# 4. EXISTING ENVIRONMENT

## 4.1 ENVIRONMENTAL STUDIES

Numerous studies and investigations have been undertaken within the Mine Site Development Envelope and Derby Port Development Envelope in order to provide a comprehensive overview of the existing environment and to identify any potential impacts that may occur as a result of the Thunderbird Mineral Sands Project. These are presented in Table 14.

**Table 14: Studies Undertaken for the Thunderbird Mineral Sands Project**

| Environmental Factor | Report Title | Report Author | Date Completed |
|---|---|---|---|
| **Mine Site Factors** | | | |
| Flora and Vegetation* | Thunderbird Dampier Peninsula Project Level 1 Flora and Fauna Assessment | Ecologia | 2012a |
| | Thunderbird Project Level 2 Flora and Vegetation Report | Ecologia | 2014b |
| | Thunderbird Project Haul Road and Accommodation Village Flora and Fauna Assessment | Ecologia | 2015 |
| | Flora and Vegetation of the Thunderbird Mineral Sands Project Area | Mattiske | 2016a |
| | Potential Groundwater Dependent Ecosystems in the Thunderbird Mineral Sands Project Area | Mattiske | 2016b |
| Terrestrial Fauna* | Thunderbird Dampier Peninsula Project Level 1 Flora and Fauna Assessment | Ecologia | 2012a |
| | Thunderbird Project Level 2 Terrestrial and Subterranean Fauna Assessment | Ecologia | 2014a |
| | Thunderbird Project Haul Road and Accommodation Village Flora and Fauna Assessment | Ecologia | 2015 |
| | Thunderbird Project Targeted Greater Bilby Assessment | Ecologia | 2016 |
| Hydrological Processes* Inland Waters Environmental Quality* | Thunderbird Surface Hydrology | MBS | 2016a |
| | H3 – Level Hydrogeological Assessment of the Thunderbird Project | Rockwater | 2016 |
| Heritage* | Final open Report. Nyikina Mangala Native Title Claim Group and Other Traditional Owners. Survey of Tenement E04/2083, Mt Jowlaenga. Confidential Report. | Cox Anthropology | 2012 |
| | Ethnographic Heritage Survey Report - Open Survey of Tenement E04/2081,2083-84,2159, 2191-94, 2171: Mt. Jowlaenga. Confidential Report. | Beit Holmes and Associates | 2013 |
| | Ethnographic Heritage Survey Report - Open Survey of Tenements E04/2081, 2083-84, 2159, 2171, 2191-94: Mt Jowlaenga. Confidential Report. | Beit Holmes and Associates | 2014 |
| | Ethnographic Heritage Survey Report - Open Survey of Tenements E04/2083-84, 2159, 2171, 2192-94, 2349: Mt. Jowlaenga. Confidential Report. | Beit Holmes and Associates | 2015 |
| | Ethnographic Heritage Survey Report - Open Survey of MO4/459 within EO4/2083: Thunderbird Project proposed Mining Operations Area. Confidential Report. | Beit Holmes and Associates | 2016a |

| Environmental Factor | Report Title | Report Author | Date Completed |
|---|---|---|---|
| | Ethnographic Heritage Survey Open Report – BFS Activities Mt Jowlaenga Polygon #2 May 2016. Confidential Report. | Beit Holmes and Associates | 2016b |
| Rehabilitation and Decommissioning* | Thunderbird Mine Waste Characterisation | MBS | 2016b |
| | Thunderbird Soil and Landform Assessment | MBS | 2016c |
| | Revised Radionuclide Mass Balance and Regulatory Summary | SGS | 2016 |
| Landforms | Thunderbird Soil and Landform Assessment | MBS | 2016c |
| Subterranean Fauna | Thunderbird Project Level 2 Terrestrial and Subterranean Fauna Assessment | Ecologia | 2014a |
| Terrestrial Environmental Quality | Thunderbird Mine Waste Characterisation | MBS | 2016b |
| | Revised Radionuclide Mass Balance and Regulatory Summary | SGS | 2016 |
| | Geotechnical Report | Hatch | 2016 |
| Air Quality and Atmospheric Gases | Thunderbird Mine Site Air Quality Assessment | Atmospheric Solutions | 2016a |
| Human Health | Revised Radionuclide Mass Balance and Regulatory Summary | SGS | 2016 |
| | Radionuclide Mass Balance | Radiation Professionals | 2016 |
| | Investigations as for 'Air Quality and Atmospheric Gases' | | |
| **Derby Port Development Envelope** | | | |
| Amenity* | Product Transport and Derby Port Air Quality Assessment | Atmospheric Solutions | 2016b |
| | Environmental Noise Impact Assessment – Port of Derby | WSP \| Parsons Brinckerhoff | 2016a |
| Hydrological Processes | This Public Environmental Review (Section 4.2.6 and Section 4.3.8) | MBS | 2016 (this PER) |
| Marine Environmental Quality* | Revised Radionuclide Mass Balance and Regulatory Summary | SGS | 2016 |
| | Thunderbird Mineral Sands Project Derby Export Facility Baseline Contamination and Acid Sulfate Soil Assessment | MBS | 2016 |
| Benthic Communities and Habitat | This Public Environmental Review (Section 4.3.13) | MBS | 2016 |
| Terrestrial Environmental Quality | Investigations as for 'Human Health' and 'Amenity' | | |
| Human Health | Revised Radionuclide Mass Balance and Regulatory Summary | SGS | 2016 |
| | Radionuclide Mass Balance | Radiation Professionals | 2016 |
| | Investigations as for 'Amenity' | | |

* = *Key Environmental Factor*

## 4.2 MINE SITE DEVELOPMENT ENVELOPE

This section describes information regarding the physical, biological and socio-economic characteristics of the proposed Mine Site Development Envelope. This includes all information gathered during physical and biological surveys conducted for the project for this area.

## 4.2.1 Regional Setting

The Mine Site Development Envelope is located on the Dampier Peninsula in the western part of the Kimberley region, within the Dampierland bioregion and Pindanland subregion as defined by the Interim Biogeographic Regionalisation of Australia (IBRA) classification system (Graham 2001). The Pindanland subregion (5,198,904 ha) is described as a fine-textured sand-sheet with subdued dunes, comprised of the sandplains of the Dampier Peninsula and western part of Dampierland, including the Fitzroy River paleodelta. The climate is semi-arid and vegetation is primarily described as Pindan. Broad scale vegetation mapping of the Pindanland subregion describes the following components:

- Mangroves around coastal areas.
- Coastal dune communities.
- Ephemeral herblands and/or grasslands with scattered low trees.
- Mixed species tussock grasslands or sedgelands.
- Various Eucalypt and Melaleuca woodlands.

The topography largely consists of flat sandy plains with some small rock hills approximately 50 m high. The rocky hills are confined to an area of approximately 3 $km^2$ between the proposed operations and accommodation village areas. The gradient of the plains is flattest to the west of the Mine Site Development Envelope (averaging approximately 0.75%) tending to increase to approximately 1% to the east (MBS 2016a).

## 4.2.2 Climate

The climate of the Mine Site Development Envelope is classified as 'grassland, hot (winter drought)' under the modified Köppen classification for Australia (Stern et. al. 2000). It has summer dominant rainfall, with hot, humid summer temperatures (BoM 2016a).

### *4.2.2.1 Temperature, Evaporation and Humidity*

Most rainfall occurs during the wet season between November and April. Potential evapotranspiration is very high, averaging 1,980 mm per year, and varies moderately across seasons. Evapotranspiration generally remains higher than rainfall even in the wet season, resulting in water limited conditions for vegetation (CSIRO 2009).

Weather data has been collected from an automatic weather station at the Mine Site Development Envelope since November 2014. Monthly maximum and minimum temperatures and mean humidity are shown in Chart 1. Maximum temperatures are generally between 33°C and 45°C, with minimum temperatures rarely dropping below 15°C during the dry season. Average humidity is around 40% in the dry season and approaches 80% in the wet season. Days with maximum humidity over 90% were observed in all months.

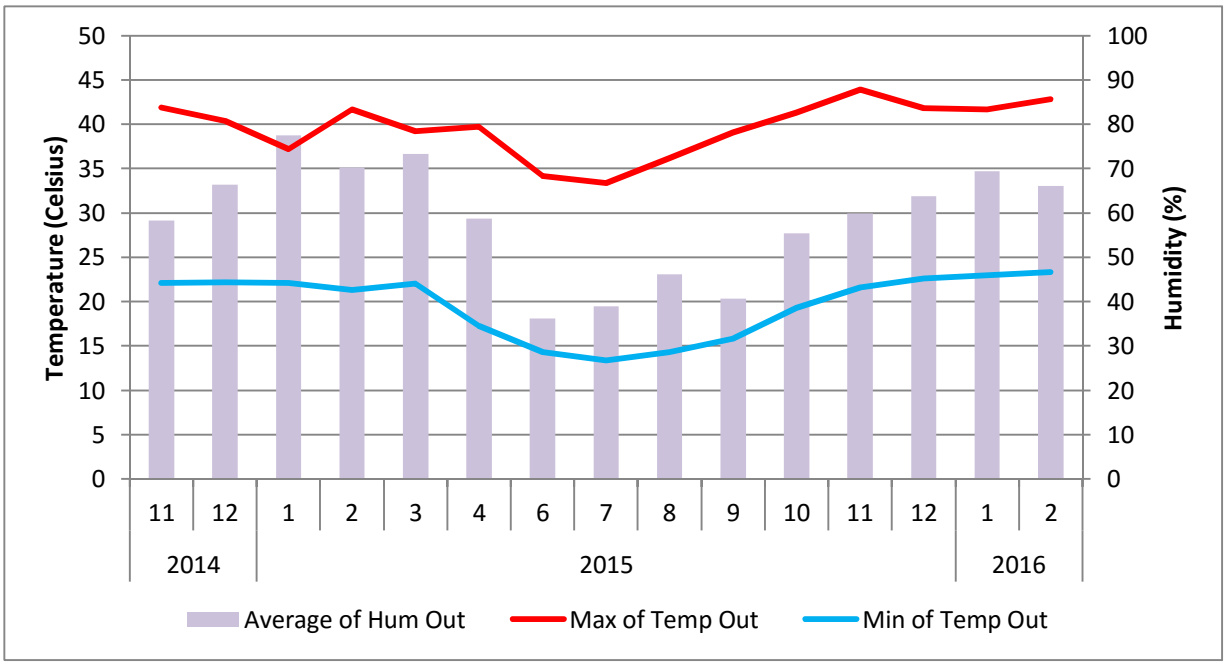



**Chart 1: Temperature and Humidity at Mine Site Development Envelope**

#### *4.2.2.2 Rainfall*

Spatially extrapolated rainfall data is available for the Mine Site Development Envelope from the SILO Data Drill data set (Queensland Government 2016). This data is calculated by extrapolation from all available Bureau of Meteorology (BoM) data including the closest BoM sites (Thunderbird, Mt Jowlaenga, Country Downs, Beagle Bay, Yeeda, and Derby Aero) to give a continuous estimated record for a specific location. Comparison with local stations shows that the data drill closely matches Mt Jowlaenga rainfall records (when available), and is similar to Country Downs and other nearby stations at other times. It is recommended this dataset be used for long term rainfall patterns.

Monthly rainfall statistics for the Mine Site Development Envelope based on the Data Drill dataset from 1889 to 2015 are shown in Table 15 and Chart 2, with annual figures based on a rainfall year from September to August. Mean annual rainfall is 694 mm, however, is very variable with a lowest annual rainfall of 153 mm and highest of 1,503 mm. Median annual rainfall is 675 mm. Median monthly rainfall is 1.2 mm or less during the dry season from May to October. Very low or zero rainfall may occur in any month. Details on modelled estimated rainfall from extreme events is described in Appendix 5.

**Table 15: Rainfall Statistics for Mine Site Development Envelope 1889 to 2015 (Data Drill)**

| Month | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 1.0 | 3.9 | 17.8 | 92.4 | 193.1 | 181.0 | 128.9 | 29.9 | 23.4 | 14.9 | 6.5 | 3.5 | 695.3 |
| Highest | 48.5 | 53.9 | 229.1 | 668.5 | 1031.8 | 556.9 | 535.1 | 261.7 | 308.4 | 159.4 | 157.6 | 56.1 | 1502.7 |
| Decile 9 | 1.1 | 12.0 | 44.3 | 181.4 | 365.3 | 334.9 | 288.1 | 73.5 | 80.6 | 53.7 | 19.8 | 5.9 | 1003.6 |
| Median | 0.0 | 0.3 | 8.4 | 66.1 | 156.6 | 164.7 | 96.7 | 12.4 | 0.9 | 0.3 | 0.0 | 1.2 | 675.2 |
| Decile 1 | 0.0 | 0.0 | 0.3 | 10.8 | 54.7 | 47.0 | 26.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 401.2 |
| Lowest | 0.0 | 0.0 | 0.0 | 1.1 | 21.0 | 12.7 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 152.6 |

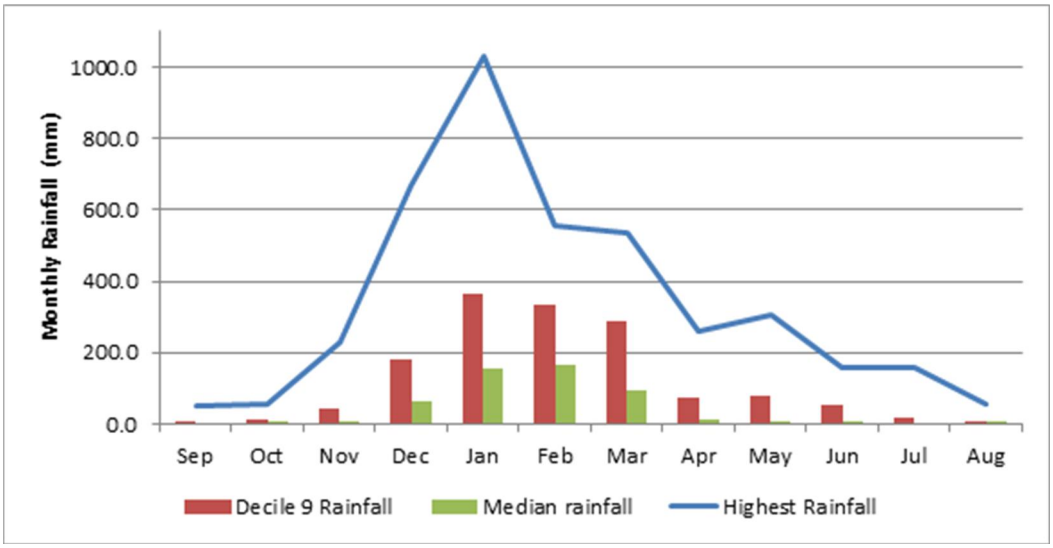



**Chart 2: Monthly Rainfall Statistics for Mine Site Development Envelope**

#### *4.2.2.3 Wind Speed and Direction*

The closest BoM site with wind speed records is Derby Aero (Site 003032). A summary of wind speeds for the Derby BoM site and Thunderbird weather station are presented in Table 16. Morning wind directions tend to be from the east between April and August and from the northwest between September and March. Afternoon wind directions are predominantly from the northwest all year round with the exception of May and June when wind from the southeast is also likely (BoM 2016b).

**Table 16: Mean Wind Speeds (km/h)**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Derby Aero (BoM Site 003032)** | | | | | | | | | | | | | |
| **9 am** | 13.1 | 11.8 | 11.2 | 10.9 | 13.7 | 14.6 | 14 | 13 | 12.9 | 13 | 12.7 | 12.7 | 12.8 |
| **3 pm** | 18.6 | 16.5 | 15.1 | 14.8 | 14.8 | 14.7 | 15.4 | 16 | 19.1 | 23 | 24.1 | 22 | 17.8 |
| **Thunderbird Weather Station** | | | | | | | | | | | | | |
| **9 am** | 8.0 | 5.6 | 5.8 | 5.9 | - | 7.2 | 8.5 | 8.7 | 8.5 | 7.1 | 8.4 | 7.8 | 7.4 |
| **3 pm** | 6.2 | 7.2 | 6.5 | 8.4 | - | 7.7 | 8.0 | 7.9 | 9.6 | 8.3 | 7.8 | 8.2 | 7.8 |

#### *4.2.2.4 Tropical Cyclones*

Across the Kimberley region widespread rainfall event total volumes in excess of 100 mm are commonly associated with tropical lows and cyclones. Such rainfalls can occur well to the east of the cyclone due to moisture-laden northwesterly monsoon winds. Rainfall is not directly related to the intensity of the cyclone and some of the largest flood events have been associated with tropical lows below cyclone intensity.

Although rainfall associated with tropical cyclones is a likely contributor to flooding in the inland Mine Site Development Envelope, cyclone risk with respect to wind is much lower than for Broome and coastal Pilbara towns due to fewer cyclones, including severe cyclones, impacting on the area. On average, for the northwest coast as a whole, approximately five cyclones occur each year, two of which cross the coast with one rated as severe (BoM 2016c). When taken in isolation, the risk of a cyclone occurring at any particular location inland from the coast is much lower. Figure 17, shows the tracks of some notable cyclones affecting the Dampier Peninsula (BoM 2016c).

The cyclone season officially runs between November and April, although cyclones only rarely occur in November and have been observed as late as May. The highest risk of category 4 or 5 cyclones is late in the season during March and April. The impact of early cyclones on flooding is also likely to be lessened due to dry catchment conditions.

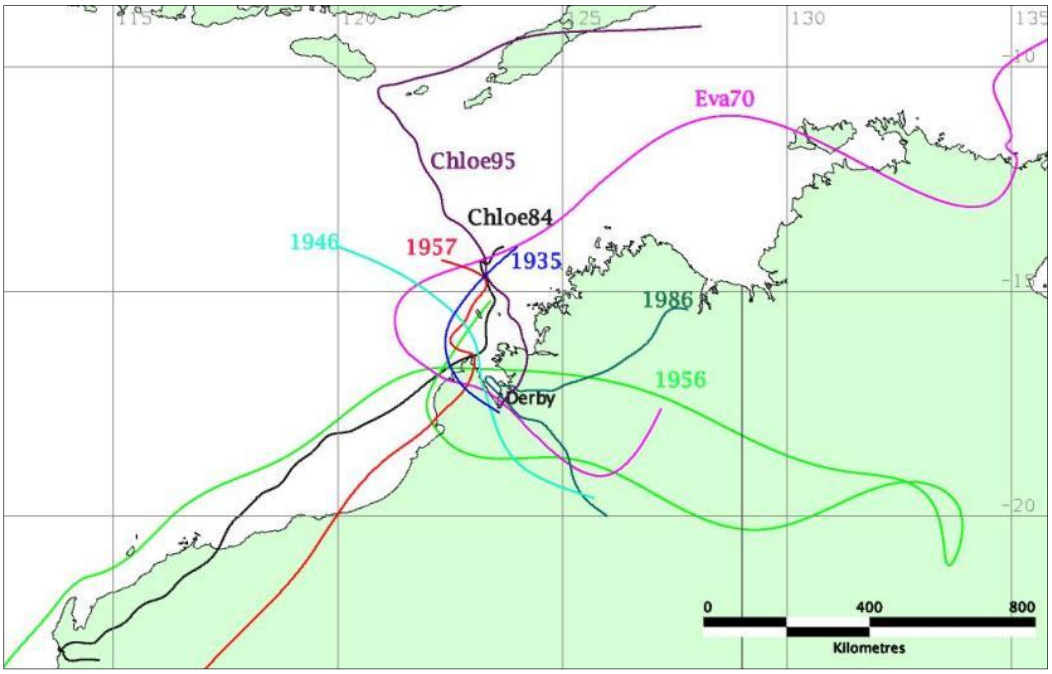



**Figure 17: Tracks of Notable Cyclones Affecting the Mine Site Development Envelope**

## 4.2.3 Geology

### *4.2.3.1 Regional Geology*

The Mine Site Development Envelope is located in the west Kimberley on the Dampier Peninsula, located within the Fitzroy Trough in the north of the Phanerozoic Canning Basin, an intracratonic basin covering 640,000 km$^2$ with a dominant onshore area of 530,000 km$^2$.

The Fitzroy Trough is bounded by the Beagle Bay Fault in the north and the Fenton Fault in the south (Figure 18), which are near-vertical normal faults (Searle 2012). The faults extend through the Triassic and older sediments. The faults' prevalence in younger sediments is unknown. The major fold within the Trough is the Baskerville Anticline, in the centre of the Dampier Peninsula. The anticline strikes east-west and plunges to the west. Strata on the southern limb dip gently to the south-west and strata on the northern limb dip gently to the northwest.

The main geological units of interest in the Dampier Peninsula are the Broome Sandstone and the Mowanjum Sand (Table 17). The Broome Sandstone is mainly concealed at the surface by the younger units, however it does outcrop at some locations across the Peninsula, mostly along the shoreline. Outcrops of various facies of the Broome sandstone have been mapped near the Mine Site Development Envelope (Figure 18).

**Table 17: Stratigraphy of the Dampier Peninsula**

| Age | Formation | Maximum Thickness (m) | Lithology | Extent |
|---|---|---|---|---|
| Quaternary | Mowanjum Sand ('Pindan') | 10 | Fine-grained (very fine to medium) silty sand. | Widespread across the peninsula |
| Late Cretaceous | Emeriau Sandstone | 30 | Fine- to coarse-grained poorly sorted sandstone, minor conglomerate, commonly ferruginous. | North-west of the peninsula only near Bobbys Creek and Lollywell Springs |
| Early Cretaceous | Broome Sandstone | 384* | Fine- to coarse-grained sandstone, gravel, some siltstone, mudstone and conglomerate. Heavy minerals near top & base. | West and central part of the Dampier Peninsula, except where it has been eroded away towards the east. |
| Late Jurassic | Jarlemai Siltstone | 240 | Shallow marine laminated pink and purple siltstone with a sugary texture, massive and partly sandy mudstone, limestone. Includes thin coal seams. | Underlies the whole of the study area. |

** The unit follows Towner and Gibson's (1980) usage and includes the "Jowlaenga Formation" basal transitional unit.*
*Source (after Rockwater 2016)*

### *4.2.3.2 Local Geology*

**Mowanjum Sand**

The Mowanjum Sand (Searle 2012) occurs at the surface or beneath a veneer of other superficial units within the Dampier Peninsula. It is a widespread sheet deposit of Quaternary age and unconformably overlies a weathered contact on the Broome Sandstone. It is overlain itself by thin younger deposits in places. Various other unconsolidated deposits of sand, limestone, silt, clay, gravel, and conglomerate occur along beaches, and tidal flats, and are associated with the dunes. The unit consists of red-brown, fine-grained (very fine to medium) silty sand (colloquially termed 'Pindan'), and is generally between 8 and 14 m thick (maximum 29 m) in the holes drilled by Wright (2013) near the Broome townsite. At the Mine Site Development Envelope it is typically 6 to 12 m thick and unsaturated.

**Emeriau Sandstone**

The Emeriau Sandstone consists of fine- to coarse-grained, poorly sorted sandstone and conglomerate. It is of Late Cretaceous age and is only present in the northwest of the Dampier Peninsula, about 60 km northwest of the Mine Site Development Envelope. It overlies the Broome Sandstone.

**Broome Sandstone**

The Broome Sandstone is present over the west and central part of the Dampier Peninsula, except where it has been eroded away towards the east and over the nose of the Baskerville anticline. To the west, the Broome Sandstone extends offshore beneath the Indian Ocean.

The unit description here follows Towner and Gibson's (1980) usage and includes the basal transitional unit known as the Jowlaenga Formation. The sediments of the Broome Sandstone and basal Jowlaenga Formation are of Early Cretaceous age. They are overlain by superficial units comprising shoreline, aeolian, and alluvial deposits; mainly the Mowanjum Sand ('Pindan sand'). The contact with the Mowanjum Sand is weathered and is frequently difficult to recognise in drill cuttings. The Broome Sandstone is underlain by the Jarlemai Siltstone, which is of Late Jurassic to Early Cretaceous age and has a maximum onshore recorded thickness of 388 m (DMP 2016b).

**Broome Sandstone (Upper)**

The Broome Sandstone consists of weakly cemented, fine- to coarse-grained quartzose sandstone, with minor beds of siltstone and claystone, thin coal seams, and minor pebble conglomerate (Laws 1991). Vogwill (2003) reports that these lithologies are contained within four subfacies, three upper deltaic facies ('Broome Sandstone 1–3') and a lower fluvial subfacies ('Broome Sandstone 4') in the southwest of the Peninsula. The fluvial facies comprises mainly coarse grained sand and granule-sized particles with minor siltstone and claystone, while the upper deltaic facies is mainly medium- to coarse-grained sand with abundant silt. The Broome Sandstone is characterised in geophysical logs by low gamma radiation and high resistivity where the formation is saturated by fresh groundwater. Gamma-radiation signatures have higher intensity where there are intercalated siltstone and claystone beds. Gamma-radiation signatures have lower intensity where pebble conglomerate beds are present.

**Heavy Mineral Sands**

At the Mine Site Development Envelope, the lower part of the Broome Sandstone comprises high grades of fine-grained heavy mineral sands (HMS), containing valuable heavy minerals ilmenite, zircon, leucoxene and rutile. Mineralisation is in a thick, broad, anticlinal, sheet-like body striking northwest. The HMS section of the Broome Sandstone in the Mine Site Development Envelope is relatively thick (35–55 m). The HMS lithology of the Broome Sandstone is comparably finer-grained to that of the upper section of the Broome Sandstone. The areal extent, width, grade, geological continuity and grain size of the Thunderbird deposit are interpreted to indicate an off-shore sub-wave base depositional environment.

**Basal Transitional Unit**

The Broome Sandstone basal transitional unit (also referred as the Jowlaenga Formation) is very similar lithologically to the upper part of the Broome Sandstone although it contains more silts and clays. It can be difficult to differentiate in drill cuttings; however, the transition is recognisable in geophysical logs by a progressive increase in gamma-intensity and a decrease of resistivity with depth. Resource exploration drilling data show an increased concentration of very-fine grained sediment (slime) in the basal transitional unit.

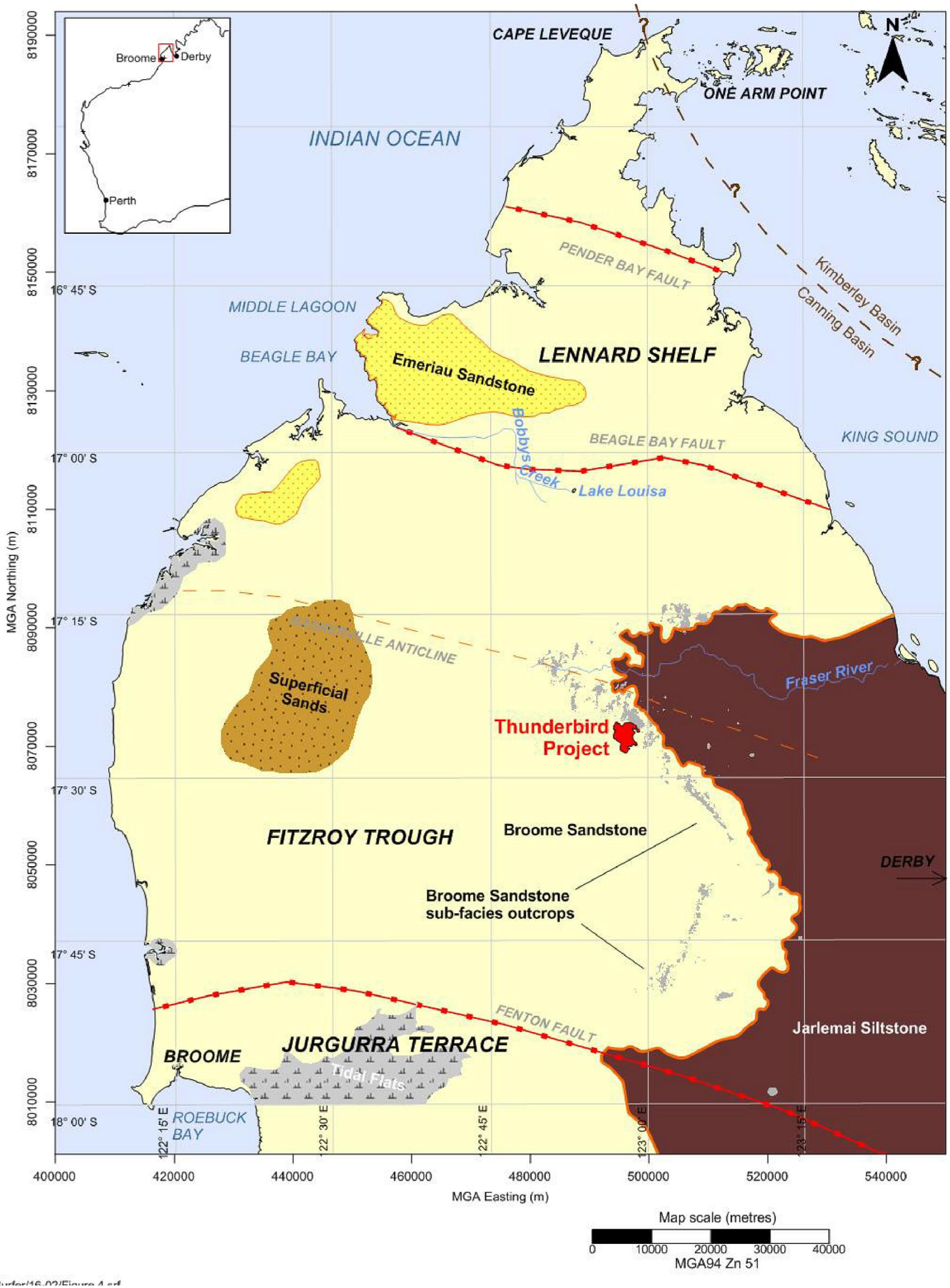
The transitional unit has been interpreted as generally 15–30 m thick (Rockwater 2016), in general agreement with the maximum recorded thickness of 40 m for the Jowlaenga Formation in Geoscience Australia's online geological database.

## Jarlemai Siltstone

The Jarlemai Siltstone is a shallow marine deposit of early Cretaceous to late Jurassic age that is unconformably overlain by the Jowlaenga Formation (Gibson 1983). The formation is up to 218 m thick (in the bore Fraser River 1) and has an average thickness of about 100 m in the Dampier Peninsula.

The formation is primarily a mudstone, consisting of silty claystone, sandy and fossiliferous siltstone, and clayey sandstone. The siltstone and claystone are micaceous and pyritic. They are generally medium to dark grey, brownish grey, and light brown, but can be oxidised dark red-brown, purple, and yellow. Sands are light grey, coarse- to medium-grained, loose to friable, sub-rounded to rounded. Shell fragments, including pelecypods, brachiopods and foraminifera are common, and the formation is calcareous through the middle portion.

Structure contours on the top of the Jarlemai Siltstone indicate an asymmetric east-west trending anticline that probably developed over the pre-existing Baskerville anticline (Laws 1991). Some erosion may also have occurred, particularly south of the Mine Site Development Envelope, but the overall structure is an anticline-like feature.

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## 4.2.4 Land Systems, Landforms and Soils

A baseline soil and landform assessment was undertaken for the Mine Site Development Envelope (Appendix 6).

### *4.2.4.1 Land Systems*

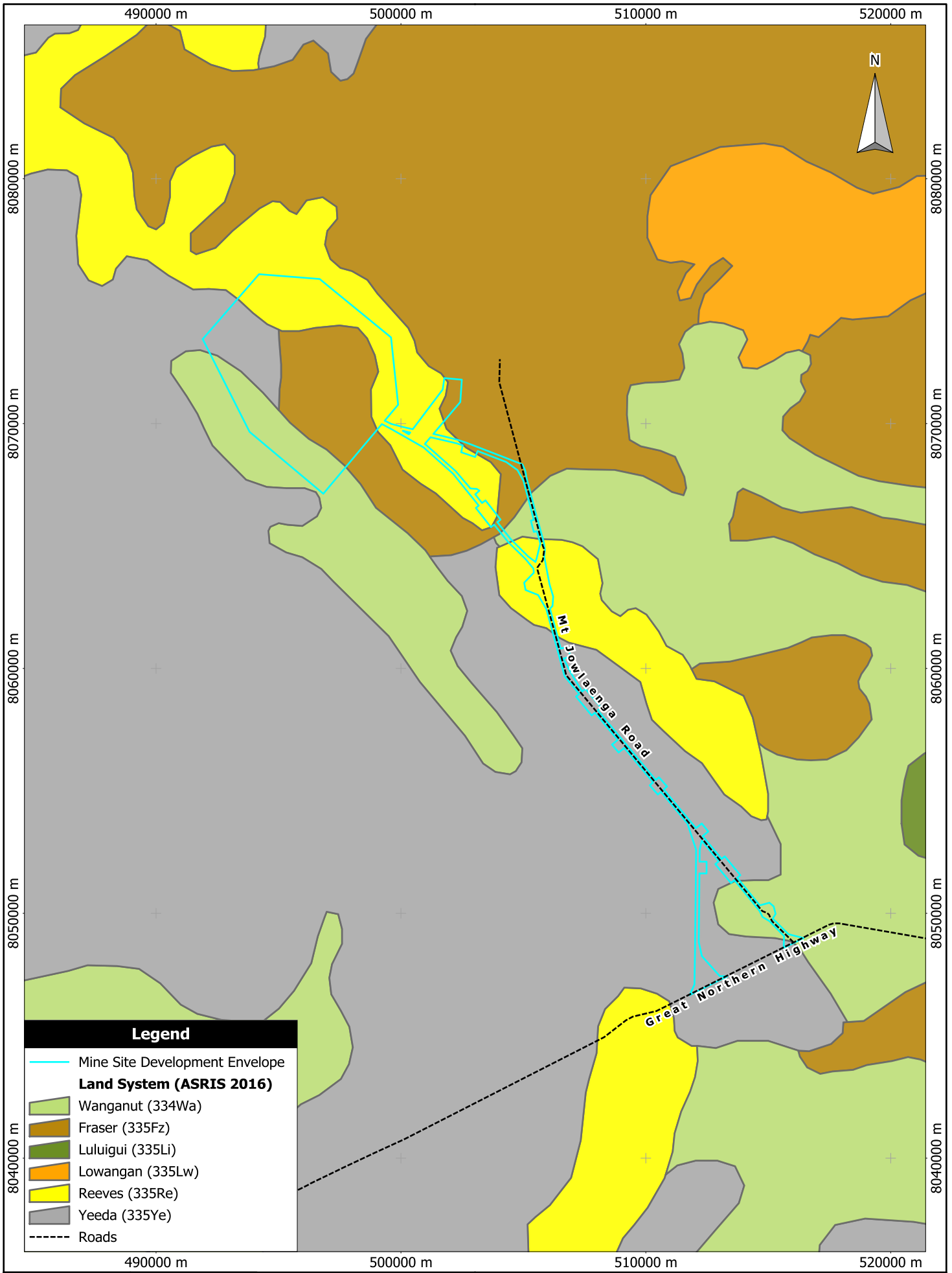
Nine land systems have been identified within the eastern Dampier Peninsula (Figure 19) (Payne and Schoknecht 2011; Australian Soil Resources Information System [ASRIS] 2016), four of which are located within the Mine Site Development Envelope:

- The Fraser land system (ASRIS mapping unit 335Fz) - characterised by sandplains and dunes with Pindan woodlands and spinifex/tussock grasslands.
- The Reeves land system (ASRIS mapping unit 335Re) - characterised by sandplains, scattered hills and minor plateaux.
- The Wanganut land system (ASRIS mapping unit 335Wa) - characterised by low-lying sandplains and dunefields with through-going drainage.
- The Yeeda land system (ASRIS mapping unit 335Ye) - characterised of sandplains and occasional dunes.

Summaries of geomorphology, surficial geology and vegetation characteristics of these land systems are presented in Table 18.

The sensitivity of land systems to damage or degradation has been considered. The Waganut and Yeeda land systems are subject to frequent fires, but generally not prone to degradation or erosion (Payne and Schoknecht 2011). The Reeves land system contains Pindan vegetation, which is subject to frequent fires. The sandplains and sand dunes are moderately susceptible to wind erosion after fire, but stabilise after rain (Payne and Schoknecht 2011). Similar to the Reeves land system, the Fraser land system is generally stable with low susceptibility to erosion except for sand dunes, which are moderately susceptible after fire but stabilise after rain.

The land systems are generally not prone to degradation or erosion by pastoral activities, provided grazing pressure is controlled and frequency of burning is maintained (Appendix 6). As livestock will be excluded from the project area, risk of degradation within undisturbed areas will be reduced.




Scale: 1:200000
Original Size: A4
Grid: MGA94(51)

0 4 km

Sheffield Resources Limited
Thunderbird Mineral Sand Project

**Figure 19**

**Land Systems of the Dampier Peninsula**

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MBS ENVIRONMENTAL

**Table 18: Characteristics of Major Regional Land Systems (ASRIS 2016)**

| Land System | Geomorphology | Geology | Vegetation | Land Management | Significant Values |
|---|---|---|---|---|---|
| Fraser | Sandplain and dunefields with through-going drainage, sandplain with irregular dunes, plains with thin sand cover and local outcrop, low-lying sandplain flanking drainage features. Relief less than 9 m. | Quaternary aeolian sand and minor outcrops of gently dipping Cretaceous sandstones. | Pindan woodlands and spinifex/tussock grasslands. | Generally stable with low susceptibility to erosion except for sand dunes, which are moderately susceptible after fire, but stabilise after rain. | No known scientific or evolutionary values associated with this land system. |
| Reeves | Formed by dissection of the Kimberley surface - scattered hills, dip slopes with thin sand cover and local outcrop and sandplain. Sparse branching drainage pattern. Relief to 60 m. | Subhorizontal or gently dipping sandstone, silty sandstones and silicified sandstones of Cretaceous age. Quaternary aeolian sand. | Pindan woodlands and spinifex/tussock grasslands. | Pindan vegetation subject to frequent fires. Sandplains sand dunes are moderately susceptible to wind erosion after fire, but stabilise after rain. | No known scientific or evolutionary values associated with this land system. |
| Waganut | Sandplain and dunefields with through-going drainage, sandplain with stable dunefields, scattered pans and depressions. Sparse to moderately dense branching drainage pattern. Relief less than 9 m. | Quaternary aeolian sands. | Pindan woodlands and spinifex/tussock grasslands. Dense wattle scrub. | Subject to frequent fires, but generally not prone to degradation or erosion. | No known scientific or evolutionary values associated with this land system. |
| Yeeda | Sandplains and dunefields with little organised drainage. | Quaternary aeolian sands. | Shrubby spinifex grasslands and Pindan woodlands. | Subject to frequent fires, but generally not prone to degradation or erosion. | No known scientific or evolutionary values associated with this land system. |

#### *4.2.4.2 Landforms*

Topography within the Mine Site Development Envelope is relatively subdued, with elevations ranging between 89 and 119 m RL AHD (Australian Height Datum), with an average elevation of approximately 110 m RL AHD (Figure 20). Rocky hills associated with the Reeves Land System occur as outcrops of shallow dipping Cretaceous sediments cover approximately 20% of the Mine Site Development Envelope. Plate 3 shows a typical low hilly landscape within the Reeves Land System.

**Plate 3: Typical Low Hill Landform of the Reeves Land System**

The deposit area experiences relatively even change in elevation along its length, from 130 m in the north to 95 m in the south. To the south of the deposit area, the Site Access Road crosses an area that is relatively low lying between two outcroppings, and then continues to undulate gently until reaching the Great Northern Highway.

495000 m 500000 m 505000 m 510000 m 515000 m

8080000 m 8075000 m 8070000 m 8065000 m 8060000 m 8055000 m 8050000 m

N

125 m
115 m
105 m
95 m
85 m
65 m
75 m
85 m
95 m
85 m
105 m

Mt Jowlaenga Road

Great Northern Highway

**Legend**

**Elevation (m)**

Heights

175
150
130
110
95
80
65
50
35

10 m Contours

Mine Site Area Outline

Mine Site Development Envelope

Roads

Scale: 1:100000
Original Size: A3
Grid: Australia MGA94 (51)

0 4 km

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Sands Project

**Figure 20**

**Topography of Mine Site Development Envelope**

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### Local Assessment Unit

The EPA's definition of landform is a distinctive, recognisable physical feature of the earth's surface having a characteristic shape produced by natural processes (EPA 2015g). For the purpose of defining the local assessment unit (LAU), the landforms in the area within and surrounding the Mine Site Development Envelope were derived through the use of contour line data and development of a GIS digital elevation model (full methodology provided in Appendix 7).

From an initial review of regional contours surrounding the Mine Site Development Envelope (up to 30 km away), it is clear that the most distinctive landforms in relation to the Mine Site Development Envelope are a north-west to south-east trending band of low hills parallel to the Mine Site Development Envelope associated with the Reeves Land System. This area was therefore selected as the focus of the LAU. The distinctive landform features within the band are Reeves Hill, Dampier Hill, Mt Jowlaenga and several unnamed smaller hills to the east and north of the Mine Site Development Envelope (Figure 21). None of these landforms will be impacted by the project.

The remainder of the LAU comprises flat or gently undulating sandplain areas within the Fraser, Wanganut and Yeeda Land Systems, which will be impacted by the project. The geomorphology of all three of these land systems is described as sandplains and dunefields. These land systems are widely represented within the Dampier Peninsula and in the broader Kimberley Region. The Reeves land system, associated with the distinctive hills located in the LAU, is relatively underrepresented in the Kimberley Region and predominantly occurs on the Dampier Peninsula. The area of these land systems contained in the Kimberley Region is as follows (Payne and Schoknecht 2011):

- Yeeda = 21,308 $km^2$.
- Wanganut = 6,973 $km^2$.
- Fraser = 728 $km^2$.
- Reeves = 428 $km^2$.

### Character and Condition of Landforms

The hills of the Reeves land system are characterised as being up to 60 m high, with flat or gently sloping rocky crests up to 800 m wide. They have marginal escarpments up to 70%, locally vertical, and basal scree slopes up to 45% (Payne and Schoknecht 2011). The hills in the LAU generally match this description however some have significantly higher elevations (e.g. Reeves Hill which extends up to 170 mAHD). A slope analysis was not considered to be required given that none of the hills identified in Figure 21 will be impacted by the project (See Section 10.1).

The sandplains and dunefields of the Yeeda, Wanganut and Fraser land systems within the LAU are considered to be representative of those that occur widely on the Dampier Peninsula.

### Integrity and Previous Disturbance

From a review of aerial photography and use of DMP's GeoVIEW database, none of the landforms present in the Mine Site Development Envelope appear to have been previously disturbed or fragmented. A small sandstone quarry is located near Dampier Hill, however it is unlikely this has significantly disturbed or fragmented any of the landforms present.

Disturbance to vegetation communities has occurred in the Mine Site Development Envelope from cattle grazing and construction of roads. The nature of these disturbances are considered to have minimal, and only superficial, impacts to the integrity of landforms in that they are unlikely to affect a landform in a permanent or significant way.

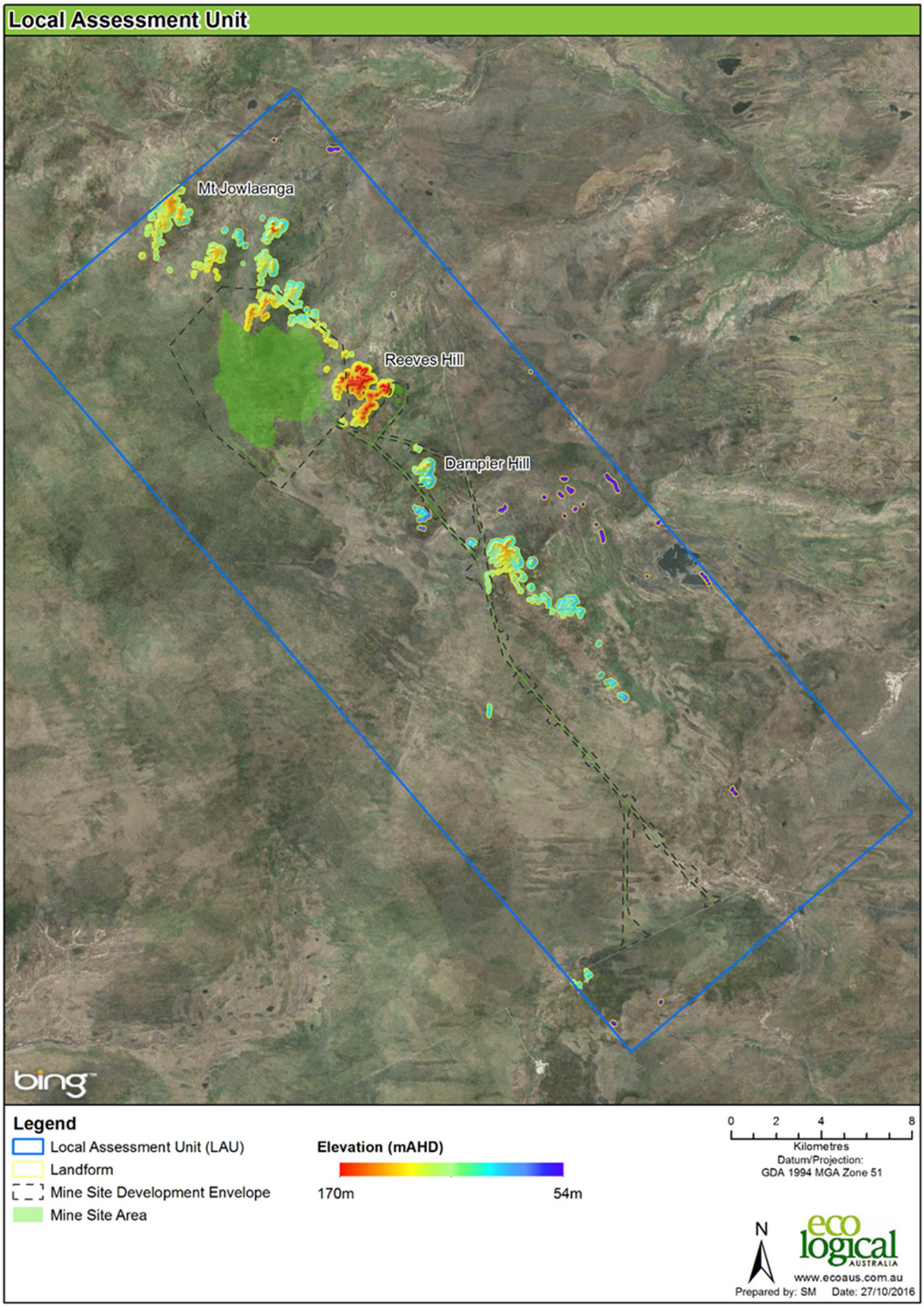


**Figure 21: Landform Local Assessment Unit**

**Ecological Functions**

Ecological features of the Mine Site Development Envelope do not appear to be restricted to any one land system.

**Scientific or Evolutionary Values**

There are no known scientific or evolutionary values associated with the land systems in the Mine Site Development Envelope (Table 18).

Landforms with significant scientific or evolutionary values in WA are identified as geoheritage sites or reserves. A State register of all geoheritage sites and reserves (currently 150 sites and 8 reserves) is managed by the Executive Director of the Geological Survey of Western Australia (GSWA) to assist in managing, preserving and protecting exceptional geological features. Geoheritage focuses on the diversity of minerals, rocks, fossils, and features that indicate the origin and/or alteration of minerals, rocks and fossils. It also includes landforms and other geomorphological features that illustrate the effects of present and past effects of climate and earth forces (McBriar 1995 as cited in Brocx and Semeniuk 2007).

Currently there are no registered geoheritage sites or reserves on the Dampier Peninsula. The closest geoheritage site to the Mine Site Development Envelope is 100 km to the southeast at Gantheaume Point near Broome where dinosaur footprints and other Cretaceous fossils have been recorded along the coast. It is not considered likely that the hills, sandplains or dunefields of the LAU would be considered to be geoheritage sites given they are not unique or restricted to this area and are represented more broadly on the Dampier Peninsula.

#### *4.2.4.3 Regional Soils*

The four main soil types (Bettenay *et al*. 1967) within the Land Systems of the region described in Table 18 are:

- Red earthy sands with associated hummocks of siliceous sands.
- Red earthy sands associated with soils on the plains, with dunes and hummocks of red sands. Some soils in lower sites often have a heavy surface layer of ferruginous gravel.
- Neutral red earths and sandy neutral red soils on plains with minor sandstone residuals overlain by extensive rocky outcrops.
- Neutral red earths and red earthy sands within sand plains with irregular dunes/active drainage systems.

#### *4.2.4.4 Local Soils*

A baseline assessment of the Mine Site Development Envelope was undertaken through field test pit excavation and laboratory analysis of selected samples (Appendix 6). The assessment examined the soil physical and chemical properties and their suitability for use as cover materials for rehabilitation.

Soils in the Mine Site Development Envelope are dominated by red sands (Pindan) of aeolian origin, which are widespread throughout the Dampier Peninsula. Soil profiles are typically deep (greater than 1 m), although relatively shallow profiles were recorded at several locations where Cretaceous sandstone sedimentary rocks or silcrete hardpan were present within 1 m of the natural soil surface. Minor soil types included deep yellow sand and shallow bleached sand over clay or loam, usually associated with drainage lines or depressions. As such, four soil types were identified within the Mine Site Development Envelope (Table 19):

- Shallow red Pindan sands over sandstone.
- Deep red sandy Pindan soils.
- Yellow sandy soils.
- Bleached Sands Over Clay/Loam.

**Table 19: Assessed Soil Type Characteristics**

| Soil Type | Characteristics |
|---|---|
| Shallow red Pindan Sands over sandstone | • Uniform fine to medium red sandy soil<br>• Similar to Deep red Pindan sands, but with limited B-horizon due to sandstone less than 1 m from the surface.<br>• Abundant leaf litter.<br>• Absence of gravels (surface and subsoil).<br>• Uniform characteristic red colour, no visible distinction between A and B horizons. |
| Deep red Pindan Sands | • Uniform fine to medium red sandy soil<br>• Abundant leaf litter.<br>• Absence of gravels (surface and subsoil).<br>• Uniform characteristic red colour, no visible distinction between A- and B- horizons.<br>• At least 1 m deep uniform fine to medium sand B-horizon.<br>• Deeper subsoil may be more yellowish or grey. |
| Yellow Sands | • Yellow coloured B-horizon and pale surface A-horizon.<br>• Absence of gravels (surface and subsoil).<br>• Limited in extent – restricted to topographical lows. |
| Bleached Sands Over Clay/Loam | • Shallow distinctively coloured bleached grey loamy sand over a compact grey clay or loam.<br>• Associated with shallow depressions or drainage lines - expected to be prone to seasonal waterlogging.<br>• Abundant termite mounding. |

All four soil types displayed uniform physical and chemical properties throughout the depth of their sandy profiles. Laboratory analysis indicated that:

- Soils are non-saline with low sodicity apart from one saline soil collected from a depression with restricted drainage.
- Soils have low cation exchange capacity values, with calcium being the dominant exchangeable cation.
- Soils have low concentrations of organic matter, major plant nutrients, and some minor nutrients.
- Soils have very low concentrations of environmentally significant metals and metalloids.
- Soils exhibit no evidence of uranium enrichment despite the presence of elevated uranium concentrations in ore and mineralised waste materials.
- pH was variable, however the majority (70%) were circum-neutral or slightly alkaline.

Low nutrient availability, coupled with an environment of strong leaching associated with free-draining sandy soils and moderate to high rainfall means that nutrient cycling is critical for sustaining healthy vegetation communities. Woody debris, leaf litter and termite mounds are important repositories of nutrients and organic matter. Frequent fires (Section 4.2.11) and soil biological activity, especially by termites, are essential for efficient nutrient recycling in this environment.

#### *4.2.4.5 Acid Sulfate Soils*

The Mine Site Development Envelope is characterised in the ASRIS Acid Sulfate Soil (ASS) mapping as having 'Extremely Low' probability (low confidence) of occurrence within 2 m of the natural soil surface.

Geochemical assessment of mine waste samples for the Mine Site Development Envelope indicate that the majority of waste is Non Acid Forming. Two of the deepest samples assessed were classified as Potentially Acid Forming, and may be reached in the final years of proposed mining. Further detail is provided in Section 8.4.2.

## 4.2.5 Hydrogeology

Several baseline hydrogeology studies were undertaken for the Mine Site Development Envelope (Pennington Scott 2014; Rockwater 2016) (Appendix 8).

### *4.2.5.1 Setting*

The water table on the Dampier Peninsula is deep inland and becomes progressively shallower on the coastal plain where discharge occurs at coastal springs in the mud flats around Broome. The Baskerville anticline divides groundwater flows, with water flowing northward north of the anticline and south to southwest in areas south of the anticline. The Mine Site Development Envelope is on the southern limb of the anticline where the hydraulic gradient is very low ($1.2 \times 10^{-3}$) and flattens towards the coast (Laws 1991).

### *4.2.5.2 Broome Sandstone Aquifer*

The Broome Sandstone Aquifer is hosted in the Broome Sandstone and the saturated parts of the overlying Emeriau Sandstone and Mowanjum Sand, which are generally in hydraulic continuity. It is a major unconfined to semi-confined aquifer that supplies groundwater to the Broome townsite, rural subdivisions, horticultural areas and pastoral properties. The Jarlemai Siltstone underlies the Broome Sandstone Aquifer and acts as a major aquiclude between it and the Alexander Formation (part of the Wallal Aquifer) below.

#### Regional Groundwater Levels and Flow

Groundwater levels in the Broome Sandstone Aquifer range from about 75 m AHD near the centre of the Dampier Peninsula to about 0–1 m AHD at the coast (Figure 22). In the northern and eastern parts of the study area, there are regions with sparse groundwater monitoring data and data are most concentrated in the Broome townsite region. The contours (Figure 22) imply that regional groundwater flow is towards the coast under an average hydraulic gradient of 0.00085 (0.85 m per km).

Variations in groundwater levels in monitoring bores for the Broome townsite, although within close proximity to production bores, appear to closely correspond to variations in rainfall. Groundwater levels vary by about 3 m in response to inter-decadal variations in rainfall. This is evident when comparing the cumulative rainfall variation with groundwater levels. The groundwater level trends closely match the trends in cumulative-deviation-from-mean annual rainfall, with an apparent lag of two to three years as observed in other studies (CSIRO 2009; Rockwater 2013, 2014).

#### Groundwater Levels within the Mine Site Development Envelope

The water table elevation over the mineral deposit area ranges from about 62 m AHD in the south to about 75 m AHD at its northern edge, with groundwater in the Broome Sandstone Aquifer flowing to the south. The hydraulic gradient is steep across the deposit (0.0016; or 1.6 m per km) and decreases to the south (0.0007; or 0.7 m per km) where the upper Broome Sandstone is the main component. Interpreted groundwater level contours are shown in Figure 23. Groundwater levels trends in selected monitoring bores in the mine area appear to closely match the trends in cumulative-deviation-from-mean annual rainfall. The depth to groundwater is in excess of 20 m over most of the area.

#### Hydraulic Parameters

Test pumping for the HG-series of bores near the Broome town water supply indicates that hydraulic conductivity of the Broome Sandstone Aquifer ranges from 12–23 m/d, averaging 15 m/d (Rockwater 2016). Searle (2012) reports hydraulic conductivities ranging from 2–42 m/d (generally about 15 m/d) over the entire Dampier Peninsula. The Broome Sandstone Aquifer therefore has moderately high hydraulic conductivity, however significant variability occurs.

Results from test pumping of bores within the Mine Site Development Envelope generally agree with reported hydraulic conductivity data for the Broome Sandstone Aquifer sandstone and suggest that the HMS have a comparatively lower hydraulic conductivity value (around 1 m/d) whereas the Broome Sandstone Aquifer basal transitional unit has an intermediate hydraulic conductivity (around 5–10 m/d) (Appendix 8).

#### *4.2.5.3 Recharge*

The Broome Sandstone Aquifer is recharged mainly by the direct percolation of rainfall, which falls mostly during summer (Rockwater 2016). Coastal dunes north of Broome are a significant local source of groundwater recharge to the Broome Sandstone Aquifer, which is apparent from the groundwater flow pattern and chemistry (Laws 1991). Recharge rates of 4% to 5% of rainfall were estimated from chloride ratios and flow net interpretations (Laws 1987). This corresponds to groundwater recharge rates of 22 mm to 52 mm from an average annual rainfall of 780 mm/year.

Minor seasonal surface water ponding areas may occur locally in the overlying Pindan sand.

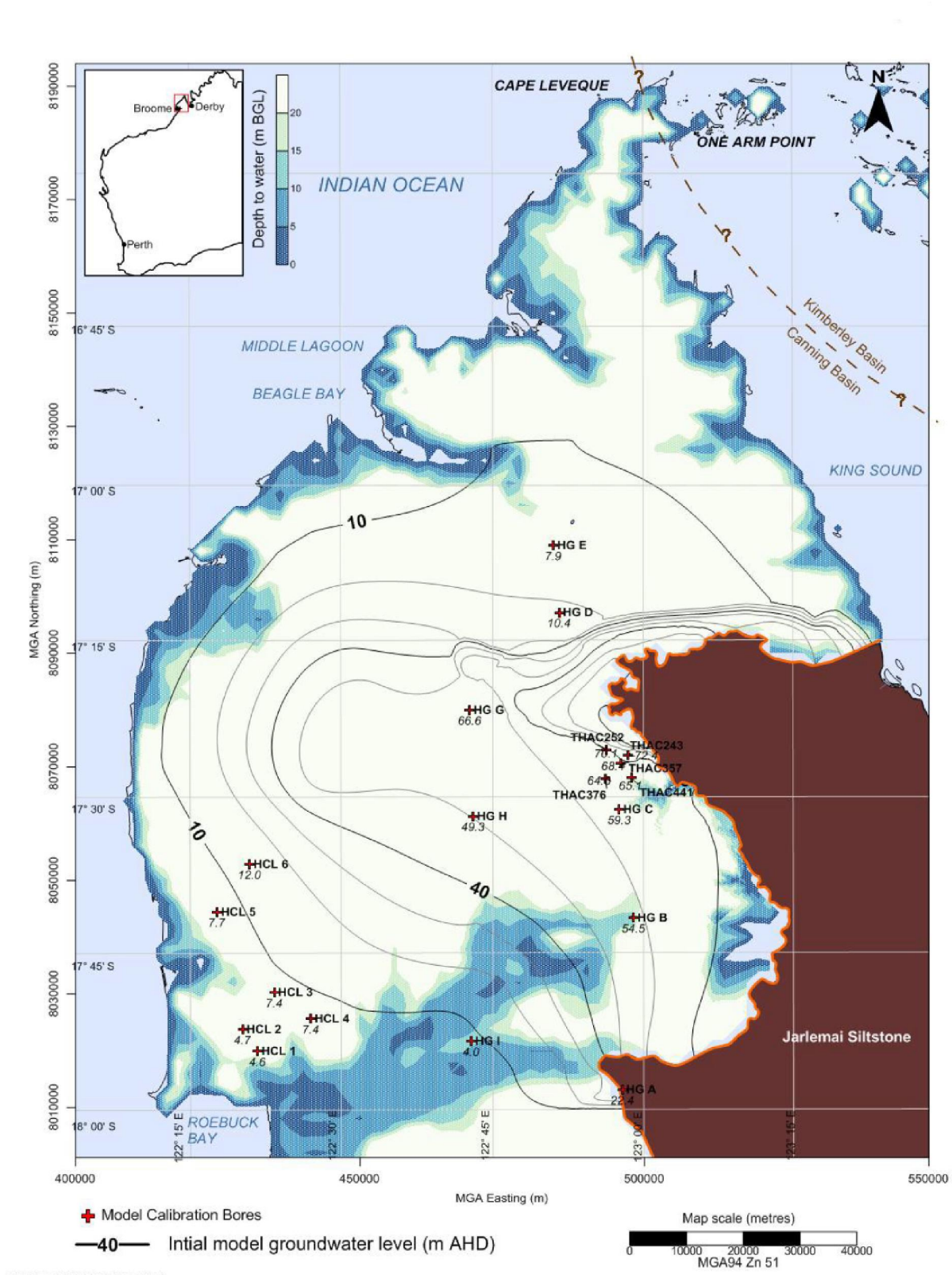


**Figure 22: Broome Sandstone Aquifer Groundwater Levels 1997 – 1998**

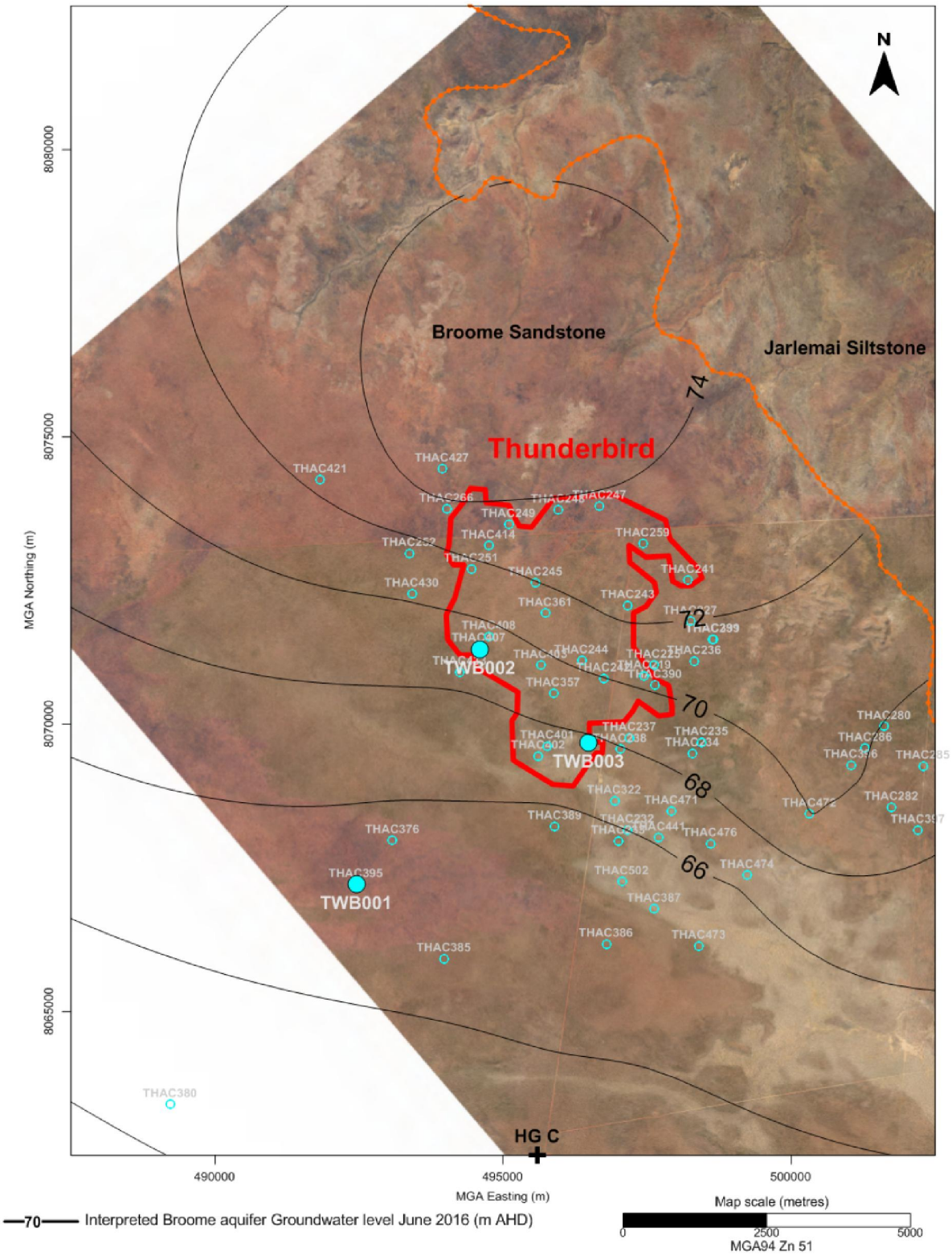


**Figure 23: Mine Site Development Envelope Interpreted Groundwater Levels (2016)**

#### *4.2.5.4 Groundwater Discharge*

Groundwater in the Broome Sandstone Aquifer is discharged to the coast in Gantheaume and Roebuck Bays and to wetlands along Dampier Creek and depressions in the Roebuck and Buckleys Plains (Rockwater 2016). Where there is an upward hydraulic head gradient and a shallow water table, there is a potential for groundwater to discharge upward to the surface environment near the coast. These areas are a significant distance from Mine Site Development Envelope.

No groundwater discharge areas have been identified in the Mine Site Development Envelope.

#### *4.2.5.5 Potential Groundwater Dependant Ecosystems*

Groundwater dependent ecosystems (GDEs) are ecosystems that require groundwater in order to maintain their species composition, ecological processes and ecosystem services (SKM 2007). Many ecosystems rely purely on rainfall for their water requirements, but GDEs rely on additional input from groundwater. Changes in the timing, quantity, quality or distribution of groundwater may result in negative impacts on growth and health of vegetation of a GDE and ultimately lead to plant deaths and changes in ecosystem composition (Eamus 2009, Murray *et al.* 2003).

Several areas of vegetation associated with ephemeral waterlogging were noted during early investigations of the project area as potential GDEs, including intermittent 'soaks' to the southeast and northeast of the Mine Site Development Envelope (Pennington Scott (2015) in Rockwater (2016)).

The intermittent, ephemeral 'nearby soak' occurs about 3 km southeast of the Thunderbird deposit (Plate 4). Rockwater (2016) (Appendix 8) indicates that this area is more likely to be related to seasonal surface water ponding, disconnected from the deeper (approximately 18 m below ground level) Broome Sandstone Aquifer.

An intermittent 'soak' occurs over the Jarlemai Siltstone to the northeast in the Fraser River North area. Connection to the deeper Broome Sandstone Aquifer is likely limited in this area due to low hydraulic connectivity with the low-permeability Jarlemai Siltstone (aquitard).

The ephemeral drainage channels in the Fraser River South valleys (Figure 24), about 10.5 km southeast of the mine area, are the only vegetation community which may be supported by groundwater, however, it is also likely that creek line vegetation are sustained by the upper alluvial sands lenses rather than any deeper aquifers. Depths to groundwater range from less than 5 m to more than 20 m (Appendix 8).

Further discussion on the assessment of these vegetation communities as potential GDEs is provided in Section 4.2.8.4.

**Plate 4: 'Soak' Approximately 3km to the South East of the Mine Site Development Envelope in June 2012**

#### *4.2.5.6 Groundwater Quality*

The salinity of groundwater in the Broome Sandstone Aquifer is low, but increases near the coastline and Roebuck Plains. Groundwater salinity values of 110 mg/L to 200 mg/L were obtained from the aquifer test boreholes (Pennington Scott 2014).
Groundwater in the Broome Sandstone Aquifer is predominantly of sodium – chloride type, with elevated levels of bicarbonate in some areas (Laws 1991). Silica levels are high, with reported values of 18 to 119 mg/L. Nitrate levels are frequently over 40 mg/L, probably as a result of nitrate fixation by native acacias and termite activity.

A saltwater interface occurs within the Broome Sandstone aquifer along the coastline. The Department of Water areal electromagnetic survey (AEM) indicates it is typically situated about 3 km inland, but can also extend much further inland beneath the Roebuck Plains. Areas of saltwater intrusion and tidal inundation tend to have elevated magnesium and sulphate (Laws 1991).

#### *4.2.5.7 Other Groundwater Users*

The main groundwater users for the Broome Sandstone Aquifer are the Water Corporation Broome town water supply borefield, Beagle Bay water supply borefield and isolated pastoral station bores. The closest users to the Mine Site Development Envelope are water bores located at the abandoned Mt Jowlaenga homestead, at the Bedanburu Aboriginal Community and the recently developed Yeeda Abbatoir (Figure 24).

The project is located in the Canning–Pender sub-area of the Canning-Kimberley Groundwater Area, which encompasses the majority of the Dampier Peninsula except for the area near Broome which classified as the Broome Groundwater Area (Figure 24). This area has 95.4% of its available groundwater resources (50 GL/yr) available for allocation. Licence entitlements within the sub-area total 2.3 GL/yr, with one major user (Kilto Station, 2 GL/yr) located about 40 km southwest of the project.

**Water Corporation Broome Borefield**

The Water Corporation operated Broome borefield is located about 12 km northeast of Broome. It was commissioned in the 1960s and initially consisted of three production bores extracting about 0.4 GL/yr. Borefield extraction has increased as the population of Broome has expanded and the borefield now consists of about 20 production bores extracting about 5 GL/yr. The Water Corporation's current groundwater licence allocation is 6.2 GL/yr. The borefield also contains six monitoring bores that are regularly monitored to provide aquifer response data for borefield operation. A Priority 1 Drinking Water Protection Zone extends north and east from the borefield in the Town Water Reserve (Figure 24).

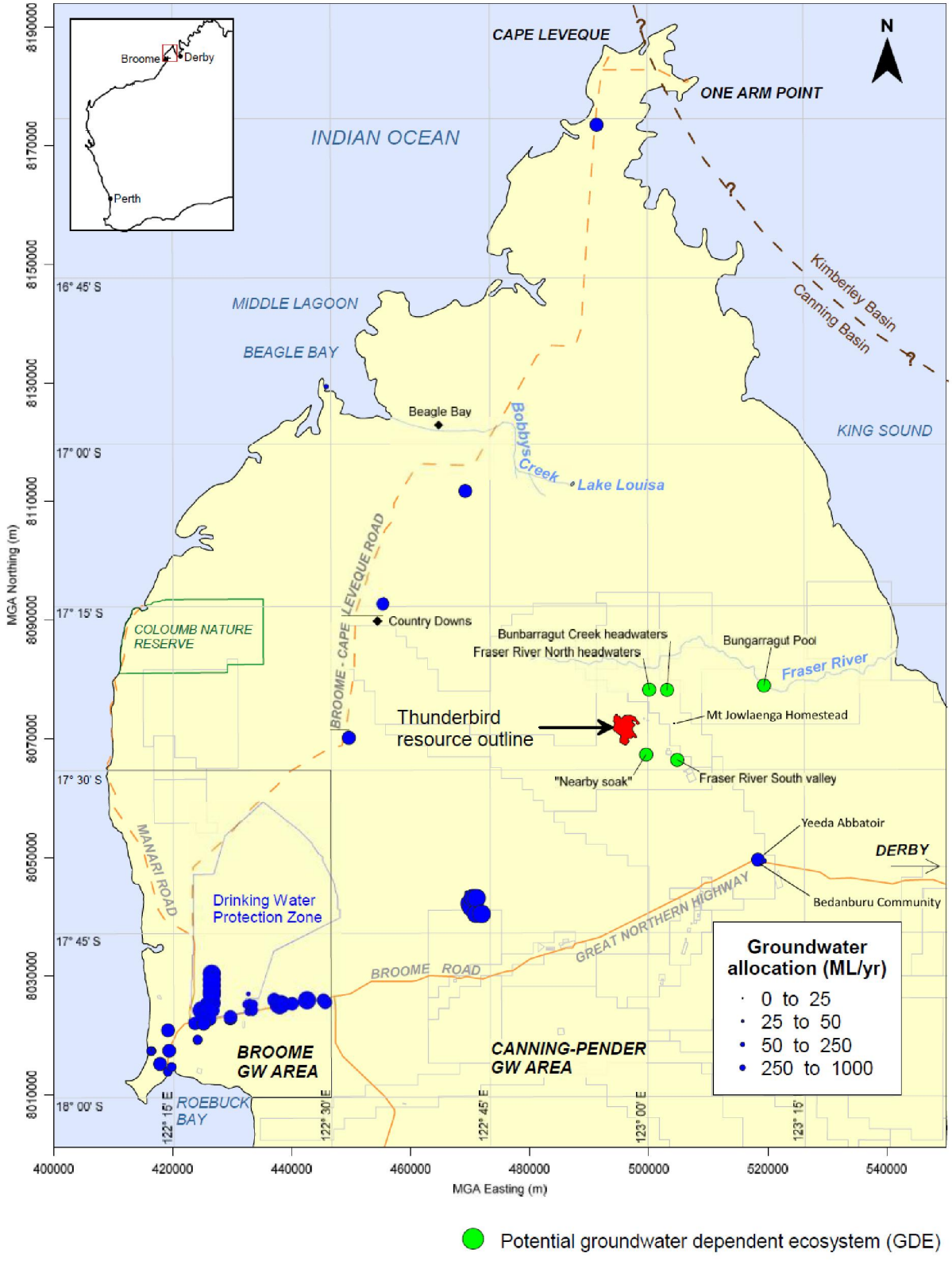


**Figure 24: Location of Other Groundwater Users**

## 4.2.6 Hydrology

A Baseline Surface Hydrology Study was undertaken for the Mine Site Development Envelope (MBS 2016a; Appendix 5). The Mine Site Development Envelope is located on sandy soils with low runoff generation and there are no defined watercourses within the main mine development areas. The nearest watercourse is the Fraser River South. Plate 5 shows the Fraser River South Channel near the Site Access Road crossing, approximately 10.5 km downstream from the mineral deposit area. There are no year-round surface water bodies within the Mine Development Envelope. The nearest ephemeral pools are approximately 25 km downstream on Fraser River South.

**Plate 5: Fraser River South Near Access Road Crossing**

### *4.2.6.1 Regional Catchments*

The Mine Site Development Envelope is within the National Catchments Boundaries Level 2 Cape Leveque Coast River Region of the Level 1 Tanami-Timor Sea Coast Division (Stein *et al*. 2011). The Cape Leveque Coast River Region consists of several river systems draining to the coast and extending approximately 100 km inland.

The Mine Site Development Envelope lies within the catchments of Fraser River, Fraser River South and Little Logue River (Figure 25). While the Fraser River enters King Sound from the west, Little Logue River discharges via Logue River to King Sound at Jarrananga Plain immediately adjacent to the Fitzroy River. The adjacent Fitzroy River Basin is a much larger river basin extending approximately 500 km inland and representing the primary surface water inflow to King Sound.

The majority of project infrastructure is to be located within the Fraser River South catchment (Figure 26). The only infrastructure proposed to be located in the Fraser River Catchment is the accommodation village, though some margins of the mineral deposit area extend approximately 300 m into that catchment. The Little Logue River catchment is crossed by the Site Access Road corridor and does not contain any other project infrastructure besides the Site Access Road and groundwater reinjection infrastructure.

### *4.2.6.2 Local Catchments*

Local catchments of the Mine Site Development Envelope are shown in Figure 26. The catchments of the plant, initial Tailings Storage Facility, and Village have small rocky hills at their heads, and are very small at less than 3 $km^2$. Defined watercourse channels do not extend far past the base of the hills, but wet ground conditions further down the catchment have been observed following intense rainfall events.

The southern portion of the mineral deposit area has a larger catchment of 108 $km^2$ extending 17 km upstream referred to as the Deposit South Catchment. There is no distinct watercourse channel associated with the

drainage line, but there is a broad valley approximately 450 m wide exhibiting variation in vegetation associated with surface water or shallow groundwater.

The Site Access Road crosses four larger catchments (referred to as R1 to R4) that correspond to each of the drainage lines in the southern portion of the Mine Site Development Envelope:

- R1 (Fraser River South) is by far the largest catchment, and includes the mineral deposit area in its upper reaches. A small defined watercourse channel is visible within a broader flood plain at the road crossing point (Plate 5).
- R2 and R3 are much smaller. R2 is very flat with no visible watercourse within the Mine Site Development Envelope while R3 is steeper and has a distinct water course channel.
- R4 includes both visible sandy drainage channels of the Little Logue River in the lower 2 km and broad valleys with no visible watercourse upstream of this.

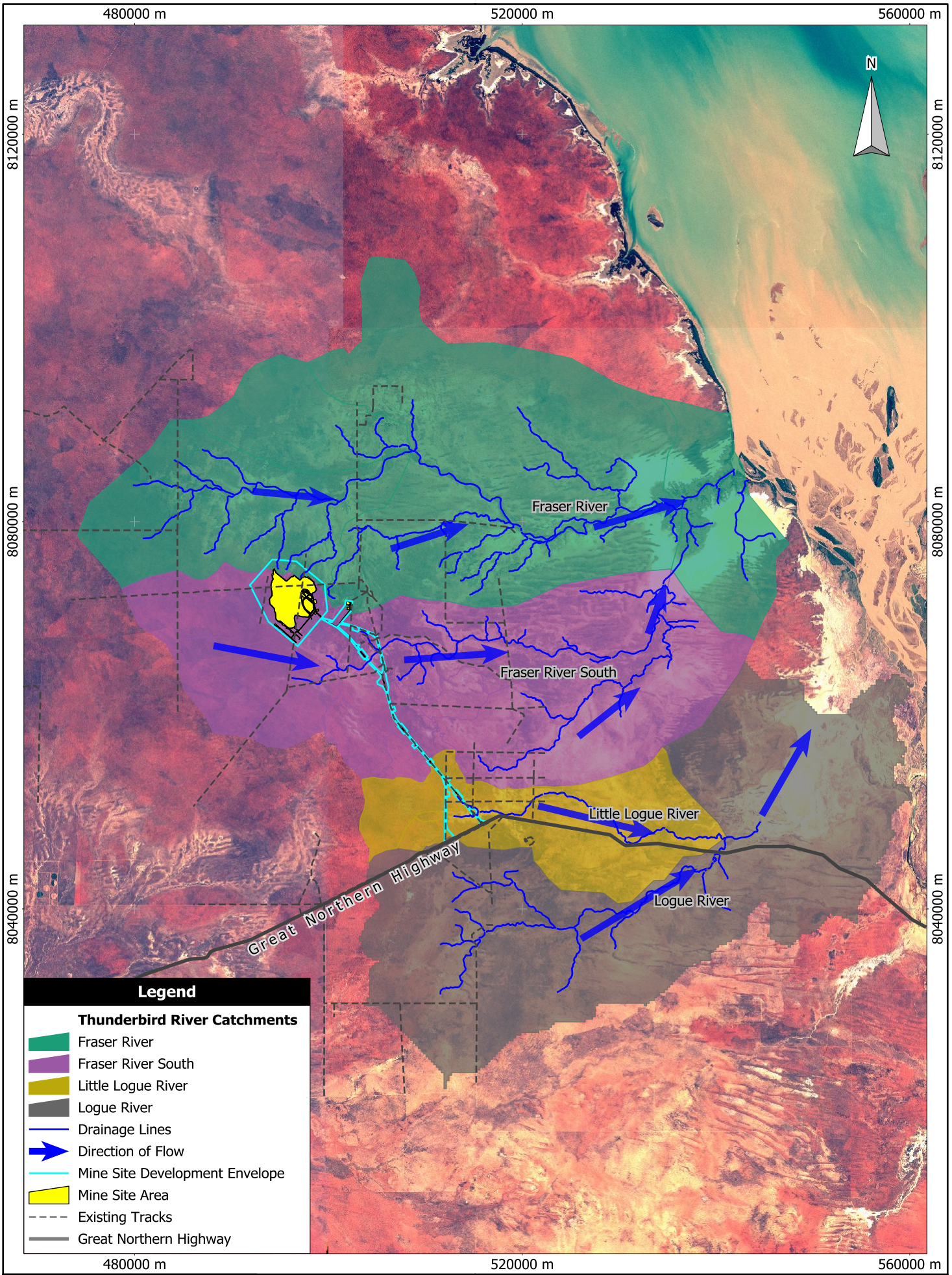


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Image: Copernicus Sentinel Data 2016
Grid: Australia MGA94 (51)
0 10 km

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Thunderbird Mineral Sands Project

**Figure 25**

**Regional Catchment Boundaries**

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info@mbsenvironmental.com.au
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MBS ENVIRONMENTAL

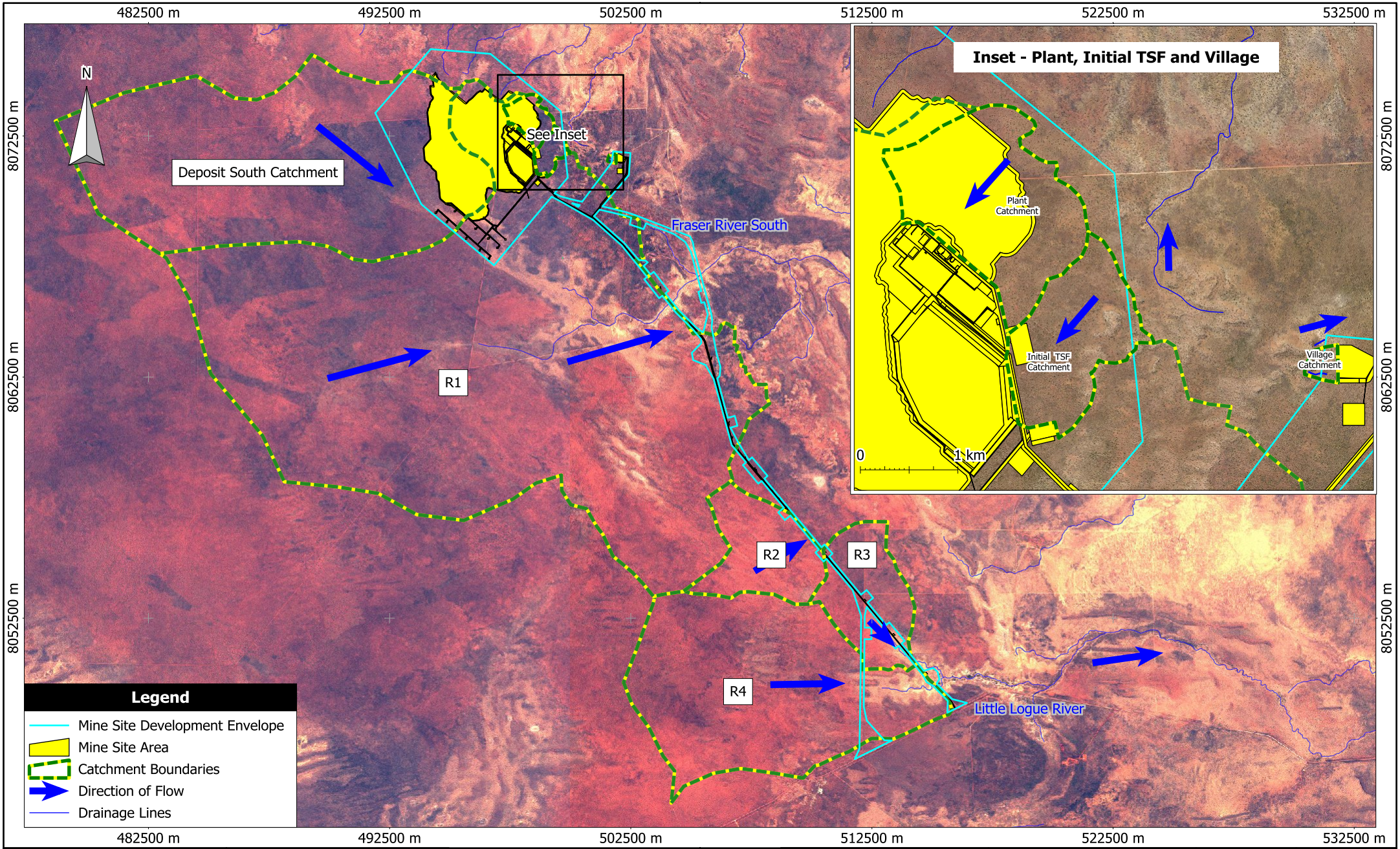


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Image: Copernicus Sentinel Data 2016
Grid: Australia MGA94 (51)
0 5 km

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**Figure 26**

**Mine Site Development Envelope Local Catchments**

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MBS ENVIRONMENTAL

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#### *4.2.6.3 Runoff Coefficients and Catchment Yield*

The sandy soils within the Mine Site Development Envelope are considered to have very high infiltration rates (high hydraulic conductivity of over 200 mm/hr) and therefore low runoff rates (Appendix 5). The small hills with sandstone outcrops will have less hydraulic conductivity, but make up a very small proportion of the catchment area. CSIRO modelling indicates that the average annual runoff coefficients for the Dampier Peninsula are the lowest (0.00 to 0.07) for the entire Northern Australia region (Petheram *et al*. 2009). Runoff coefficients over the remainder of the Fitzroy region, where better calibration data was available, varied from 0.08 to 0.25. The runoff coefficients discussed above are annual averages useful for estimating long term yield of the catchments. Substantially higher coefficients are possible for short periods during individual rainfall events, but runoff rates will still be low relative to other parts of northern Australia.

#### *4.2.6.4 Surface Water Quality*

No surface water quality monitoring data is available for the Mine Site Development Envelope or elsewhere on the Dampier Peninsula. Given the lack of industry and other sources of potential contamination, surface runoff is expected to be of good quality suitable for livestock and agricultural use.

All watercourses in the Mine Site Development Envelope remain dry during the dry season. Some salinity records are available from the Fitzroy River, where wet season river flows representing surface runoff quality are typically less than 250 mg/L and often less than 100 mg/L (Lindsay and Commander 2005).

The nearest water quality information available on the Statewide River Water Quality Assessment dataset (DoW 2016) is for the Isdell River (Site 804001), 266 km east of the Mine Site Development Envelope, which had a median total dissolved solids concentration of 106 mg/L and median pH of 7.97 for the period 2005 to 2007.

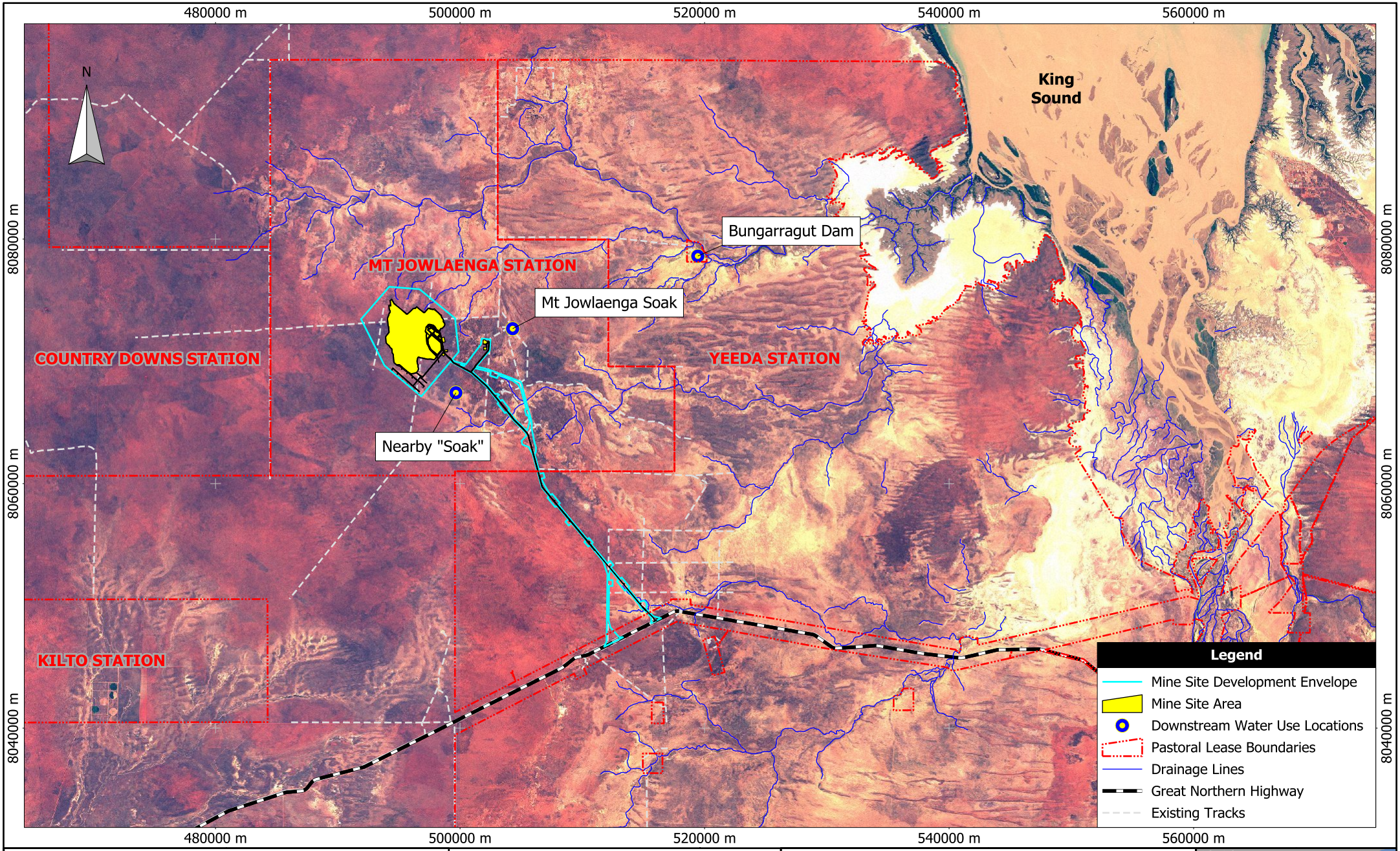
#### *4.2.6.5 Downstream Water Uses*

There are no declared surface water areas (*Rights in Water and Irrigation Act 1914*) in either the Mine Site Development Envelope or the Logue and Fraser River catchments. The nearest Public Drinking Water Source Area reserves are near Broome and Derby, well outside the project catchments. The same is true for the Fitzroy River and Tributaries Irrigation area. The Mine Site Development Envelope is located within the Canning-Kimberley Groundwater Area.

Local surface water use is primarily in support of environmental values and some pastoral use. Livestock and domestic water use is not required to be licensed meaning there is no quantitative data on current water use. Figure 27 shows the most significant water use locations identified downstream of the Mine Site Development Envelope. A minor surface expression of groundwater referred to as a 'soak' has been identified approximately 3 km southeast of the proposed mineral deposit area. As part of their agreement with local indigenous people, Sheffield currently maintains a 2 km buffer around this 'soak' which is left undisturbed. It is located off the main watercourses leading from the Mine Site and will not receive surface runoff from the Mine Site Development Envelope.

As shown in Figure 27, the Mine Site Development Envelope and locations 15 to 20 km downstream are within Mt Jowlaenga Pastoral Station. Downstream of this is Yeeda Station which extends to the edge of the King Sound mud flats. Livestock on both stations are likely to utilise surface water for drinking when available.

There is little formal extraction of surface water for pastoral use. There is a natural depression (ephemeral soak) approximately 2 km downstream of the proposed accommodation village which normally contains some water year round, although water levels are augmented from a bore at the nearby unoccupied Mt Jowlaenga Homestead towards the end of each dry season. Historically water was pumped using pipes from this area for station and livestock use; since the station was abandoned the cattle have direct access to the area. Bungarragut Dam is an off-stream water storage facility for livestock water, located near Bungarragut Creek 24 km from the Mine Site Development Envelope and not directly affected by runoff from the Mine Site Development Envelope.

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Original Size: A4
Image: Copernicus Sentinel Data 2016
Grid: Australia MGA94 (51)

0 10 km

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Thunderbird Mineral Sands Project

**Figure 27**

**Downstream Water Use Locations**

4 Cook St
West Perth WA 6005
Ph: (08) 9226 3166
Fax: (08) 9226 3177
info@mbsenvironmental.com.au
www.mbsenvironmental.com.au
MBS ENVIRONMENTAL

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## 4.2.7 Mine Waste Characterisation

A description of the general mine design describing stripping and removal of topsoil, removal of any overburden present and progressive filling of the mine void and replacement of topsoil was provided in Section 3.3.2. A geochemical assessment was made on 57 selected samples from 16 drill holes (Appendix 19) which were considered representative of the materials comprising overburden and mine waste over the life of the project. The samples comprised overburden (13), mineralised waste above the orebody (15), Thunderbird Formation orebody sands (12), mineralised waste below the orebody (14) and basement/marker bed samples (3). The latter two materials are below the limit of excavation, but may be disturbed to some degree by mining operations.

A description of the ore processing and types of waste generate from processing of the mineral sands ore was provided in Section 3.4. A geochemical assessment was made on four samples of process residues (MSP Rejects, combined CUP MSP tails, WCP tails and gypsum acid neutralisation residue - refer Table 8) as well as two samples of oversize material from MUP screening (>2 mm and > 5 mm size fractions was made and provided in (Appendix 20).

A summary of the results of the assessments for overburden, mine waste and residues is provided below.

### *4.2.7.1 Overburden*

Most overburden material from the project consists of highly leached and weathered Pindan sands located above the watertable with properties matching that of subsoils taken in the soil and landform survey within the Mine Site Development Envelope (Appendix 6). This material was found to be:

- Circum-neutral to slightly acidic in pH with a range of pH values from 5.5 to 6.7 with very low levels of soluble salts and essentially no soluble alkalinity.
- All 13 samples of overburden assessed had essentially no sulfur or sulfides capable of oxidation to generate acidic conditions (maximum 0.01% S). The samples were deemed to be 'barren', having no acid forming nor acid neutralising capacity.
- Overburden samples did not contain any metals or metalloids considered enriched versus global crustal averages, and concentrations of all environmentally significant metals and metalloids tested were low to very low indicating a very low risk to the environment.
- Concentrations of water soluble elements of environmental significance in mine waste samples were generally very low to non-detectable and below ANZECC livestock drinking water guidelines for all samples indicating there is an extremely low risk of mine waste leachates from circum-neutral mine waters adversely impacting the surrounding environment by rainfall or groundwater interaction.
- Exposure of overburden to conditions of dilute acid leaching confirmed negligible levels of calcium and magnesium carbonates were available for buffering capacity/acid neutralisation. Low levels of aluminium and iron were the primary elements solubilised, which is consistent with a natural presence of hydrated aluminium and iron oxides from weathering and groundwater interactions. Concentrations of all other environmentally significant metals and metalloids were very still very low in all samples under acidic conditions and below corresponding ANZECC livestock drinking water guidelines.
- Particle size analysis indicated all samples had approximately 10% clay content with clay and silt fractions (<20 µm) together combining for approximately 50% by weight of material however cation exchange capacity measurements indicated samples of overburden were non-sodic to marginally sodic with a correspondingly lower risk of dispersion.

Overburden material from the Mine Site Development Envelope is therefore considered extremely benign and highly leached sands from the Pindan formation which are not deemed particularly dispersive and are not considered to pose any risk due to handling to the surrounding environment.

#### *4.2.7.2 Mine Waste*

Geochemical assessment of 44 samples of mine waste from below the overburden layer indicated properties which were generally similar to the overlying overburden and key points are outlined as follows:

- Similar to the overburden, the vast majority of samples of mine waste contained very low concentrations of sulfur and acid neutralising capacity and were classified as non-acid forming and 'barren'. Natural pH values for all but two samples were circum-neutral to slightly acidic (pH 5.1 to 7.2) and very low in soluble salts and soluble alkalinity
- The two deepest samples assessed (SB006113 and SB012707) at or below 53.5 m below the natural water table (approximately 88.5 m below surface) were found to contain 0.22% and 0.96% sulfur respectively and were classified as potentially acid forming and indeed had pH values of 3.1 upon receipt indicating acid generation prior to assessment with elevated salinity resulting from acid sulfate formation. These samples were identified as basement material or mineralised waste below the orebody and are not intended for excavation and this depth of mining will not be encountered until at least 38 years into the project.
- Thorium was the most significantly enriched element associated with orebody samples and mineralised waste samples below the orebody. Thorium concentrations in these samples ranged from 110 to 160 mg/kg (global abundance index of three) versus a crustal average of 10 mg/kg. Thorium enrichment is associated with the naturally elevated concentrations of monazite present in the Thunderbird deposit. Both water and dilute acid leachate testing indicated these total concentrations will not be mobilised under any mining conditions.
- Minor enrichment in selenium in orebody and mineralised waste samples below the orebody was also noted (2.6 to 3.8 mg/kg) versus the average soil concentration of 0.2 mg/kg. Both water and dilute acid leachate testing indicated these total concentrations will not be mobilised under any expected mining conditions.
- Concentrations of all water soluble elements of environmental significance in mine waste samples at circum-neutral pH were very low to non-detectable and below ANZECC livestock drinking (the only current beneficial use of groundwater) water guidelines for all samples tested. Overall, results indicate there is an extremely low risk of mine waste leachates from circum-neutral waters adversely impacting the surrounding environment by rainfall or groundwater interaction.
- Exposure of mine waste samples to conditions of dilute acid leaching indicated low levels of aluminium and iron were the primary elements solubilised. As for overburden samples, the concentrations of all other environmentally significant metals and metalloids were very still very low in all samples under acidic conditions and below corresponding ANZECC livestock drinking water guidelines.
- Cation exchange capacity measurements of mine waste samples were moderately to highly sodic with orebody samples being highest in sodicity (ESP values of 10.9 to 26.8%) and at higher risk of dispersion than overburden material when also combined with the fine particle size of the material. Processing of the ore will use flocculants to control this tendency and other mine waste will be returned to the mine void and not placed on the surface.

Overall, results indicate that mine waste at depths less than 48.5 m below the natural water table (approximately 83.5 m below surface) will be non-acid forming and barren with essentially no capacity for acid generation or acid neutralisation similar to overburden material. Levels of soluble salts, metals and metalloids in any seepage from these materials will be extremely low, even under artificially generated mildly acidic conditions of tests. Between 48.5 m and 53.5 m below the natural water table some potentially acid forming material was encountered and although the potential for leaching of metals under acid conditions was restricted to iron and aluminium, further investigation and management prior to any disturbance will be required. As this material will not be encountered until very late in the life of mine (>35 years) these studies and management plans can be conducted well in advance of any potential disturbance including from mine dewatering.

#### *4.2.7.3 Residues*

Geochemical assessment of the four residue samples and two oversize ore streams from metallurgical trials for the project indicated the following:

- All samples were classified as non-acid forming and 'barren', having essentially no acid forming or acid neutralising capacity.
- Natural pH values for samples other than 'gypsum' were marginally acidic (5.7 to 6.5 pH) as for general mine waste, overburden and Pindan sands with essentially no soluble alkalinity. The gypsum residue sample had low levels of residual alkalinity (29 mg/L as $CaCO_3$) and a slightly higher pH (7.6).
- With the exception of the gypsum residue, all samples all had extremely low levels of soluble salts. Gypsum residue was a source of slightly soluble calcium sulfate but comprises a very minor waste stream (0.025% of materials processed).
- As expected for a mineral sand deposit, thorium and uranium were the most commonly enriched elements and considered associated with naturally elevated concentrations of the mineral monazite present in the Thunderbird deposit. Despite enrichment versus global crustal averages, both water and dilute acid leachate testing indicated thorium and uranium will not be mobilised under any expected mining conditions, indicating these naturally enriched elements are present in a highly insoluble and environmentally unavailable form.
- Lead (357 mg/kg) and selenium (4 mg/kg) were also marginally enriched in MSP rejects as a result of mineral separation from the source ore material. Again water and dilute acid leaching indicated this natural enrichment was in an environmentally unavailable form.
- As for overburden and mine waste samples, concentrations of all environmentally significant metals and metalloids in water or dilute acid conditions from residue samples were very low to non-detectable apart from minor concentrations of aluminium under acidic conditions (but still below ANZECC livestock drinking water guidelines in the 1:20 extract). Gypsum had very low concentrations of some metals but remained below ANZECC guidelines and is a very minor waste stream by volume for the project (0.025%). Overall, results indicate there is an extremely low risk of process residue leachates adversely impacting the surrounding environment by rainfall/groundwater/process water interaction.
- Analysis of the gypsum residue indicated the presence of significant unreacted calcium and magnesium carbonates (calcite and dolomite total 51%) in the lime being used for neutralisation of the sulfuric acid leach of the zircon concentrate. The soluble components of the gypsum and underlying calcite and dolomite are expected to gradually dissolve following co-disposal of this minor waste stream in the mine void with other waste by interaction with rainfall/groundwater.
- As for general mine waste, there is a tendency for dispersion/creation of turbid water of fine material in the residues streams other than gypsum. This will be controlled during processing by use of flocculants and placement of the slurry waste into the mine void.

Overall, results indicate that project tailings will be barren with essentially no capacity for acid generation or acid neutralisation. Predicted concentrations of soluble salts, metals and metalloids in any seepage are expected to be extremely low. Low overall (in relation to waste volumes) levels of calcium sulfate and calcium carbonate will gradually be mobilised by leaching from the 'gypsum' residue, however seepage water quality will mostly reflect process groundwater quality as drawn from local aquifers. Although various residues are geochemically enriched in thorium, uranium, lead and selenium, these elements were not found to be mobile, even under artificially applied acidic conditions. All process waste streams are thus considered environmentally benign for the project.

## 4.2.8 Flora and Vegetation

Five flora and vegetation surveys have been undertaken for the Mine Site Development Envelope and surrounds between 2012 and 2016 (
Table 20). All are provided in Appendix 9.

**Table 20: Flora and Vegetation Surveys**

| Survey | Timing | Methodology |
|---|---|---|
| Thunderbird Dampier Peninsula Project Level 1 Flora and Fauna Assessment (Ecologia 2012a). | June 2012 | 17 quadrats as well as transects. |
| Thunderbird Project Level 2 Flora and Vegetation Assessment (Ecologia 2014b). | April 2013 | 71 quadrats, as well as opportunistic collections, releves, and traverses |
| Thunderbird Haul Road and Accommodation Camp Flora and Fauna Assessment (Ecologia 2015). | May 2015 | 16 quadrats as well as transects. |
| Flora and Vegetation of the Thunderbird Mineral Sands Project Area (Mattiske 2016a). | June 2016 | 155 quadrats, as well as opportunistic collections, releves, and traverses. |
| Potential Groundwater Dependent Ecosystems in the Thunderbird Mineral Sands Project Area (Mattiske 2016b) | Nov 2016 | Aerial imagery assessment and field tree health ( |

The flora and vegetation surveys were undertaken in accordance with Guidance Statement 51 (EPA 2004c) and the later surveys, also in accordance with the EPA and Department of Parks and Wildlife (DPaW) Technical Guide (2015a). In 2016, Mattiske Consulting conducted a technical peer review of the Ecologia botanical reports (Ecologia 2012a, 2014b and 2015). Following the technical peer review, an additional survey was conducted in June 2016 to address issues and methodological gaps within earlier surveys (Mattiske 2016a). MBS Environmental conducted a gap analysis between items identified within the peer review and the Mattiske (2016a) report to ensure the key issues had been addressed. A copy of the gap analysis is contained in Appendix 9.

An additional survey was conducted in November 2016 to specifically address potential GDE vegetation within the project area.

A total of 255 vascular plant taxa, representative of 129 genera and 44 families were recorded in the survey area (the survey area was larger than the Mine Site Development Envelope) (Mattiske 2016a). The majority of taxa recorded were representative of the Poaceae (46 taxa), Fabaceae (45 taxa), Malvaceae (18 taxa), Cyperaceae (14 taxa), Myrtaceae (14 taxa), Amaranthaceae (12 taxa) and Convolvulaceae (10 taxa) families.

### *4.2.8.1 Conservation Significant Flora*

No Threatened flora pursuant to Schedule 1 of the *Wildlife Conservation Act 1950* or *Environment Protection and Biodiversity Conservation Act 1999* were recorded within the Mine Site Development Envelope by any survey (Ecologia 2012a, 2014b, 2015, Mattiske 2016a).

Two Priority taxa were recorded within the flora survey area by Mattiske (2016a) and Ecologia (2012a, 2014b, 2015a), *Triodia caelestialis* (P3) and *Pterocaulon intermedium* (P3) (Mattiske 2016a) (Table 21 and Figure 28). *Triodia caelestialis* was recorded widely, with *Pterocaulon intermedium* (P3) recorded infrequently. Neither taxon was associated with any specific landforms, soil types or vegetation communities.

Three other Priority flora taxa were recorded infrequently in the survey area by Ecologia (2012a, 2014b, 2015) (Table 21 and Figure 28). These taxa were *Fuirena incrassata* (P3), *Fuirena nudiflora* (P1), and *Tephrosia valleculata* (P3). *Eriachne* sp. *Dampier Peninsula* (K.F. Kenneally 5946) was previously reported as a Priority 3 (Ecologia 2014b), however, is no longer listed as a priority taxon (DPaW 2016b). None of these three taxa were recorded during the Mattiske (2016a) survey of the Mine Site Development Envelope.

Poor rainfall conditions prior to the 2016 survey may have precluded *Fuirena incrassata* (P3), an annual species, from being recorded. However, according to DPaW (2016b), the distribution of *Fuirena nudiflora* (P1) is restricted to the Victoria Bonaparte and Central Range IBRA regions, near to the borders of the Northern Territory and South Australia. Its presence in the Mine Site Development Envelope survey area would represent a range extension of approximately 1,000 km to the west (DPaW 2016b). No specialist taxonomic identification was undertaken in 2014 to confirm its presence within the Mine Site Development Envelope survey area.

*Tephrosia valleculata* (P3) is known to occur within approximately 200 km of the Thunderbird Project Area (DPaW 2016b) on rock outcrops and soil around sandstone (DPaW 2016b). Due to poor seasonal conditions or possible opportunistic occurrence of the taxon, it was not recorded during the 2016 survey. It cannot be certain that the taxon was present as no specialist taxonomic identification was undertaken in 2014. Notwithstanding, given its preference for rocky outcrops (DPaW 2016b), it is unlikely to be impacted by Project development within the Mine Site Development Envelope (Mattiske 2016a).

**Table 21: Priority Flora Taxa Recorded Within Mine Site Development Envelope**

| Species | Conservation Listing | Within Development Envelope |
|---|---|---|
| *Pterocaulon intermedium* | P3 | Yes by Mattiske and Ecologia |
| *Triodia caelestialis* | P3 | Yes by Mattiske |
| *Tephrosia valleculata* | P3 | Yes by Ecologia |
| *Fuirena incrassata* | P3 | No |
| Fuirena nudiflora | P1 | No |

One taxon, *Aristida contorta,* had an approximately 300 km range extension from known records to either the east or southwest of the survey area (DPaW 2016b). This taxon is not considered to be of conservation significance as it is a common grass widely distributed throughout the state. Ecologia (2014b) reported 26 taxa that represented range extensions of more than 100 km from their then known range. All range extensions are likely to be associated with the low level of survey of the less accessible areas of the Dampier Peninsula (Mattiske 2016a).

Another species of interest is *Tephrosia* aff. *crocea*. This species was recorded across the survey area and not restricted to a unique landform, but predominantly collected on the red sandy soils containing Pindan vegetation on the flats. This species could not be fully identified due to only sterile specimens being collected. Should this species be observed in flower or fruit, specimens should be collected to permit an accurate identification.

#### *4.2.8.2 Vegetation Communities*

A total of 15 vegetation communities were defined and mapped, based on a statistical analysis of the combined data from Ecologia (2012a, 2014b and 2015) and Mattiske (2016a) (Figure 28).

Two of the pindan vegetation communities (low sparse eucalypt woodlands over *Acacia tumida* shrubland over *Triodia/Chrysopogon* grasslands), W6 and W8, accounted for approximately 86% of the surveyed area and were considered the most representative of the Mine Site Development Envelope (Mattiske 2016a).

The other main communities mapped were associated with the drainage channels (*Melaleuca viridiflora/Melaleuca alsophila* woodland) and rocky hills. Vegetation associated with the hills and drainage channels within the Mine Site Development Envelope were statistically different from the vegetation communities defined on the flats.

In broad terms, the vegetation of the Mine Site Development Envelope consists of vegetation with a sparse overstorey of *Eucalyptus/Corymbia* species – typically *Corymbia greeniana/Eucalyptus tectifica* – over a mid-storey of *Acacia* species, dominated by *Acacia tumida* var. tumida, and a ground cover of mixed grasses, with *Triodia caelestialis* (P3), *Triodia schinzii,* and *Chrysopogon species* (*C. pallidus, C. timorense*) being dominant. Other common species in the upper storey included *Brachychiton diversifolius Corymbia zygophylla, Erythrophleum chlorostachys*, and *Eucalyptus flavescens. Atalaya hemiglauca, Bauhinia cunninghamii,*

*Dolichandrone heterophylla, Ehretia saligna, Gardenia pyriformis* subsp. *keartlandii, Grevillea pyramidalis, Hakea arborescens,* and *Hakea macrocarpa* were common midstorey species. Some of these, such as *Bauhinia cunninghamii*, were often of sufficient size as to form a component of the upper storey. The vegetation is essentially Pindan and is common and widespread through the broader Kimberley region.

Overall, the vegetation communities mapped and species recorded in the wider area surrounding and including the Mine Site Development Envelope are consistent with the historical mapping of Beard (1976) and the more recent land systems mapping of Kimberley by Schoknecht and Payne (2010).

492000 m 497000 m 502000 m 507000 m 512000 m 517000 m

8078000 m 8073000 m 8068000 m 8063000 m 8058000 m 8053000 m 8048000 m

N

## Legend

- Mine Site Development Envelope
- Mine Site Area

**Priority Species**
(Mattiske 2016)

- Pterocaulon intermedium
- Triodia caelestialis

(Ecologia 2012, 2014, 2015)

- Fuirena incrassata
- Fuirena nudiflora
- Pterocaulon intermedium
- Tephrosia valleculata
- Triodia caelestialis

**Vegetation Complexes**
(Mattiske 2016)

- CL
- S1
- W1
- W2
- W3
- W4
- W5
- W6
- W7
- W8
- W8a
- W9
- W10
- W11
- W12
- W13
- W14

Scale: 1:100000
Original Size: A3
Air Photo Date: 2015
Grid: Australia MGA94 (51)
0 4 km

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**Figure 28**

**Vegetation Communities and Conservation Significant Flora within the Minesite Development Envelope Survey Area**

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#### *4.2.8.3 Threatened and Priority Ecological Communities*

No Threatened Ecological Communities (TECs), pursuant to Schedule 1 of the *WC Act* or *EPBC Act* occur within 50 km of the Mine Site Development Envelope.

No Priority Ecological Communities (PECs) as listed by DPaW (2016c) currently intersect the Mine Site Development Envelope. There are currently three Priority 1 and five Priority 3 PECs, as listed by DPaW (2016c, DPaW Reference 01-0816EC), which occur within 50 km of the Mine Site Development Envelope.

A 14.5 ha drainage channel community consisting of *Melaleuca viridiflora*/*Melaleuca alsophila* (statistically groups with community W1) within the Mine Site Development Envelope was claimed by Ecologia (2014b) to have some resemblance to the Lolly Wells Spring wetland complex Priority 3 PEC assemblage. The Lolly Wells Spring assemblage is groundwater dependant, as it is likely to exist in areas of permanent fresh water, such as areas with numerous low organic mound springs with moats. The assemblage supports groves of *Melaleuca cajuputi* and *Melaleuca viridiflora*, together with aquatic species such as *Nymphaea violacea*, *Nymphoides indica* and *Nymphoides beaglensis.*

The survey area does not contain areas of vegetation consistent with permanent water associated with springs (Mattiske 2016a). The claim that community W1 was similar to the Lolly Wells Spring assemblage was not supported by any statistical analysis or reasonable argument. Mattiske (2016a) reported that the potential PEC area is set in a low lying area amongst gentle slopes and receives internal surface water drainage (Appendix 9).

#### *4.2.8.4 Potential Groundwater Dependent Ecosystems*

Pennington Scott (2015) inferred potential GDEs within the project area and wider region as reported in Rockwater (2016). These are described in Section 4.2.5.5.

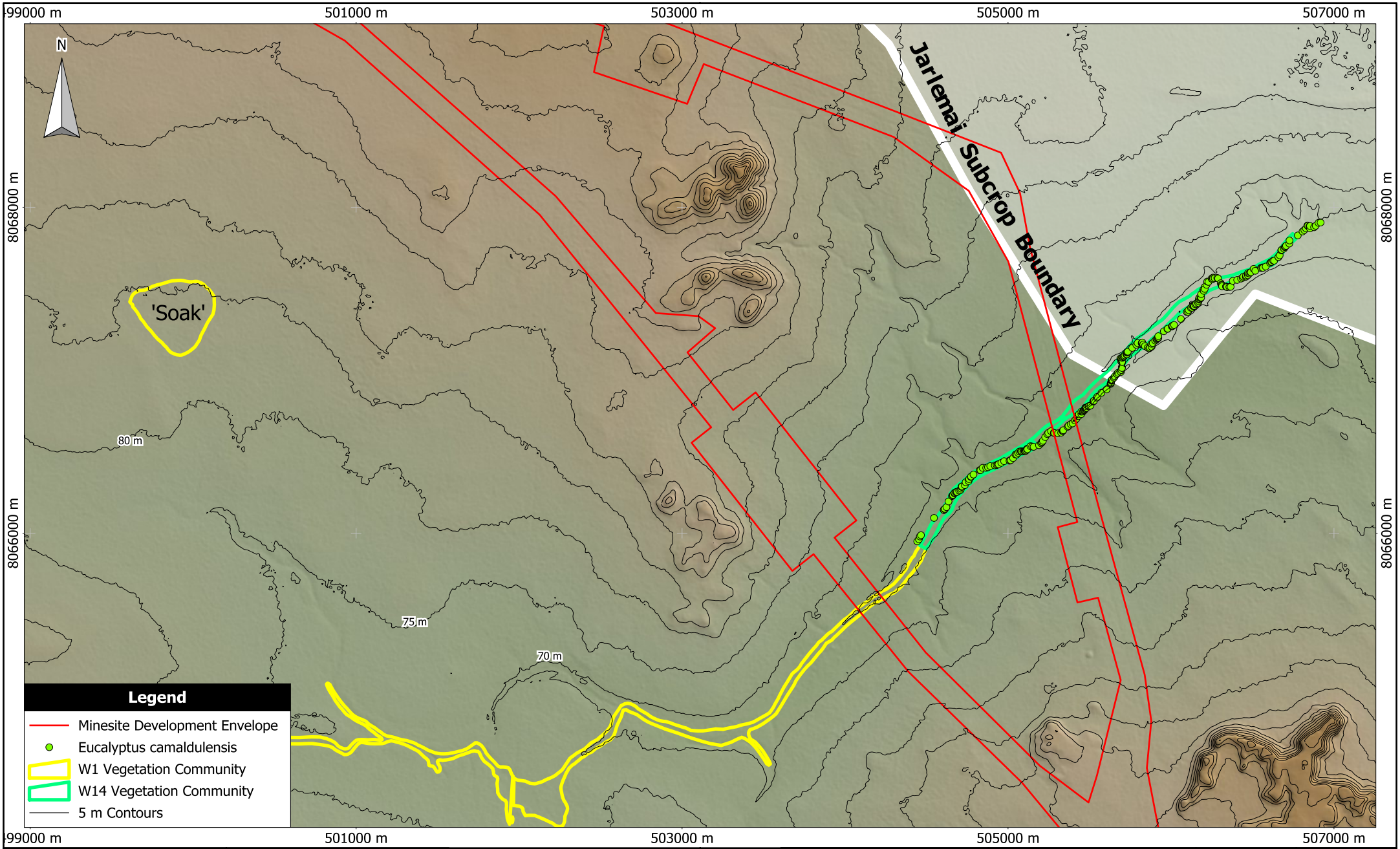
Ecologia (2014b) also indicated the potential presence of a PEC that may be groundwater dependent. This potential PEC correlates to the "nearby soak" as identified by Pennington Scott (2015). However, the potential PEC was not supported by Mattiske (2016a) (see Section 4.2.8.3). Additional observation of the soak at the end of the 2016 dry season showed the dominant species *Melaleuca alsophila* and *Melaleuca viridiflora* as severely water restricted and consequently in a very stressed condition, indicating that they do not have access to groundwater (Mattiske 2016b). Additionally, Rockwater 2016 suggested that the area is likely to be a perched aquifer not connected to the deeper Broome Sandstone Aquifer (Rockwater 2016).

Pennington Scott (2015) as reported in Rockwater (2016) also identified the ephemeral drainage line of the Fraser River South valleys as a potential GDE. The 3 km eastern section of the Fraser River South was classified as the W14 community (Figure 29), defined as "*Eucalyptus camaldulensis* mid open woodland over *Melaleuca viridiflora, Melaleuca alsophila* and *Bauhinia cunninghamii* mid sparse shrubland over *Ectrosia schultzii, Eriachne sulcata* and *Fimbristylis littoralis* low sparse grassland on grey to light brown sandy clay soils in drainage channels" (Mattiske 2016a). This community was the only location where *Eucalyptus camaldulensis* was recorded, however it occurs widely outside of the project area, across most of the Australian mainland (Chippendale 1988, DPaW 2016b). *Eucalyptus camaldulensis* is considered to be facultatively dependant on groundwater, in that its root structure allows it to access water at different depths in the soil profile depending on the availability of water in different seasons and conditions (Mattiske 2016b).

The November 2016 GDE survey (Mattiske 2016b; Appendix 9) assessed species for their groundwater dependence. The W14 community was the only community considered to groundwater dependent. *Eucalyptus camaldulensis* were sparsely scattered along the drainage channel from their first recorded occurrence, with trees becoming more frequent in number and more evenly distributed further east along the drainage channel and its banks (Figure 29). The distribution of *Eucalyptus camaldulensis* along Fraser River South conforms with the interpolated shallow depth to groundwater (as presented in Rockwater 2016; Appendix 8). However, the source of plant available groundwater is still undetermined as it is possible that vegetation is sustained by upper alluvial sands lenses, rather than any deeper aquifers.

#### *4.2.8.5 Introduced Flora*

A total of 11 introduced (exotic) plant taxa have been recorded within the wider survey area by Ecologia (2012, 2014b) and Mattiske (2016). These include **Cyanthillium cinereum, *Cynodon dactylon, *Digitaria ciliaris, *Echinochloa colona, *Sida acuta, *Stylosanthes hamata, *Stylosanthes scabra, *Tridax procumbens, *Cenchrus ciliaris, *Portulaca pilosa* and **Stylosanthes humilis. *Sida acuta*, a Declared Pest common to the Kimberley, was recorded by Ecologia (2014b). However this weed was recorded outside the Mine Site Development Envelope.




Scale: 1:30000
Original Size: A4
Satellite Image: Copernicus Sentinel Data 2016
Grid: Australia MGA94 (51)
0 800 m

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**Figure 29**

**Distribution of *Eucalyptus camaldulensis* along Fraser River South**

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W:\Sheffield Resources\PER\Drawings\PER Map.map 21/12/2016 F29 GDE location Layout

### 4.2.9 Terrestrial Fauna and Habitats

A total of four fauna assessments have been undertaken for the Mine Site Development Envelope and surrounding areas between 2012 and 2016 (Appendix 9), including:

- Level 1 Flora and Fauna Assessment (Ecologia 2012a).
- Level 2 Terrestrial and Subterranean Fauna Assessment (Ecologia 2014a).
- Haul Road and Accommodation Village Flora and Fauna Assessment (Ecologia 2015).
- Targeted Greater Bilby Assessment (Ecologia 2016).

These surveys covered an area of approximately 14,891 ha compared to the Mine Site Development Envelope of 5,875 ha. The surveys all included detailed literature reviews that informed the survey methodology and guided the studies. This included but was not limited to:

- A review of background information (including literature and database searches).
- An inventory of fauna species observed at the study area.
- An inventory and a map of species of biological and conservation significance recorded or likely to occur within the study area and surrounds;
- An inventory of fauna species occurring at the study area incorporating recent published and unpublished records.
- A map and detailed description of fauna habitats at the study area.
- An appraisal of the current knowledge base for the area, including a review of previous surveys conducted in the area relevant to the current study.
- A review of regional and biogeographical significance, including the conservation status of species recorded at the study area.

Each survey was undertaken in accordance with the following:

- Section 4a of the EP Act.
- EPA Position Statement No. 3, Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002).
- EPA Guidance Statement No. 56, Terrestrial Fauna Surveys for Environmental Impact Assessment (EPA 2004d).
- EPA and DEC Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA and DEC 2010).
- Survey Guidelines for Australia's Threatened Mammals (DSEWPC 2011).

In addition a technical peer review of the fauna surveys undertaken for the project was completed by Western Wildlife and is attached as Appendix 10. The peer review concluded that the surveys were generally consistent with relevant State and Commonwealth guidelines, and that vertebrate fauna surveys were completed at an appropriate level and to a generally high standard. The peer review did not recommend any further actions.

#### *4.2.9.1 Fauna Habitats*

Three broad fauna habitats were identified within the Mine Site Development Envelope (Ecologia 2012a, 2014a, 2015):

- Pindan Shrubland.
- Savannah Woodland.
- Sandstone Range and Footslopes.

The Pindan Shrubland habitat (Plate 6) is most extensive covering most of the central and southern region. The geology of this habitat is characterised by flat plains, with weak orange to red sandy-loam soils. The dominant tree species is scattered *Corymbia greeniana*, over a moderately open to dense shrub layer consisting primarily of *Acacia tumida* var *tumida*, *Acacia platycarpa* and *Grevillea refracta*. The ground vegetation layer consists of a mix of grasses including *Triodia caelestialis*, *Aristida holathera* var *holathera*, *Crysopogon* sp., *Eriachne obtusa* and *Sorghum plumosum*. Leaf litter density is highly variable as a result of fire history and patchy shrub density.

**Plate 6: Pindan Shrubland Habitat**

The Sandstone Range and Footslopes habitat is the second most widespread within the study area found mainly across the northern region of the study area, but also extends partly down into the east. The geology is primarily undulating hills, slopes and gullies of orange sandy soils with sandstone residuals ranging from moderately dense pebbles to dense rocks. Several rock outcrops are also present in the eastern region of the study area (Plate 7 and Plate 8). The vegetation in this habitat is characterised by sparse *Corymbia dendromerinx* over moderately dense *Acacia drepanocarpa* subsp. *latifolia* over a ground vegetation layer of dense *Triodia caelestialis* hummock grassland and *Sorghum plumosum* tussock grassland.

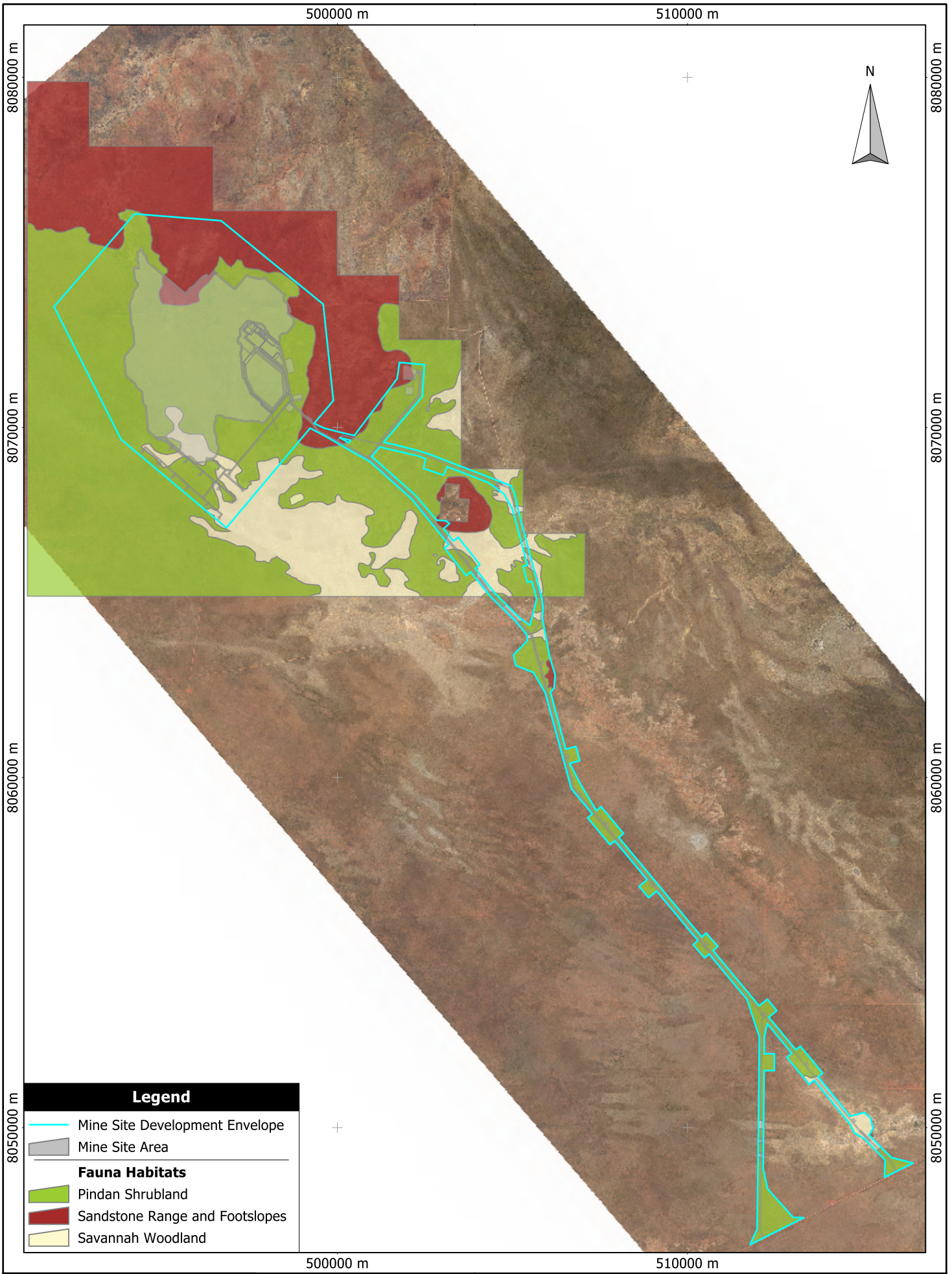
**Plate 7: Undulating Rocky Hills in the Sandstone Range and Footslopes Habitat**

**Plate 8: Rock Outcrop in the Sandstone Range and Footslopes Habitat**

The Savannah Woodland habitat is the least extensive, characterised by plains in the low-lying areas to the south and east of the study area, with firm brown-white sandy clay soils. The dominant vegetation consists of scattered *Eucalyptus tectifica* and *Brachychiton diversifolius*, with open to moderately dense shrubs of mainly *Acacia platycarpa*. There is a ground vegetation layer of *Eriachne obtusa* tussock grassland and *Triodia caelestialis* hummock grassland, and termite mounds are frequently present (Plate 9).

**Plate 9: Savannah Woodland Habitat**

A conceptual site layout over habitat type is shown in Figure 30.




Scale: 1:140000
Original Size: A4
Air Photo Date: 2015
Grid: Australia MGA94 (51)
0 4 km

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**Figure 30**

**Fauna Habitat of the Mine Site Development Envelope and Surrounding Area**

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#### *4.2.9.2 Fauna Species*

Fauna surveys recorded a total of 20 mammals, 118 birds, 44 reptiles and 8 amphibians occurring within the Mine Site Development Envelope or surrounding areas. Of note was an approximate 80 km range extension of *Lerista apoda* (Dampier Land Limbless Slider) from coastal areas of the west coast of the Dampier Peninsula (Ecologia 2014a).

A comprehensive table of all the fauna species with potential to occur in the project area has been supplied in Appendix 10 as per Environmental Scoping Document requirements.

#### *4.2.9.3 Conservation Significant Fauna*

Fauna surveys identified a number of conservation significant fauna that have potential to occur within the Mine Site Development Envelope and surrounding areas. Appendix 10 lists these species and describes the likelihood of them occurring within the Mine Site Development Envelope. The locations of conservation significant species observed during project specific surveys is shown in Figure 31.

Nine conservation significant fauna species were recorded within the wider survey area, however, only three were recorded within the Mine Site Development Envelope as shown in Table 21 and Figure 31. These were the Greater Bilby, the Short-tailed Mouse, and the Rainbow Bee-eater; impacts to these species have been assessed in this Public Environmental Review. Species recorded in the wider survey area, but not in the Mine Site Development Envelope are the Fork-tailed Swift, Common Greenshank, Eastern Yellow Wagtail, Grey Wagtail, Wood Sandpiper, and the Dampierland Peninsula Goanna. In addition, suitable habitat for the Gouldian Finch, Oriental Pratincole, Dampierland Plain Slider, and Dampierland Burrowing Snake is present in the Mine Site Development Envelope.

The Bush-stone Curlew (*Burhinus grallarius*) and Australian Bustard (*Ardeotis australis*) were observed and reported by Ecologia (2012a) as being of conservation significance; however are no longer listed species.

**Greater Bilby**

The Greater Bilby (*Macrotis lagotis*) is listed as Vulnerable under the *EPBC Act* and Schedule 3 under the *WC Act 1950*. This species is the only surviving member of the Peramelidae family. It is characterised by soft silky fur that is ash grey over most of the body, except the belly which is pure white to cream. The tail is distinctive, with the first 20% being the same colour as the upper-body, the central 40% being black and the distal 40% pure white. The forelimbs have three stoutly clawed toes (and two unclawed toes) that enable the animal to burrow effectively. The long snout is well equipped with sensory vibrissae.

Mature males attain double the body mass of mature females (males 800 – 2,500g, females 600 – 1,100g), have longer canines and a noticeably enlarged forehead (Pavey 2006).

Once common throughout the arid and semi-arid regions of Australia, European settlement brought about changes to the Greater Bilby's habitat and as a result during the 20th century its range reduced significantly with the species now being absent from its previous southern and central range. Populations are now restricted to within the Tanami Desert of the Northern Territory, the Great Sandy and Gibson Deserts, parts of the Pilbara and Kimberley regions of Western Australia and the clayey and stony soils of the Mitchell grasslands of southwest Queensland.

Bilbies are largely solitary, widely dispersed and found in low numbers. Contemporary habitat utilisation was investigated in the mid-1980s; Southgate (1990) reported that a broad range of environments were still occupied by the Greater Bilby and recognised three major vegetation types:

- Open tussock grasslands (grasses and forbs) growing on uplands and hills.
- Mulga woodlands/shrublands (pure mulga and mixed stands of mulga/witchetty bush) growing on ridges and rises.

- Hummock grasslands growing on sand plains and dunes, drainage systems, salt lake systems and other alluvial areas.

In the Kimberley region of Western Australia, Bilbies have been recorded in similar habitats, typically in areas with soft, sandy substrates, such as eolian sand dunes, swales and sandplains, which can be easily excavated to construct burrows and dig for food. It is likely that bilbies have a preference for habitats with easily excavated substrates. Consequently, it is possible that the bilbies would find man-made earth structures such as topsoil stockpiles to be ideal for burrowing.

The Greater Bilby usually spends the daytime in burrows up to 3 m deep, often built against termite mounds, spinifex hummocks or shrubs, coming out at night to forage. Over a dozen burrows may be used by the same individual within its home range (Southgate 1987).

The Greater Bilby has an opportunistic feeding strategy and forages on insects, bulbs and fruit, with a wide range of plant and animal taxa being consumed. This strategy enables it to survive in arid regions despite the unpredictable temporal and spatial availability of food resources (Gibson 2001). Populations are known to move long distances when habitat ranges become unsuitable.

The impact of predators such as foxes and cats has had the greatest impact on Greater Bilby populations and continues to be the most serious threat to their survival. The addition of artificial water points within arid zones has contributed to their decline, primarily as a result of these predators being able to roam over greater areas when provided with access to additional water points.

Fragmentation, degradation and destruction of Greater Bilby habitat is also increasing as a result of indirect competition for food with exotic species (such as rabbits), presence of feral and domestic herbivores, changed fire regimes, increased development, drought, and road mortality (DEHP 2016).

During the Targeted Bilby survey, Ecologia reported 754 records of Bilby activity, evidenced by diggings (670 records), scats (25 records), active and inactive borrows (17 and 42 records respectively). Bilby presence was also confirmed at two active burrows using motion sensor cameras.

Scats observed during the targeted Bilby survey underwent DNA analysis. The results indicated that at the time of the survey, at least nine individuals utilised the area in the vicinity of the Mine Site.

In the broader region surrounding the proposed Mine Site, the Greater Bilby has been reported within open woodland and open forest pindan vegetation types, with occurrence in pindan shrubland and other vegetation communities having a lower degree of preference.

During the Targeted Bilby survey at the Thunderbird Mineral Sand Project, evidence of Bilby occurrence was primarily recorded within the Pindan Shrubland vegetation type. More specifically, within the Mine Site Development Envelope, the Bilby was recorded predominantly within dense, mature *Acacia tumida var. tumida* woodland micro-habitat. This micro-habitat appears to be influenced by fire age, with older fire age (>2 years) than surrounding areas. The dense, mature *Acacia tumida var. tumida* woodland micro-habitat forms a dense canopy layer, but relatively open ground cover, which is in contrast to surrounding areas which appear to have been burnt more frequently and are characterised by dense ground vegetation.

**Short-tailed Mouse**

The Short-tailed Mouse (*Leggadina lakedownensis*) also known as the Lakeland Downs Short-tailed mouse is listed as Priority 4 by DPaW. It is a small elusive rodent that occupies a diverse range of habitats from monsoon tropical coasts to semi-arid climates, including spinifex and tussock grasslands, samphire and sedgelands, *Acacia* shrublands, tropical eucalypt and *Melaleuca* woodlands and stony ranges. Populations fluctuate greatly in response to rainfall and seasonal food availability (Ecologia 2015).

This species is nocturnal and spends its days in small burrows, coming out at night to feed. The Short-tailed Mouse is omnivorous, feeding on a variety of invertebrates and plant material. The amount of invertebrate material varies with the time of year, and is consumed more during the dry periods when plant water content is low (DPaW 2016d).

One individual was recorded by Ecologia within the Mine Site Development Envelope at a trap site consisting of tussock grasses.

**Rainbow Bee-eater**

The Rainbow Bee-eater (*Merops ornatus)* is listed as Schedule 5 under the *WC Act*.

It is scarce to common throughout much of Western Australia, except for the arid interior, preferring lightly wooded, preferably sandy country near water (Johnstone and Storr 1998).

In WA the Rainbow Bee-eater may occur as a resident, breeding visitor, post-nuptial nomad, passage migrant or winter visitor. It nests in burrows usually dug at slight angles on flat ground, sandy banks or cuttings. Eggs are laid from August to January and are most susceptible to predation during breeding as it spends significantly more time on the ground during this period (Ecologia 2015).

The Rainbow Bee-eater was recorded 57 times during the Mine Site Development Envelope surveys (2014 and 2015), 41 of which were within the proposal area (Ecologia 2014a and 2015). Two Rainbow Bee-eater nests were also recorded. Based on the transient nature of this species and the amount of habitat available in, and surrounding, the Mine Site Development Envelope, it is considered highly probable that this species will occur in the wider area.

**Fork-tailed Swift**

The Fork-tailed Swift (*Apus Pacificus)* is a marine species listed under the *EPBC Act* as migratory and Schedule 3 under the *WC Act.* It is a small, insectivorous species with a white throat and rump, and a deeply forked tail (Morcombe 2000) with distribution ranging from central Siberia and throughout Asia. The Fork-tailed Swift is a relatively common trans-equatorial migrant, arriving in WA between September and December each year. This species overwinters in Australia and south New Guinea, and breeds in north-east and mid-east Asia (Ecologia 2015).

Forked-tailed Swifts are nomadic in response to broad scale weather pattern changes and are attracted to thunderstorms. They rarely land, living almost exclusively in the air, feeding entirely on aerial insects, especially swarms of beetles, ants, termites, and native bees (Simpson and Day 2004; Ecologia 2015).

Two Fork-tailed Swifts were recorded flying over the Mine Site Development Envelope in 2013; subsequent surveys in 2014 and 2015 have not recorded this species again (Ecologia 2014a). The species is considered a transient visitor to the Mine Site Development Envelope (Ecologia 2014a, 2015) and may at times be found in varying numbers foraging in the air above the project area.

**Common Greenshank**

The Common Greenshank (*Tringa nebularia*) is listed as migratory species under the *EPBC Act*, Schedule 3 under the *WC Act* and has an Intentional Agreement under DPaW It is a large, rather heavily built wader, which is mainly grey-brown above and pale below. The head and neck are flecked with dark grey and the bill is dark to green-grey with a long slight upward curve (Birdlife 2016).

The species breeds in the Palaearctic regions and is widespread in Africa, coastal Asia, the Indian subcontinent, the Philippines, and southern New Guinea. They are common throughout Australia in the summer months as a non-breeding visitor to well-watered regions that can be observed in all months of the year and normally remain in the same locations with some local movement (Ecologia 2015).

Greenshanks eat insects, worms, molluscs, small fish and crustaceans both along the coast and inland in estuaries and mudflats, mangrove swamps, lagoons, billabongs, swamps, sewage farms, and flooded crops.

Two Common Greenshanks were observed foraging at a turkey's nest dam containing water not far from the Great Northern Highway within the savannah woodland habitat, but outside the Mine Site Development Envelope. The Common Greenshank has a medium likelihood of occurrence of being found within small drainage lines which occur in the savannah woodland habitats and low lying landscape features and grasslands should these areas flood during the wet season to create suitable foraging habitats (Ecologia 2015).

### Eastern Yellow Wagtail

The Eastern Yellow Wagtail (*Motacilla tschutschensis*) is listed as migratory under the *EPBC Act* and Schedule 3 under the *WC Act*. It is a small passerine in the wagtail family. It is a slender 15–16 cm long bird, with the characteristic long, constantly wagging tail of its genus. The breeding adult male is olive above and yellow below. In other plumages, the yellow may be diluted by white.

This species feeds on the ground or along the edge of very shallow waters where they pick small insects from the ground after a short chase or bounce in the air. The diet consists almost entirely of insects including midges and other flies, beetles, aphids, ants, and many others (Ecologia 2014a).

The Eastern Yellow Wagtail breeds in temperate Asia and has a foothold in North America in Alaska. Populations migrate to south Asia and Australia.

Two individuals of this species were recorded at Mt Jowlaenga homestead (outside the Mine Site Development Envelope) during the 2014 survey (Ecologia 2014a). The Eastern Yellow Wagtail has a medium likelihood of occurrence within small drainage lines which occur in the savannah woodland habitats, low lying landscape features, and grasslands, should these areas flood during the wet season to create suitable foraging habitats (Ecologia 2015).

### Grey Wagtail

The Grey Wagtail (*Motacilla cinerea*) is listed as migratory under the *EPBC Act* and Schedule 3 under the *WC Act*. It measures around 18 – 19 cm overall in length and looks somewhat similar to the Yellow Wagtail but has the yellow on its underside restricted to the throat and vent. The species is widely distributed, with several breeding populations in Europe and Asia, migrating to tropical regions in Asia and Africa, and occasionally Australia.

The species is almost always associated with running water during the breeding season. Outside the breeding season they can occupy areas around lakes, coasts, and other watery habitats. The diet of the Grey Wagtail consists of a variety of aquatic invertebrates including adult flies, mayflies, beetles, crustaceans, and molluscs (Johnstone and Storr 2004).

One individual was recorded at Mt Jowlaenga homestead (outside the Mine Site Development Envelope) during the 2014 survey (Ecologia 2014a). The Grey Wagtail has a medium likelihood of occurrence within small drainage lines which occur in the savannah woodland habitats and low lying landscape features and grasslands should these areas flood during the wet season to create suitable foraging habitats (Ecologia 2015).

### Wood Sandpiper

The Wood Sandpiper (*Tringa glareola*) is listed as migratory under the *EPBC Act* and Schedule 3 under the *WC Act*. It is a small slim, sharp-tailed wader which is dark grey-brown above, with light flecks or spots, and a white underbody. The legs are yellow-green, and the bill is black. Their flight is strong, with distinctive clipped wing beats (Simpson and Day 2004). The species can often be seen in small flocks or singly on inland shallow freshwater wetlands; however they prefer ponds and pools with emergent reeds and grass surrounded by tall plants. In Australia the species can typically be found around the muddy or grassy edges of freshwater wetlands where they feed mainly on aquatic insects and their larvae, as well as molluscs (Birdlife 2016).

The Wood Sandpiper is a trans-equatorial migratory species which breeds widely in subarctic wetlands from the Scottish Highlands across Europe and Asia. They migrate to Africa, southern Asia, particularly India and Australia to overwinter in the southern hemisphere. The species is a regular migrant to WA in small numbers, mostly between August and May (Johnstone and Storr 1998; Ecologia 2015).

Twelve individuals of this species were recorded at Mt Jowlaenga Homestead (outside the Mine Site Development Envelope) during the 2013 survey. The Wood Sandpiper has a medium likelihood of occurrence within small drainage lines which occur in the savannah woodland habitats, low lying landscape features, and grasslands, should these areas flood during the wet season to create suitable foraging habitats (Ecologia 2015).

**Dampier Peninsula Goanna**

The Dampier Peninsula Goanna (*Varanus sparnus*) is listed as Priority 1 by DPaW. Recent fauna surveys conducted by the West Australian Museum on the Dampier Peninsula identified unusual specimens of *Varanus brevicauda*. Subsequent morphological and molecular genetic appraisals identified a new species *Varanus sparnus*. *V. Sparnus* is slightly smaller than *V. brevicauda* in maximum body size, making it the smallest known Varanus. The new species is currently only known from four individuals collected from two locations about 90 km apart in the central portion of the Dampier Peninsula which represent the specimens used to describe the species (Doughty et al. 2014). The known distribution extends from coastal areas at Coulomb Point to central Dampier Peninsula. Specimens were collected from habitats broadly described as Pindan Shrubland with sandy soils associated with alluvial or sandstone deposits (Doughty *et al*. 2014). The species regularly excavates and lives in burrows (Doughty et. al. 2014) and thus any soil substrate on the Dampier Peninsular able to be excavated could currently be considered as potential suitable habitat.

One confirmed *V. sparnus* individual was recorded during the haul road survey outside the Mine Site Development Envelope. Eleven further individuals were also identified during this survey however they were not able to be identified definitively in the field as either *Varanus sparnus* or *Varanus brevicauda*.

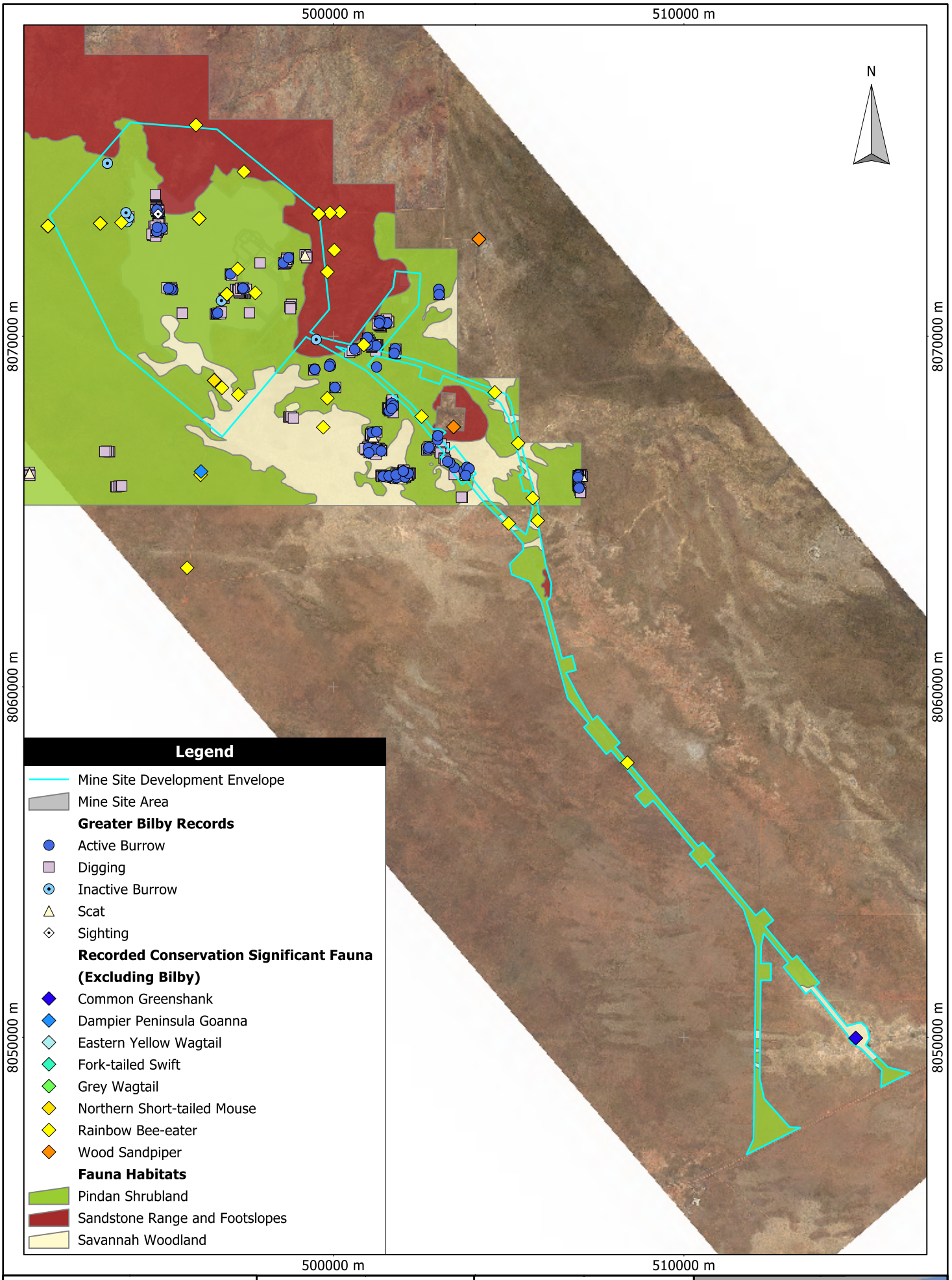
**Table 22: Conservation Significant Species with Potential to Occur in Mine Development Envelope and/or Surrounding Areas**

| Species | Conservation Significance | | | Habitat | Likelihood of Occurrences | Recorded during Surveys |
|---|---|---|---|---|---|---|
| | EPBC Act | WC Act | DPaW | | | |
| **Mammals** | | | | | | |
| *Dasycercus cristicauda*<br>Crest-tailed Mulgara | VU | S1 | | Sandy areas predominately on the top of sand dunes at the base of large Canegrass clumps or Nitre Bush hummocks. | Low - No suitable habitat. Not previously recorded within 100 km of the Study Area. | No |
| *Dasyurus hallucatus*<br>Northern Quoll | EN | S1 | EN | Rocky areas, also eucalypt forest and woodland. | Low - Some suitable habitat in rocky hills, but not previously recorded on Dampier Peninsula. | No |
| *Hipposideros stenotis*<br>Northern Leaf-nosed Bat | | | P2 | Sandstone caves. | Low - No potential roost caves. Not previously recorded on Dampier Peninsula | No |
| *Isoodon auratus auratus*<br>Golden Bandicoot | VU | S1 | | Rocky sandstone spinifex and vine thickets. | Low - Few records within 100 km, and limited suitable habitat. | No |
| *Leggadina lakedownensis*<br>Short-tailed Mouse | | | P4 | Spinifex and tussock grassland on cracking clays. Also acacia shrubland, samphire, woodlands, and stony ranges. | High - Suitable habitat occurs throughout the area. | Yes |
| *Macroderma gigas*<br>Ghost Bat | | | P4 | Caves, rock piles and abandoned mines. | Low - No potential roost caves. Not previously recorded on Dampier Peninsula | No |
| *Macrotis lagotis*<br>Bilby | VU | S1 | VU | Variety of habitats on soft soil, including spinifex grassland, acacia shrubland, open woodland, and cracking clays. | High - Suitable habitat occurs in the area | Yes |
| *Mormopterus loriae cobourgiana*<br>Mangrove Freetail Bat | | | P1 | Roost in mangrove stands, hunt in mangroves and forests. | Low - No suitable habitat within the study area. | No |
| *Rhinonicteris aurantius*<br>Golden Horseshoe Bat | VU | S1 | VU | Roost in caves with high humidity (95%) and temperature (32 °C). Forage along waterbodies with fringing vegetation. | Low - No potential roost caves. Not previously recorded on Dampier Peninsula | No |
| *Vespadelus douglasorum*<br>Yellow-lipped Cave Bat | | | P2 | Tropical woodlands of West Kimberley | Low - No potential roost caves. Not previously recorded on Dampier Peninsula | No |
| **Birds** | | | | | | |
| *Ardea ibis*<br>Cattle Egret | M | S3 | | Grassy habitats and wetlands, particularly damp pastures. | Low - Very little suitable habitat, but may occur during the wet season in open flooded depressions. | No |

| Species | Conservation Significance | | | Habitat | Likelihood of Occurrences | Recorded during Surveys |
|---|---|---|---|---|---|---|
| *Apus pacificus*<br>Fork-tailed Swift | M | S3 | | Almost entirely aerial, particularly associated with storm fronts. | High - A relatively common summer migrant in the northwest of Australia that will occasionally forage in the aerial space above the Study Area. | Yes<br>(Not within Mine Site Development Envelope) |
| *Ardea modesta*<br>Eastern Great Egret | M | S3 | | Floodwaters, rivers, shallows of wetlands, intertidal mud-flats. | Low - Very little suitable habitat, but may occur during the wet season in flooded depressions. | No |
| *Calidris acuminata*<br>Sharp-tailed Sandpiper | M | S3 | | Coasts and well-watered parts of the interior. Prefer grassy areas of non-tidal fresh or brackish wetlands, coastal marshes and tidal flats. | Medium - Suitable habitat occurs within the Study Area. | No |
| *Calidris melanotos*<br>Pectoral Sandpiper | M | S3 | | Uncommon in WA. Shallow, fresh waters, often with low grass or other herbage; swamp margins, flooded pastures, sewage ponds; occasionally tidal areas, saltmarshes. Breeds in Arctic. | Low - Suitable foraging habitat may occur within the Study Area. | No |
| *Calidris ruficollis*<br>Red-necked Stint | M | S3 | | Coastal areas: sheltered inlets, bays, lagoons and estuaries with intertidal mudflats, often near spits, islets and banks; also saline and freshwater inland wetlands. | Medium – Suitable foraging habitat may occur within the Study Area. | No |
| *Calidris subminuta*<br>Long-toed Stint | M | S3 | | Shallow water surrounded by dense low vegetation. | Medium - Suitable foraging habitat may occur within the Study Area. | No |
| *Charadrius veredus*<br>Oriental Plover | M | S3 | | Bare rolling country; bare claypans; open ground near inland swamps. | Medium - Suitable foraging habitat may occur within the Study Area. | No |
| *Chlidonias leucopterus*<br>White-winged Black Tern | M | S3 | | Mainly estuaries and sheltered seas in north, freshwater lakes and swamps in south. | Low - Suitable foraging habitat may occur within the Study Area | No |
| *Erythrotriorchis radiatus*<br>Red Goshawk | VU | S1 | VU | Open forests and woodlands, tropical savannas traversed by wooded rivers, rainforest margins, and gorge and escarpment country | Low - Suitable foraging habitat may occur within the Study Area. | No |
| *Erythrura gouldiae*<br>Gouldian Finch | EN | | P4 | Tropical savannas; breed in rocky hills with hollow-bearing eucalypts near water. | Medium - Suitable habitat occurs within the Study Area. However, known from very few locations on Dampier Peninsula. | No |
| *Falco hypoleucos*<br>Grey Falcon | | S1 | VU | Lightly wooded coastal and riverine plains. | Low - Little suitable habitat within the Study Area. | No |

| Species | Conservation Significance | | | Habitat | Likelihood of Occurrences | Recorded during Surveys |
|---|---|---|---|---|---|---|
| *Falco peregrinus*<br>Peregrine Falcon | | S4 | Other | Coastal cliffs, riverine gorges and wooded watercourses. | Low - Little suitable habitat within the Study Area. | No |
| *Gallinago megala*<br>Swinhoe's Snipe | M | S3 | | Shallow freshwater wetlands of various kinds including paddy fields and sewage farms, with bare mud or shallow water for feeding, with nearby vegetation cover | Low - Suitable foraging habitat may occur within the Study Area | No |
| *Glareola maldivarum*<br>Oriental Pratincole | M | S3 | | Plains, shallow wet and dry edges in open bare wetlands, tidal mudflats, beaches. | Medium - Suitable habitat exists within the study area, and there are records nearby. | No |
| *Haliaeetus leucogaster*<br>White-bellied Sea-Eagle | M | S3 | | Coastal and near coastal water bodies. | Low - Very little suitable habitat, but may occur during the wet season in open flooded depressions. | No |
| *Hirundo rustica*<br>Barn Swallow | M | S3 | | Open country, agricultural land, especially near water. | Low - Little suitable habitat within the Study Area. | No |
| *Merops ornatus*<br>Rainbow Bee-eater | | S5 | | Open country, most vegetation types, dunes, banks. | High - Some nesting habitat present along drainage lines. | Yes |
| *Motacilla cinerea*<br>Grey Wagtail | M | S3 | | Predominantly banks and rocky areas along flowing freshwater habitats | Medium - Suitable habitat exists within the study area. | Yes<br>(Not within Mine Site Development Envelope) |
| *Motacilla tschutschensis*<br>Eastern Yellow Wagtail | M | S3` | | Short grasslands (usually damp or watered), swamp margins, sewage ponds, bore overflows, and irrigated areas | Medium - Suitable habitat exists within the study area. | Yes<br>(Not within Mine Site Development Envelope) |
| *Neochmia ruficauda subclarescens*<br>Star Finch (western) | | | P4 | Vegetation around watercourses, particularly thick reed beds. | Low - Little suitable habitat within the Study Area. | No |
| *Numenius minutus*<br>Little Curlew | M | S3 | | Short dry grasslands, including artificial grassed areas. | Medium - Suitable habitat exists within the study area. | No |
| *Pandion cristatus*<br>Eastern Osprey | M | | | Mangroves, rivers, estuaries, inland seas, coastal islands. | Low - Little suitable habitat within the Study Area. | No |
| *Phaps histrionica*<br>Flock Bronzewing | | | P4 | Sparsely wooded plains near water. Nomadic visitor to areas of suitable habitat. | Low - Little suitable sparsely wooded habitat. | No |

| Species | Conservation Significance | | | Habitat | Likelihood of Occurrences | Recorded during Surveys |
|---|---|---|---|---|---|---|
| *Plegadis falcinellus*<br>Glossy Ibis | M | S3 | | Shallows and adjacent flats of freshwater lakes and swamps; river pool; flooded samphire; sewage ponds. Nest in freshwater/brackish wetlands with tall, dense stands of emergent vegetation and low trees or bushes. | Low - Very little suitable habitat, but may occur during the wet season in flooded depressions. | No |
| *Australian Painted Snipe*<br>Rostratula australis | EN, M | S1, S3 | EN | Shallow, vegetated wetlands | Low - Very little suitable habitat, but may occur during the wet season in flooded depressions. | No |
| *Tringa glareola*<br>Wood Sandpiper | M | S3 | | Mainly shallow, fresh waters, river pools, claypans; occasionally brackish swamps; rarely salt lakes, estuaries and intertidal mudflats. | High – Suitable habitat in the study area. | Yes<br>(Not within Mine Site Development Envelope) |
| *Tringa nebularia*<br>Common Greenshank | M | S3 | | Intertidal mudflats, estuaries, freshwater and saline wetlands along the coast and inland. | High – Suitable habitat in the study area. | Yes<br>(Not within Mine Site Development Envelope) |
| *Turnix castanota*<br>Chestnut-backed Button-quail | | | P4 | Savannah woodlands in sandstone and lateritic country. | Low - Little suitable habitat and no records nearby. | No |
| *Tyto novaehollandiae*<br>Masked Owl | | | P1 | Forest, woodland, caves, mature trees with hollows. | Low - Little suitable habitat within the Study Area. Not known from Dampier Peninsula. | No |
| **Reptiles** | | | | | | |
| *Crocodylus porosus*<br>Salt-water Crocodile | | S4 | Other | Tidal rivers, coastal floodplains and channels, billabongs and swamps up to 150 km inland. | Low - No suitable habitat within the Study Area. | No |
| *Lerista separanda*<br>Dampierland Plain Slider | | | P2 | Sandy areas. | Low - Little suitable habitat within the Study Area. | No |
| *Simoselaps minimus*<br>Dampier Burrowing Snake | | | P2 | Coastal dunes or sandy areas between dunes and adjacent acacia shrublands. | Low - No suitable habitat within the Study Area. | No |
| *Varanus sparnus*<br>Dampierland Peninsula Goanna | | | P1 | Sandy areas. | High – Suitable habitat within the Study Area | Yes<br>(Not within Mine Site Development Envelope) |




Scale: 1:140000
Original Size: A4
Air Photo Date: 2015
Grid: Australia MGA94 (51)
0 4 km

Sheffield Resources Limited
Thunderbird Mineral Sands Project

**Figure 31**

**Location of Conservation Significant Fauna Observations**

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MBS ENVIRONMENTAL

### Gouldian Finch

The Gouldian Finch (*Erythrura gouldiae*) is listed as Endangered under the *EPBC Act* and Priority 4 by DPaW. It is a small bird, with a bright green back, yellow belly and purple breast. The facial colour is usually black, and is found in about 75% of the birds. Red-faced forms make up about 25% of the population, and rare, yellow-faced birds occur from time to time. The yellow colour results from a lack of red pigment in the red-faced birds.

The Gouldian Finch occurred throughout tropical savannahs of northern Australia; however it is now restricted to isolated areas mostly within the Northern Territory and Kimberley region of Western Australia (Woinarski and Palmer 2006). Breeding habitat is characterised by rocky hills with hollow-bearing, smooth-barked gums that are close to small waterholes or springs that persist through the dry season. As is common in most grassfinch species, the Gouldian Finch is seldom found far from water, and needs to drink several times during the day.

This species forages on the ground, feeding predominantly on seeding grasses, particularly native *Sorghum* spp. (Pizzey and Knight 2003). Due to this very restricted diet, they are particularly vulnerable to seed shortages (O'Malley 2006). The decline in populations of the Gouldian Finch is representative of the general decline of granivorous birds occurring as a result of current land management practices.
This species was not recorded during surveys of the Mine Site Development Envelope; however the study area did contain suitable foraging and breeding habitat. Given the scarcity of surrounding records of the species there is only a medium likelihood of it occurring, and based on current knowledge will most likely be a transient visitor.

### Oriental Pratincole

The Oriental Pratincole (*Glareola maldivarum*) is listed as migratory under the *EPBC Act*, Schedule 3 under the *WC Act* and under the DPaW international Agreement. It is an atypical wader, with sandy brown above and paler brown below, with a white rump and black primaries and tail. The buffy throat is edged by a thin black band and the underwings are chestnut. The bill is short and black, with red at the base; legs are slim and dark.

The Oriental Pratincole is a non-breeding migrant to Australia, which breeds in Mongolia, Siberia, and China and further south to Sri Lanka, Thailand, and Vietnam. It overwinters in northern Australia (Johnstone and Storr 1998). Oriental Pratincoles occur on open plains, bare ground around swamps, and claypans.

An unusual feature of the pratincoles is that although classed as waders, they typically hunt their insect prey on the wing like swallows, although they can also feed on the ground. Birds may feed in the evening until nearly dark (Johnstone and Storr 1998).

The Oriental Pratincole was not recorded during the surveys of the Mine Site Development Envelope, however it has a medium likelihood of occurrence as suitable habitat exists in the Savannah Woodland habitat type, which contains small drainage lines and occurs in low lying landscape features and grasslands. Should these pastures flood during the wet season, then temporary suitable foraging habitat may exist for this species.

### Dampierland Plain Slider

The Dampierland Plain Slider (*Lerista separanda*) is listed as Priority 2 by DPaW. It is currently known to be found in sandy soils along the southwest Kimberley coastline, between Kimbolton and Nita Downs (Wilson and Swan 2010). It is one of the smallest species in the genus and has a fused lower eyelid (Wilson and Swan 2010). Whereas most other Lerista species have greatly reduced or only two limbs, *L. separanda* has four of the relatively largest limbs.

This species is apparently restricted to coastal habitats, however it is a poorly known species and as sandy habitat occurs within the Pindan Shrubland habitat of the Mine Site Development Envelope, it is possible that the species will occur in the area.

**Dampierland Burrowing Snake**

The Dampierland Burrowing Snake (*Simoselaps minimus*) is listed as Priority 2 by DPaW. It is currently known only from the western side of the Dampier Peninsula. Its preferred habitat is on coastal dunes or the sandy areas between dunes and adjacent *Acacia* shrublands (Wilson and Swan 2010).

Little is known about this species however it is presumed to be similar to other *Simoselaps* species, which are sand-swimmers which feed mostly on *Lerista* skinks.

The Dampierland Burrowing Snake was not recorded during surveys of the Mine Site Development Envelope, however given the sandy soils are characteristic of the Pindan Shrubland and Savannah Woodland habitats, the Dampierland Burrowing Snake may occur within the area.

#### *4.2.9.4 Introduced Fauna*

A total of four introduced mammal species were recorded in the Mine Site Development Envelope (Ecologia 2012a, 2014a, 2015):

- Dog/Dingo (*Canis lupus*).
- Cat (*Felis catus*).
- Cow (*Bos taurus*).
- House Mouse (*Mus musculus*).

#### *4.2.9.5 Short Range Endemics*

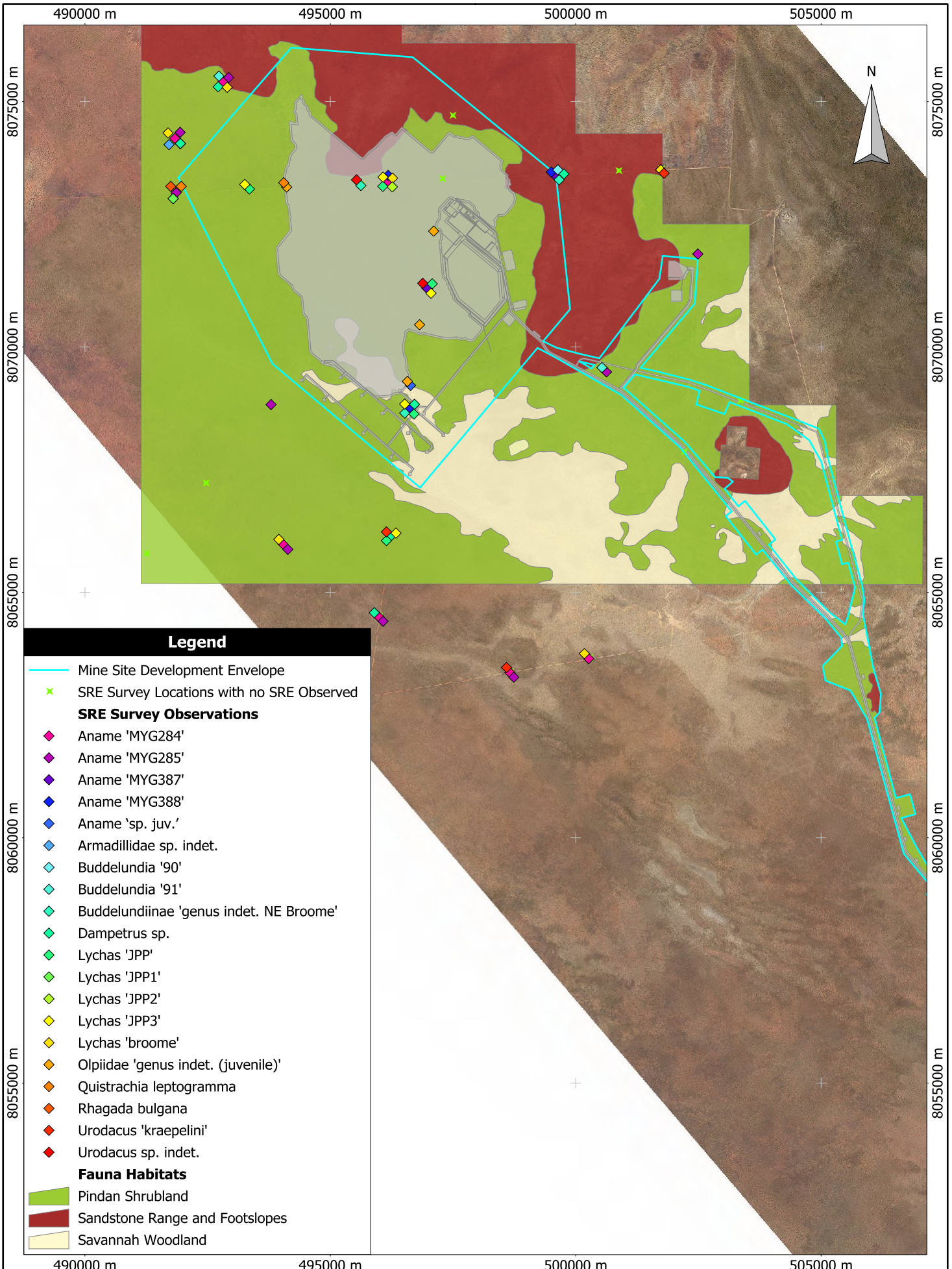
A Level 2 Short Range Endemic (SRE) survey was undertaken by Ecologia in March 2014 (Ecologia 2014a), followed by a targeted survey in December 2014 (Ecologia 2014c), are attached as Appendix 9.

The surveys yielded a total of 200 invertebrate specimens with a total of 6 orders, 11 families, and 31 taxa. Of these species, 22 were identified as being potential SRE, with one species (the land snail *Rhagada bulgana*) confirmed as a SRE (Table 23). The distribution of SREs at the Mine Site Development Envelope is depicted in Figure 32.

Of the 23 confirmed and potential SREs:

- Seventeen were found in similar habitats outside the Mine Site Development Envelope.
- Three (*Olpiidae* 'genus indet. (Juvenile)', *Aname* 'sp. Indet.' and *Aname* 'sp. Juv.') were represented by juveniles and due to a lack of morphological data and sub-adult stage could not be identified to species level. Given that all three of these specimens were collected from the extensive Pindan Shrubland habitat throughout the impact area, they are likely to have distributions that extend well beyond the boundary of the impact area.
- One (*Urodacus* sp. Indet) was unable to be identified to species level based on morphological characteristics, however based on distribution patterns of *Urodacus* 'kraepelini' and given this species was collected from the extensive Pindan Shrubland habitat, its distribution is expected to extend well beyond the boundary of the impact area.
- One (*Aname* 'MYG387?') was represented by a single female specimen. It is possible that this female is conspecific with the male species of *Aname* 'MYG387', which would indicate that its habitat preferences includes both the extensive Pindan Shrubland and Sandstone Range and Footslopes habitats, and is therefore widespread in the area.
- One (*Lychas* 'JPP2') was restricted to the impact area, however utilising *Lychas 'JPP', 'JPP1'* and *'JPP3'* as species surrogates and based on their distribution within the extensive Pindan Shrubland and Savannah Woodlands habitats it can be inferred that *Lychas* 'JPP2' will have a home range that extends well beyond the impact area.

Based on the above results as well as the habitat preferences for the invertebrate taxa recorded within the Mine Site Development Envelope and surrounding area, no potential SRE taxa are expected to be restricted to the proposed Mine Site Development Envelope.

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Air Photo Date: 2015
Grid: MGA94(51)
0 2 km

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**Figure 32**

**Location of SRE Observations**

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**Table 23: SREs Collected from the Mine Site Development Envelope**

| Order | Family | Species | SRE Status | Survey | | Presence Confirmed Outside Development Envelope |
|---|---|---|---|---|---|---|
| Mygalomorphae (Spiders) | Nemesiidae | *Aname* 'MYG284' | Potential | X | X | Yes |
| | | *Aname* 'MYG285' | Potential | X | X | Yes |
| | | *Aname* 'MYG387' | Potential | X | | Yes |
| | | *Aname* 'MYG387?' | Note 1 | X | | No |
| | | *Aname* 'MYG388' | Potential | X | | Yes |
| | | *Aname* 'sp. indet.' | Note 2 and 3 | X | | No |
| | | *Aname* 'sp. juv.' | Note 2 and 3 | X | | No |
| Arachnida (Opiliones) | Assamiidae | *Dampetrus* sp. | Potential | X | X | Yes |
| Scorpiones (Scorpions) | Buthidae | Lychas 'annulatus' | No | X | | Yes |
| | | Lychas 'broome' | Potential | X | X | Yes |
| | | *Lychas 'JPP'* | Potential | X | | Yes |
| | | *Lychas 'JPP1'* | Potential | X | | Yes |
| | | *Lychas 'JPP2'* | Potential | X | | No |
| | | *Lychas 'JPP3'* | Potential | X | | Yes |
| | | *Lychas* 'multipunctatus' | No | X | X | Yes |
| | Urodacidae | *Urodacus 'kraepelini'* | Potential | X | X | Yes |
| | | *Urodacus sp.* indet. | Note 2 | X | | No |
| Pseudoscorpiones | Sternophoridae | *Afrosternophorus* sp. indet. | No | X | | Yes |
| | Chernetidae | *Haplochernes* sp. Indet. | No | X | | Yes |
| | Olpiidae | *Beierolpium* 'sp. 8/4' | No | X | | Yes |
| | | *Olpiidae* 'genus indet. (juvenile)' | Note 2 and 3 | X | | No |
| | | *Indolpium'sp. Indet.'* | No | | X | Yes |
| Isopoda (Slaters) | Armadillidae | *Armadillidae* 'EE1501C' | Potential | X | X | Yes |
| | | Buddelundiinae 'genus indet. NE Broome' | Potential | X | X | Yes |
| | | *Buddelundiinae* sp. 74 | Potential | X | X | Yes |
| | | *Buddelundia sp. '90'* | Potential | | X | Yes |
| | | *Buddelundia sp. '91'* | Potential | | X | Yes |
| Gastropoda (Snails) | Subulinidae | *Eremopeas interioris* | No | X | | Yes |
| | Pupillidae | *Pupoides pacificus* | No | X | | Yes |
| | Camaenidae | *Quistrachia leptogramma* | Potential | X | | Yes |
| | | *Rhagada bulgana* | Confirmed | X | | Yes |

*Note 1: Single female specimen captured. Could be conspecific with* Aname 'MYG387'.

*Note 2: Specimen was unable to be identified to species level.*

*Note 3: Only juveniles collected.*

### 4.2.10 Subterranean Fauna

A Level 2 subterranean fauna survey of the Mine Site Development Envelope was undertaken by Ecologia in March 2014 (Ecologia 2014a) (Appendix 9). A total of 21 drill holes (located within and outside the Mine Site Development Envelope) from within the Broome Sandstone Aquifer were sampled for troglofauna and stygofauna species as represented in Figure 33.

The subterranean fauna sampling was said to be tapping the Broome Sandstone Aquifer, a non-karstic, unconfined aquifer. The majority of this area is dominated by clays and sand strata (pindan units), which consequently suggests limited saturated habitat space beneath the watertable (Ecologia 2014a).

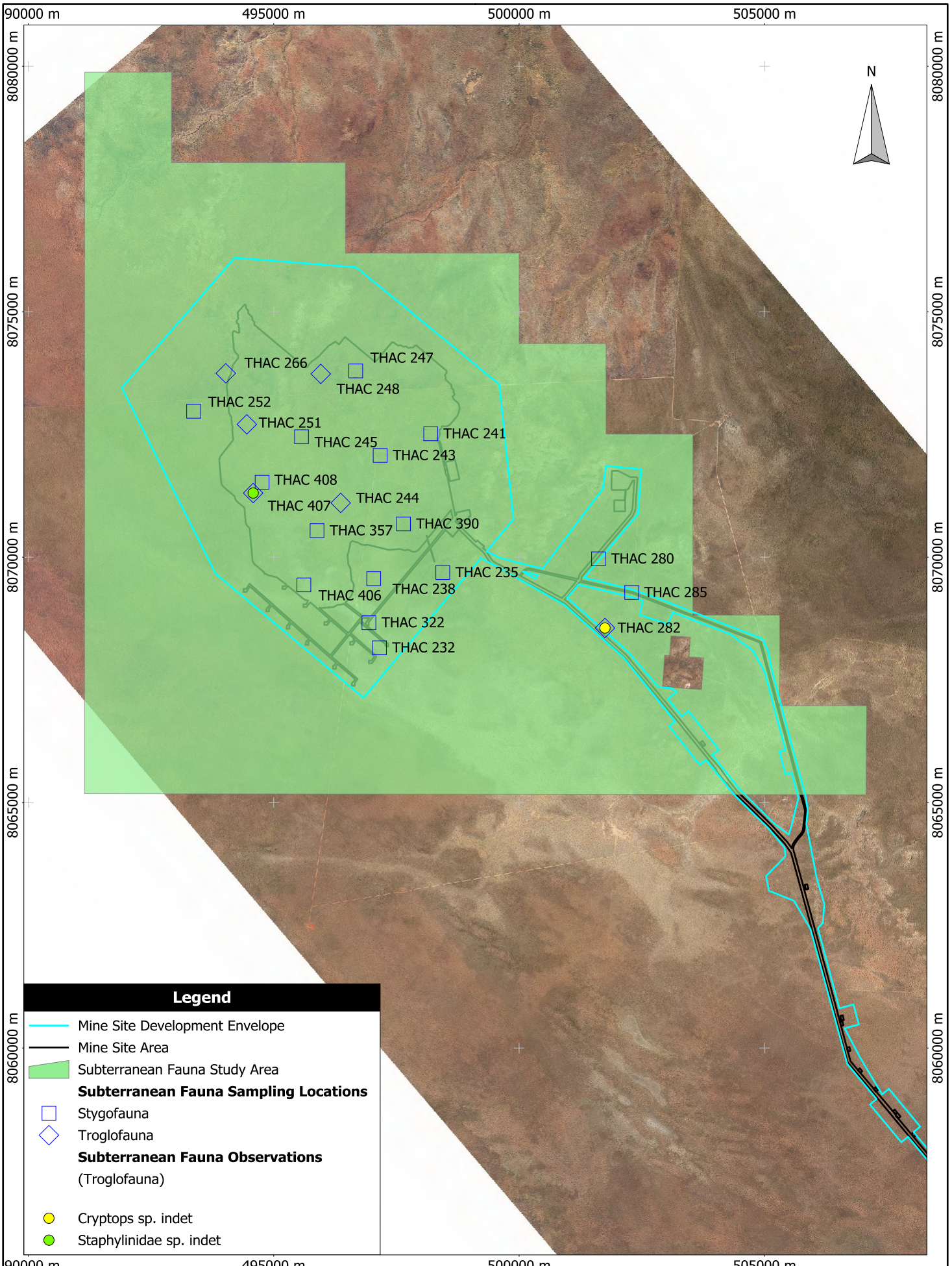
Should the Broome Sandstone Aquifer have secondary porosity developed in the form of fractures, and/or evidence of restricted calcareous sandstone geology with evidence of karst solution, then this could potentially provide habitat for stygofauna (Ecologia 2014a).

Results identified a low diversity and abundance of subterranean fauna with no stygofauna being recorded during the survey.

Similarly to stygofauna, there appears to be a low diversity and abundance of troglofauna present, this is potentially due to the habitat being dominated by Pindan sand plains which have little or no cavernous or vuggy habitat space. Only a single specimen (*Staphylinidae* sp. Indet) was recorded from bore THAC 407 within the Mine Site Development Envelope (Table 24 and Figure 33). As such, it is likely that habitat occurs within the Mine Site Development Envelope, but given the relatively continuous and expansive geology outside of this area and with no obvious dispersal barriers, this species is unlikely to have a restricted distribution and may occur within the extensive sandstone habitats in the ranges to the east and north of the project.

**Table 24: Subterranean Fauna of the Mine Site Development Envelope**

| Site | Class | Family | Lowest Identification | Type | Inside/Outside Mine Site Development Envelope |
|---|---|---|---|---|---|
| THAC 282 | Scolopendromorpha | Cryptopidae | *Cryptops* sp. indet | Troglofauna | Outside |
| THAC 407 | Coleoptera | Staphylinidae | *Staphylinidae* sp. indet | Troglofauna | Inside |

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Grid: Transverse Mercator
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**Figure 33**

**Stygofauna and Troglofauna Sampling Locations and Observations**


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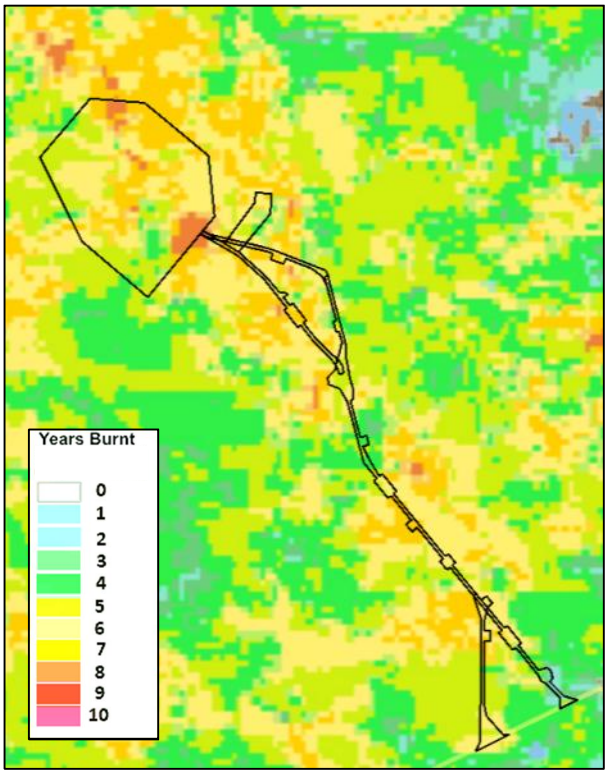
### 4.2.11 Fire History

The Mine Site Development Envelope is located within the Mt Jowlaenga pastoral lease and is subject to regular burning by pastoralists, other stakeholders, and as a result of natural causes such as lightning strikes. The burning pattern within the Mine Site Development Envelope is reflective of controlled burning by land users to reduce the amount of combustible fuel in the area rather than sporadic and localised burning caused by wet season thunderstorms (Ecologia 2015b).

A 2006 EPA investigation into the frequency and intensity of fires in the Kimberley and other regions suggested that areas of the Dampier Peninsula have been historically burnt by Aboriginal people, pastoralists, authorities, travellers, accidents, and from natural sources (EPA 2006b). An assessment of the North Australian Fire Information database for the Mine Site Development Envelope indicates that there is an increasing trend in fire activity as shown in Figure 34, which may be impacting on flora and fauna in the region (EPA 2006b). Fire regimes in the Kimberley are very different from those once managed by Aboriginal people where historic burning was guided by seasons as well as cultural and hunting practices.

**Number of Years Burnt Between 2000 and 2009**




**Number of Years Burnt Between 2006 and 2015**

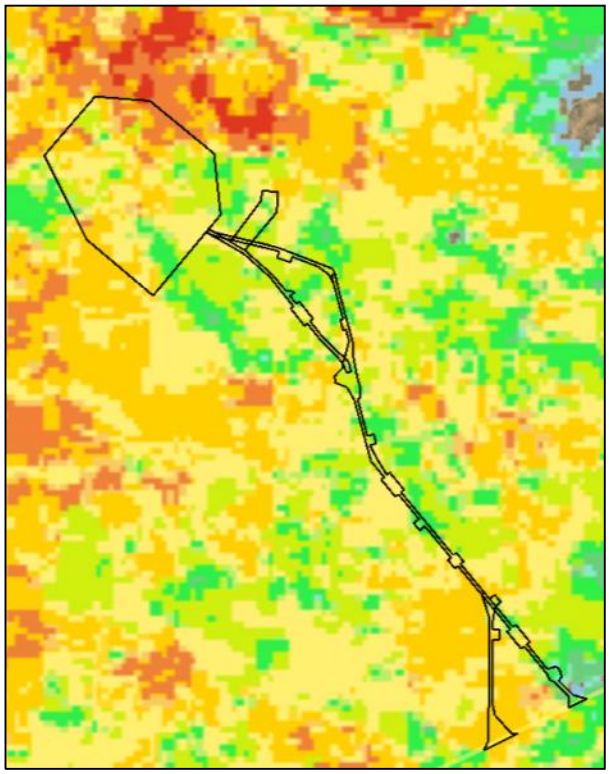


**Figure 34: Mine Site Development Envelope Fire History**

### 4.2.12 Land Use

The dominant land use within the subregion is native pastures, Unallocated Crown Land, and Crown reserves. The northern part of the project is located within the Mt Jowlaenga Pastoral Station and the southern part (Site Access Road) is located within the Yeeda Pastoral Station. Both pastoral stations are owned by Yeeda Australian Rangeland Meat Pty Ltd and produce beef products.

There are no nature reserves within the immediate vicinity of the Mine Site Development Envelope. The closest Nature Reserve is Coulomb Point Nature Reserve approximately 60 km to the northwest.

## 4.2.13 Heritage

### *4.2.13.1 Aboriginal Heritage*

The broader west Kimberley is a region renowned for its rich diversity of Aboriginal heritage, and Aboriginal people have occupied the west Kimberley for at least 50,000 years. Aboriginal people in the west Kimberley maintain strong links with traditional culture and spirituality, and are active in caring for Aboriginal sites and places with Aboriginal heritage values.

Recently, the world's oldest ground edge axe fragment was found in an archaeological site near Fitzroy Crossing, dated between 44,000 and 49,000 years before present, and archaeological research in the area continues to push this date further into the past as new finds and older occupational deposits are discovered and reported.

Parts of the west Kimberley constitute a world class rock art precinct, famous for its richness, diversity, and unique assemblage of motifs. The rock art, generally found in the gorges and rocky outcrops of the river systems and plateaus, is amongst the oldest, and owing to the remoteness of most of the sites, best preserved in the world. Aboriginal rangers across the west Kimberley routinely care for and record the rock art sites, and work in collaboration with researchers.

The central, northern, and eastern areas of the west Kimberley are characterised by dramatic land formations and geological diversity, with many river carved gorges, rugged ranges, and plateaus. The Dampier Peninsula (the location of the project) is situated in the south west Kimberley, and is a region of relatively low topography, undulating pindan, and savannah. The Dampier Peninsula is adjacent to but not part of the rock art precinct, and has a comparative lack of suitable rock surfaces for creating and preserving painted rock art.

A search of the Mine Site Development Envelope and surrounds was undertaken using the Department of Aboriginal Affairs 'Aboriginal Heritage Inquiry System' to identify:

- Aboriginal Heritage Surveys over or near the Mine Site Development Envelope.
- Registered Heritage Places within or near the Mine Site Development Envelope.
- Other Heritage Places within or near the Mine Site Development Envelope.

No registered Aboriginal sites are located within the Mine Site Development Envelope. The nearest Heritage Place is the Nilli Bubbaca Well about 2 km from the intersection of the Site Access Road and Great Northern Highway, well away from any possible effect of the project.

Engagement with Traditional Owners and their representatives, the Kimberley Land Council (KLC) and KRED Enterprises' (KRED) subsidiary EHSIS (Environmental Heritage Social Impact Services), has been ongoing for five years. In 2011, Sheffield entered into a Native Title, Heritage Protection and Mineral Exploration Agreement, which has governed the undertaking of surveys and exploration work programs.

Aboriginal heritage surveys to support exploration activities have been undertaken in consultation with Traditional Owners annually since 2012 (Cox 2012; Ecologia 2012b; Biet Holmes 2013, 2014, 2015, 2016a, 2016b). In 2016, an Aboriginal heritage survey was carried out with Traditional Owners through KRED's subsidiary EHSIS (Biet Holmes 2016a). This survey focussed on the areas of the Mineral deposit footprint and Development Envelope, identifying and evaluating any potential impacts to Aboriginal heritage from the proposed project. The results of this survey have been used to inform project feasibility and detailed planning for the project and this PER.

All surveys have been undertaken using aerial (helicopter) and pedestrian (on ground) methods, utilising the existing knowledge of Traditional Owners and targeting on-ground investigations especially to locations considered to have most potential for Aboriginal sites to exist, such as rocky outcrops, water sources and areas of good ground surface visibility. Over the past five years these surveys have covered the entire Mine Site Development Envelope.

A summary of Aboriginal survey activity and outcomes is provided in Table 25. Aboriginal heritage survey coverage of the project area is shown on Figure 35.

**Table 25: Summary of Aboriginal Heritage Surveys, Outcomes and Actions**

| Survey Season | Location | Native Title Group(s) | Outcomes Related to the Thunderbird Project |
|---|---|---|---|
| 2012 | E04/2083<br>Mt Jowlaenga<br>Thunderbird Project area | Nyikina Mangala<br>Bardi Jawi<br>Nyul Nyul<br>Nimanburr. | • Heritage survey and flora & fauna study completed with Traditional Owners<br>• Avoidance buffers approved by Traditional Owners<br>• Cultural heritage monitors employed<br>• Exploration work program completed – approx.49km of drill track cleared and 164 drill holes completed |
| 2013 | E04/2081,2083-84,2159, 2191-94, 2171<br>Mt. Jowlaenga<br>Thunderbird Project and surrounding area | Nyikina Mangala | • Heritage survey completed with Traditional Owners<br>• Avoidance buffers approved by Traditional Owners<br>• Cultural heritage monitors employed<br>• Exploration work program completed – 64km of new drill tracks cleared and 281 drill holes completed |
| 2014 | E04/2081, 2083-84, 2159, 2171, 2191-94<br>Mt Jowlaenga Unclaimed Area<br>Thunderbird Project and surrounding area | Nyikina Mangala | • Heritage survey completed with Traditional Owners<br>• Avoidance buffers approved by Traditional Owners<br>• Cultural heritage monitors employed<br>• Exploration work program completed – approx.30km of drill tracks cleared and 142 drill holes completed |
| 2015 | E04/2083-84, 2159, 2171, 2192-94, 2349<br>Mt. Jowlaenga (now claimed)<br>Thunderbird Project and surrounding area (including the Mine Site Development Envelope) | Bindunbur<br>Nyikina Mangala<br>Mt Jowlaenga Polygon#2 Claim Group | • Heritage surveys completed with Traditional Owners<br>• Avoidance buffers approved by Traditional Owners<br>• Cultural heritage monitors employed<br>• Exploration work program completed – approx.8km of drill tracks cleared and 115 holes completed. |
| 2016 | MO4/459 within EO4/2083<br>Thunderbird Project proposed Mining Operations Area (including mineral deposit footprint and Mine Site Development Envelope) | Mt Jowlaenga Polygon#2 Claim Group | • First survey covered trenching and geotechnical drilling required for BFS works, second survey was completed to determine the ground available for mining purposes within the Mining Operations. Cultural heritage monitors employed during the BFS works.<br>• Avoidance buffers around sites of significance were established and approved by Traditional Owners.<br>• Survey clearance was to assist with heritage understanding within the Public Environmental Review. |

The outcomes of the surveys were:

- The project area has been extensively and comprehensively surveyed, and all areas considered sensitive to Aboriginal cultural values in the Mine Site Development Envelope and surrounds have been covered.
- Aboriginal sites and areas of Aboriginal cultural value have been identified and mapped.
- Avoidance buffer zones have been determined by Native Title claimants.

Further detail regarding the results of the Aboriginal heritage surveys are subject to a confidentiality agreement between Sheffield and the Native Title claimants at the claimants' request. As such, Sheffield is unable to disclose details or the location of the Aboriginal heritage sites for public review.

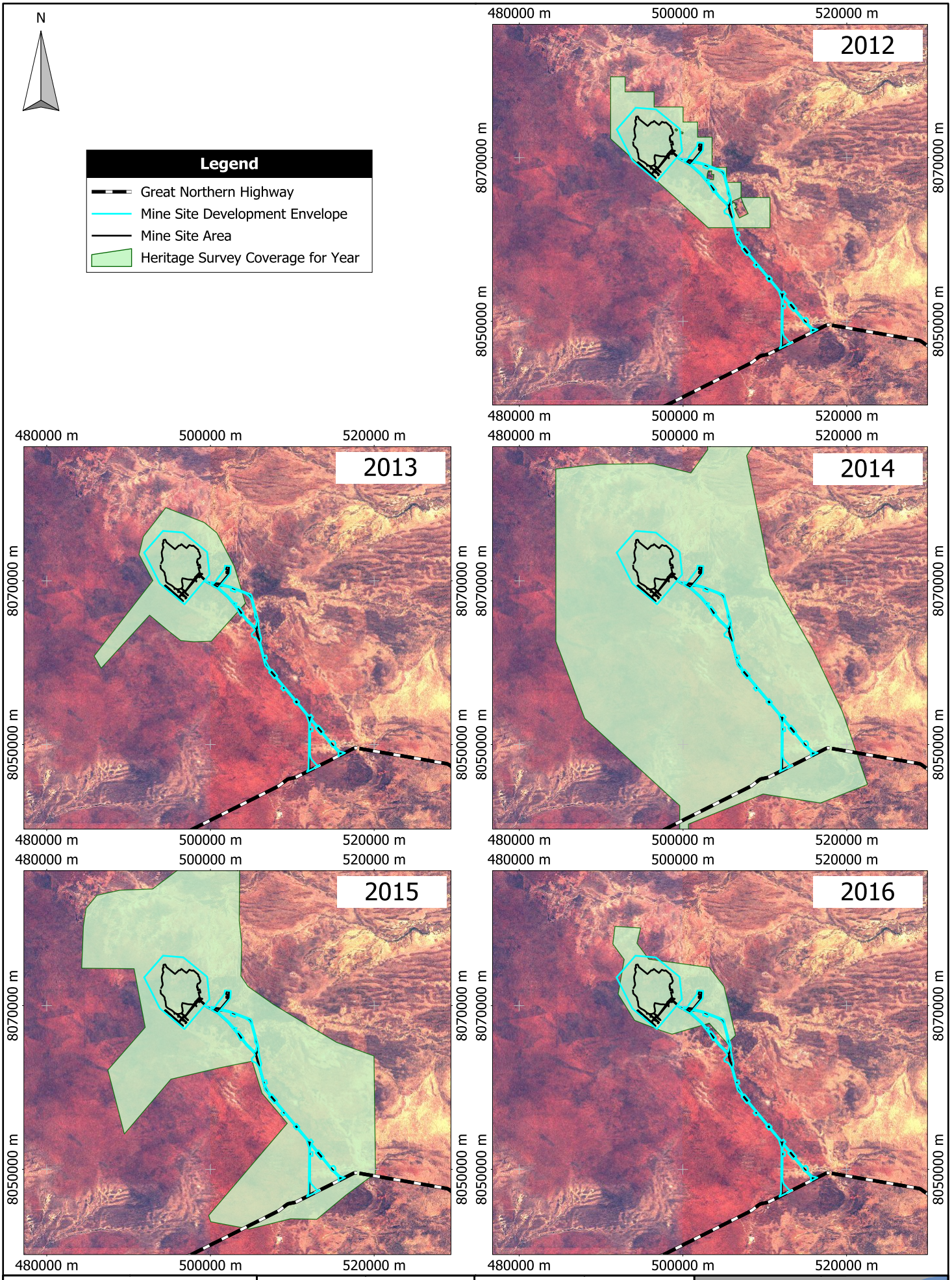



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**Figure 35**

**Aboriginal Heritage Survey Coverage of Mine Site Development Envelope**

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#### *4.2.13.2 Native Title*

The Thunderbird Mineral Sands Project tenure sits within three distinct areas:

- Mt Jowlaenga #2 People Native Title Determination Application (National Native Title Tribunal reference number WC2014/005).
- Nyikina Mangala Consent Determination Area (National Native Title Tribunal Reference Number WCD2014/003). The southern sections of the Site Access Road are located within this area.
- An area between the two which is unclaimed.

Figure 36 shows Native Title Applications over and surrounding the Mine Site Development Envelope.

Sheffield is working in close consultation with Traditional Owners to reach a Mining Agreement for the project. Details of the consultations are necessarily subject to a confidentiality agreement and therefore cannot be released for public review.

#### *4.2.13.3 European Heritage*

A search of the following databases was carried out to identify registered, non Aboriginal heritage sites within or near the Mine Site Development Envelope:

- *EPBC Act* Protected Matter (Search Tool).
- Commonwealth Heritage List (CHL).
- World heritage List (WHL).
- State heritage Council Western Australia Register of Heritage Places.
- Shire of Derby/West Kimberley Municipal Register of Heritage Places.
- Shire of Broome Municipal Inventory of Heritage Places

No heritage places were identified within the Mine Site Development Envelope.

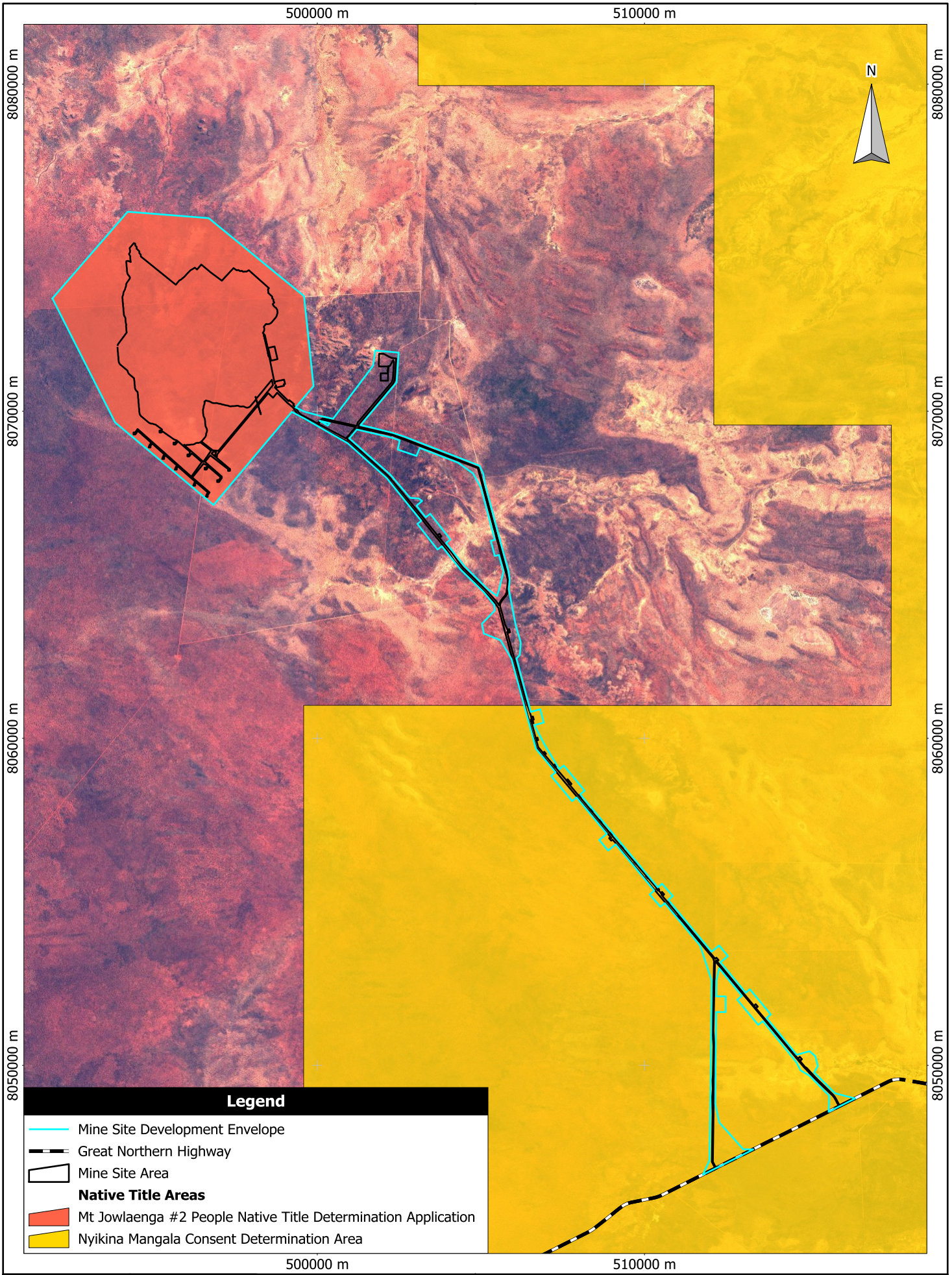


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Image: Copernicus Sentinel Data 2016
Grid: Australia MGA94 (51)
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**Figure 36**

**Native Title Applications - Mine Site Development Envelope**

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## 4.2.14 Air Quality

There are no significant emissions sources in the vicinity of the Mine Site Development Envelope and due to the remote location, it is presumed that air quality will typically be very good. The main contributors to air quality, specifically particulate levels are ambient wind-borne dust (from dust storms, cattle, and vehicle movements) and smoke from dry season bush fires. Background and cumulative emissions from other industrial activities are expected to be negligible and naturally occurring background particulate concentrations are expected to be minor.

During project design, in order to be conservative, the average ambient dust concentrations found in northwest Western Australia have been used to ensure the worst-case scenario is considered (40 µg/m$^3$ for TSP, 20 µg/m$^3$ for $PM_{10}$ and 7 µg/m$^3$ for $PM_{2.5}$). These concentrations are based on a number of studies of ambient monitoring in the Kimberley and Pilbara areas, which both experience a higher level of activity than the Mine Site Development Envelope and as such are seen to be a conservative choice in lieu of local data (Atmospheric Solutions 2016a; Appendix 12).

## 4.2.15 Light

Given the remote location of the Mine Site Development Envelope, background artificial light levels are very low and would be typical of most rural sites where pastoral activities occur, varying with the extent of vehicle traffic, machinery operation, and general activity at any given time.

## 4.2.16 Noise

A noise assessment was undertaken for the Mine Site Development Envelope (WSP Parsons Brinckerhoff 2016b; Appendix 13).

### *4.2.16.1 Background Noise Levels*

No background noise studies specific to the Mine Site Development Envelope have been undertaken, however, given the remote location, background noise levels are expected to be very low and would be typical of most rural sites where pastoral activities occur. Noise would generally be from non-anthropogenic sources such as wind-induced foliage noise, and insect, bat, and bird noise.

Table 26 details the low attended noise measurements measured at the start of the Mt Jowlaenga road in May 2016, approximately 27 km from Mine Site infrastructure.

**Table 26: Mt Jowlaenga Site Access Road Attended Noise Measurement**

| Time | $L_{A90}$ dB | $L_{A10}$ dB | $L_{Amax}$ dB | Comments |
|---|---|---|---|---|
| 10:55 am | 23 | 26 | 30 | Paused for traffic passing by on Great Northern Highway. Insect and wind noise in foliage dominant |
| 11:05 am | 27 | 50 | 62 | Not paused. Traffic, insect and wind noise in foliage dominant |

A literature review was carried out to identify studies of background noise levels in the Kimberley, with the most appropriate identified as the *Browse Liquefied Natural Gas Precinct – Strategic Assessment Report Part 4: Environmental Assessment – Terrestrial* (DSD 2010). Noise levels from this study are outlined in Table 27.

**Table 27: Background Noise Levels Within North Western Australia**

| Measurement Site | $L_{A90}$ Sound Pressure Level $d_{BA}$[1] | | |
|---|---|---|---|
| Northern Carnarvon Basin | 24 | 33[2] | 29 |
| Burrup Peninsula | 25 - 30 | 25 - 30 | 25 - 30 |

*1 Lowest 10th percentile of $L_{A90}$*

*2 Noise Levels influenced by people on the beach*

Additionally, based on similar inland location within the Pilbara, Western Australia, noise levels could be expected to be within those listed in Table 28.

**Table 28: Expected Existing Noise Levels**

| Sound Pressure Level dBA | Day (0700-1900) | Evening (1900 – 2200) | Night (2200 – 0700) |
|---|---|---|---|
| $L_{10}$ | 39 - 45 | 34 – 45 | 37 - 42 |
| $L_{90}$* | 22 - 30 | 27 - 34 | 17 - 32 |

** Lowest 10th percentile of $L_{A90}$*

#### *4.2.16.2 Nearest Sensitive Receptors*

The nearest residence, Mt Jowlaenga Station Homestead (currently uninhabited), is located approximately 2 km from the Mine Site Development Envelope. The identified nearest potential sensitive human receivers (and their distance from the Mine Site Development Envelope) are:

- Mine Site accommodation village - 5 km.
- Nillibubbica designated rest area, Great Northern Highway - 27 km.
- Bidan (formerly known as Bedanburu) Aboriginal Community - 28 km.
- Yeeda Outstation, Mt Jowlaenga Road - 28 km.

## 4.3 DERBY PORT DEVELOPMENT ENVELOPE

This section describes information regarding the physical, biological and socio-economic characteristics of the proposed Derby Port Development Envelope (Figure 15). This includes all information gathered during physical and biological surveys conducted for the project for this area. The product transport route from the Mine Site to Derby Port is shown on Figure 14, and the transhipment route is shown on Figure 16.

### 4.3.1 Regional Setting

The townsite of Derby is located on a peninsula of slightly elevated Pindan soils that sits above the surrounding tidal mud flats within the Dampierland bioregion and Fitzroy Trough subregion, as defined by the IBRA classification system. Derby Port is located on the edge of King Sound, approximately 2 km northwest of the townsite and is accessed via a narrow manmade causeway (Jetty Road). The location of Derby Port and IBRA regions are shown on Figure 37.

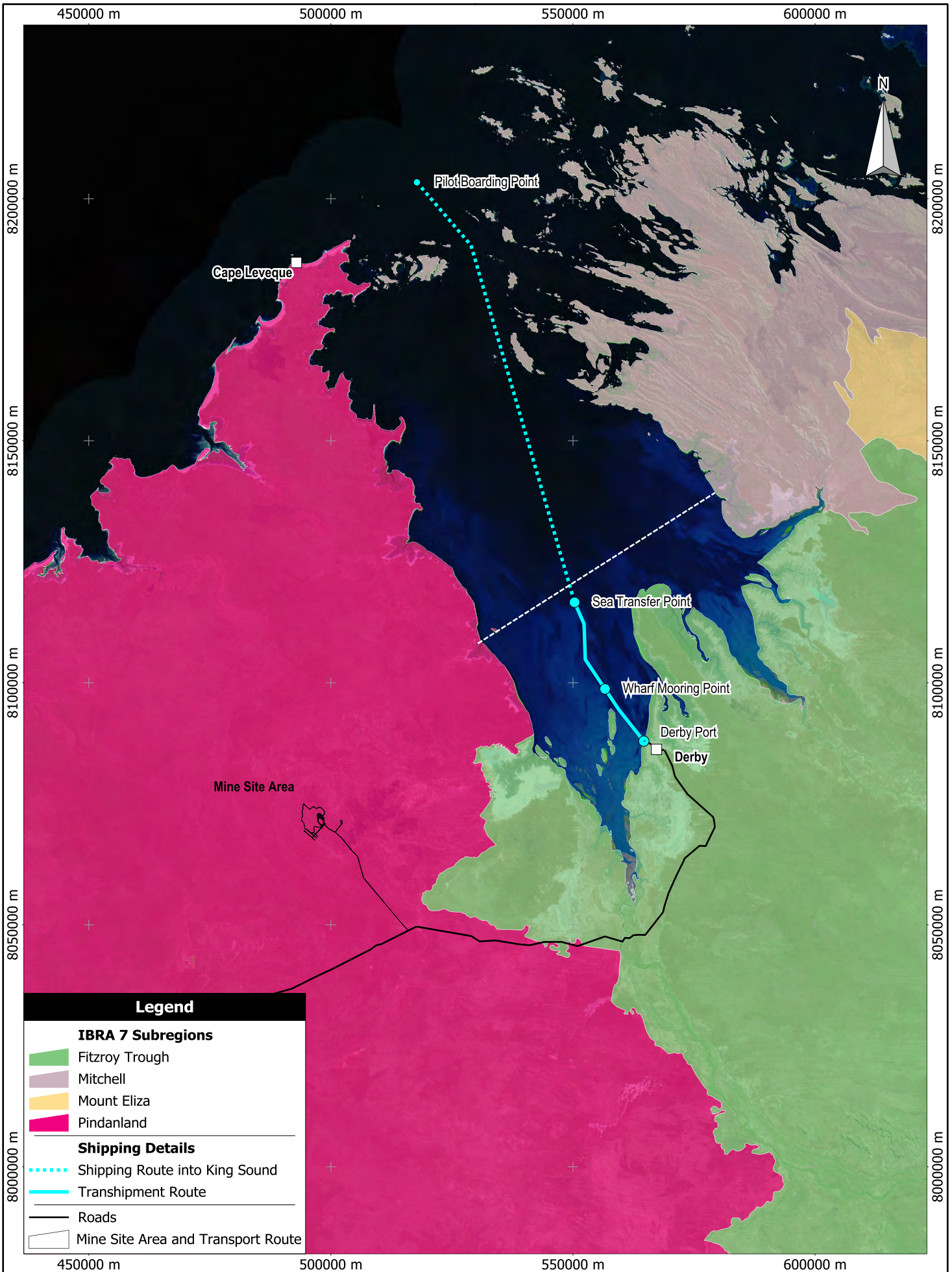


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Image: Geoscience Australia LS7 2007
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**Figure 37**

**Interim Biogeographic Regionalisation for Australia (IBRA 7) for Transport Route**

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### 4.3.2 Port History

The town of Derby was declared in 1883 and was established to service the pastoral industry. It has since expanded, along with the West Kimberley region, to service the growing number of industries including tourism, mining, oil, and natural gas (Derby Tourism 2016).

Historically, Derby Port comprised a wooden T-shaped jetty structure located at the northern end of the present steel and concrete wharf, and was first constructed in 1885 to facilitate sheep export. It was linked to the town of Derby by a horse-drawn tramway, crossing the mud flats via a causeway where the present day Jetty Road is located. The wharf was upgraded in 1964 to steel and concrete and serviced sheep and cattle export, as well as the intermittent export of mining products. Derby Port was officially closed to commercial shipping in 1982 and the wharf was closed by the Department of Transport in 1994.

Derby Port was reopened in 1997 as a lead and zinc export facility which operated until 2008 when the Lennard Shelf Lead and Zinc Operations closed. While it was operational, lead and zinc concentrate was delivered to the port via road trains which tipped into a purpose-built storage facility adjacent to the wharf, which has now been decommissioned. The storage facility used a hopper system fed by front-end-loaders to transport lead and zinc concentrate to the end of the wharf and to an awaiting shallow transhipment vessel. Transhipment vessels were loaded at high tide via a conveyor belt and ship-loading infrastructure (which remains in place). The loaded vessels then transported lead and zinc concentrates from the wharf to the sea transfer point located near Point Torment, where they were then transferred onto a handymax vessel for export.

The location of the storage facility was determined to be a contaminated site by Department of Environment Regulation (DER). The site was subsequently remediated by the previous lessee in accordance with plans approved by DER. Further details on the site's contaminated site status are provided in Section 4.3.7.1.

Since closure of the lead and zinc export operations, Derby Port has been used to fuel and load transhipment vessels that supply iron ore operations at Koolan and Cockatoo Islands, and to support aquaculture and tourism ventures. The port area is also used by the public for fishing, boat launching, and sightseeing, as it is the only access point to coastal waters off Derby; however the public can only access parts of the wharf. Derby Port is managed by the Shire of Derby/West Kimberley under a lease from the Department of Transport.

### 4.3.3 Derby Society and Population

The Shire of Derby/West Kimberley has a population of approximately 5,940 people, of which 3,380 reside within the town of Derby, and a further 2,560 reside in communities and regional areas associated with Derby. As of the 2011 Census, Derby has an unemployment rate of 5.0%, slightly higher than the Western Australian rate (4.7%) and lower than the Australian rate (5.6%). The main occupation in Derby is 'Professional' at 21% followed by 'Community and Personal Service Workers', 'Labourers', 'Technicians and Trades Workers', and 'Clerical and Administrative Workers' (between 13 to 15% each) (ABS 2016).

Within the town of Derby, a number of potentially sensitive land uses are located along or just off Loch Street, which leads to Derby Port (Figure 38), including:

- Holy Rosary Catholic Primary School.
- Holy Rosary Catholic Church.
- Derby District High School.
- The Rural Clinical School of Western Australia.
- Derby Hospital.
- The Scallywags Child Care Centre (approximately 1 km from Loch Street and Derby Highway).

### 4.3.4 Climate

The climate at Derby is very similar to that at the Mine Site Development Envelope (Section 4.2.2), comprising a tropical monsoon climate with a winter dry season and a summer wet season. The mean annual rainfall for Derby is 691.0 mm. Mean monthly rainfall is highest in February (199.6 mm) and lowest in August (0.8 mm). Rainfall intensity may be high (e.g. the highest 24 hour rainfall recorded at Derby was 418 mm in January 1917), and is mostly associated with cyclonic activity. Average monthly minimum temperatures are lowest in July (14.7°C) and average monthly maximum temperatures are highest in November (38.1°C; BoM 2016b). Prevailing winds are mainly strong easterly to southeasterly in the morning and mainly southeasterly to northwesterly in the afternoon. Cyclone risk with respect to wind is much lower than Broome and coastal Pilbara towns due to fewer cyclones and fewer severe cyclones impacting on the area. Section 4.2.2 details cyclone risk within respect to the Mine Site Development Envelope, and is also relevant for the Derby Port Development Envelope.

### 4.3.5 Topography

The topography in the Derby region is gently undulating. The main features are the Grant Range and isolated erosion scarps, including the Sisters Plateau, Erskine Range in the east and the Reeves Hill – Dampier Hill Scarp in the west. The terrain is generally low lying in the north and rises to approximately 150 m AHD southwest and southeast of King Sound. Wide-spaced, easterly trending longitudinal sand dunes occur throughout the area. The principal drainage systems for Derby include the Fitzroy, May, Meda, and Fraser Rivers, as well as the Alexander and Hawkstone Creeks which are fed by groundwater (DoW 2008).

Derby Port is situated on a narrow stabilised mangrove mudflat system that lies in a north to south direction approximately 2 km from the town of Derby. The mangrove area is surrounded by the tidal mudflats of King Sound to the east and west, with a narrow causeway linking the port to the town across the eastern mudflats. The causeway and port were reclaimed from the mudflats by use of local rock and soil material sourced from the Derby hinterland. Elevation is very low and flat, with most of the stabilised land no more than a few metres above the tidal mudflats (MBS 2009).


Scale: 1:20000
Original Size: A4
Image: Landgate Locate WA
Grid: Australia MGA94 (51)

0 500 m

Sheffield Resources
Thunderbird Mineral Sands Project

**Figure 38**

**Sensitive Land Uses Near Derby Port Development Envelope and Transport Route**

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W:\Sheffield Resources\PER\Drawings\PER Derby Port.map 21/12/2016 F38 Derby Sensitive Land Uses Layout

## 4.3.6 Geology and Soils

### *4.3.6.1 Geology*

The geology of the catchment area draining into King Sound is extremely diverse. The southern areas overlay the Canning Basin, which is a sedimentary sequence of rocks extending from the early Ordovician to the Cretaceous and overlain by recent alluvial and aeolian sediments (MBS 2009).

To the north of the Canning Basin, the geology consists of diverse igneous and metamorphosed sedimentary rocks of Proterozoic to Archaean age (Halls Creek Orogen). Between these two geological provinces is the Lennard Shelf, which is a Devonian system of reef carbonates, limestones and sandstones. The karst limestone geology is commonly associated with zones of lead and zinc sulfides, several of which have been mined. These included mines operated by Western Metals and Lennard Shelf, namely the Cadjebut, Pillara, Goongewa, and Kapok mines (MBS 2009).

### *4.3.6.2 Soils of the Derby Region*

The soils of the Derby region belong to the Dampier Sandplain zone, comprising sandplains, dunes and coastal mudflats overlying the sedimentary rocks of the Canning Basin. Locally, the dunes and sandplains belong to the Yeeda system. The soils are referred to as 'Pindan'. They are usually red-brown sands to sandy earths and are believed to be of aeolian origin. Soils from the dunes tend to have a higher sand content than those of the associated swales (MBS 2009).

### *4.3.6.3 Intertidal Mudflats*

The geomorphology of the tidal mudflats of King Sound has been described by Semeniuk (1982). Erosion over the past 5,000 years has been the dominant shore-forming process, resulting in the erosion of coastal sediments deposited from the major river systems during the Holocene (up to 10,000 years before the present; Semeniuk 1982).

The sub-tidal areas between Derby Port and the townsite comprise the following landforms:

- Tidal mudflats, which are partially or fully exposed at low tide.
- Mangal flats, which are stabilised by mangroves and incised by numerous creeks.
- Saline mudflats, which are devoid of vegetation and only inundated following high rainfall or at spring high tide.
- Samphire flats, which are vegetated with salt tolerant (halophytic) plants.
- Red sand dunes, as described in Section 4.3.6.2.

The stratigraphy of the natural soil sequence near Derby Port from the surface downwards is:

- A surface horizon of bio-turbated brown mud within the root zone of the mangroves.
- Christine Point Clay, which is a slate grey coloured clay horizon containing fossil mangrove stumps.
- Mowanjum Sand, similar to the red Pindan soil of the West Kimberley region.
- Airport Creek Formation, a semi-lithified and nodular cemented deposit of interlayed sand and mud.

The physical presence of the wharf structure has resulted in substantial deposition of coarse sand sediments immediately below and to the north and south of the wharf. These sand banks are exposed at low tide (MBS 2009).

#### *4.3.6.4 Reclaimed Land*

The causeway across the mudflats between the port and town of Derby was constructed from local rock and soil sourced from the Derby hinterland. Much of the soil at the proposed storage facility area consists of fill material, typically Pindan soil sourced from the mainland over the Port's 120 year history. A large proportion of this material was imported and placed in 1997 as part of construction works for the former lead and zinc concentrate storage facility.

### 4.3.7 Derby Storage Facility Baseline Contamination Assessment

#### *4.3.7.1 Contaminated Site History*

The Derby Port area has a long history of contaminated sites due to the former storage and export of lead and zinc concentrates from the Lenard Shelf Lead and Zinc Operations.

The Contaminated Sites Branch of DER carried out inspections at the port in June and August 2007. A Notice of Classification of a Known or Suspected Contaminated Site was subsequently issued by DER on 12 September 2008 to the former sublessees, Lennard Shelf Pty Ltd. The category of site classification was 'Possibly Contaminated - Investigation Required' on the basis of the identification of lead and zinc in concentrations above the Ecological Investigation Levels (EILs) for soil.

The site was investigated and a closure plan prepared in March 2009 (MBS 2009). This included a site management plan for remediation of contaminated areas. The closure plan was assessed as satisfactory by DER in a letter dated 7 April 2009 and the site was subsequently closed and remediated during 2010 to 2011 by Rey Resources Limited.

Validation sampling and reporting was undertaken at the site in 2012. While some residual lead and zinc concentrations exceeded the respective EILs but remained within discrete locations across the site, the risk to the surrounding environment was assessed as low. The site was deemed to be remediated to a level appropriate for its intended land use (industrial/commercial), with minimal risk to the surrounding environment as a result of residual soil contamination (MBS 2012). Due to the absence of any groundwater data beneath the site, the site remains classified as 'Possibly Contaminated – Investigation Required'.

#### *4.3.7.2 2016 Baseline Contamination Assessment*

Given the history of the Port area, a detailed inspection was undertaken by MBS Environmental senior geochemists during June 2016. This included a review of previous site history and contamination assessment reports, and a site visit to collect representative samples of soils, basement clays, and marine sediment. These samples were analysed for potential contaminants of concern and potential presence of acid sulfate soils (ASS). A summary of the findings are reported below, with the full report provided in Appendix 14.

Residual low level zinc concentrations remain in some of the imported Pindan soils across the Port area, however these levels are significantly below industrial health investigation levels (HILs). The maximum concentration of zinc (360 $mg/kg^{-1}$) was equal to the site specific calculated National Environmental Protection Measure (NEPM) 2013 added contaminant level for this sandy soil type and would be at or below the EIL for the site depending on background concentrations. This is consistent with the previous site history and validation report (MBS 2012).

Concentrations of lead were correlated with zinc and were consistent with previous site use of exporting lead/zinc sulfide mineral concentrates, however no samples were found to exceed the industrial EILs or HILs for lead.

Examination of subsoil basement clays in accessible parts of the Port area indicated a slight presence of sulfidic material in an otherwise alkaline clay matrix, which was insufficient for classification as ASS materials. Further samples for assessment were taken from the eastern mudflats as they are considered to represent the same underlying heavy clay/silt; these were also classified as not being ASS.

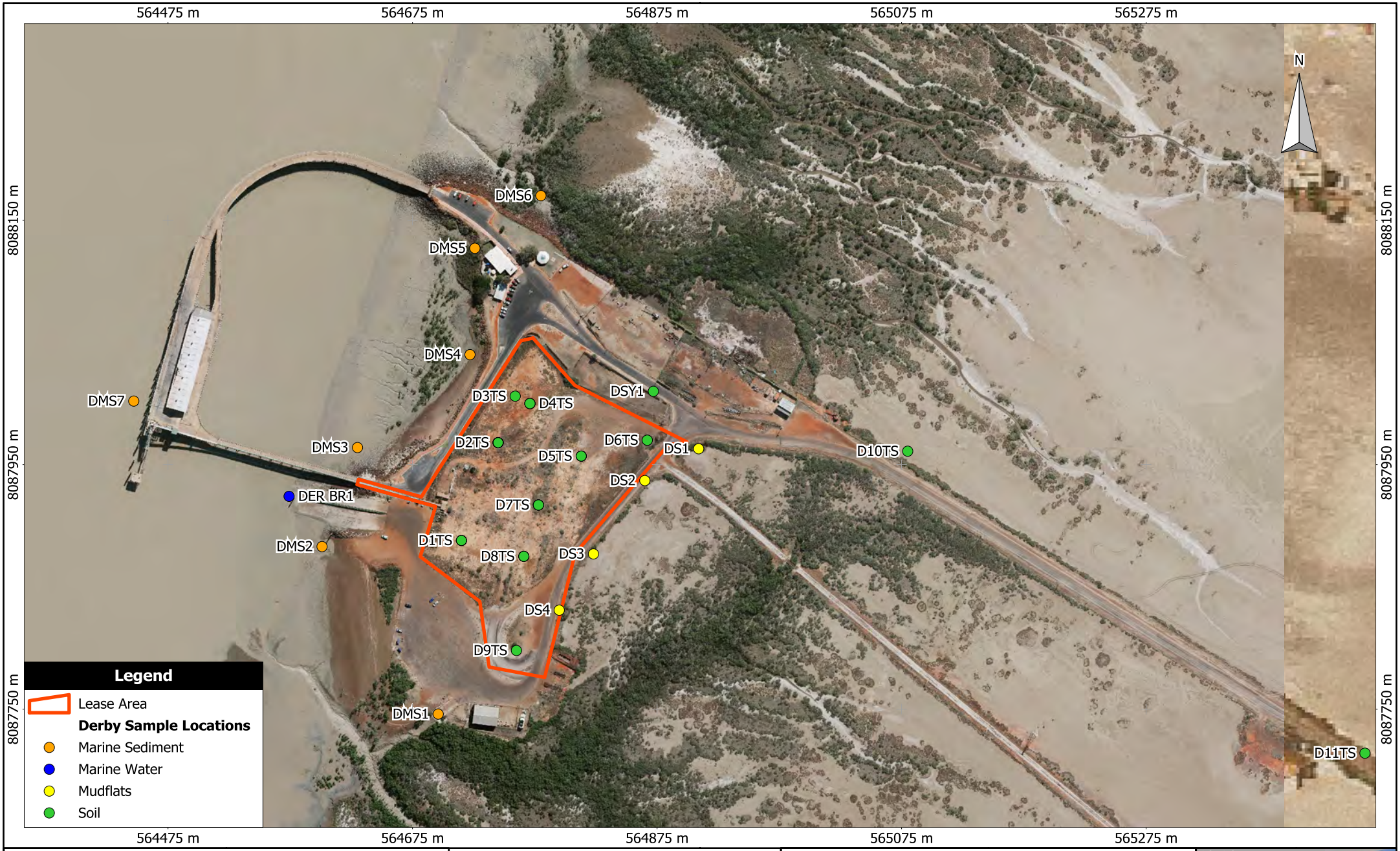
Samples of the mudflats east of the lease area indicate some elevation of zinc and lead above background levels adjacent to the culverts, and particularly at location DS4 (Figure 39; 360 mg/kg zinc, 95 mg/kg lead). These elevated results were attributed to previous site history and road run off. The zinc concentration is above the lower interim sediment quality guideline (ISQG-Low) of 200 mg/kg, but below the calculated NEPM 2013 added contaminant level of 1,200 mg/kg (based on an assigned land use of recreational/public open space).

All samples of clay/silt sediment including inshore marine, mudflats, and basement clays were in range of 22 to 31 mg/kg for nickel, which marginally exceeds the ISQG-Low of 21 mg/kg. This strongly suggests a natural enrichment of nickel at this concentration in the estuarine silt/clay from the area.

Copper concentrations in marine sediment samples DMS1 (90 mg/kg) and DMS2 (66 mg/kg) were above the ISQG-Low of 65 mg/kg, and significantly higher than other clay/silt based samples (23 to 35 mg/kg). Both these locations are used for boat launching and marginally elevated copper levels may be the result of copper anti-fouling paint from boat hulls.

No ISQG exceedances for arsenic, cadmium, chromium, silver or mercury were recorded. Selenium concentrations were all below the level of reporting. Uranium concentrations in silt/clay dominant sediment samples were consistently between 2.4 to 5.2 mg/kg, which similar to the average crustal abundance (2.7 mg/kg). Samples of sandier substrate at DS1 and DMS7 had lower concentrations (0.81 and 0.75 mg/kg respectively).

Overall the assessment of all samples taken in and adjacent to the proposed Derby product storage facility for analysis of metals and metalloids indicated concentrations considered either representative of the region or reflective of a Port facility with prior history of (in particular) lead and zinc exports. Further assessment of the soils and sediments within the lease area which may be disturbed in minor volumes by construction of a product storage facility indicated no significant risk of ASS. No significant disturbance of marine sediment and hence opportunity for oxidation and metals/metalloids release is expected as the wharf is already constructed.




Scale: 1:4000
Original Size: A4
Air Photo: Landgate 2015
Grid: MGA94(51)

0 100 m

**Figure 39**

**Baseline Contamination Assessment Sampling Locations**

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W:\Sheffield Resources\PER\Drawings\Derby BCA-PER.map 21/12/2016 F39 Baseline Sampling Layout

## 4.3.8 Hydrology and Hydrogeology

### *4.3.8.1 Hydrology*

Derby Port and the proposed Product Storage Facility are situated on a raised section of reclaimed land. King Sound is located to the immediate northwest and its associated saline mudflats are situated to the immediate east. Stormwater runoff from the reclaimed section of land drains directly into either King Sound or the mudflats. Inundation of the mudflats is rare, but can occur following a high rainfall event or during a spring high tide (MBS 2009). Within the proposed Product Storage Facility, stormwater generally reports to the northwestern corner and is managed by an existing earth v-drain that runs along the northwestern perimeter. This drain ultimately reports to King Sound.

### *4.3.8.2 Subsurface Water Quality and Levels*

Subsurface water underlying the proposed storage facility is controlled by tidal movements (Section 4.3.11.2), consisting predominantly of brackish water becoming more saline with depth as levels approach the seawater interface. The position of the site, on the western edge of the tidal mudflats, and the very low elevation results in saturated subsurface conditions at depths greater than 2 m below the ground surface, with the water table expected to occur slightly above mean sea level.

### *4.3.8.3 Hydrogeology*

Derby is located on the northern part of the Canning Basin that comprises Phanerozoic sediments of approximately 8,000 m thickness at the Derby Peninsula (DoW 2008).

The stratigraphic sequence at Derby in order of increasing age is:

- Quaternary sediments.
- Meda Formation.
- Wallal Sandstone.
- Munkayarra Shale.
- Erskine Sandstone.
- Blina Shale.
- Liveringa Group.
- Nookanbah Formation.
- Poole Sandstone.
- Grant Group.

The principal regional aquifers with potential for potable water supply are the Wallal Sandstone and the Erskine Sandstone. The Liveringa Group, Poole Sandstone, and Grant Group also contain groundwater at depth. With the exception of the Liveringa Group in the deep Derby Town Bore (600 to 700 m), these aquifers have been exploited only in areas where they occur at shallow depths (DoW 2008).

An unconfined aquifer with a maximum saturated thickness of 60 m is located in the Derby area, comprising of the Quaternary sediments, the Meda Formation, and the Wallal Sandstone (DoW 2008). The Wallal Sandstone aquifer receives recharge via direct rainfall infiltration. Groundwater flow in the aquifer is westerly toward King Sound.

The Erskine Sandstone is a multilayered aquifer with shale interbeds, and is generally confined by the overlying Munkayarra Shale. Groundwater flow in the aquifer is generally northerly toward the May River, however near

Derby the Erskine Sandstone is in direct hydraulic connection with the Wallal Sandstone as the confining Munkayarra Shale is absent (DoW 2008).

Groundwater in the vicinity of the proposed storage facility has no beneficial water use.

## 4.3.9 Land Use

The Derby town includes a number of areas zoned for a variety of different land uses including commercial, industrial, residential, and various other public and recreational land uses. The Port area has been zoned for 'port industry'.

There are no other industrial or agricultural land uses in the immediate vicinity of the Port. The closest operating commercial enterprises are the privately run Wharf Cafe located approximately 150 m north of the Derby Port Development Envelope, and an industrial laydown area located approximately 100 m northeast of the Derby Port Development Envelope, the latter of which was previously used for the former Cockatoo and Koolan Island iron ore operations (MBS 2009). A portion of the wharf is used for storage and export of fish produce (barramundi). A non-operating mud crab enterprise is located approximately 100 m northeast of Derby Port.

The wharf area is a popular recreational area for local residents and tourists, and a public boat ramp is located to the immediate west of the proposed storage facility. The most popular activities include fishing (including mud crabs) and passive recreation. Several professional fishermen are licensed to catch barramundi and other species (Fletcher and Santoro, 2015). Existing regional marine use is detailed in Section 4.3.12.

## 4.3.10 Terrestrial Flora and Fauna

### *4.3.10.1 Vegetation*

The Derby Port Development Envelope is located in a previously disturbed industrial area, with very limited native vegetation or fauna habitat present. The site of the proposed storage facility was previously used for the storage of lead and zinc metal concentrates prior to export. The site has been the subject of contaminated sites investigations and remediation, refer to Section 4.3.7.1.

### *4.3.10.2 Conservation Significant Fauna*

A search of the following databases was undertaken over the Derby Port Development Envelope and transhipment vessel transport route to determine conservation significant coastal fauna species that may occur in the area:

- *WC Act* & DPaW Threatened and Priority Fauna Database using a polygon shown in Appendix 15.
- *EPBC Act* Protected Matters Search including 0.5 km buffer as shown in Appendix 16.
- Naturemap database (DPaW 2016a).

In addition to the species found in these database searches, other species of conservation significance were identified from searches of the scientific literature. Most of the species identified during the database searches are marine and migratory fauna and these are discussed in Section 4.3.14.2.

Twelve terrestrial bird species and two terrestrial mammal species were identified in the searches as potentially occurring within the Derby Port Development Envelope. Of these, eight species are listed as Threatened under the *EPBC Act*, Vulnerable or Endangered under the *WC Act*, or listed as a Priority species by DPaW. These species have been termed 'conservation significant' species and are shown in Table 29.

Suitable habitat for most of these species is limited in the Derby Port Development Envelope, indicating most of these species are unlikely to be residents or regular visitors in the area.

**Table 29: Conservation Significant Species Potentially Occurring Within Derby Port Development Envelope**

| Species | Conservation Status | | | Habitat | Likelihood of Occurrence | Recorded |
|---|---|---|---|---|---|---|
| Common Name | EPBC Act | WC Act | DPaW | | | |
| **Birds** | | | | | | |
| Gouldian Finch *Erythrura gouldiae* | E | - | P4 | Rocky hills with smooth-barked gums within 2 km to 4 km of permanent freshwater (O'Malley 2006). | Medium – Possible foraging habitat | No |
| Grey Falcon *Falco hypoleucos* | - | T(V) | - | Inland drainage systems with an average annual rainfall <500 mm. Prefers timbered lowland plains (especially those that are acacia-dominated) which are interspersed with tree-lined watercourses (Johnstone and Storr 1998). | Low – lack of suitable habitat | No |
| Letter-winged Kite *Elanus scriptus* | - | - | P4 | Extreme population fluctuations linked to rat populations. In years of rat plague, the kite may be found around many parts of the country. Normal range is the Coopers Creek drainage system (Birdlife 2016). | High – only in rat plague years | Yes (Birdlife 2016) |
| Princess Parrot, Alexandra's Parrot *Polytelis alexandrae* | V | - | P4 | Occurs in swales between sand dunes and sand flats in the arid zone of western and central Australia; open savanna woodlands and shrublands. (Garnett and Crowley 2000). | Low – lack of suitable habitat | No |
| Purple-crowned Fairy-wren *Malurus coronatus subsp. coronatus* | E | T(E) | - | Only found in northern Australia. Inhabits dense, riparian vegetation in the wet-dry tropics of Western Australia and the Northern Territory. Mangrove habitat not utilised. Now locally extinct in the lower Fitzroy River catchment (Rowley 1993). Does not utilise mangrove habitats (DoE 2016). | Low – locally extinct | No |
| Red Goshawk *Erythrotriorchis radiatus* | V | T(V) | - | Coastal and sub-coastal tall, open forests and along edges of rainforests. Infrequently immature birds use mangroves. Nests in trees >20 m (Garnett et al. 2011; DoE 2016). | Medium – Possibly immature birds | No |
| **Mammals** | | | | | | |
| Northern Quoll *Dasyurus hallucatus* | E | T(E) | - | Rocky habitats that provide for den sites. Tidally flooded mangrove areas are not used (DoE 2016). | Low – rocky habitats not present on the reclaimed land at the Port | No |
| Water Mouse, False Water Rat *Xeromys myoides* | V | - | - | Mangroves and associated marshlands, sedgelands, clay pans, heathlands and freshwater wetlands (DoE 2016). | Medium – possibly present in low numbers | No |

*Legend:* T – Threatened; V – Vulnerable; E – Endangered; P – Priority list; '-' No classification

## 4.3.11 Physical Marine Environment

Derby is located at the head of King Sound, which is a large embayment (approximately 130 km long and 40 km wide). The Buccaneer Archipelago lies between the opening of King Sound and the open ocean. Bulk product export is proposed to occur from Derby Port, via transhipment to a sea transfer point near Point Torment, and then across King Sound to the open ocean.

The open water area of King Sound is approximately 2,325 $km^2$ and the intertidal salt and mud flats occupy 209 $km^2$. Supra-tidal salt flats occupy 590 $km^2$ and are inundated at the highest spring tides in summer. Mangroves occupy an area of 165 $km^2$ between the intertidal and supra-tidal zones (Wolanski and Spagnol 2003). The Fitzroy River, one of Australia's largest river systems, flows into King Sound and affects the water quality in King Sound.

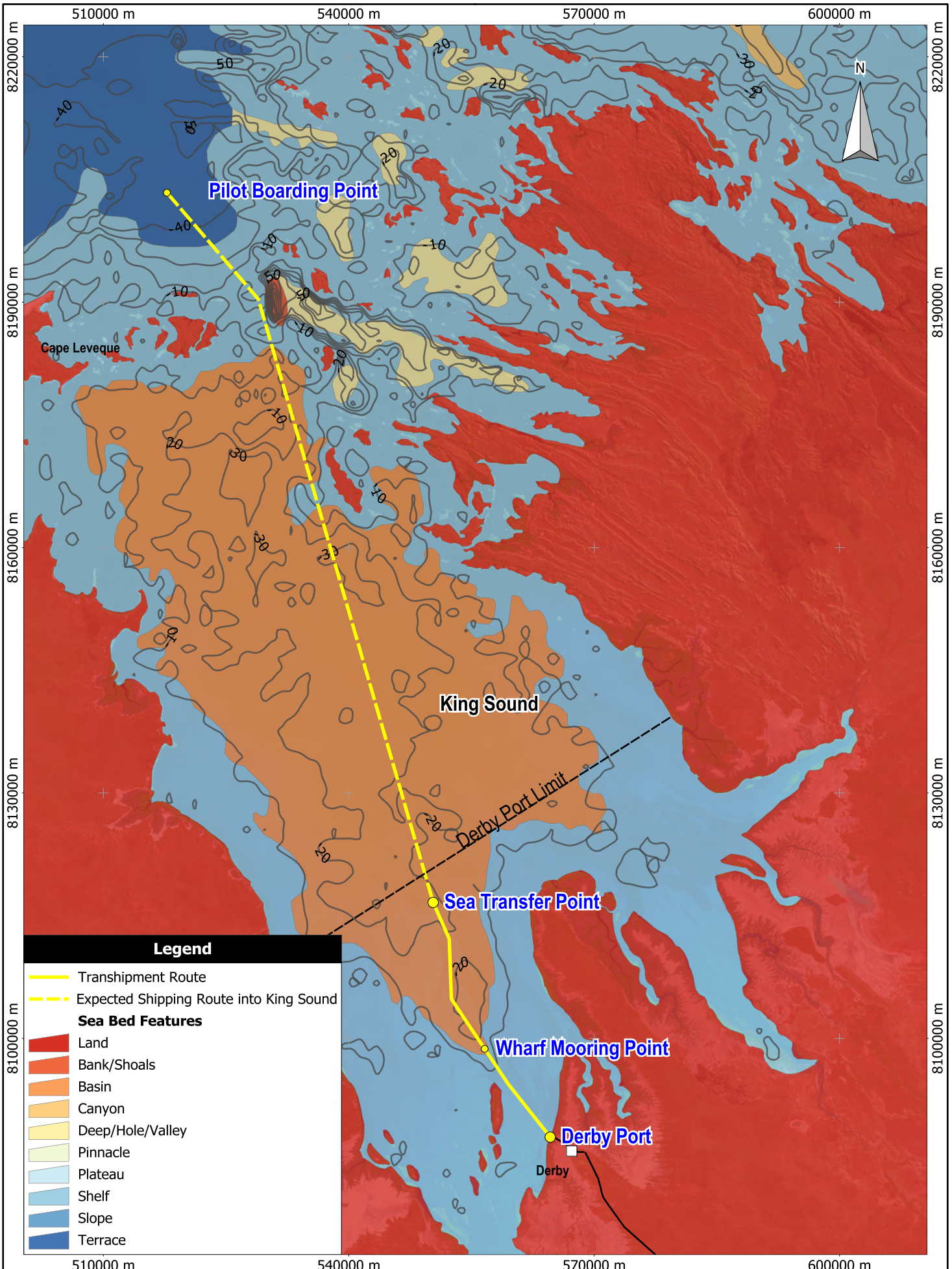
In the dry season, the water of King Sound is vertically well mixed in both temperature and salinity. High evaporation levels cause the maximum salinity to occur in the upper reaches of the Sound (Wolanski and Spagnol 2003).

The existing regional marine environment of King Sound has been characterised in the following sub sections.

### *4.3.11.1 Bathymetry*

Within the Port Limits, King Sound is relatively shallow at around 15 m deep at the wharf mooring zone and around 20 m deep at the sea transfer point (measured at the lowest astronomical tide). From Derby Wharf to the wharf mooring zone, the sea bed consists of a gently sloping plateau, with the seafloor at Derby Wharf being exposed at low tide.

Beyond the Port Limits, the depth of water increases to 30 m in certain points. Deeper areas from 15 m to 30 m are described as basins. Beyond Sunday Strait near the Pilot Boarding Point, the depth increases to 40 m to 50 m and the seafloor feature in this area is terraced.
Figure 40 shows the seafloor features and the bathymetry of King Sound.




Scale: 1:600000
Original Size: A4
Aerial Photo Date: 2016
Aerial Photo Source: Copernicus Sentinel Data
Grid: MGA94(51)
0 10 km

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Thunderbird Mineral
Sands Project

**Figure 40**

**Seafloor Features**

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#### *4.3.11.2 Tidal Movement*

King Sound is a highly dynamic environment and has one of the world's largest tidal ranges of almost 12 m (Table 30). Tides within King Sound are semi-diurnal with a full tidal cycle of approximately 12.5 hours.

Extreme high tide events can leave parts of the Port area inundated, while extreme low tide events can expose the sea bed below the wharf. The tides have been a significant constraint on historical shipping operations from Derby Port, limiting berthing time at the wharf to between six and seven hours.

There are no historical records of a significant storm surge at Derby. The large tidal variations and low probability of a significant cyclone over King Sound results in a low chance of a significant storm tide (BOM 2016a). However, the worst possible scenario of a severe cyclone arriving at high tide and coinciding with floodwaters from the Fitzroy and other rivers into King Sound would likely inundate the Derby townsite. This extreme scenario has a very low probability of occurring (BoM 2016c).

**Table 30: Astronomical tides and heights for Derby**

| Tide | Height (m) |
|---|---|
| Highest astronomical tide | 11.8 |
| Mean spring high tide | 9.7 |
| Mean neap high tide | 5.4 |
| Mean neap low tide | 3.5 |
| Mean spring low tide | 0.5 |
| Lowest astronomical tide | 0.0 |

Tidal currents in King Sound reach velocities of 1.5 m/s to 2.0 m/s in open water, and 3 m/s or more in narrow tidal creeks, generally during ebbing spring tides (Semeniuk 1980). Waves in the dry season are up to 1.5 m high when the wind and tide are in opposite directions (Wolanksi and Spagnol 2003).

#### *4.3.11.3 Marine Water Quality Parameters*

As part of the Derby Storage Facility Baseline Contamination Assessment (see section 4.3.7), marine water samples were collected near the boat ramp at the site known as DER BR1 (Appendix 14). Water samples were analysed for dissolved metals and general parameters such as pH, electrical conductivity, and total dissolved solids.

Estuarine tidal water sampled at the public boat ramp located to the immediate west of the proposed storage facility indicate no results above the ANZECC and ARMCANZ (2000) EIL trigger values with dissolved metals and metalloids very low, and mostly below laboratory limits of reporting (including for lead, zinc, copper and nickel). As expected for the silt laden waters of this estuary area, the turbidity (62 nephelometric turbidity units) and suspended solids (89 mg/L) were very high. Other general parameters of salt content and salt composition are consistent with typical seawater. Dissolved uranium was observed at a concentration of 0.0035 mg/L, which is consistent with the value reported by Miyake et al. (1966) (as cited in MBS 2016c) of 0.0033 mg/L for seawaters of the western north Pacific (MBS 2016).

A comparison of analytical results for the water sample collected at the boat ramp with ANZECC 2000 EIL trigger values is provided in Table 31.

**Table 31: Marine Water Analysis Results**

| Analyte | Units | DER BR1 | ANZECC 2000 Marine Trigger Value |
|---|---|---|---|
| Ag | mg/L | <0.0010 | 0.0014 |
| Al | mg/L | <0.005 | N/G |
| Alkalinity | mg/L | 129 | N/G |
| As | mg/L | <0.010 | N/G |
| Carbonate | mg/L | <1 | N/G |
| Calcium | mg/L | 423 | N/G |
| Cadmium | mg/L | <0.0010 | 0.0007 |
| Chloride | mg/L | 19500 | N/G |
| Cobalt | mg/L | <0.0010 | 0.001 |
| Chromium | mg/L | <0.001 | 0.027 |
| Copper | mg/L | <0.0010 | 0.0013 |
| EC | mS/m | 5350 | N/G |
| Fe | mg/L | <0.005 | N/G |
| Bicarbonate | mg/L | 157 | N/G |
| Potassium | mg/L | 447 | N/G |
| Magnesium | mg/L | 1240 | N/G |
| Manganese | mg/L | 0.017 | N/G |
| Molybdenum | mg/L | 0.014 | N/G |
| Sodium | mg/L | 11800 | N/G |
| Nickel | mg/L | <0.010 | 0.007 |
| Lead | mg/L | <0.0010 | 0.0044 |
| Sulfate | mg/L | 2800 | N/G |
| Selenium | mg/L | <0.010 | N/G |
| TSS | mg/L | 89 | N/G |
| Thorium | mg/L | <0.0010 | N/G |
| Titanium | mg/L | <0.002 | N/G |
| Turbidity | NTU | 62 | N/G |
| Uranium | mg/L | 0.0035 | N/G |
| Vanadium | mg/L | 0.0036 | N/G |
| Zinc | mg/L | <0.005 | 0.015 |
| Zirconium | mg/L | <0.002 | N/G |
| pH | pH Units | 8 | N/G |

*N/G indicates no guideline value is applicable. NTU are nephelometric turbidity units.*

In a study by McAlpine *et al.* (2012) outside of King Sound, it was concluded that the waters are usually clear and that the marine waters of the Kimberley are generally of very high quality. The concentrations of metals across the region were relatively low at the time of sampling and met the guideline trigger values from ANZECC and ARMCANZ (2000) for a very high level of ecological protection. The nearest survey site to the proposed project infrastructure was in the Sunday Strait. The total suspended solids on the surface and bottom at this site were 1 and 2 mg/L respectively. The study also indicated that cobalt may be naturally elevated in some Kimberley coastal waters.

#### *4.3.11.4 Sediment*

The sediments in King Sound are mostly of Precambrian and upper Palaeozoic rocks such as sandstones, granite, and porphyritic volcanics. Mean particle size in the Fitzroy Estuary is approximately 1 mm with a maximum grain size of 20 mm (Gellatly 1970 cited in MScience 2011). See Section 4.3.7 for discussion on contamination of marine sediments.

#### *4.3.11.5 Fitzroy River Discharge*

The Fitzroy River contributes the most discharge to King Sound. The river has a catchment of around 90,000 $km^2$ and flows for approximately 733 km from the King Leopold and Mueller Ranges into King Sound. Upstream at Fitzroy Crossing, the river has an average annual flow of 6,150 GL/year making it the largest river in Western Australia in terms of annual flow. During the dry season, the river can cease to flow altogether (Ruprecht and Rodgers cited in Morgan *et al.* 2004).

As a result of its variable flow, discharge from the Fitzroy River is also highly variable thought the year. Discharge is minimal during eight months of the year in the dry season, with nil flow recorded in June to November 1987 (Wolanksi and Spagnol 2003). In the wet season, flows have been recorded up to 30,000 $m^3/s$ (in April 1983), and can be highly unpredictable, with 70-90% of the rainfall and runoff occurring between January and March.

Turbidity within the Fitzroy River can exceed 1,000 nephelometric turbidity units in the wet season.

#### *4.3.11.6 Turbidity Processes*

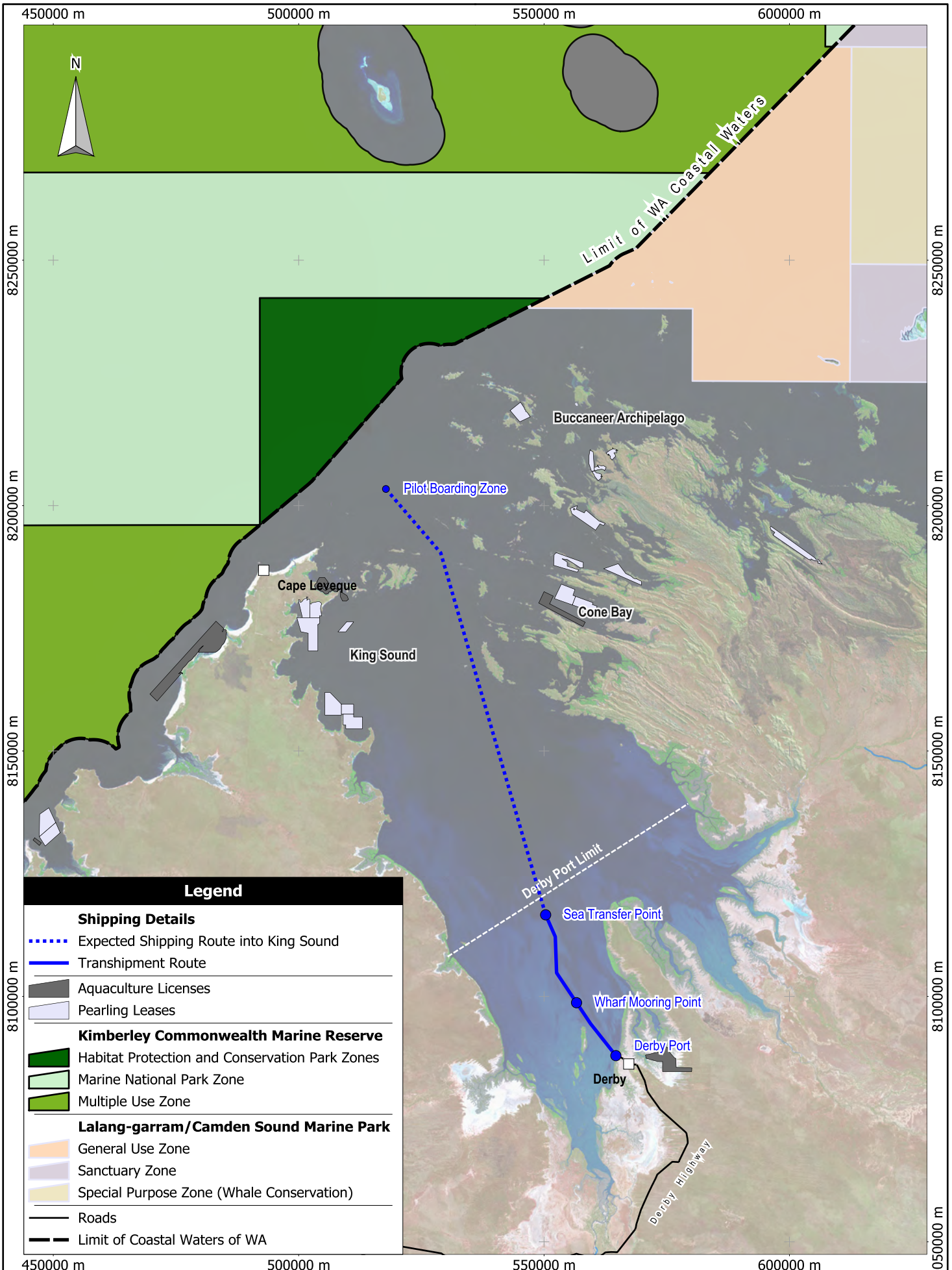
The upper reaches of King Sound are naturally high in turbidity, primarily as a result of Fitzroy River discharge, with suspended solids concentrations reaching 3 $kg/m^3$. The turbidity maximum is in the upper reaches (southern) and shallow part of the Sound, even in the dry season when inputs from the Fitzroy River are minimal. Based on the limited data available for sediment loading of the river, it is estimated the Fitzroy River transports 10 to 15 million cubic metres of sediment into the upper reaches of King Sound per year (Ruprecht and Rodgers (in prep) cited in MScience 2011).

There are several other processes that contribute to the turbidity maximum occurring in the southern part of the Sound, including wind-driven waves, evaporation-driven elevated salinity and stratification, tidal pumping due to asymmetrical tides (stronger currents on flood tides than ebb tides), and muddy marine snow formed further seaward in the Sound and pushed shoreward by tidal pumping Despite the huge tidal range and flushing, fine sediment does not easily escape King Sound (Wolanksi and Spagnol 2003).

### 4.3.12 Existing Regional Marine Uses

#### *4.3.12.1 Aquaculture and Pearling*

The northwest of King Sound, and the islands and bays of the Buccaneer Archipelago to the northeast of King Sound, support a cultured pearl industry and several aquaculture operations. Cone Bay hosts several pearling sites as well as the Kimberley Aquaculture Development Zone (KADZ). The KADZ is a 2,000 hectare area of water that has been pre-approved by the Department of Fisheries for the development of aquaculture. The zone presently includes a finfish aquaculture facility that is licensed to produce up to 15,000 tonnes per annum of barramundi or other local finfish in floating sea cages, located approximately 90 km north of Derby Port (DoF 2013; Fletcher and Santoro 2015). An indigenous project at One Arm Point features a marine hatchery for ornamental and edible marine species. In addition, Kimberley Prawn Farm holds a licence from the Department of Fisheries for the culture of prawns in ponds near Doctors Creek, although this is not currently operational. Figure 41 shows the location of existing aquaculture and pearling operations.




Scale: 1:1000000
Original Size: A4
Image: Geoscience Australia LS7 2007
Grid: MGA94(51)
0 20 km

Sheffield Resources Limited
Thunderbird Mineral Sands Project

**Figure 41**

**Existing Regional Marine Uses**

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MBS ENVIRONMENTAL

#### 4.3.12.2 Fishing

Five commercial fishers (four of which were active in the 2014/15 season) hold licenses within the Kimberley Gillnet and Barramundi Fishery, which includes the waters of King Sound and other areas in the north coast bioregion (Fletcher and Santoro 2015). Species caught in this fishery are almost all Barramundi (*Lates calcarifer*), King Threadfin (*Polydactylus macrochir*) and Blue Threadfin (*Eleutheronema tetradactylum*), with 44.2 tonnes of Barramundi and 23.4 tonnes of the two Threadfin species caught in the 2014 fishing year. Small quantities of sharks and rays and other species were reported as bycatch and interaction was reported with one crocodile and 17 Sawfish, with all but one Sawfish reportedly released alive.

The Northern Shark Fishery was closed permanently in 2009 and trawling for fish or prawns is permanently prohibited in King Sound and the surrounding rivers. Other fisheries that may utilise the waters of King Sound or the Buccaneer Archipelago include the Broome Prawn Fishery, the Mackerel Fishery, and the Northern Demersal Scalefish Fishery. There are three emerging fisheries in the area, with several Ministerial Exemptions being issued for the collection of Beche-de-mer, Trochus, and Mud Crab species.

Recreational fishers in King Sound also target Barramundi and Threadfin species. In the north coast bioregion in 2011/12, recreational catches amounted to 8.4 tonnes of Barramundi and 7.0 tonnes of Threadfin species (Fletcher and Santoro 2015).

#### 4.3.12.3 Tourism

The tourism industry utilises the Derby Port and the wider King Sound area. A small number of tour operators run boat tours including mud crab and barramundi fishing tours, and multi-day boat excursions to the Buccaneer Archipelago operate from April to October. Tours range from four to 12 days and villaging or live-aboard options are available. Air charters and seaplane tours run all year depending on demand and weather; scenic flights visit the tidal phenomenon of the "horizontal falls", and usually the Buccaneer Archipelago (Derby Tourism 2016).

#### 4.3.12.4 Resources

Presently there are no resource projects utilising the Derby Port on a regular basis. The Cockatoo Island and Koolan Island operations previously utilised the Port; however both of these projects have ceased operations and have been placed in care and maintenance, with the Port occasionally utilised for movement of supplies.

#### 4.3.12.5 Shipping

Shipping in the Kimberley is a well-established industry, supporting exports from mining and agricultural industries. The main ports in the Kimberley are Broome and Wyndham, both of which receive ocean-going vessels. Ocean-going vessels do not currently visit the Derby Port, although smaller vessels berth on a regular basis. The number of vessels using Derby Port has dropped to an estimated 120 per year following cessation of mining at Koolan and Cockatoo Islands, with the current vessels being mostly those that support the aquaculture and tourism industries (R. Sullivan, Shire of Derby/West Kimberley, pers. comm.). The total estimated number of ships utilising Kimberley waters per year is approximately 1,500 (Table 32).

**Table 32: Numbers of vessels utilising Kimberley Waters 2014/15**

| Port | Number of Vessels 2014/15 Financial Year^ | Reference |
|---|---|---|
| Broome | 1,126 | Kimberley Ports Authority, 2016. |
| Wyndham | 121 | G. Taylor, CGL Wyndham Port Ltd, pers. comm. |
| Derby | 268* | R. Sullivan, Shire of Derby/West Kimberley, pers. comm. |
| **Total** | **1,515** | |

^ *Excluding private recreational vessels not using port facilities.* * *Only smaller tourist vessels and barges*

#### *4.3.12.6 Marine Reserves*

Both State and Commonwealth marine reserves exist in the region, although these are well outside King Sound. The Lalang-garram/Camden Sound Marine Park was created in 2012 under Section 13 of the *Conservation and Land Management Act 1984* about 150 km north of Derby. The subtidal portion of the marine park has been proclaimed and covers an area of approximately 673,000 ha. Within the marine park, various zones have been established including sanctuary zones, special purpose zones (for whale conservation, wilderness and pearling), and general use (DPaW 2013).

Beyond Western Australian coastal waters, the Commonwealth has established the Kimberley Commonwealth Marine Reserve. This reserve covers a total area of 74,469 km$^2$ and includes a habitat protection zone of 1,129 km$^2$ (DSEWPC 2012b). Figure 41 shows the two marine protected areas in relation to King Sound.

### 4.3.13 Benthic Primary Producer Habitat

Benthic primary producer habitats are functional ecological communities that inhabit the seabed within which algae, seagrass, mangroves, corals, or mixtures of these groups are prominent components. Benthic primary producer habitats also include areas of seabed that can support these communities. Benthic primary producer habitats play important roles in maintaining the integrity of marine ecosystems and the supply of ecological services (EPA 2009b).

#### *4.3.13.1 Mangroves*

Mangrove communities (mangals) in the Kimberley region display a very high degree of intactness (EPA 2009b). Mangrove forests are the most important benthic primary producers in the wider Derby Port area.

At Derby Port, vegetation surrounding the proposed storage facility is dominated by mangals that lie in a 500 m wide band between the open water of King Sound and extensive saline mudflats.

Approximately 165 km$^2$ of intertidal mangal habitat occurs within King Sound. In general, around the coastline of King Sound, *Avicennia* dominates the seaward zone, *Rhizophora* the middle zone and *Ceriops* the landward zone. Inland of the intertidal mangals are extensive saline mud flats which are bare and vary from two to four kilometres in width. They are inundated at high spring tide and after heavy rainfall. Where these mud flats extend above the level of the spring high tides, they form grassy or samphire flats (Semeniuk 1980).

Eleven mangrove species are known to occur around King Sound, none of which are conservation significant (Table 33).

**Table 33: Mangrove Species at King Sound**

| Common Name | Scientific Name | Relative Abundance |
|---|---|---|
| Club Mangrove | *Aegialitis annulata* | Common |
| River Mangrove | *Aegiceras corniculatum* | Common |
| White Mangrove | *Avicennia marina* | Abundant |
| Ribbed Mangrove | *Bruguiera exaristata* | Uncommon |
| Smallflower Bruguiera | *Bruguiera parviflora* | Uncommon |
| Kapok Mangrove | *Villagetostemon schultzii* | Common |
| Spurred Mangrove | *Ceriops tagal* | Common |
| Milky Mangrove | *Excoecaria agallocha* | Uncommon |
| Myrtle Mangrove | *Osbornia octodonta* | Uncommon |
| Spotted-leaved Red Mangrove | *Rhizophora stylosa* | Common |
| Cedar Mangrove | *Xylocarpus australasicus* | Uncommon |

*Source: Semeniuk (1980)*

**Derby Port**

The mangroves of King Sound form associations or communities and are commonly found in predictable groups of species. Johnstone (1990) studied mangrove associations around Derby Port and reported the mangals grow on a long sloping grey mudbank, which assists them to form well-defined belts. On the seaward zone is a thin belt of *Avicennia*. Proceeding landward there is a band of *Villagetostemon*, *Aegialitis*, *Aegiceras* and *Rhizophora* and in many places these are mixed. In some places *Rhizophora* is the only species. The landward zone consists of mainly of *Ceriops* and *Avicennia*, with saline flats found on the landward side of the mangal.

**Point Torment**

On the northeastern side of Point Torment at Stokes Bay, Johnstone (1990) reported a wide belt of mangroves growing in dark grey mud cut through by many small creeks. The mangals run parallel to the coast and have well defined zonation. The seaward side of the main creeks have the most complex marginal vegetation, with communities of *Rhizophora, Villagetostemon* (along the creeks)*, Bruguiera exaristata, Avicennia and Aegiceras*. On the landward side, the tributaries are more numerous and the marginal vegetation is less diverse, mainly *Avicennia* and *Bruguiera* with some *Ceriops, Villagetostemon* and *Rhizophora*. Closest to the land, the belts consist mostly of scattered *Avicennia*, *Excoecaria* and *Osbornia*, and thickets of *Ceriops*. Landward of the mangal are samphire flats with *Sporobolus virginicus* and landward of this is a belt of *Melaleuca acaciodes*.

#### *4.3.13.2 Other Benthic Primary Producers*

Seagrasses require high levels of light penetration in order to conduct photosynthesis. High turbidity is known to impede access to light and therefore the growth of seagrasses in tropical waters (Chartrand *et al*. 2012). In colder waters of Australia, seagrasses are known to occasionally inhabit waters as deep as 45 m. In northern Australia where environments can be extreme, this depth limit is likely to be less. Studies show that large tidal movements, natural turbidity, oceanic swells, or freshwater runoff in the wet season reduce the diversity and extent of seagrasses. Seagrasses in the north of Western Australia only occur sparsely in between coral reef environments or in lagoonal areas where water ponds at low tide (Green and Short 2003). Some areas in the Kimberley are known for high diversity and abundance of seagrasses, with the closest site being One Arm Point (McKenzie and Yoshida 2013). One Arm Point is a shallow site, characterised by much lower turbidity than conditions found in King Sound.

Inshore areas of King Sound are not likely to support seagrasses, as they experience extremely high turbidity levels and large tidal movements. At the pilot boarding point, although the water is less turbid, the water is 40 m - 50 m deep. This depth affects light attenuation, and combined with the extreme tidal fluctuations is likely to prohibit the growth of seagrasses at this point.
Figure 40 shows the seafloor, relative depths of the water in King Sound and the pilot boarding point.

Coral reefs are known to be a diverse and important form of benthic primary producer habitat. Coral reefs usually develop in clear, nutrient poor, shallow waters in tropical oceans. The zooxanthellae algae within the coral polyps require sunlight for photosynthesis to occur. In areas where the water is exceptionally clear, corals have been known to occasionally grow to a depth of 60 m (WA Museum 2016). However, it is noted that the most productive growing depths for coral reefs is 18 m - 27 m (Coral Reef Systems 2016). The high turbidity inside King Sound precludes the growth of corals. The 40 m – 50 m depth at the pilot boarding point prevents the growth of significant amounts of coral at this point (see
Figure 40).

At Cone Bay (to the east of the entrance to King Sound), the Department of Fisheries (2013) found minimal seagrasses and corals grow on mostly bare, sandy, fine to coarse sediments. It is thought that the scarcity of benthic primary producers in this area is due to the lack of hard substrate and the lack of available light due to the relatively high levels of turbidity (DoF 2013). The seafloor at the pilot boarding point may be broadly similar to Cone Bay, and although seagrasses and corals are unlikely to be present, benthic invertebrate and burrowing organism habitat could potentially be present.

## 4.3.14 Marine Fauna

A search of the following databases was undertaken over the Derby Port Development Envelope and vessel routes to determine marine fauna species that may occur in the area:

- *WC Act* & DPaW Threatened and Priority Fauna Database using a polygon as shown in Appendix 15.
- *EPBC Act* Protected Matters Search Tool as shown in Appendix 16.
- Naturemap database (DPaW 2016a).

In addition to the species found in these database searches, other species of conservation significance were identified through searches of scientific literature.

For the marine and migratory species, a total of 40 birds, 32 fish (including sharks and rays), 16 mammals and 22 reptile species were identified during the database searches. Most of the species are common and well represented in the region.

### *4.3.14.1 Species of Particular Concern*

Species of particular concern to the project include the following, all of which were raised by DoEE during preparation of the Environmental Scoping Document, but were not listed as part of the *EPBC Act* 'Controlled Action' decision:

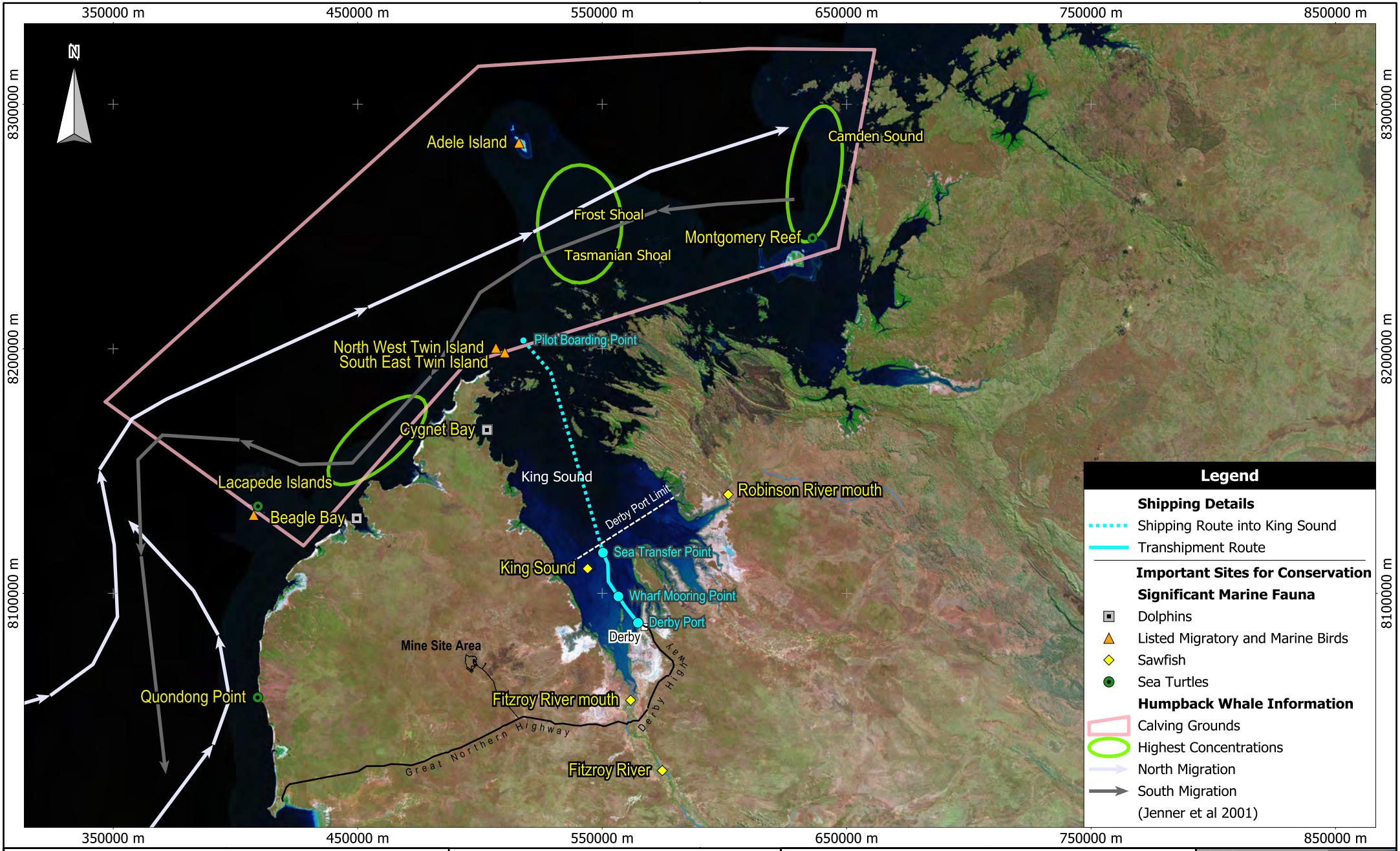
- Humpback Whale (*Megaptera novaeangliae*) – listed as Vulnerable under the *EPBC Act*.
- Dwarf Sawfish (*Pristis clavata*) – listed as Vulnerable under the *EPBC Act.*
- *Green Sawfish (Pristis zijsron) – listed as Vulnerable under the EPBC Act*.
- Largetooth Sawfish (*Pristis pristis*) – listed as Vulnerable under the *EPBC Act.*
- Northern River Shark (*Glyphis garricki*) – listed as Endangered under the *EPBC Act*.

**Humpback Whale**

The Humpback Whale is known to occur in significant numbers in the Kimberley region. Whales migrating up the west coast of Australia belong to a distinct population (Group IV population) to those occurring on the east coast of Australia (Group V population). The total number of whales in the Group IV population is estimated to be 21,750 (Hedley *et al*. 2008), although only a small proportion of these pass the mouth of King Sound each year between the months of July and November on their south/north migration to calving grounds. Humpback Whales do not use King Sound as a calving ground and the area is not part of the whale migration path.

Humpback whale calving grounds occur from Broome to north of Camden Sound, with the greatest concentration of calving whales found near Camden Sound (Jenner *et al*. 2001). Camden Sound is considered the most important Humpback calving site in the southern hemisphere, and the State and Commonwealth waters in the area are protected by marine reserves. Both include habitat protection areas in recognition of the importance of the area to whales (DPaW 2013; DoEE 2016c).

The Group IV population mostly favours a fixed migration route known as the 'whale highway', which tends to follow the series of shelf-edge canyons that occurs off the west coast. Most whales appear to prefer the 20 m depth contour (Hedley *et al*. 2008; SoE 2011). Most whales on their north and south-bound migration pass to the west of the Lacepede Islands to avoid the shoals inshore and a substantial number also pass further offshore (Double *et al*. 2010). When heading north from the Lacepede Islands, most whales remain offshore, pass the mouth of King Sound, and aggregate at the Frost and Tasmanian Shoals. These shoals are most likely used as staging grounds where whales wait for the right tidal conditions to proceed to or from Camden Sound. Figure 42 shows the areas of highest concentration of whales and main migration routes used by Humpback Whales in the region (Jenner *et al.* 2001).




Scale: 1:2000000
Original Size: A4
Image: Geoscience Australia LS7 Mosaic 2007
Grid: MGA94(51)

0 50 km

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**Figure 42**

**Important Habitat for Conservation Significant Marine Fauna**

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W:\Sheffield Resources\PER\Drawings\PER Derby Port.map 21/12/2016 F42 Important Habitat for Conservation Significant Marine Fauna Map Layout

### Sawfish and Sharks

Sawfish are shark-like rays, and three species are known to occur in the King Sound area: Dwarf Sawfish (*Pristis clavata),* Green Sawfish (*P. zijsron)* and Largetooth Sawfish *(P. pristis).* All of these Sawfish are considered Vulnerable under the *EPBC Act*, with breeding likely to occur in the area (DoE 2015a). The Dwarf Sawfish is also listed as Priority 1, and the Largetooth Sawfish as Priority 3 by DPaW. The Green Sawfish is listed as Vulnerable under the *WC Act*. All three species of Sawfish and the Northern River Shark are also protected under the *Fish Resources Management Act 1994*.

The main threats to the Sawfish are associated with bycatch from commercial fishing using nets and entanglement in marine debris. The barbed rostrum and inshore and estuarine habitat preferences of the Sawfish mean they are sometimes caught as bycatch by fishers targeting Barramundi or King Salmon, however the impact of recreational fishers on the species is currently unquantified (DoE 2015b). Habitat modification caused by developments in the Sawfish species' range may also represent a threat, but to date these have been of lesser concern than fishing (DoE 2015b). Threats to Sawfish also include the shark-fin trade, which is known to occur within Australian waters, and collection of the rostrums as curios.

### Dwarf Sawfish

The Dwarf Sawfish is found in tropical waters of Australia from south of Port Hedland to eastern Cape York Peninsula (DoE 2015b). It prefers habitats of 2-3 m depth in coastal and estuarine waters and does not use any purely freshwater habitats. Thorburn *et al.* (2007a) studied Dwarf Sawfish in King Sound and several of the Sound's river estuaries. They determined that estuarine, and possibly brackish habitats in the Fitzroy River, are used as nursery areas and juveniles may stay in these areas until three years of age. Stevens *et al.* (2008) found the Dwarf Sawfish had limited daily movements and a range of only a few square kilometres. Its movements are influenced by the tides, with high tide being spent resting in inundated mangroves and on a moving tide they are active, presumably feeding. No habitat suitable for the species is located within the Mine Site Development Envelope.

### Green Sawfish

The Green Sawfish was historically found throughout the Indian Ocean to South Africa and Indonesia, however the species' range is now considered to be much reduced. In Australia, the species currently occurs from Shark Bay in Western Australia to the Whitsundays in Queensland and it utilises marine and estuarine waters, but not freshwater (Harry *et al.* 2011; Stevens *et al.* 2005). In a recent paper by Morgan *et al.* (2015), a large influx of Green Sawfish pups was reported for the Ashburton Estuary in the Pilbara. The authors speculate this may be the most important nursery area for the species globally. As with the Dwarf Sawfish, Stevens *et al.* (2008) found the movements of the Green Sawfish to be tidally influenced. The Green Sawfish swim towards mangroves on the incoming tide and away from mangroves on the outgoing tide. The species is thought to be long lived, reaching maturity at around nine years of age, and reaching 95% of its maximum size at 24 years of age (Stevens *et al.* 2005). It is a species of low fecundity, which contributes to its Vulnerable status under the *WC Act*. No habitat suitable for the species is located within the Mine Site Development Envelope.

### Largetooth Sawfish

The Largetooth Sawfish, previously known as the Freshwater Sawfish (*Pristis microdon)*, is the largest of the three species of Sawfish found in the Kimberley (DoE 2015a). Its range in Australian waters is from Port Hedland in WA to Cooktown on the Cape York Peninsula in Queensland (DoE 2015b). The freshwaters of the Fitzroy River are a nursery for this species, with immature fish remaining in the river until up to five years of age. This is the only species of Sawfish to utilise purely freshwater habitats and it has been found up to 400 km inland (DoE 2015b). Mapping of potential habitat of the species shows juveniles may occur in the wet season in Fraser River and Fraser River South, the headwaters of which are around 4 km from the Mine Site. As the fish matures, it is found in estuarine and marine habitats including King Sound (Thorburn *et al*. 2007b). It has a worldwide distribution, although Australia may be the last viable population stronghold (DoE 2015a).

**Northern River Shark**

The Northern River Shark (*Glyphis garricki*) is known from King Sound in the west to the Northern Territory, west of the Gulf of Carpentaria and may potentially use King Sound as a pupping ground (DoE 2015b). The Northern River Shark is found only in Australia and Papua New Guinea. Juveniles may occupy freshwater habitats and adults are found in estuarine and marine habitats (Pillans *et al.* 2009). Males of the species are thought to mature at 14 years of age, and females at 17 years. Life expectancy is predicted to be more than 25 years (Stevens *et al.* 2005). Threats to the shark include commercial gill-net fishing, with the shark being recorded in the bycatch in the Kimberley Gillnet and Barramundi Fishery and recreational fishing (Fletcher and Santoro 2015). Habitat modification, such as restriction of tidal flow or damming of preferred rivers is also of concern for the species.

#### *4.3.14.2 Threatened, Migratory and Marine Species*

Several marine species are listed as Threatened or Migratory under the *EPBC Act*, Vulnerable or Endangered under the *WC Act* or listed as a Priority species by DPaW. These species have been termed 'conservation significant' species.

A summary of Marine and Migratory fauna of conservation significance with potential to occur within and around the Derby Port Development Envelope or the transhipment route is provided in Table 34. Of the 20 conservation significant species identified in the searches, there are four birds, seven reptiles, six sharks and three mammals. Important habitat for these species is illustrated in Figure 42.

**Table 34: Threatened Marine and Migratory Fauna – King Sound**

| Species | Conservation Status | | | Habitat | Likelihood of Occurrence | Recorded |
|---|---|---|---|---|---|---|
| Name | EPBC Act | WC Act | DPaW | | | |
| **Birds** | | | | | | |
| Australian Painted Snipe *Rostratula australis** | E | T(E*) | - | Cryptic and scarce species generally inhabiting ephemeral, seasonal or temporary wetlands. Records for western part of Dampier Peninsula, but most records are in eastern Australia (Birdlife 2016). | Medium – possible | No |
| Curlew Sandpiper *Calidris ferruginea* | CE, M | T(V) | - | Occurs around the coast on intertidal mudflats in sheltered coastal areas, such as estuaries, bays (DoE 2016). | High Recorded previously, non-breeding. | Yes (Birdlife 2016) |
| Eastern Curlew *Numenius madagascariensis* | CE, M | T(V) | | Primarily has coastal distribution in non-breeding range. Roosts on sandy spits and islets, especially on dry beach sand near the high-water mark (DoE 2016). | High Recorded previously, non-breeding. | Yes (Birdlife 2016) |
| Lesser Sand Plover *Charadrius mongolus* | - | T(E) | - | Feeds mostly on extensive, freshly-exposed areas of intertidal sandflats and mudflats in estuaries or beaches. Roost near foraging areas, on beaches, banks and spits (DoE 2016). | High Recorded previously, non-breeding. | Yes (Birdlife 2016) |
| **Reptiles** | | | | | | |
| Flatback Turtle *Natator depressus* | V, M | T(V) | - | Recorded from King Sound and known to feed in shallow, turbid waters. Unpublished account of nesting at Point Torment (R.I. Prince, pers. comm. cited in SWOT 2009). Not expected to be a major nesting site. | High Often found in turbid waters | Yes (NatureMap, DPaW Threatened Fauna Search 2016). Recorded outside of Port Limits on eastern side of King Sound. |
| Green Turtle *Chelonia mydas* | V, M | T(V) | - | Pelagic for first 5-10 years and then prefers shallow benthic foraging habitats such as coral and rocky reef habitat or inshore seagrass beds. Neither of these habitats occurs in King Sound. Uncommon in King Sound, but common at offshore islands of the Kimberley (DoE 2016). | Medium Outside King Sound. | Yes (NatureMap, DPaW Threatened Fauna Search 2016). Sighted near Port. |

| Species | Conservation Status | | | Habitat | Likelihood of Occurrence | Recorded |
|---|---|---|---|---|---|---|
| Name | EPBC Act | WC Act | DPaW | | | |
| Hawksbill Turtle *Eretmochelys imbricata* | V, M | T(V) | - | Nesting occurs in the Dampier Archipelago and foraging may occur throughout the region in coral and/or rocky reef habitat (Limpus 2009a). | Low Suitable habitat not found. | No |
| Leatherback Turtle *Dermochelys coriacea* | E, M | T(V) | - | A pelagic species rarely nesting in Australia. Very wide-ranging in its distribution, but preferring open ocean habitats (Limpus 2009b), although one record exists near One Arm Point. | Low – prefers open ocean | No |
| Loggerhead Turtle *Caretta caretta* | E, M | T(E) | - | No breeding in area and no critical feeding habitats. Foraging may occur in a wide range of habitats including rocky and coral reef, seagrasses and estuaries (DSEWPC 2012b). | Medium Rarely found inside King Sound | Yes (DPaW Threatened Fauna Search 2016). Recorded near Point Torment. |
| Olive Ridley Turtle *Lepidochelys olivacea* | E, M | T (E) | | The least common turtle in the area. Rarely nests in WA near Camden Sound (DPaW 2016e), mostly nests in Northern Territory. Forages on invertebrates from soft bottoms (DSEWPC 2012b). | Low Uncommon in Australia. | Yes (NatureMap, DPaW Threatened Fauna Search 2016). Two records near One Arm Point, no sightings inside King Sound. |
| Short-nosed Seasnake *Aipysurus apraefrontalis* | CE | T(CE) | - | Significant habitats are not near the King Sound area (DSEWPC 2012b). | Low Prefers coral reefs | No |
| **Sharks** | | | | | | |
| Dwarf Sawfish *Pristis clavata* | V, M | - | P1 | Known to inhabit the area of the Fitzroy estuary and King Sound (Thorburn *et al.* 2007a). | Medium In King Sound but uncommon | Yes (Thorburn *et al.* 2007a) |
| Great White Shark *Carcharodon carcharias* | V, M | T(V) | - | Oceanic, temperate waters (DSEWPC 2013) | Low Habitat not suitable. | No |
| Green Sawfish *Pristis zijsron* | V, M | T(V) | - | May inhabit King Sound and estuarine or brackish locations nearby (DoE 2015a). | Medium In King Sound but uncommon | Yes (DoE 2015b) |

| Species | Conservation Status | | | Habitat | Likelihood of Occurrence | Recorded |
|---|---|---|---|---|---|---|
| Name | EPBC Act | WC Act | DPaW | | | |
| Largetooth Sawfish *Pristis pristis* | V, M | - | P3 | Uses the freshwaters of the Fitzroy River and some tributaries as a nursery and moves into estuarine and marine habitats when it matures (Thorburn *et al*. 2007b). | Medium In King Sound but uncommon | Yes (Thorburn *et al*. 2007b) |
| Northern River Shark *Glyphis garricki* | E | - | P1 | Known to occur in King Sound and estuarine and freshwater habitats (DoE 2015a). | Medium In King Sound but uncommon | Yes (DoE 2015b) |
| Whale Shark *Rhincodon typus* | V, M | Schedule 7 | - | Oceanic, associated with coral reefs (DEH 2005). | Low Habitat not suitable. | No |
| **Mammals** | | | | | | |
| Humpback Whale *Megaptera novaeangliae* | V, M | Schedule 6 | - | Prefers oceanic waters around the 200 m isobath (Jenner *et al*. 2001). | High Waters outside King Sound | Yes (Jenner *et al*. 2001) |
| Australian Humpback Dolphin *Sousa sahulensis* | M | - | P4 | Shallow estuarine, river mouth and coastal waters of less than 10 metres depth, including turbid waters (Hanf *et al*. 2015). | High Known from King Sound | Yes (Brown *et al.,* 2016) |
| Snubfin Dolphin *Orcaella heinsohni* | M | - | P4 | Shallow estuarine, river mouth and coastal waters (Allen *et al.* 2012). | High Known from King Sound | Yes (Brown *et al.,* 2016) |

*Legend:*
*T – Threatened; V – Vulnerable; E – Endangered; CE – Critically endangered; M – Migratory; P – Priority list; '-' No classification.*

** Rostratula australis is listed as Endangered under the WC Act as Rostratula benghalensis australis.*

## Marine and Migratory Birds

Marine birds are birds that spend most of their lives at sea, coming to land to breed, with several species known to breed in the region (DSEWPC 2012c). Migratory shorebirds can also be found in the region, as many nest in the northern hemisphere summer in Siberia and Alaska and migrate to Australia in the Australian winter and spring, to return north in March and April. The migration occurs within the East Asian – Australasian Flyway, which is one of ten migratory bird flyways recognised worldwide (Bamford *et al*. 2008; DSEWPC 2012c).

In addition to the conservation significant birds listed in Table 34, there are 36 species of migratory birds protected under international agreements[1] that may overfly the Derby Port area, some of which may breed near the port and transhipment route (Table 35). None of the birds identified are listed as threatened under the *EPBC Act* or *WC Act*.

**Table 35: Migratory Birds Protected Under International Agreement**

| Scientific Name | Common Name | Recorded Near Derby Port (DPaW Fauna Search) or Birdata Atlas Species Distribution Maps | Potentially Occurring Near Derby Port (EPBC Act Protected Matters Search Tool) |
|---|---|---|---|
| *Actitis hypoleucos* | Common Sandpiper | Yes | Yes |
| *Anous stolidus subsp. ileatus* | Common Noddy | - | Yes |
| *Apus pacificus subsp. pacificus* | Fork-tailed Swift | Yes | Yes |
| *Ardea alba* | Great Egret | - | Yes |
| *Ardea ibis* | Cattle Egret | Yes | Yes |
| *Ardea modesta* | White-necked Heron | Yes | Yes |
| *Ardea sacra subsp. sacra* | Eastern Reef Egret | Yes | Yes |
| *Arenaria interpres interpres* | Ruddy Turnstone | Yes | - |
| *Calidris acuminata* | Sharp-tailed Sandpiper | Yes | - |
| *Calidris alba* | Sanderling | Yes | Yes |
| *Calidris ruficollis* | Red-necked Stint | Yes | Yes |
| *Calonectris leucomelas* | Streaked Shearwater | - | Yes |
| *Cecropis daurica* | Red-rumped Swallow | - | Yes |
| *Charadrius leschenaultii* | Greater Sand Plover | Yes | Yes |
| *Charadrius veredus* | Oriental Plover | - | Yes |
| *Cuculatus opatus* | Oriental Cuckoo | Yes | Yes |
| *Fregata ariel* | Lesser Frigatebird | - | Yes |
| *Glareola maldivarum* | Oriental Pratincole | Yes | Yes |
| *Haliaeetus leucogaster* | White-bellied Sea-Eagle | Yes | Yes |
| *Hirundo rustica* | Barn Swallow | Yes | Yes |
| *Limosa lapponica* | Bar-tailed Godwit | Yes | Yes |
| *Limosa limosa* | Black-tailed Godwit | Yes | Yes |
| *Numenius minutus* | Little Curlew | Yes | Yes |
| *Numenius phaeopus* | Whimbrel | Yes | Yes |
| *Merops ornatus* | Rainbow Bee-eater | Yes | Yes |

[1] International agreements include Japan-Australian Migratory Bird Agreement, China-Australia Migratory Bird Agreement, and Republic of Korea-Australia Migratory Bird Agreement.

| Scientific Name | Common Name | Recorded Near Derby Port (DPaW Fauna Search) or Birdata Atlas Species Distribution Maps | Potentially Occurring Near Derby Port (EPBC Act Protected Matters Search Tool) |
|---|---|---|---|
| *Motacilla cinerea* | Grey Wagtail | - | Yes |
| *Motacilla flava* | Yellow Wagtail | Yes | Yes |
| *Pandion haliaetus* | Osprey | Yes | Yes |
| *Plegadis falcinellus* | Glossy Ibis | Yes | Yes |
| *Pluvialis fulva* | Pacific Golden Plover | Yes | Yes |
| *Pluvialis squatarola* | Grey Plover | Yes | Yes |
| *Sternula albifrons* | Little Tern | - | Yes |
| *Sterna dougallii subsp. gracilis* | Roseate Tern | - | Yes |
| *Tringa glareola* | Wood Sandpiper | Yes | Yes |
| *Tringa nebularia* | Common Greenshank | Yes | Yes |
| *Tringa stagnatilis* | Little Greenshank | Yes | - |

Most habitats of particular importance to conservation significant bird species are found on offshore islands and further west near 80 Mile Beach and Roebuck Bay. The closest areas of significance to the Derby Port Development Envelope are the Lacepede Islands, Adele Island and North-east and North-west Twin Islands. In addition, the Derby Sewage Ponds are listed as an area of international importance for the Little Curlew. Table 36 shows the species for which these areas are particularly significant. Figure 42 shows the proximity of the Derby Port Development Envelope to these significant bird habitats.

**Table 36: Significant Habitats for Marine and Migratory Birds**

| Site | Common Name | Scientific Name | Conservation Significance | Maximum No. Birds Recorded | Reference |
|---|---|---|---|---|---|
| Lacepede Islands | Grey-tailed Tattler | *Tringa brevipes* | Marine, Migratory | 500 | 1 |
| | Ruddy Turnstone | *Arenaria interpres* | Marine, Migratory | 1,050 | 1 |
| | Brown Booby | *Sula leucogaster* | Marine, Migratory | 18,000 | 2 |
| | Roseate Tern | *Sterna dougallii* | Marine, Migratory | 20,000 | 2 |
| Adele Island | Lesser Frigate Bird | *Fregeta ariel* | Marine, Migratory | 10,140 | 3 |
| | Grey-tailed Tattler | *Tringa brevipes* | Marine, Migratory | 5,500 | 3 |
| | Brown Booby | *Sula leucogaster* | Marine, Migratory | 17,000 | 3 |
| Northeast and Northwest Twin Islands | Roseate Tern | *Sterna dougallii* | Marine, Migratory | Major breeding colony | 4 |
| Derby Sewage Ponds | Little Curlew | *Numenius minutus* | Marine, Migratory | 5,000 | 1 |

*Reference Key: 1: Bamford et al. (2008); 2: Birdlife (2016); 3: Birdlife (2016); 4: Mustoe and Edmunds (2008)*

## Inshore Dolphins

In the vicinity of King Sound, there are three species of dolphin of conservation significance that may occur: Australian Humpback Dolphin (*Sousa sahulensis*; listed as Migratory and a Cetacean under the *EPBC Act* and as Priority 4 by DPaW), Snubfin Dolphin (*Orcaella heinsohni;* listed as Migratory and a Cetacean under the *EPBC Act* and as Priority 4 by DPaW) and Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*; listed as Migratory and a Cetacean under the *EPBC Act*).

The Australian Humpback Dolphin is known to occur in coastal waters of Western Australia as far south as Shark Bay, and is endemic to Australia and New Guinea. The species is poorly studied; however the available data indicate that the local populations may be quite distinct from one another and that these populations are discontinuously distributed, exhibiting site fidelity (Parra *et al*. 2004; Parra *et al*., 2006). The species is thought to prefer shallow estuarine, river mouth and coastal waters of less than 10 m depth. Brown *et al.* (2012) studied Australian Humpback Dolphins at North-west Cape and recorded animals in waters from 1.2 to 20 m deep and at ranges from 0.3 to 4.5 km off the coastline. Around one quarter of the individuals recorded were found in mixed groups with Indo-Pacific Bottlenose Dolphins. Australian Humpback Dolphins may be associated with intertidal areas including those around islands and can utilise a range of inshore habitats including turbid waters (Hanf *et al.* 2015; Allen *et al*. 2012). Accurate population numbers are not available, but one estimate for total numbers in Western Australia is less than 5,000 (Bejder *et al*. 2012).

The Snubfin Dolphin is endemic to Australian waters. Like the Australian Humpback Dolphin, information on the Snubfin Dolphin is scarce. The two species have some habitat overlap and the Snubfin Dolphin is known to live in shallow, coastal and estuarine waters. The species is known from King Sound with several records on the NatureMap search facility (DPaW 2016a). The species has been recorded as far south as Exmouth Gulf, although it is more commonly recorded in Roebuck Bay, which is thought to be an important site for the species (Allen *et al*. 2012; Brown *et al.* 2016).

The Indo-Pacific Bottlenose Dolphin often associates with the Australian Humpback Dolphin and Snubfin Dolphin. Little is known of the species' abundance across northern Australia. The species was recently separated from Common Bottlenose Dolphins (*Tursiops truncatus*) and its range is considered fragmented (Allen *et al*. 2012; Brown *et al.* 2016).

Table 37 shows the relative abundance of the three species of dolphin of conservation significance that may occur in King Sound (Brown *et al*. 2016).

**Table 37: Approximate Numbers of Dolphins at Kimberley Sites**

| Location | Snubfin Dolphin | Australian Humpback Dolphin | Indo-Pacific Bottlenose Dolphin |
|---|---|---|---|
| Cygnet Bay | 54^ | 20^ | 60^ |
| Cone Bay | 20* | 12* | 0 |
| Beagle Bay | 2* | 7* | 184^ |
| Roebuck Bay | 133^ | 12* | 9* |

*Source: Brown et al. (2016). Key: ^ Highest count for estimated total population size at each site; * indicates insufficient data was gathered to determine population size. The number listed is the maximum number of individuals sighted on any of the repeated surveys.*

The abundance of the dolphin species varies markedly per site. Brown *et al*. (2016) noted that a fifth site, Inner Cambridge Gulf, which had highly turbid and estuarine conditions, showed the lowest abundance of any dolphin species. It was speculated that dolphins may avoid certain sites due to habitat and prey distribution, predation risk or social dynamics. Repeated sampling over various seasons at Cygnet Bay found that Snubfin Dolphins were resident in the area with almost no emigration to other populations. Australian Humpback and Indo Pacific Bottlenose Dolphins also showed site fidelity, but with movement of some individuals between Cygnet Bay and other areas. The study also found that some sites are far more important for one species than others.

## Sharks

### Whale Shark

The Whale Shark is migratory and known from many tropical and sub-tropical waters. In Australia, the shark has specific aggregation points and these are Ningaloo Reef, and to a lesser extent Christmas Island and the Coral Sea (off Queensland) (DEH 2005). Whale sharks are most commonly found around Ningaloo Reef and

northwards along the 200 m isobath (DSEWPC 2012b). Once the migrating sharks reach the Dampier Terrace and Argo Abyssal Plain, most move into oceanic waters (Wilson et al. 2006, cited in DoE 2016).

Aggregations of Whale Sharks appear to be associated with pulses in food, such as following a mass coral spawning. While it is possible for Whale Sharks to occur in King Sound, the species is considered an oceanic species preferring clear water (DEH 2005). There were no records from NatureMap or the DPaW fauna search of the species in King Sound.

**Great White Shark *(Carcharadon carcharias)***
While it is noted that the Great White Shark does occasionally occur in tropical waters, this is considered rare. The regular range of the species in Australia is from central Queensland, around the southern coast and only occasionally as far north as North West Cape. Particular foraging areas are known around islands and coastlines that are home to seals and sealions (Last and Stevens 2009 cited in DSEWPC 2013; DSEWPC 2012b). There were no records from NatureMap or the DPaW fauna search of this species in King Sound.

**Sea Turtles**
Six of the seven species of sea turtle worldwide have the potential to occur in the region of the project: the Flatback Turtle (*Natator depressus*), Green Turtle (*Chelonia mydas*), Hawksbill Turtle (*Eretmochelys imbricata*), Leatherback Turtle (*Dermochelys coriacea*), Loggerhead Turtle (*Caretta caretta*), and the Olive Ridley Turtle (*Lepidochelys olivacea*) (DSEWPC 2012b). The Flatback, Green, and Hawksbill Turtles are listed under the *EPBC Act* as Vulnerable and Migratory. The Leatherback, Loggerhead, and Olive Ridley are listed as Endangered and Migratory under the *EPBC Act*.

DSEWPC (2012b) stated that in the North-west Marine Region, there are several areas of critical habitat for sea turtles based on their importance as foraging grounds or nesting and inter-nesting sites. None of these areas are in close proximity to King Sound, and the Sound is not considered critical habitat for sea turtles. Critical habitats for sea turtles are shown on Figure 42. Neither the Hawksbill Turtle, nor the Leatherback Turtle have been recorded in or around King Sound. Through the EPBC and DPaW search tools, the other four species have been recorded in or around King Sound. Records of each species and the likelihood of occurrence are shown in Table 34.

**Sea Snakes**
The Short-nosed Seasnake is endemic to the North-west Marine Region and offshore oceanic reef areas. Scarce data are available on the species' habitat preferences, although most specimens have been collected from Ashmore and Hibernia Reefs, where seasnakes species were previously diverse and abundant. The number of seasnakes found on Ashmore Reef has declined rapidly, with the Short-nosed Seasnake now considered to be locally extinct at this location (Lukoscheck *et al.* 2013). The Short-nosed Seasnake utilises coral reef habitat and usually stays within 50 m of the coral reef. As a result, this species is unlikely to be found in King Sound and has not been recorded using EPBC and DPaW search tools in King Sound.

**Marine and Migratory Fauna**
In addition to the threatened marine fauna listed in Table 34, there are seven species of migratory fauna protected under an international agreement known as the Bonn Convention. These species may occasionally pass by King Sound or the transhipment route (Table 38). None of these species are listed as threatened under the *EPBC Act* or *WC Act*. Given the habitat preferences and the wide ranging nature of these migratory marine fauna species, they are unlikely to be encountered on a regular basis, with the exception of the Indo-Pacific Bottlenose Dolphin.

**Table 38: Migratory Marine Fauna Protected Under Bonn Convention**

| Scientific Name | Common Name | Likely Occurrence |
|---|---|---|
| *Balaenoptera edeni* | Bryde's Whale | Potential to occasionally occur in the ocean-going vessel route. Found Australia-wide (DoE 2016). |
| *Crocodylus porosus* | Salt-water Crocodile | Likely to occasionally occur near Derby Port. Found in the ocean and most major river systems of the Kimberley (DoE 2016). |
| *Dugong dugon* | Dugong | Unlikely to occur as suitable habitat (seagrass beds) are not present (DoE 2016). |
| *Manta alfredi* | Reef Manta Ray | Unlikely to occur. Prefers coral or rocky reef habitats (IUCN 2016). |
| *Manta birostris* | Giant Manta Ray | Unlikely to occur. Prefers coral reef and offshore oceanic habitats (IUCN 2016). |
| *Orcinus orca* | Killer Whale | Potential to occasionally occur in the ocean-going vessel route. Mostly prefers oceanic habitats, often close to seal colonies (DoE 2016). |
| *Tursiops aduncus* | Indo-Pacific Bottlenose Dolphin | Confirmed as occurring in coastal areas near the mouth of King Sound (Brown *et al.* 2016). |

## 4.3.15 Heritage

### *4.3.15.1 Aboriginal Heritage*

A search of the Derby Port Development Envelope and surrounds was undertaken using the Department of Aboriginal Affairs 'Aboriginal Heritage Inquiry System'. Searches were undertaken for the Derby Port Development Envelope to identify the following:

- Aboriginal heritage surveys over or near the Derby Port.
- Registered heritage places within or near the Derby Port Development Envelope.
- Other Heritage Places within or near the Derby Port Development Envelope.

No Registered Sites or Other Heritage Places are present within the Derby Port Development Envelope or transhipment route (DAA 2016). The transport route along the Great Northern Highway to Derby Port has been previously surveyed as part of the Great Northern Highway survey area. No surveys have been undertaken within the Derby Port Development Envelope as it is an established industrial zone.

### *4.3.15.2 European Heritage*

The Derby Port was established in 1880 to ship general supplies from Perth to the pastoral leases of the West Kimberley. The Port was later used to transport wool, cattle, lead and zinc ores. Some of the historic cattle yards remain adjacent to the proposed storage facility. Derby is also the Western end of the Gibb River Road which was constructed for pastoralists to transport their cattle from north eastern pastoral stations for export.

Strickland-Munro *et al.* (2016) conducted a community survey to determine ways in which people value the Kimberley coastline. The results for Derby indicated that people in the community value the area for its European heritage foremost, and secondarily for its recreational fishing, learning, and research opportunities and for economic reasons.

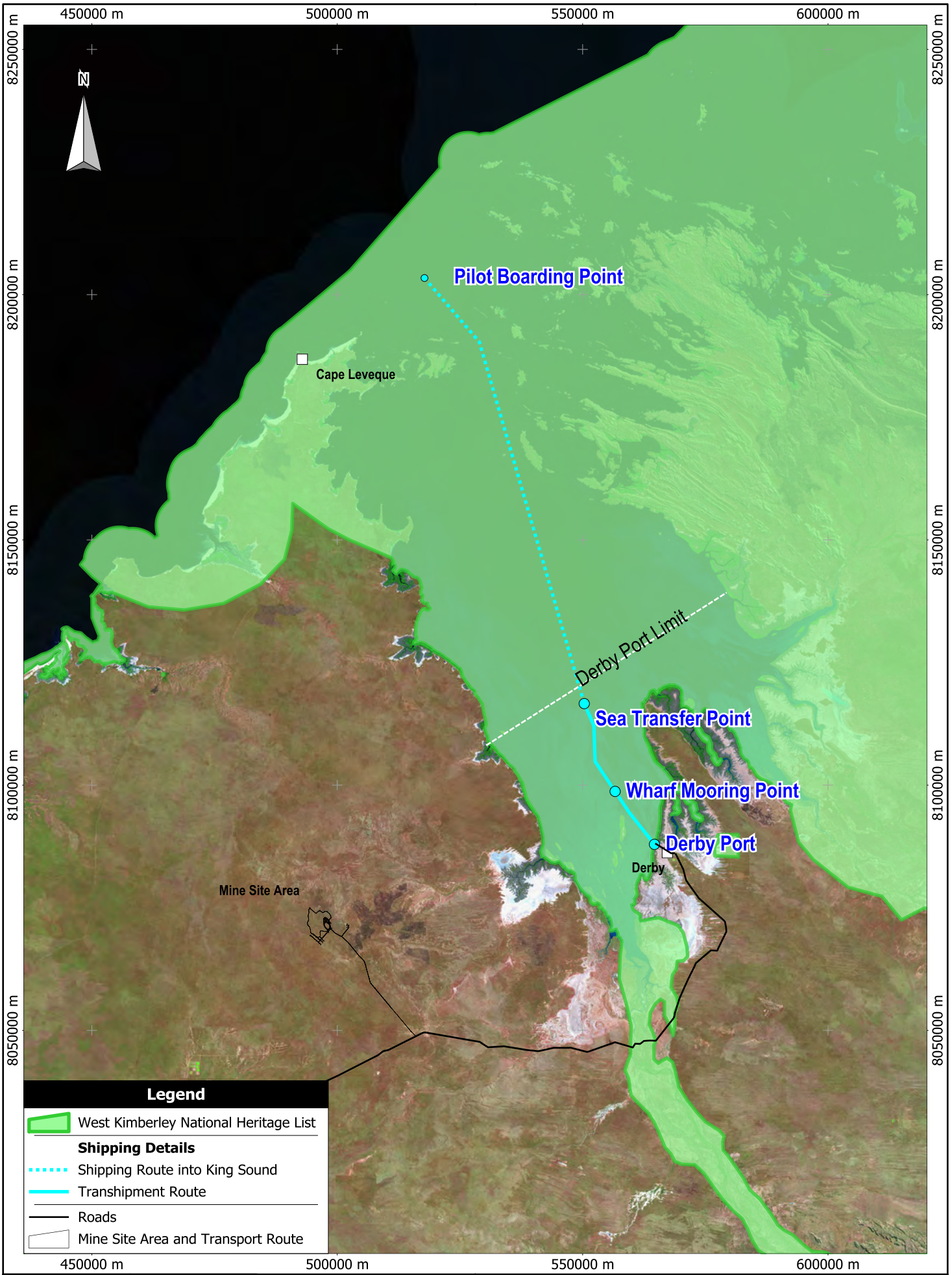
A search of the following databases was carried out to identify registered, non-Aboriginal heritage sites:

- *EPBC Act* Protected Matters (Search Tool).
- Commonwealth Heritage List (CHL).
- World Heritage List (WHL).
- Western Australia Register of Heritage Places.
- Shire of Derby/West Kimberley Municipal Register of Heritage Places.

No municipal, State, CHL, or WHL places were identified within the Derby Port Development Envelope.

The West Kimberley National Heritage Place (WKNHP) (Figure 43), protected under the *EPBC Act*, was found to occur within the Derby Port Development Envelope. It was gazetted on 31 August 2011 based on a number of key heritage values and comprises most of the west Kimberley covering an area of around 19 million hectares. Key heritage values relate to dramatic landscapes, ancient geology, biological richness, Aboriginal culture, early European exploration and pastoral and pearling history.

King Sound is included in the WKNHP due to its association with early European exploration by William Dampier and the influence of his published observations. William Dampier was known to land in several places to the north-west of King Sound (i.e. Karrakatta and Pender Bays). The environment in these places is mostly unmodified since his 1688 landing (Commonwealth of Australia 2011).




Scale: 1:1000000
Original Size: A4
Image: Geoscience Australia LS7 Mosaic 2007
Grid: MGA94(51)
0 20 km

Sheffield Resources Limited
Thunderbird Mineral Sands Project

**Figure 43**

**West Kimberley National Heritage Place**

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### 4.3.16 Air Quality

No background measurements of air quality could be found within the literature for Derby. However, as there are no significant emissions sources within the Derby region, air quality is expected to be good, but may be affected by dust generation from unsealed roads, deposited dust on sealed roads that is remobilised by traffic and occasionally by smoke from bushfires (Atmospheric Solutions 2016b).

The Derby Port and conveyor system have been unused for export activities since 2008 and no other industrial activities exist in the region. As such, background and cumulative emissions are expected to be negligible (Atmospheric Solutions 2016). However, conservative background concentrations of the average ambient dust concentrations found in northwest Western Australia have been used during project design to ensure the worst-case scenario is considered. These are 40 µg/m$^3$ for total suspended particulates, 20 µg/m$^3$ for particulate matter 10 microns and below, and 7 µg/m3 for particulate matter 2.5 microns and below averaged over 24 hours. These concentrations are based on a number of studies on ambient monitoring of the Kimberley and Pilbara areas, which both experience a higher level of activity than Derby and as such are seen to be a conservative choice in lieu of local data (Atmospheric Solutions 2016b; Appendix 17).

### 4.3.17 Amenity

Bulk products from the Mine Site will be loaded on to road trains and transported by road to Derby Port for export to overseas markets. Product will be transported using a fleet of five quad road trains, with each road train completing two trips per 12 hour shift. Up to 10 return truck journeys (20 truck movements) per day will occur between the Mine Site and Derby Port, operating 24 hours per day 7 days per week. Approximately 6 km of the transport route is located in residential/commercial areas within Derby, with the remaining 144 km located in unpopulated areas.

The Great Northern Highway forms the longest portion of the transport route to Derby Port (75 km). It is also the main road link between Perth and the Kimberley Region and is the only sealed road connecting Perth with the Northern Territory. As a result, it is used extensively by heavy vehicles.

Loch Street is a continuation of the Derby Highway and is zoned as a 'major highway' according to Derby Town Planning Scheme 5 (SWKD 2003). Derby Highway transitions into Loch Street in the Derby town centre as it passes through residential and commercial areas. Loch Street transitions into Jetty Road at the northwestern most tip of the Derby township, at the intersection with Elder Street. The proposed bulk product transport route is shown in Figure 14.

Existing heavy vehicle movements within the Town of Derby, along Derby Highway and Loch Street, account for between 10% and 18% of all vehicle movements in Derby (MRWA 2015). Approximately 2,220 vehicle movements per day, of which 421 were heavy vehicle movements, occurred along Loch Street east of Ashley Street in 2013/2014. Total vehicle and heavy vehicle movement numbers decreased further from Derby with approximately 580 vehicle movements per day, of which 82 were heavy vehicles occurring on the Derby Highway, north of the Great Northern Highway.

Current and historic daily vehicle movements around Derby and the percentage of these that are heavy vehicle movements are shown in Table 39.

**Table 39: Current and Historic Daily Vehicle Movements Around Derby**

| Road | Location | Total Vehicle Movements / Heavy Vehicle (HV) Movements / % HV | | | | |
|---|---|---|---|---|---|---|
| | | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
| Derby Highway | North of Great Northern Highway | 440 / 73 (16.6%) | 400 / 55 (13.7%) | 560 / 92 (16.5%) | - | 580 / 82 (14.1%) |
| | South of Russ Street | 1,640 / 179 (10.9%) | 1,980 / 182 (9.2%) | 2,330 / 284 (12.2%) | 3,000 / 330 (11.0%) | - |
| | North of Russ Street | - | - | - | - | 2,220 / 240 (10.8%) |
| Loch Street | East of Ashley Street | 4,350 / 409 (9.4%) | 3,970 / 409 (10.3%) | - | 5,350 / 942 (17.6%) | 4,050 / 421 (10.4%) |

*Source: MRWA 2015, '-' No data available. 2014/2015 data not available.*

Historically, the Great Northern Highway, Derby Highway, Loch Street, and Jetty Road have been used to transport lead and zinc metal concentrates from the Lennard Shelf Operations, located east of Fitzroy Crossing, to Derby Port. While the Lennard Shelf Lead and Zinc Operations were operational (1997 - 2008), up to 500,000 tonnes per annum of lead and zinc concentrates were transported along the transport route from east of Fitzroy Crossing to Derby Port (MBS 2009).

#### *4.3.17.1 Noise*

A noise assessment was undertaken for the Derby Port Development Envelope (WSP Parsons Brinckerhoff 2016a; Appendix 18), in which continuous unattended noise monitoring was conducted simultaneously for seven days between 24 and 31 May 2016 at the Main Roads Western Australia offices on Woodhouse St and the Derby Shire Offices on Loch Street to understand the existing background noise environment. The noise loggers were programmed to record various statistical noise levels over consecutive 15 minute intervals and were used to continuously measure ambient noise, which included all noise sources present at the time (Table 40). The $L_{A90}$ is a good indicator of background noise as it is relatively insensitive to noises that are short term in duration.

Additionally, operator attended monitoring was undertaken at the Jetty Cafe, Fishing Club, Derby Shire Office and Spinifex Hotel in order to understand the composition of the current noise environment and to supplement the unattended noise monitoring data, results of which are presented in (Table 41). All noise measurements were obtained over a sufficient duration to provide a representation of the typical noise emissions.

**Table 40: Derby Background Unattended Noise Monitoring Results**

| Location | Period | $L_{A90}$ (dB) | $L_{A10}$ (dB) | $L_{A1}$ (dB) |
|---|---|---|---|---|
| Main Roads Office | Night | 28 | 43 | 50 |
| | Day | 41 | 54 | 59 |
| | Evening | 40 | 47 | 55 |
| Shire Office | Night | 31 | 41 | 51 |
| | Day | 38 | 56 | 64 |
| | Evening | 38 | 47 | 59 |

**Table 41: Derby Background Attended Noise Monitoring Results**

| Location | Time | $L_{A90}$ (dB) | $L_{A10}$ (dB) | $L_{Amax}$ (dB) | Comments |
|---|---|---|---|---|---|
| Jetty Cafe | 3:05 pm | 38 | 53 | 72 | Cars visiting café and jetty<br>Bird noise |
| | 7:25 pm | 34 | 45 | 57 | Cars visiting café and jetty |
| Spinifex Hotel | 3:35 pm | 34 | 47 | 72 | Occasional bird and traffic |
| Shire Offices | 4:30 pm | 43 | 60 | 69 | Traffic Loch Street<br>Bird noise<br>Plant noise shire offices |
| | 7:50 pm | 37 | 43 | 65 | Traffic Loch Street |
| Fishing Club | 8:05 pm | 37 | 40 | 69 | Insect noise dominant<br>Domestic condenser unit<br>Traffic |
| | 10:00 pm | 40 | 42 | 45 | Insect noise dominant<br>Domestic condenser unit<br>One vehicle pass by |

#### *4.3.17.2 Visual Amenity*

The wharf is a popular place for fishing and dining at the Derby Wharf Restaurant. With respect to visual amenity at the Derby Port, there are several buildings of single storey currently existing. The site is zoned for industry and includes the wharf, conveyor and existing buildings on the wharf.

The nearest residences are about two kilometres from the Derby Port Development Envelope.