layer of live coral on a veneered limestone pavement or rock substratum as has been observed in nearby Onslow to the south and Cape Preston to the north (GHD 2013; Worley Parsons 2009; and URS 2008). Coral families were identified in the highest densities (>25%) on low profile limestone platforms (shoals) in the shallow nearshore waters (<5m LAT) of the Project area and found fringing the nearshore islands, generally in areas associated with high cover of macroalgae. Low (5-10%) to moderate (10-25%) cover of coral was also observed in association with macroalgae and bordering sparse to low cover Filter Feeder/Macroalgae/Seagrass BCH.

The fact that the coral communities in the Mardie area were dominated by sparse Dendrophylliid, and Faviid corals with diameters of less than or equal to 0.5 m indicates slow growth rates as a result of sedimentation and poor light conditions, or high colony turnover rates due to seasonal cyclonic activity and coral bleaching caused by elevated water temperatures. These observations suggest that over time the composition of corals around Mardie have developed to be represented by species that have a high tolerance to the natural stressors (i.e. cyclones, waves, sedimentation, etc.) that are commonly experienced in the region (Ayling & Ayling 2005; Chevron 2014). These observations are further supported by the findings of O2 Marine (2019f) which found that the high mean turbidity (i.e. 14 NTU) reported for the inshore waters in LAU7 are unlikely to support the diverse coral communities that are typical of clearer water Pilbara environments located further offshore.

### 5.5.3. Functional Ecological Value

Corals are important in terms of their role in contributing to primary production, nutrient recycling, and providing habitat and a food source for a myriad of marine species (Moberg and Folke 1999). In addition to ecosystem services associated with fishing and recreational use including tourism, corals are very significant because of their ability to form habitats with high levels of associated biodiversity.

The coral communities found on the limestone platforms and fringing reefs surrounding the nearshore Islands on the Mardie Coast appeared to support high levels of biodiversity and showed some similarities (i.e. species composition and distribution patterns) to the regionally important coral communities found north of Mardie on the barrier islands located in the Proposed Regnard Marine Management Area (O2 Marine 2018). The coral communities were therefore considered to be some regional importance and impacts to these areas should be avoided. In contrast, the coral communities found within LAU7, are generally low in terms of diversity and abundance and represent less than 2% of the total area of BCH within LAU7, therefore the likely contribution of these coral communities to local and regional ecosystem services is considered to be limited.

# 6. Conservation and Social Values

## 6.1. Conservation Areas

### 6.1.1. Nature Reserves & Marine Parks

In WA the conservation of ecologically significant marine, estuarine or terrestrial ecosystems may be managed through reserves established under the CALM Act. The subtidal habitats within the Mardie Project area have not been identified as containing significant ecological communities warranting protection through the introduction of marine conservation reserves. The nearest Marine Park is the Montebello Islands Marine Park, which is located over 60km northwest of the Mardie Project area.

All inshore islands of the West Pilbara are listed as Class C Nature Reserves and although no inshore islands are located within LAU7, several inshore Islands including the Passage Islands group, Sholl Island, Angle Island and Mardie Island are located adjacent to the Mardie Project area. These islands are known to be important areas for migratory seabirds, turtles and dugong and support large areas of macroalgal beds and both biogenic coral reef and coral communities on pavement. However, the subtidal areas surrounding the inshore islands are not afforded the same conservation status as the islands themselves.

There are no implications from any of the proposed Commonwealth Marine Reserves for the Mardie Project due to the Project area being completely contained within State Waters.

## 6.2. Social and Cultural Significance

Being an extremely remote location, the social significance of the Mardie Project area is considered to be low. The site has limited, to no access and no public facilities. Any access to the site would require a well provisioned vessel. The site may hold occasional values for recreational and commercial fishing, although these activities are far more likely to occur around nearshore and offshore islands or around the Fortescue Rivermouth campground located approximately 25 km north of the Project area.

Cultural heritage importance of the site is beyond the scope of this assessment and as such is addressed through other studies undertaken for the Mardie Project.

# 7. Conclusion

The subtidal BCH assessment identified and mapped three broad BCH classes within the vicinity of the Project area, including:

- Bare / Bioturbated Sand;
- Filter Feeder / Macroalgae / Seagrass; and
- Coral / Macroalgae.

The benthic cover varied between survey locations and classes, however, was generally sparse to low across more than 95% of the study area. All habitats identified within LAU7 were determined to be widespread across the turbid nearshore environments of the Pilbara coastline and as such were not considered to represent habitats of particular regional or conservation significance.

Locally important seagrass communities were observed in the vicinity of the Mardie Project area, approximately 5 km to the south of LAU7. Whilst locally important coral communities were observed fringing the nearshore islands, between 5-10 km offshore from the Mardie coast. However, neither of these locally important BCH were contained within any of the mapped LAU boundaries and as such are expected to be beyond the influence of the proposed Mardie Project. Nevertheless, these areas should be considered in future operations of the proposed Mardie port facility and any future amendments to the Mardie Project should also aim to avoid impacts to these areas.

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