PART B EXISTING ENVIRONMENT

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4.0 Bio-physical Setting

The project area includes the east and west branches of Doctor's Creek, the marine environment inside and at the mouth of the creek system, the intertidal flats including the mangrove and salt pan communities, and the peninsula with particular respect to proposed infrastructure locations.

A number of detailed scientific studies have been undertaken to assess the existing environment including flora and vegetation, sedimentation and erosion, geotechnical, hydrology, and fauna surveys. Baseline information from these surveys has been used to inform and assess the potential impacts resulting from the development of the project.

The following sections include descriptions of the physical environment, climate, hydrology, vegetation, and fauna of the local area of Doctor's Creek.

4.1 Data Sources

Data were collected between 1997 and 2011. TEA has discussed the validity of using studies older than five years with DOTE. Although vegetation and fauna studies were conducted in 1997 to support the Consultative Environmental Review completed by HGM, results from these studies are unlikely to have changed significantly over time.

A recent environmental protected matters search was conducted for the area to identify any changes to listed MNES since the collection of original data in 1997. A summary of studies and their completion dates is provided below:

- Consultative Environmental Review under the WA EP Act was completed in 1998.
- Sediment and erosion modelling was completed in 2014 (Appendix C).
- Mangrove habitat mapping was completed in 1997 (Appendix D).
- A study on the cause-effect pathways of mangroves was completed in 2011 (Appendix E).
- Assessment of changes in mangroves in Doctor's Creek was completed in 2011 (Appendix F).
- Engineering design report was completed in 2012 (Appendix G).
- Geotechnical studies were completed in 1997 and 2002. (Appendix H and Appendix I).
- Preliminary sedimentation assessment of Doctor's Creek was undertaken in 2003 by HGM (Appendix L).
- A Consultative Environmental Review was completed for the Prawn Farm in Doctor's Creek by Diamond Island Pty Ltd in 1997 (Appendix M).
- An assessment of impacts on migratory shorebirds was completed in 2002 (Appendix J).
- Dynamics of turbidity was investigated by Wolanski and Spagnol in 2003 and published in Estuarine Coastal and Shelf Science.
- A review of freshwater fishes of the Kimberley region of WA was completed Morgan *et al* in 2011 and published in Zootaxa.
- A review of the occurrence of Glyphis (River Shark) and Pristis (Sawfish) species in Doctor's Creek, Western Australia (Appendix P Thorburn 2014).

Additional information on the technical sources used for this EIS is provided in Section 12.0. A complete list of references and resources is provided in the reference list and bibliography in Section 13.0.

4.2 Biogeography

The Australian continent has been divided into 89 large geographically distinct bioregions based on common climate, geology, landform, native vegetation and species formation (DSEWPC, 2013). This classification is known as the Interim Biogeographic Regionalisation for Australia (IBRA). The 89 bioregions are further refined into 419 subregions.

The proposed onshore facilities are located within the Fitzroy Trough sub-region of the Dampierland bioregion. The Fitzroy Trough sub-region is the northern periphery of the Canning Basin containing the middle and lower catchments of the Fitzroy River. At 3,614.096 ha the Fitzroy Trough extends from Fitzroy Crossing to the coastal town of Derby, of this, 99.64% of the pre-European vegetation remains. The area is further comprised of alluvial plains, areas of sandplains and eroded dune surfaces derived from the Canning Basin (Graham, 2001).

The Beard (1979) broad-scale vegetation mapping identifies the area as the Fitzroy Sandplains (vegetation association 127). According to the comprehensive, adequate and representative National Reserve System of the Fitzroy Sandplains within the Dampierland bioregion, 97.41% of vegetation remains intact.

4.3 Climate and Weather

The project area is located 14km north of Derby utilising the two branches of Doctor's Creek in the southern Kimberley coastline. The southern Kimberley coastline experiences a tropical semi-arid climate with low monsoonal rainfall (WA Museum 1995). There are two distinct seasons within the Kimberley region, the dry season runs from May to October, and the wet season runs from November to April. Tropical cyclones, which can result in intense rainfall events, are not common in the Derby area due to the town site being located a significant distance from the true coast. Around 15 cyclones have passed within 100km of Derby in the last century.

At Derby, winds are predominantly from the east and south-east in the dry season of April to September with some north-west and westerly sea breezes. In the wet season of October to March, north-west and west winds dominate with lighter land and sea breezes (WA Museum, 1995).

Derby AERO, situated within the town centre of Derby is the nearest Bureau of Meteorology (BoM) weather station with the most complete data set. The average mean maximum wet season temperature is 35.9 degrees Celsius (°C), with daily maximum temperatures over 35°C often recorded. In the dry season, the mean maximum temperature is 33.1°C, with a mean minimum of 17.9°C (Bureau of Meteorology, 2013). Derby AERO receives an average annual rainfall of 688mm (BoM, 2013). The majority of rainfall falls from January to March during the wet season.

4.4 Geology and Soils

Derby is located in the northern part of the Canning Basin, a large intra-cratonic basin located between Halls Creek Province and the Pilbara Block and underlying the Great Sandy and Gibson Desert Regions of Western Australia. The Canning Basin contains a faulted and folded sequence of Phanerozoic sedimentary rocks up to 18,000m thick and ranging in age from Ordovician to Quarternary.

The surface geology of the intertidal system is mapped as Qe, estuarine and delta deposits made up of coastal silt and evaporate deposits, and estuarine, lagoonal and lacustrine deposits (Geological Survey of WA, 2008). The soil is mapped as Jw1 classified as low-lying coastal plains with some sand dunes: chief soils are saline clays on flat to very sloping plains.

The geology of the dry land adjacent to the intertidal system is mapped as Qd, comprised of dunes, sandplains with dunes and swales, may include numerous interdune claypans, residual and Aeolian sand with minor silt and clay, Aeolian red quartz sand, clay and silt, in places gypsiferous, and yellow hummocky sand (Geological Survey of WA 2008). Soils are mapped as AB26, described as sandplains with longitudinal sand dunes and some active drainage-ways. Chief soils are red earthy sands associated with other soils on plains and dunes and hummocks of red sands.

Soil testing of the sand bank located at the mouth of Doctor's Creek, and the site of the power station on the peninsula located between the east and west e of the creek was undertaken by Coffey (2002). The power station site had a high concentration of Calcium Carbonate in the soils. The sand bank in the mouth of Doctor's Creek consists of three major soil units including: alluvium, silty clay and sand. The alluvium is confined by the overlying silty clay unit and was generally hard clays to dense sands. The silty clay are marine or estuarine deposits with traces of limestone nodules that was firm to stiff. The uppermost layer of soil was predominantly sand comprised of subangular to subrounded quartz grains with calcium carbonate content of 5-25%. High calcium carbonate content will prevent acid sulphate soil potential. The soil profile from the sand bar was described as:

- 0-5m clay soft to tight
- 5-15m sand and silt
- 15-16m hard sand (refusal).

Underlying bedrock under Doctor's Creek and the tidal/supratidal flats is made off Erskine Sandstone which is very fine to fine sandstone, laminated to thin-bedded, with minor dry-pellet conglomerate, and laminated mudstone upper parts (Coffey, 1997). Further east there are subcrops of Blina Shale which underlies most of the Point Torment peninsula (Coffey, 1997).

4.5 Geotechnical Context

Coffey (1997) undertook geotechnical testing of the peninsula at the proposed turbine channel location, the East Branch and the West Branch. The peninsula showed very soft to soft clay soils down to 3m with clay. The banks of the East and West Branches have high plasticity clay varying from very soft to firm (Coffey, 1997). Geotechnical testing showed clays continued to a significant depth with stiffness increasing with depth with the soil horizon described as follows (Coffey, 1997):

- Layer 1: 0.4-2.4m surface crust (velocity range 330-650)
- Layer 2: 2.4-11.8m soft clay (velocity range 1300-1600)
- Layer 3: 11.8m+ firm/stiff clay (velocity range 1550-1900)

The East Branch showed an increase in seismic velocity with depth less than 1.6km/sec to 1.8 km/sec, consistent with clays between soft and stiff and uncemented sands. The seismic traversing was undertaken in waters at -10m AHD to -12m AHD and penetrated to -18m AHD to -20m AHD (25m below the HAT with no indication of bedrock. The West Branch was similar to the East Branch with soils of seismic velocity less than 1.8km/sec extending deeper than -18m AHD. A few anomalies were attributed to "rock" on the seabed however did not indicate bedrock.

In 2002 Coffey completed additional geotechnical testing of the sand bank located in the mouth of Doctor's Creek. During high tides this bank is inundated, however is exposed during spring tides by more than 2m. The alluvium soil horizon was considered a suitable founding layer for gravity structures, with high bearing capacity and relatively high elastic modulus. The silty clay has low strength and is compressible making it difficult material to work on due to cohesiveness. Depressurisation systems may be required to penetrate sandy horizons into underlying alluvium to relieve water pressure and prevent floor heave. The surface sand layers are considered suitable for founding purposes as long as consideration is given to compressibility of underlying silty clay.

4.6 Coastal Processes

Erosion and deposition are both taking place in different parts of the embayment of King Sound however erosion predominates, with short term localities undergoing rapid erosion (Semeniuk, 1980).

Three types of erosion affecting the development of mangroves are sheet, cliff, and tidal-creek erosion, which all occur at some extent within King Sound. Seminiuk (1980) describes the three types of erosion as:

- Sheet erosion- involving large expanses of tidal flats that are progressively lowered a few millimetres at a time. Sheet erosion occurs at all shore levels but is most important on salt flats as these would eventually degrade to mangrove level. Salt flats are where sheet erosion occurs more readily as these areas have been drying out during neap tide. At this time, cavity systems form from gas production, animal burrows and shrinkage cracks. During prolonged drying-out the soil water evaporates and salt crystals grow into mud-disrupting aggregates. A spring tide returning after 2-4 weeks quickly traverses this indurated mud pavement but picks up virtually no sediment. Water fills mud cavities and salt crystals dissolve and cease to support the mud which then collapses. Fine organic matter in the mud helps to disperse the suspension and the substrate which now readily erodes. The top-most layer is removed as ebb tide carries abundant mud particles in suspension out to sea. Sheet erosion occurs within mangrove flats and on inclined slopes in front of mangroves.
- Cliff erosion- leads to cliff development 1-2m high and locally up to six metres high. Unequal cliff erosion rates cause a scalloped coastline. The baffle effect of mangroves on currents and the binding effect on their roots make a marked disjunction between inclined slopes and mangrove flats, and a sea cliff is formed most readily at their junction. Cliff erosion is caused by tidal scour, mass slumping, undercutting of mangrove root systems, and wave action.

- Tidal-creek erosion- caused by the development of channels. Tidal creeks vary from small ruts and gullies less than one metre deep and wide to large channels more than ten metres deep and one kilometre wide. Creeks meandering in plan, ramifying and bifurcating but they do not migrate laterally because they are entrenched. Small tidal creeks and gullies are often V-shaped in cross section, with larger systems usually a broad U-shape.

The rate of erosion was predicted at 1 to 3cm per year with the rate of cliff retreat varying between areas. Sediment is also slowly building up on the salt flats, evidenced by mangroves dying as inundation decreases.

Wolanski and Spagnol (2003) disagree with this conclusion as their study results imply that sediment accumulates in the salt flats of Doctor's Creek at the rate of about 0.2cm per year.

Studies to be undertaken prior to commencement of this project include studies on the marine environment including water and sediment quality (Condition 10).

4.7 Hydrogeology

Parts of Doctor's Creek and the intertidal zone are classified as a Coastal Catchment for the Fitzroy River Basin. The mouth of Doctor's Creek is approximately 22km from the mouth of the Fitzroy River. The two river systems are separated by a land spit where the town of Derby is located. It is unlikely that the two rivers are connected hydrologically.

4.7.1 Tidal Conditions

Derby has one of the biggest tidal ranges in the world after Nova Scotia (Bay of Fundy), Canada and La Rance River, France. The tide is a high, semidiurnal tide which is classified as macro-tidal (Seminiuk, 1980). The tides in King Sound reach this height because it is an embayment within which tides resonate. This along with shoaling, where the waves increase in amplitude in shallow water, results in very high tides. The resonance of a harbour or embayment is primarily controlled by the length and depth of the basin. As the tidal front approaches a narrowing in the coastline, the water is wedged into a smaller width causing the height of the wave to increase. If the length of the bay in the direction of the tidal wave advance approximates an integral number of half wave lengths for the appropriate depth of water, then a resonant standing condition can develop. In King Sound the resonant period corresponds to approximately 11 to 12 hours.

Current and past studies include:

- HGM 1998, Derby Tidal Power Project, Doctor's Creek, Consultative Environmental Review (Appendix B)
- Cardno 2014, Proposed Derby Tidal Power Station – Hydrodynamic and Sediment Transport Modelling (Appendix C)
- Paling 1997, Mangrove Assemblages in Doctor's Creek, Derby, Their Regional Significance and the Potential Impacts of a Tidal Power Station (Appendix D)
- Paling 2011, Cause-effect pathways in mangrove ecosystems: can they make management easier (Appendix E)

Water samples were collected from both ebb and flood tides in 1997 by HGM. Suspended sediments were higher in the west branch of Doctor's Creek with a mean of 363mg/L compared to the east branch with 253mg/L. Turbidity was also higher, with the depth of penetration to 99% extinction (euphotic depth) estimated to range between 0.1m and 0.3m.

Salinity/stratification showed slight vertical density gradients due to temperature and salinity and the water column is considered to be well mixed (HGM, 1998).

The circulation within Doctor's Creek is tidally dominated with a maximum spring tidal range of approximately 10m and neap tidal range of around 5-6m (Table 5). It is predominately restricted to the channel flow, except when flooding over intertidal flats occurs during high spring tides (HGM, 1998).

Table 5 Key data from tidal studies (HGM 1997)

Tide	Height
Highest astronomical tide (HAT)	5.60m (AHD)
Mean high-water spring tide (MHWS)	4.79m (AHD)
Mean high-water neap tide (MHWN)	2.84m (AHD)
Mean low-water neap tide (MLWN)	-2.10m (AHD)
Lowest astronomical tide (LAT)	-5.96m (AHD)

During spring tides the seawater from King Sound (including Doctor's Creek) floods the tidal flats which then flows away freely during the neap tide. Neap periods occur for 36hrs in each 14-day period (at half-moon) and cover three consecutive tidal cycles (covering a 37 hour period) (DoT, 2013). Wave action is negligible except for those developed by strong afternoon sea breezes and summer storms. These waves cause coastline erosion and can be responsible for shoreward transport of sand and debris (Seminiuk, 1980).

4.7.2 Surface Water

Both the west and east branches of Doctor's Creek are blind, having no riverine discharge. Freshwater inflow is limited by surface drainage from a surrounding tidal flat catchment of about 140 km^2 (Figure 6).

4.7.3 Groundwater

Derby is dependent on groundwater for both town and private water supply needs. The Derby town water supply is sourced from the confined Lower Erskine Sandstone Formation (LESF) aquifer system situated at a minimum depth of 200m from the surface (DoW, 2008). The Erskine Sandstone Formation is a multilayered aquifer with shale interbeds and is confined from above by the Munkayarra Shale. Recharge into the LESF occurs to the south and south east of Derby where the aquifer is unconfined with groundwater flowing in a northerly direction towards May River. The lower aquifer that provides the majority of the town water supply is unlikely to be affected as it is a confined aquifer (EPA, 1999).

Saline intrusion has been a problem with private shallow bores on the Derby peninsula in the past due to excessive groundwater abstraction. There is some risk of salinisation of the upper aquifer, however excessive abstraction presents a greater risk to shallow bore users. The Department of Water (DoW), formally the Water Rivers Commission has indicated that it believes the risk to aquifers from the Project is low (EPA, 1999).

This Project could potentially affect the position of the saltwater/ freshwater interface near the peninsula due to a higher mean tidal height altering the hydraulic gradient and effectively moving the saltwater interface further onto the peninsula (EPA, 1999).

4.7.4 Marine Water Quality

During July 1997, water samples were collected from both branches of Doctor's Creek on both ebb and flood tides. Suspended sediment concentrations at close to maximum tidal extent ranged between 110mg/L and 650mg/L (mean 308mg/L). Suspended sediment loads were higher in the west branch of Doctor's Creek (mean 363mg/L) than the east branch (mean 253mg/L)(HGM1997). Further studies carried out in October 1997 and November 1998 indicated that a turbidity front is located to the north of Doctor's' Creek in King Sound which separates turbid waters with suspended sediment concentrations >0.05kg/m3 to 3kg/m3 from clearer waters (<0.01kg/m3) to the north. This was associated with a temperature and salinity front (Wolanski and Spagnol, 2003).

Turbidity was found to be significantly correlated with suspended sediment concentrations, with depth of light penetration to 99% extinction (euphotic depth) between 0.1m and 0.3m. Salinity in Doctor's Creek was around 30 to 31 parts per thousand, rising in hot drier periods and falling during the wet seasons as flow from the Fitzroy River increase. An evaporation driven, salinity maximum zone was found in the upper reaches of King Sound (south of Point Torment) and this was also where the turbidity maximum occurred (Wolanski and Spagnol, 2003). The turbidity maximum prevents fine sediment from escaping King Sound although the huge tides ensure an effective tidal flushing of water.

There are no anthropogenic sources of nutrients into Doctor's Creek. The large tidal range implies that the system is very well mixed and there is unlikely to be any significant variation in nutrient levels between Doctor's Creek and King Sound (HGM, 1998).

4.7.5 Oceanographic Processes and Natural Features

King Sound is an embayment of approximately 100km^2 with a spring tidal range of ten metres. Tides are propagating waves, shoaling and dissipating by friction as they enter King Sound (Wolanski & Spagnol, 2003). The Fitzroy River plays a large role in the oceanographic processes in the vicinity of Doctor's Creek, with flushes of fresh water entering the ocean after the rain season affecting local salinity and turbidity levels.

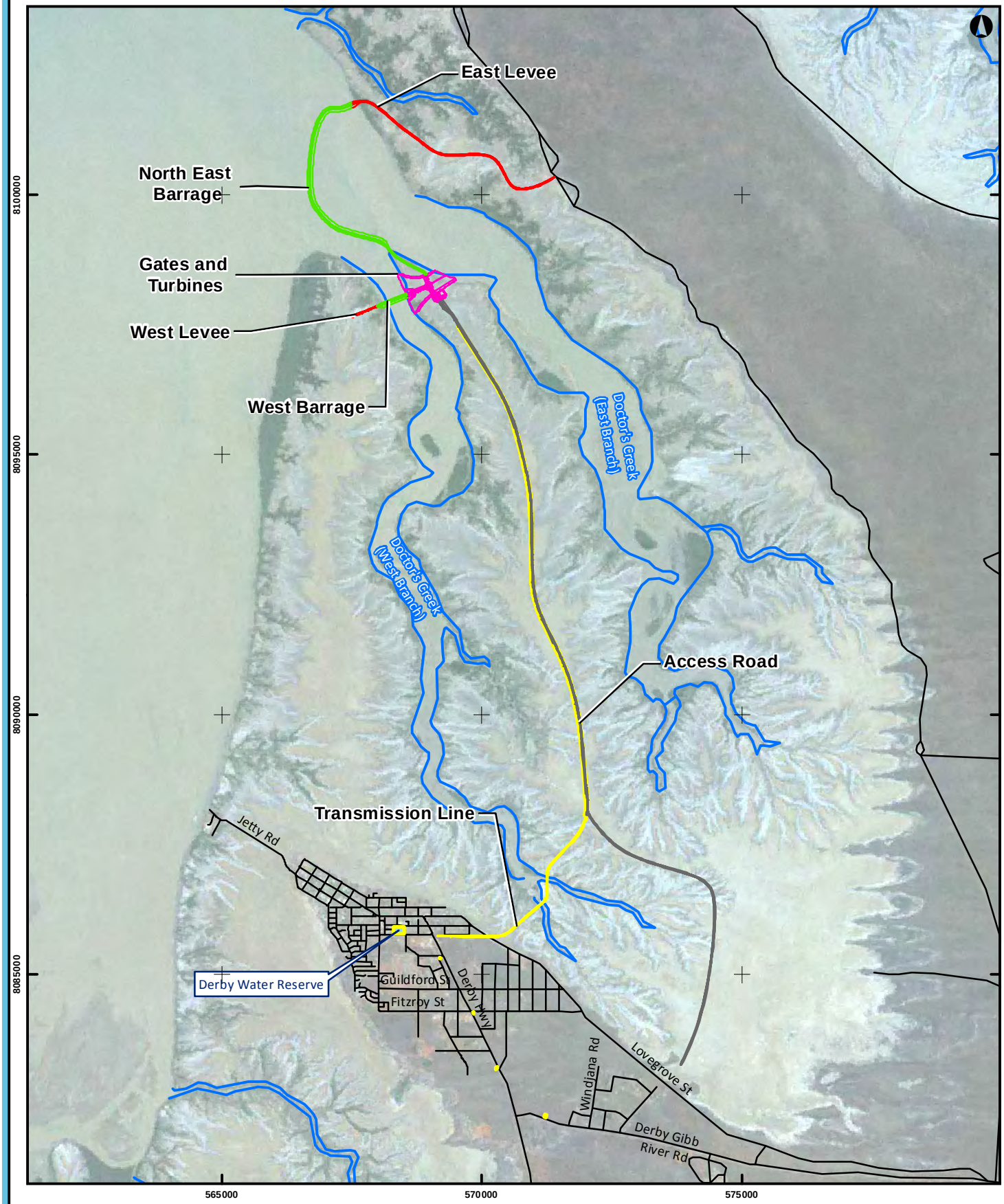
Physical processes which control hydrodynamics, sediment transport, and water quality play a major role in the health of the waterways. A bathymetry survey was completed by Coffey (1997) which found the following:

- The bed of the high basin is at an elevation of -6m AHD near the proposed western barrage location.
- The east bank of the high basin has a deep channel which reaches to -10m in some places.
- During low tide a series of banks are exposed immediately upstream of the mouth of the East Branch.
- Because of this the elevation is only -4m AHD with a deeper channel on the western edges of the sand bank and the east side of the peninsula at -9m AHD near the proposed location of the Eastern barrage.

Further upstream at the toe of the peninsula embankment the channel deepens to -13m AHD

4.8 Bathymetry

King Sound has a mean depth of about 18m, with an approximately 50m deep by 20km wide channel near the mouth.



Surface Water Features

Derby Tidal

Figure 6

Coordinate System: GDA 1994 MGA Zone 51

0 0.5 1 1.5 2

Kilometres

1:100,000 (A4)

Project Footprint

- Barrage
- Gates and Turbines
- Levee
- Access Road
- Transmission Line
- Tidal Creeks
- Public Drinking Water Source Areas

AECOM

4.9 Sedimentation

King Sound is undergoing net sedimentation on a geological time scale, caused by the Fitzroy River. The Fitzroy River has a large catchment that includes pastoral plains vulnerable to erosion due to historical overstocking and during each wet season, the river carries large quantities of sediment into King Sound. Most of this sediment is captured within King Sound due to its overall size and the distance between the river mouth and the entrance to the Sound.

Doctor's Creek has a small (approximately 140km^2) catchment and no real source of sediment from inland. The fine muddy sediments brought into the upper reaches of King Sound by seasonal flood events are easily mobilised by tidal movements. Modelling completed by Wolanski and Spagnol (2003) indicate that the upper reaches of Doctor's Creek are currently accumulating fine sediment at a rate of some 0.2cm per year. Suspended sediment loads in creeks are maintained through strong currents acting on sub tidal and intertidal deposits with net transport of sediment being into creeks from King Sound.

The gross sand bed load transport in the main north-south channel from Derby to north of Doctor's Creek is estimated (HGM, 2003) as being:

Spring Tides	Flood:	700 – 2000m^3/tide cycle (southwards)
	Ebb:	4000 – 11000m^3/tide cycle (northwards)
Neap Tides	Flood:	150 – 500m^3/tide cycle (southwards)
	Ebb:	900 – 2600m^3/tide (northwards)

Due to low energy winds and wave climate the transport of sand by way of normal nearshore surf zone processes is low 5000m^3 per year southwards and 1500m^3 northwards (HGM, 2003). Hourly spot velocity measurements were taken in September 2002 over a nine hour period measured velocity and direction. Several adjustments were made to this to allow for depth, main channel differentiation, and mean spring tide conditions. The adjustments resulted in the following:

Mean Spring Tide	Flood:	peak 0.78m/sec, average 0.56m/sec
	Ebb:	peak 1.35m/sec, average 0.93m/sec
Mean Neap Tide	Flood:	peak 0.53m/sec, average 0.37m/sec
	Ebb:	peak 0.86m/sec, average 0.6m/sec

Using these flood and ebb velocities together with a 500m wide cross sectional area (below MSL) calculated the magnitude range of sand transport potential as the following:

Spring Tides	Flood 700 – 2000m^{3}tide cycle (southwards)
	Ebb 4000 – 1100m^{3}tide cycle (northwards)
Neap Tides	Flood 150 – 500m^{3}tide cycle (southwards)
	Ebb 900 – 2600m^{3}tide cycle (northwards)

In King Sound sediment is trapped by small mud flocs adhering to sticky transparent exopolymeric (gel-like) particles creating muddy marine snow (see Alldredge and Gotschalk, 1998; Passow and Alldredge, 1994). A process called tidal pumping in the upper reaches causes this muddy marine snow to be transported towards the turbidity maximum zone in shallow coastal waters. Tidal pumping is caused by asymmetrical tidal periods, where the flood period is shorter than the ebb period, thereby affecting the speed of the flood period, causing heavy upstream transport of sediments. Fine sediment cannot escape due to the turbidity maximum zone, therefore King Sound experiences a net accumulation of sediment (Wolanski and Spagnol, 2003).

The river bed is sandy and composed of ferric rich, quartz dominated sediment, ranging in size from silts to course grained sands. The edge of the intertidal flats has steep levees composed dominantly of laminated muds, which grade laterally into super tidal flats (Pearson *et al*, 1998).

The tidal flats are zoned into several geomorphic/lithofacies units

- low tidal sand flats are underlain by mega-rippled sand and shelly sand
- mud/sand slopes encompass mid to low tidal levels and are underlain by mud/sand laminite and mud laminate
- salt flats are the highest tidal unit and they are underlain by laminated and vesicular mud.

The sand banks in the east branch were medium dense to dense in the upper 1m, becoming dense to very dense at 3.15m (Coffey, 1997).

The Delft3D model system was used to undertake hydrodynamic modelling (Cardno, 2014) to investigate morphological changes in the altered basins. The Delft3D modelling system includes wind, pressure, tide and wave forcing, three-dimensional currents, stratification, sediment transport and water quality descriptions. In the King Sound region, intertidal areas have a significant influence on hydrodynamic processes. Delft3D includes a robust and efficient wetting and drying algorithm developed to simulate this process. Hence the model is able to describe sediment transport in the breaking wave zone that shifts horizontally with the tide. Initial data came from the GHD (2003) design which was sourced from the Department of Marine and Harbours and modified by data from a gauge mounted at the mouth of Doctor's Creek.

4.10 Vegetation

Much of the project area above sea level consists of open tidal mud flats with very little vegetation. Narrow bands of mangrove line Doctor's Creeks' steep banks. In this section the discussion focuses on two of the geomorphic units in Table 6 "dune hinterland"- terrestrial vegetation and "mangrove and saltmarsh flats" -intertidal vegetation.

4.10.1 Geomorphic Units of King Sound

The main features of the geomorphic and vegetation units of King Sound are described by Seminiuk (1980) and are shown in Table 6.

Table 6 Main features of geomorphic and vegetation units (Seminiuk, 1980)

Geomorphic Unit	Vegetation	Description	Relation to tide level
Dune hinterland	*Eucalyptus – Acacia* scrub; grasses	Longitudinal dunes trending east-west	Relief up to 5m above HAT*
Supra-tidal/saltmarsh flat	Grasses on supra-tidal area, halophytes on saltmarsh	Adjoining dunes, narrow zone with gradients typically of 1 in 100	Junction between supra-tidal zone and saltmarsh at about EHWS*
Salt flat	Not vegetated	Extensive sub-horizontal surface with gradients typically of 1 in 2000	Flooded by tides higher than MHWS*
Mangrove and saltmarsh flats	Mangrove community at seaward edge, salt-marsh community at landward edge	Vegetated zone with gradients typically from 1 in 600 to 1 in 25	Height at seaward edge ranges from MSL to HWN*; landward edge at MHWS*
Inclined slope	Mostly not vegetated, rarely *Avicennia* saplings	Featureless surface with gradients of 1 in 40 to 1 in 20	Mid-tidal to LWN* levels
Low tidal flats	Not vegetated	Slope with gradient typically of 1 in 100, broken locally by rocky outcrops and sand shoals	Exposed at MLWS*
Tidal creeks	Vegetated by mangrove species or *halophytis* species if banks at appropriate level otherwise not vegetated	Ramifying and meandering channels, typically ranging in size from a few cm up to 1km in width	Creeks developed at all levels above LWN*

Geomorphic Unit	Vegetation	Description	Relation to tide level
Sea cliffs	Not vegetated but high tidal cliffs are cut into mangrove/saltmarsh flats	Steep to vertical cliff surfaces typically <1m up to 6m high	Mainly developed at HWN* and LWN* levels

* HAT = highest astronomical tide (10.9m); EHWS = equinoctial high-water spring tide; MHWS = mean high-water spring tide (10.0m); HWN – high-water neap tide (7.0m); MSL = mean sea-level (4.5m); LWN = low-water neap tide (2.7m); MLWS = mean low-water spring tide (0.2m); LAT = lowest astronomical tide (-0.6m).

4.10.2 Terrestrial Vegetation

Flora and vegetation of the transmission line alignment and Point Torment Peninsula was mapped by HGM (1998). The alignment and peninsula was traversed by vehicle and on foot and vegetation was mapped at a 1:100,000 scale. Fifteen vegetation associations were identified and classified into six vegetation types. These are illustrated in Figure 7 and described in Table 7.

Table 7 Terrestrial vegetation of the transmission line and peninsula

Vegetation	Description
Riverine woodland	
Eucalyptus camaldulensis/Melaleuca leucadendra riverine woodland	Found along the Fitzroy river, this vegetation consists of moderately dense woodland of *Eucalyptus camaldulensis* and *Melaleuca leucadendra* over an open cover of *Mallotus nesophilus* over sparse to open cover of perennial herbs and an open cover of Wild Passionfruit **Passiflora foetida* vines over sparse grasses of *Dichanthium sericeum, Eragrostis tenellula* and *Paspalidium rarum*.
Mixed Eucalyptus woodland over grasses	Occurring along prominent creeks with a more open canopy than the riverine woodland. Dominated by *Eucalyptus ?polycarpa* and *Eucalyptus tectifica* with occasional *Eucalyptus camaldulensis* over a sparse to open cover of tall shrubs including *Melaleuca acacioides* and *Melaleuca viridiflora* with scattered *Acacia colei, Acaia monitcola, Carissa lanceolata* and *Ehretia saligna* over moderately dense cover of low grasses of **Cenchrus setiger, Ectrosia scabidra, Eragrostis ?falcata, Whiteochloa airoides* and *Xerochloa laniflora* over sparse herbs.
Mixed woodland over grasses	Open to moderately dense woodlands of *Atalaya hemiglauca, Eucalyptus ?alba* and *Terminalia hadleyana* subsp. *carpenteriae* over occasional tall shrubs of *Acacia colei* over opent o dense grasses of *Dichanthium sericeum* and *Sorghum stipoideum* over sparse herbs.
Melaleuca tall shrubland/low woodland / Wetland Soaks	
Eucalyptus tectifica woodland over herbs	Occurring in inundated areas it consists of moderately dense to dense woodland of *Eucalyptus tectifica* above patchy dense cover of herbs dominated by *Alternanthera angustifolia* and other herbs including *Centipeda minima, Heliotropium ovalifolium* and *Phyllanthus maderaspatensis*.
Melaleuca tall shrubland in seasonal swamps and along small creeks	Moderately dense tall shrubland of *Melaleuca nervosa* subsp. *crosslandiana* or *melaleuca viridiflora* with scattered emergent trees of *Eucalyptus tectifica, Lophostemon grandiflorus* and *Lysiphyllum cunninghamii* over a dense cover of low sedges and herbs including *Byblis liniflora, Eriocaulon cinereum, Schoenoplectus dissacanthus, Nymphoides ?beaglensis* and *Rotala diandra.*
Tree savannah	
Tree savannah dominated by *Eucalyptus tectifica*	Found on floodplain associated with creek systems and on swales between dunes near Derby characterised by open to moderately dense low woodland of *Eucalyptus tectifica,* sometimes with a significant cover of *Atalaya hemiglauca* or *Corymbia greeniana* over a dense cover of grasses dominated by *Chrysopogon* and *Sorghum* species with *Aristida inaequiglumis, *Cenchrus ciliaris* and *Enneapogon purpurascens* over sparse variable herbs.

Vegetation	Description
Tree savannah of Bauhinia, Beefwood and Boabs	Occurs in large swathes, typically a sparse to moderately dense woodland dominated by Bauhinia, *Lysiphyllum cunninghamii,* with lesser amounts of Beefwood *Grevillea striata* and scattered Boabs *Adansonia gregorii*. Occasional shrubs included *Acacia colei* and *Acacia eriopoda* over a moderately dense grass layer of *Chrysopogon* and *Sorghum* species and *Aristida inaequiglumis* and *Eriachne glauca.*
Tree savannah dominated by *Erythrophleum chlorostachys*	Open to moderately dense tree overstorey dominated by *Erythrophleum chlorostachys* together with some *Corymbia greeniana* and *Lysiphyllum cunninghamii* over scattered shrubs of *Acacia colei* and *Carissa lanceolata* over dense herbs of *Sorghum stipoideum, Crotalaria crispate, Cynanchum pedunculatum* and *Gomphrena flaccida*.
Pindan and dunes	
Pindan dominated by tall shrublands of *Acacia eriopoda*	Open to moderately dense tall shrubland with sparse to open cover of trees dominated by *Corymbia greeniana* over *Acacia eriopoda, Acacia colei, Acacia synchronicia, Gossypium australte, Grevillea pyramidalis* and *Melaleuca* species over low shrubs including *Crtalaria crispate, Abutilon andrewsianum,* and *Blumea integrifolia* over dense grasses dominated by *Chrysopogon* and *Sorghum* species. Three variations were identified: 1) Disturbed areas such as road margins were frequently dominated by *Acacia colei* 2) Areas dominated by *Acacia monticola* 3) Some area featured *Acacia synchronicia* beneath the *Acacia eriopoda* overstorey
Pindan dominated by *Acacia tumida*	Dense tall shrubland of *Acacia tumida* with occasional trees including *Erythrophleum chlorostachys, Corymbia greeniana,* and *Eucalyptus grandifolia* over lesser amounts of other shrubs including *Acacia eriopoda, A. platycarpa, Carissa lanceolata, Distichostemon hispidulus, Grevillea refracta* and *Wrightia saligna* over a variable low shrub understorey ranging from open *Waltheria indica* to open *Corchorus sidoides* and *Crotalaria crispate* to dense patches of *Senna notabilis* with a sparse to moderately dense layer of variable herbs. Sparse grasses included *Chrysopogon* and *Aristida* species. *Calytrix exstipulata* provided sparse to open cover along the Derby Highway. This association also occurred on the Point Torment Peninsula.
Tall shrubland of *Acacia eriopoda* and *Melaleuca*	Found on poorly drained, lower-lying areas within the pindan vegetation characterised by moderately dense tall shrubland of *Acacia eriopoda* and *Melaleuca nervosa* subsp. *crosslandiana* with scattered *Hibiscus panduriformis* and *Senna notabilis* and occasional trees of *Lysiphyllum cunninghamii* and dense grasses dominated by *Chrysopogon* and some *Eriachne* species over a sparse variable herb layer.
Steppes	
Tree steppe of Bauhinia, Beefwood and Boabs	Overstorey of Bauhinia, *Lysiphyllum cunninghamii,* with Beefwood *Grevillea striata* and occassional Boabs *Adansonia gregorii* sometimes over a sparse to open cover of tall shrubs of *Acacia eriopoda* or *Acacia farnesiana* over moderately dense cover of spinifex *Triodia wiseana* and *Triodia intermedia* with some *Plectrachne pungens*.
Tree steppe dominated by *Corymbia greeniana*	Scattered trees of *Corymbia greeniana* and *Grevillea striata, Hakea arborescens* and *Lysiphyllum cunninghamii* over moderately dense to dense steppe of *Triodia wiseana, Enneapogon purpurascens* and **Cenchrus ciliaris* over an open cover of herbs including *Trichodesma zezylanicum, Buchnera urticifolia* and *Gomphrena flacida*.

Vegetation	Description
Shrub steppe of *Acacia* species	Small patches of open to moderately dense shrubland dominated by *Acacia colei, A. monticola* or *A. tumida* with additional shrubs including *A. synchronicia, Ehretia saligna, Ptilotus calostachyus* and *Senna notabilis* with occasional emergent trees of *Corymbia greeniana* over dense spinifex of *Triodia wiseana* and *Triodia intermedia* with *Chrysopogon* species, *Eriachne obtuse* and *Plectrachne pungens.*
Grass Savannah	
Grass Savannah	Found on cracking clay (black soil) plains consisting of dense low grassland of *Aristida latifolia, Chrysopogon* species, *Eragrostis tenellula, Eriachne glauca* and *Iseilema ?vaginiflorum*. This vegetation community lacked a shrub and tree overstorey with only occasional shrubs such as *Acacia farnesiana, Ehretia saligna, Grevillea striata* and *Gossypium australe*. Sparse herbs include *Gomphrena canescens, Pluchea tetranthera, Streptoglossa bubakii* and *Trichodesma zeylanicum*.

4.10.3 Intertidal Vegetation

Intertidal flats occur at the edges of most tidal estuaries. Sediments are deposited from the incoming tides in the creek systems and generally comprise of mud and sands. Dyer *et al* (2000) describes the distinct zones of mudflats being:

Lower tidal flats: lie between mean low water neap and mean low water spring tide levels, often subjected to strong tidal currents

Middle flats: located between mean and low water neaps and mean high water neaps

Upper flats: lie between mean high water neap and mean high water spring tides. These are the least inundated part of the mudflat and only submerged at high water by spring tides.

The intertidal flats are bounded by zones of vegetation, usually commencing at the MSL or at the neap tide level (Dyer *et al* 2000). At Doctor's Creek these are characterised by mangrove and samphire communities. Mangrove communities fringe the mudflats and land and consist of salt-tolerant trees. Mangroves are highly specialised tree species that perform several important ecological functions including stabilising coastal sediments, coastal protection and acting as a nursery grounds for juvenile vertebrate and invertebrate species. These habitats are often found within estuaries and fringing tidal mud flats located along the Kimberley coastline. They play an important role in carbon export, nutrient cycling and the uptake of heavy metals and other pollutants (Luck, 2008). In addition, mangroves provide habitat to terrestrial and marine plants, algae, invertebrates and vertebrates (Nagelkerken *et al*, 2008). There are approximately 25,535ha of mangroves within King Sound including Doctor's Creek. Within the tropical north-west of Western Australia, it has been estimated that there are 250,700ha of mangroves; Doctor's Creek mangroves represent 0.7% of this area. The most common and important mangrove species of King Sound were identified by Semeniuk (1980) as *Aegialitis annulata, Aegiceras corniculatum*, *Avicennia marina, Camptostemon schultzii, Ceriops australis* and *Rhizophora stylosa*.

Mangrove and samphire community surveys were completed in conjunction with the flora and vegetation surveys by HGM in 2007. Botanists traversed the project area on foot and collected vascular plant species to identify at the State Herbarium. Vegetation communities and mangroves were mapped based on spatial distribution, aerial photographs, and ground-truthing using survey sites.

Mangroves within Doctor's Creek form a relatively narrow band compared to those present in King Sound. The width of mangroves narrows and lowers in height further up the creek near the headwaters. Mangroves at the headwaters consist of *Avicennia samphire* species in bands of approximately 5 to 20m thick. Where minor creeks feed into Doctor's Creek there is often an increase in elevation of the mangroves and an increasing complexity of vegetation type.

The seaward mangrove communities of the creek are colonised by thick banks of *Ceriops* species. Monospecific bands of *Ceriops* occur, often as densely packed 5-10m trees, at the division of the main creek branches. In some areas considerable slumping of the sediment has occurred and falling trees are evident. The deposition of this sediment is visible in the creeks and is being colonised rapidly by *Aegialitis annulata* followed by *Avicennia marina* or *Camptostemon schultzii*. Thin trunks and dense packing of trees indicates that the mangroves within the creek are quite young. More specifically, six mangrove and two samphire communities were mapped within Doctor's Creek by HGM (1998). Vegetation descriptions and their spatial distribution are presented in Table 8 and Table 9 and Figure 8.

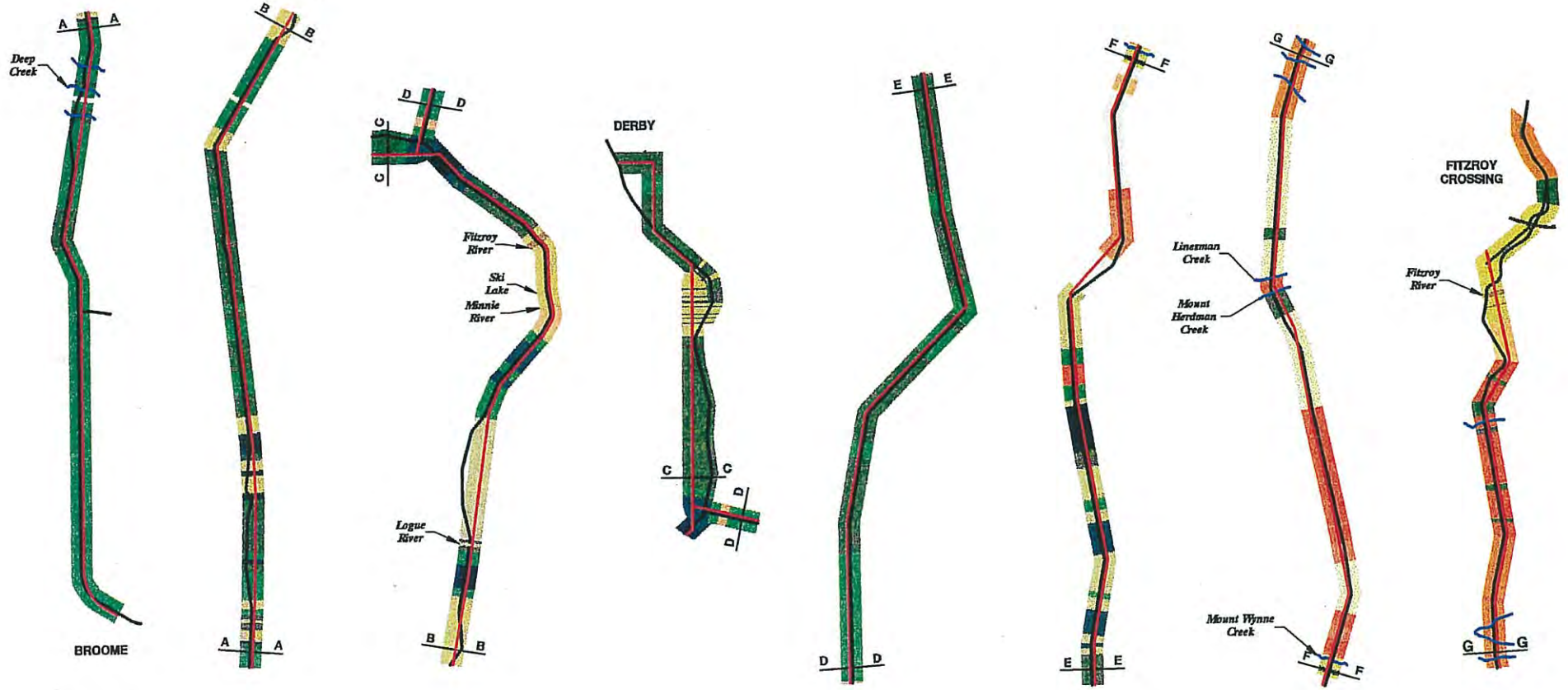
No mangrove communities within the Fitzroy Trough sub-region are considered threatened or at risk (Graham, 2001) and are not identified as Environmentally Significant Areas (ESAs).

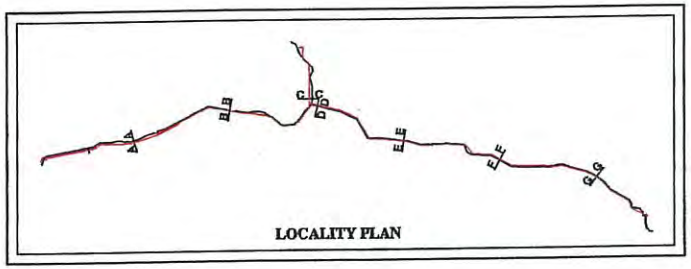
Table 8 Area of mangrove and samphire occurring upstream

Category	Species association	West branch (ha)	East branch (ha)	Total (ha)
Mangrove				
1	*Avicennia/Camptostemon* association (with *Aegialitis* understorey)	54.96	99.03	153.99
2	*Ceriops* dominant (occasional *Rhizophora/Bruguiera*)	13.07	25.23	38.30
3	*Ceriops/Avicennia/Excoecaria/Osbornia/Aegiceras* (with occasional *Xylocarpus*) association	351.09	368.93	750.02
4	*Ceriops/Avicennia* association (often with samphires)	87.78	88.76	176.54
5	*Avicennia* dominant	65.19	106.78	171.97
8	*Avicennia* with a samphire understorey (≥5m)	186.71	371.58	558.29
	Total	758.80	1060.31	1819.11
Samphire				
6	*Avicennia* with a samphire understorey (≤5m)	48.52	39.55	88.07
7	Samphires with occasional *Avicennia*	245.13	251	496.13
	Total	293.65	290.55	584.20

Table 9 Area of mangrove and samphire occurring downstream of proposed tidal barrages in the immediate area of Doctor's Creek

Category	Species association	West branch (ha)	East branch (ha)	Total (ha)
Mangrove				
1	*Avicennia/Camptostemon* association (with *Aegialitis* understorey)	237.05	78.85	315.90
2	*Ceriops* dominant (occasional *Rhizophora/Bruguiera*)	-	-	-
3	*Ceriops/Avicennia/Excoecaria/Osbornia/Aegiceras* (with occasional *Xylocarpus*) association	246.94	496.25	743.19
4	*Ceriops/Avicennia* association (often with samphires)	8.59	0.63	9.22
5	*Avicennia* dominant	19.56	-	19.56
8	*Avicennia* with a samphire understorey (≥5m)	158.44	244.54	402.98
	Total	670.58	820.27	1490.85
Samphire				
6	*Avicennia* with a samphire understorey (≤5m)	-	-	-
7	Samphires with occasional *Avicennia*	37.41	216.66	254.07
	Total	37.41	216.66	254.07





LEGEND

Tall shrublands on sandplains and dunes

- Pindan dominated by *Acacia eriopoda*
- Variation dominated by *Acacia colei*
- Variation dominated by *Acacia monticola*
- Variation with *Acacia synchronicia*
- Pindan dominated by *Acacia tumida*
- Tall shrubland of *Acacia eriopoda* and *Melaleuca*

Great Northern Highway

Transmission Line

Tree savanna

- Tree savanna dominated by *Eucalyptus tectifica*
- Tree savanna of Bauhinia, Beefwood and Boabs
- Tree savanna dominated by *Erythrophleum chlorostachyus*

Tree and shrub steppes

- Tree steppe of Bauhinia, Beefwood and Boabs
- Tree steppe dominated by *Eucalyptus dampieri*
- Shrub steppe of *Acacia* species

Grass savanna

Woodlands and tall shrublands associated with drainage areas and seasonal swamps

- *Eucalyptus camaldulensis/Melaleuca leucadendra* riverine woodland
- Mixed *Eucalyptus* woodland over grasses
- Mixed woodland over grasses
- *Eucalyptus tectifica* woodland over herbs
- *Melaleuca* tall shrubland in seasonal swamps and along small creeks

SCALE

0 5 10 15 20

kilometres

Halpern Glick Maunsell

Consulting Engineers and Environmental Scientists

HGM

Members of the Association of Consulting Engineers Australia

Figure 7

VEGETATION ASSOCIATIONS OF THE TRANSMISSION LINE ALIGNMENT

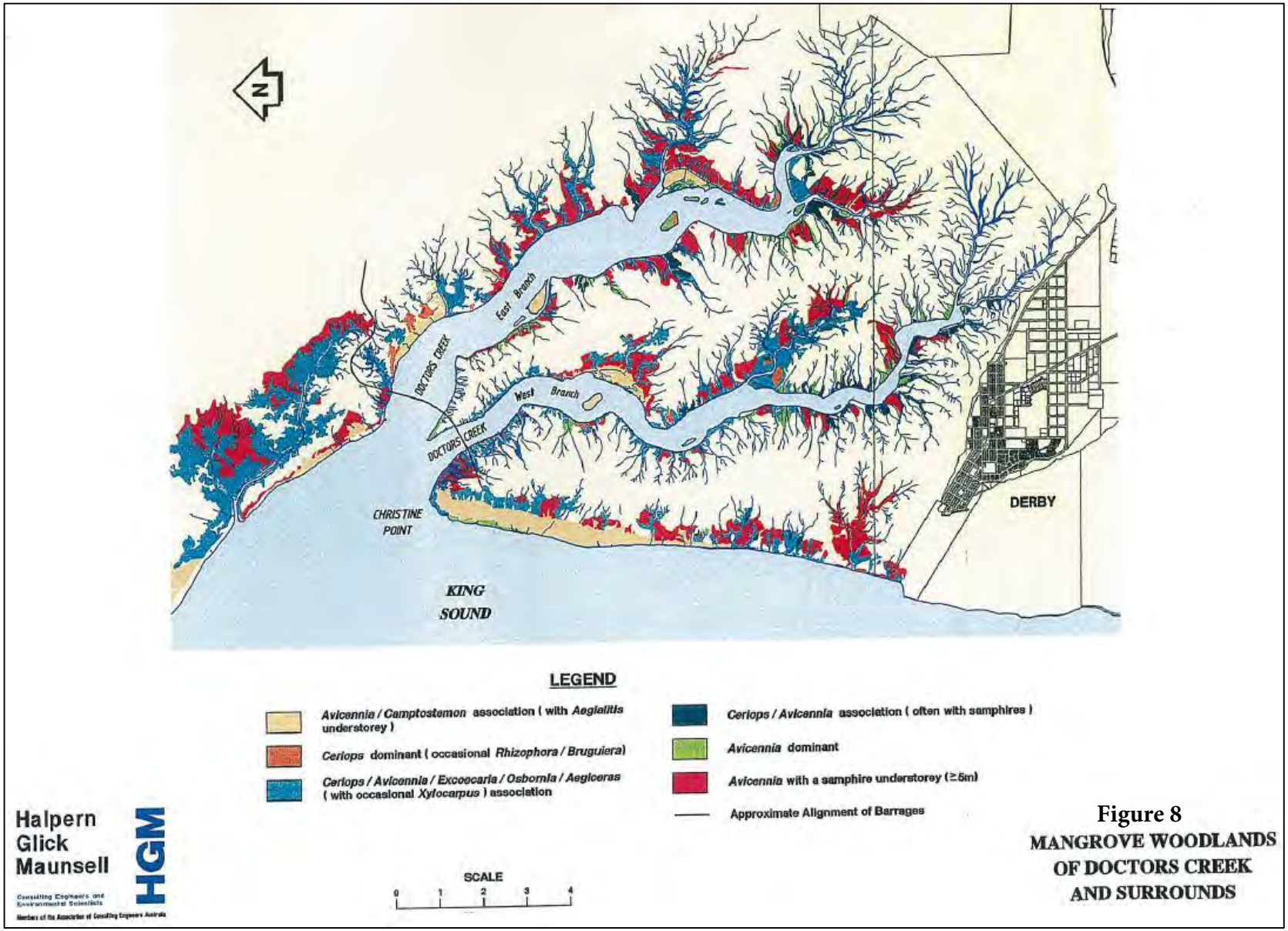


Figure 8
MANGROVE WOODLANDS OF DOCTORS CREEK AND SURROUNDS

4.10.4 Interaction of Mangroves with Water

Basic requirements of mangroves as identified by Semeniuk *et al,* (1978) include: warm climate, protected shores, salt water and tides. Furthermore, Semeniuk *et al*, (1978) explores the major influences on survival of mangroves, which include:

1) frequency of flooding by tidal waters - dependent on tidal pattern and height of shore above MSL
2) soil type
3) soil salinity
4) drainage - related to soil properties
5) plant interactions - such as interspecific competition
6) animal interactions - some are beneficial by adding nutrients to the soil, others are damaging such as boring ship-worm.

Mangroves' preferred habitat is being partially inundated part of the time at HWS (High Water Spring Tide) and not inundated at MSL. Studies completed by SKM (2011) and Semeniuk (1980) show that mangroves are resilient and adaptive to alterations in water levels (Figure 9). They are opportunistic species that have the ability to alter their distribution and zonation in response to water availability, tidal range and sediment distribution (Diamond Island Pty Ltd, 1997). Aerial imagery over time shows them to expand and contract at Doctor's Creek as local conditions change (SKM, 2011). This implies that direct temporary impacts on mangroves for establishing infrastructure may have limited long-term effects as mangroves are able to recolonise.

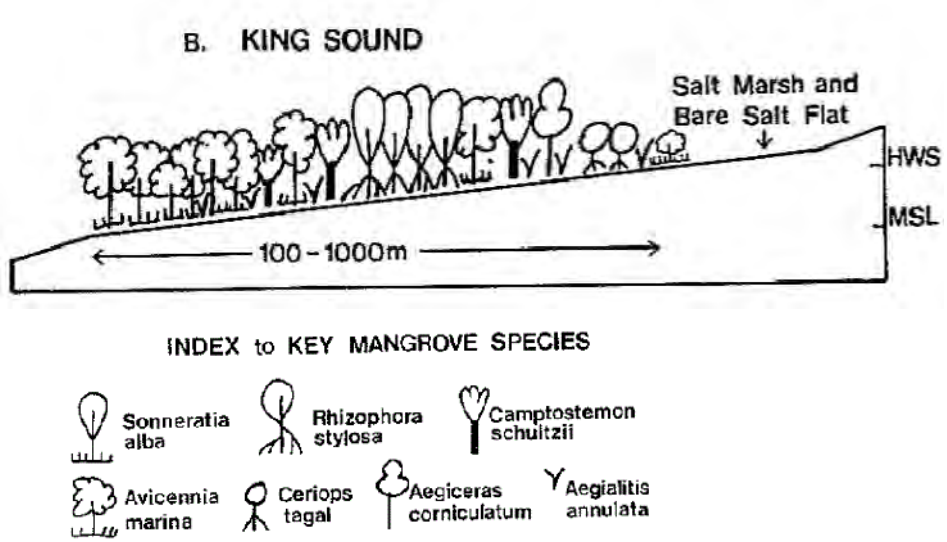


Figure 9 Diagram of King Sound mangrove zones and their relation to inundation as described by Semeniuk *et al*, 1978

4.10.5 Cyanobacterial Mats

Cyanobacterial mats (blue-green algal mats) occur in the Pilbara at the extreme landward edge of the mangroves between the samphires and the mangroves where the salinity exceeds the tolerance of both of these vegetation types. Algal mats that occur in the Pilbara may fix nitrogen (Palin *et al*, 1989) and have the potential to provide nutrients to the mangroves when inundated by spring tide (Paling and McComb, 1994). It is likely that algal mats serve a similar function in the Kimberley. Palin (1997) did not map any algal mats due to the inability to view these from a height greater than ten metres therefore their area remains uncertain. The author did recognise that the cracked desiccated mud was likely to have a thin cyanobacterial mat however it was not continuous.

4.10.5.1 Weed Species

The terrestrial flora and vegetation survey identified eight weed species as follows:

- *Cenchrus ciliaris* is a common grass that has been spread throughout arid Australia to provide fodder to cattle (Hussey *et al*, 2007). This species has a high environmental risk rating under the DEC Weed Strategy (DEC 1999)
- *Cenchrus setiger,* similar to *Cenchrus ciliaris* this species is a common fodder for cattle (Hussey *et al,* 2007) and has a high environmental risk rating (DEC, 1999)
- *Tridax procumbens* is common in disturbed areas of the Kimberley (Hussey *et al*, 2007) and has a moderate risk rating (DEC, 1999)
- *Stylosanthes humilis* is a fodder crop for cattle in the tropical regions (Hussey *et al*, 2007) this species has a mild risk rating (DEC, 1999)
- *Melochia pyramidata* is a weed of rivers, creeks and irrigated crops in the Kimberley and Pilbara regions (Hussey *et al,* 2007) with a mild risk rating (DEC, 1999)
- *Aerva javanica* was introduced to assist with revegetation of degraded rangelands but has since become widespread from the Kimberley to Carnarvon (Hussey *et al,* 2007). This species has a high risk rating (DEC, 1999)
- *Malvastrum americanum* is found along river and creek margins, wastelands and many arid zone habitats from the Kimberley to the Pilbara (Hussey *et al*, 2007). This species has a moderate risk rating (DEC, 1999)
- *Passiflora foetida* is a common weed of disturbed areas on river and creek banks between Kimberley and Carnarvon (Hussey *et al*, 2007) and has a high risk rating (DEC, 1999).

None of the weed species were listed as a Declared Pest under the *Biosecurity and Agriculture Management Act 2007*. All weed species are considered common in the Kimberley and Pilbara bioregions.

4.10.6 Important Interactions

Semeniuk *et al (*1978) conducted detailed studies of mangroves of WA. They showed that mangroves interact between plants, benthonic mobile and encrusting marine organisms, nektonic (free swimming) marine animals, and terrestrial fauna. They described mangroves as providing the basis of the food chain in the form of leaf litter and plant detritus on the ground and provide leaves, flowers and fruits for insects, birds and bats. In addition, other organisms associated with mangroves include algae and diatoms which are also primary links in the food chain.

Fauna species associated with mangroves are described as either resident or temporary. Associated fauna includes invertebrate and vertebrate groups who are distributed through the mangroves in distinct zones related to frequency of tidal flooding, soil type, salinity and the type of surrounding plant communities (Semeniuk *et al,* 1978).

4.11 Fauna and Fauna Habitat

A total of 228 bird species, 33 mammal, 15 frog and 80 reptile species may potentially occur within the project area (HGM 1998). Fauna in the Doctor's Creek area can be found in several distinct and overlapping habitats including: Marine, intertidal and terrestrial.

The online DOTE protected matters search tool (24 May 2013) with a five km buffer (Appendix N), indicates that there are several Matters of National Environmental Significance (almost all are fauna species) that are likely to occur in or near the project area. This report identified:

- 22 listed threatened species (13 marine, 9 terrestrial)
- One National Heritage Place (the West Kimberley)
- 27 listed migratory species.

The species known to or likely to occur are discussed in detail in Section 8.0.

4.11.1 Marine Habitat

Marine habitat is comprised of multiple layers including:

- Benthic: ocean floor including corals and seagrasses
- Water column: unobstructed water
- Surface: the upper surface of the water column where water tends to be warmer and more food is readily available.

There are no coral reef habitats or sea grasses on the ocean floor in Doctor's Creek or just outside the mouth of the river system. A study completed by Morgan *et al* (2011) suggests that the marine environment at Doctor's Creek is suitable for the *Glyphis garricki* northern river shark and *Pristis pristus*, Pristis *clavata* and *Pristis zijsron* which inhabit water that may be clear to very turbid and fresh to less than 35 ppt of seawater in tidal ranges of 8 to 11m.

Many of the species found in mangrove systems are an important food source for carnivorous species such as barramundi, trevallies and jacks. The nursery value of a mangrove system is related to its ability to provide suitable food, shelter, absence of turbulence and a reduction of predation (Blaber *et al*, 1985). The closest surveys have been undertaken in the islands and headlands at the mouth of King Sound (WA Museum, 1992; 1995) and these confirm that many of the species either favour or can tolerate silty water.

Doctor's Creek would not be considered a mangrove creek as it is not fed by a creek or river system and does not contain water during low tide to provide food and shelter for juveniles. The mangroves are low and sparse occupying areas of tidal flooding where banks are not too steep (Plate 4). These areas are generally too shallow for larger marine fauna.

Gobi fish burrow into mud to survive in low tides while other fish and crustaceans swim into mangroves only at high tide and retreat again at low tide (Diamond Island Pty Ltd, 1997). Mangroves of King Sound are particularly important for the Northern River Shark (*Glyphis garricki*), *Pristis pristus* (formerly *microdon*), *Pristis clavata* and *Pristis pristus*, which has been found in the King Sound in macrotidal mangrove systems (Morgan *et al*, 2009 and 2011).

Diamond Island Pty Ltd (1997) noted that crocodiles (*Crocodylus porosus*), sea snakes, turtles, and Dugongs (*Dugong dugon*) are likely to be found in the intertidal areas. These species are listed as Migratory or Marine Species under the EPBC Act. Due to turbidity in Doctor's Creek there are no seagrasses therefore Dugongs are unlikely to forage in Doctor's Creek, but are likely to transit through the area as they were recorded in Diamond Island surveys.

4.11.2 Intertidal Habitat

The intertidal habitats consist of Mangroves and Samphire flats at the edges of the mudflats. The mangroves are significant contributors to primary productivity within regions and usually sustain elaborate food chains with an energy flow pathway based on detritus and microbial decomposition (Palin, 1997). Not only benefiting the intertidal systems, organic matter is flushed out of the mangroves to benefit offshore marine ecosystems (Palin, 1997).

Mangroves provide habitat for a number of species including birds, bats, fish, crustaceans, and invertebrates. The mangrove leaf litter alone supports shrimps, amphipods, isopods, polychaete worms, clams and insects (Diamond Island Pty Ltd, 1997). Stems and leaves of mangroves supported barnacles, oysters, snails, and insects while the roots of mangroves supported xanthid and grapsid crabs (Diamond Island Pty Ltd, 1997). The HGM (1998) fauna survey identified 109 vertebrate fauna including 97 birds, six mammal species (all bats) and six reptile species in the mangrove habitat at Doctor's Creek.

Invertebrate fauna was monitored by Hanley (no date) in King Sound and compared to numerous other sites in the Kimberley and Northern Territory. Hanley (no date) found that species richness was significantly lower in King Sound and primary productivity of the mangroves is approximately 60% of the primary productivity of Darwin mangroves.

4.11.3 Terrestrial Habitat

Eight terrestrial fauna habitat types were identified (HGM 1998) along the original transmission line corridor from Broome to Derby to Fitzroy Crossing. While the project has not finalised end power users it cannot finalise a powerline impact other than to confirm that all disturbance will occur within the current previously disturbed road reserve. The fauna habitats are described as:

Riverine woodland: along major drainage lines. This habitat has the potential to support 91 non-passerine and 55 passerine bird species may occur. Trees with hollows provide roosting shelters for bird species. This habitat is likely to support up to 16 native mammal species, 14 reptile species and up to 15 frog species. Riverine Woodlands occur only along the main drainage lines. This habitat has the highest expected vertebrate species richness with a total of 196 species potentially occurring (HGM, 1998). The tall trees provide nesting or roosting shelters for many bird species.

Melaleuca tall shrubland/low woodland: occurs along creeklines and swamps and has the potential to support 39 non-passerine and 20 passerine birds, and three mammal species. Trees and tall shrubs represent suitable habitat for nesting by *Passeridae* and foraging for *Meliphagidea* (honeyeaters). Melaleuca tall shrubland occurs along relatively defined drainage areas. The tree or tall shrub overstorey represents suitable habitat for nesting and foraging. Pools of water resulting from seasonal inundation provide a food source for waterbirds.

Tree savannah: found on floodplains with second highest species richness. This habitat contains trees suitable for potential foraging and nesting sites and has the potential to support 36 non-passerine and 44 passerine birds which potential habitat for up to 21 mammal species and 52 reptile species. Tree savannah occurs broadly on floodplains. It consists of a woodland overstorey with a dense grass understorey, particularly suitable for reptile species.

Pindan: occurs on undulating plains and on Point Torment Peninsula. This habitat has the potential to support 28 non-passerine and 37 passerine bird species, eight mammal species and 24 reptile species. Among the mammals there is the potential for the Bilby (*Macrotis lagotis*) to occur in this type of habitat. This species is listed as Vulnerable under the EPBC Act, and T(VU) under the WC Act. The Pindan habitat occupies the majority of the area, occurring generally on the undulating plains and on Point Torment Peninsula. It has a tall shrub overstorey and grassy understorey.

Dunes: primarily pindan vegetation that occur on weak linear sand dunes. They are expected to support a similar array of pindan fauna and potential habitat for the Northern Marsupial Mole (*Notoryctes typhlops*). This species is listed as Endangered under the EPBC Act, T(EN) under the WC Act

Steppes: tree and shrub-steppes that occur on undulating plains. The trees and tall shrubs are expected to support up to 38 birds, 20 non-passerines and 18 passerines, three mammals, and up to 46 reptiles. The Steppes habitat comprises tree-steppes and shrub-steppes which occur broadly on the undulating plains to the east of Doctor's Creek. It has an overstory of trees and shrubs with an understory of spinifex. This habitat is particularly suitable for reptiles.

Grassland: found on cracking clay plains with a low species diversity for both flora and fauna. A potential 26 bird species comprising 21 non-passerines and 5 passerines may utilise this habitat. Six mammal species and nine reptile species are expected to occur in the dense grass cover. Grassland habitat occurs on the cracking clay plains to the east of Doctor's Creek. The low structural diversity is reflected in the low number of expected fauna species.

Wetland soaks: has the potential to support 86 non-passerines and 24 passerine bird species with areas of standing water are utilised by waterbirds. Four mammal species may occur including three bats and a water rat. Six frog species and seven reptiles may utilise the soaks. Wetland soaks are limited in the region surrounding the project area.

Bird Habitat

Mangrove habitats are well documented as supporting a diverse bird community, many of which are largely confined to this habitat within their range.

The extensive intertidal mudflats provide feeding grounds for migratory bird species after migratory flights from Siberia and Northern China through the East Asian Australasian Flyway.

The intertidal mudflats of north-west Australia provide feeding grounds for shorebirds arriving in Australia after migratory flights from Siberia and Northern China through the East Asian Australasian Flyway. The intertidal area of Doctor's Creek would be considered part of this flyway (HGM, 1998). Maintenance of tidal flats is essential to support food sources for migratory and local bird species (Walsum, 2003a).

Although Doctor's Creek is located within the East Asian Australasian Flyway, the area is unlikely to be of international significance and appears to be of limited value to shorebirds due to the relatively narrow intertidal flat available and restricted roosting sites available. Much of the intertidal flat has relatively steep areas of bank that are heavily eroded and unsuitable for wader use. Waders recorded during the field survey were observed on the flats on the floor of the creek system during low tides, however most of the area was underwater for most of the day and therefore presents little in the way of foraging resource for waders which typically follow the retreating tide.

The fauna survey was completed by HGM in 1997 as part of the CER (1998) which identified 16 migratory shorebird species as occurring in the intertidal area for foraging purposes. Of these, 15 were Asian-breeding migrants which are currently protected under international agreements and therefore protected under the EPBC Act (Table 10).

There was no evidence of seabirds using mudflats for nesting (Diamond Islands Pty Ltd, 1997) however they used the exposed creek beds at low tides for foraging (Hassell, 2002). It should be noted that as part of EPA condition 12, baseline surveys for all significant and migratory fauna species will be undertaken prior to construction of the project. This will assist in determining whether suitable habitat is present for MNES species not yet considered in this EIS.

4.12 Listed Threatened and Migratory Species

The online DOTE protected matters search tool (DOTE, 2013) indicates that there are several MNES that are likely to occur in or near the project area. This section provides a summary of the threatened and migratory species that have been recorded or are thought to occur within the project area based on previous studies. Potential impacts to these species are discussed in Section 8.0.

This section discusses the threatened species recorded or likely to occur in the project area in terms of:

- regional status
- population size
- spatial and temporal distribution in relation to breeding, nesting, roosting or feeding
- migration routes within and adjacent the site
- how species use their habitat
- breeding and feeding behaviours.

Migratory species are those animals that migrate to Australia and its external territories, or pass through or over Australian waters during their annual migrations. Listed migratory species also include native species identified in an international agreement approved by the Minister. The Minister may approve an international agreement for this purpose if satisfied that it is an agreement relevant to the conservation of migratory species.

Three such agreements, the China-Australia Migratory Bird Agreement (CAMBA), the Japan-Australia Migratory Bird Agreement (JAMBA) and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) are international bilateral agreements between the Government of Australia and the Governments of China, Japan and the Republic of Korea for the protection of migratory birds in danger of extinction.

The majority of listed species are shorebirds. The agreements require the parties to:

- protect migratory birds from take or trade except under limited circumstances;
- protect and conserve habitats
- exchange information
- build cooperative relationships.

Species denoted as listed migratory species are MNES under the EPBC Act and projects must go through the referral and assessment process if they have the potential to have an impact on a migratory species or its habitat.

Threatened and migratory species along with their status and habitat and likelihood of occurrence are outlined in Table 10.

The online DOTE protected matters search tool (24 May 2013) with a five kilometre buffer (Appendix N), indicates that there are several MNES that are likely to occur in or near the project area. This report identified:

- 22 listed threatened species (13 marine, 9 terrestrial)
- One National Heritage Place (the West Kimberley)
- 27 listed migratory species.

The species known to or likely to occur are discussed in detail in Section 8.0.

Table 10 Protected matters search listed threatened and migratory species

Species	EPBC Act status	Habitat	Comment
Fish			
Glyphis garricki Northern River Shark	Endangered	**Known to occur** in King Sound, which is recognised as important breeding ground. This shark primarily inhabits nearshore or estuarine environments (Stevens *et al,* 2005). Most collections in WA have occurred in turbid, macrotidal mangrove systems of King Sound in salinities greater than twenty parts per thousand and on sandy to silty substrates (Morgan *et al,* 2009). Not likely to breed in Doctor's Creek.	Recorded by Pillans *et al.* 2009 and Morgan *et al.* 2011 in King Sound.
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	**Known to occur in King Sound.** Dwarf sawfish are typically found on silt/sandflats in tropical shallow waters often influenced by large tides. While the majority of capture sites are from shallow, tidally influenced systems, some reports are from considerably deeper water (trawls) (Morgan *et al.* 2011).	Recorded by Morgan *et al.* 2011. King Sound (south) considered biologically important for foraging, nursing and pupping (DOTE, 2013).
Prisits microdon, now *Pristus pristus* Largetooth Sawfish [66182]	Vulnerable	**Known to occur.** Inhabits sandy or muddy bottoms of shallow coastal waters, estuaries, river mouths, freshwater rivers and lakes (Fletcher and Head 2006). The centre of their distribution and the most important nursery is the Fitzroy River in the Kimberley where both males and females have been recorded (Morgan *et al.* 2009). King Sound (south) considered an important area for foraging and nursing (DOTE, 2013).	Occur in the Fitzroy River, but may use Doctor's Creek for foraging habitat.
Pristis zijsron Green Sawfish [68442]	Vulnerable	**Likely to occur.** Inhabits muddy seabed habitats and estuaries (Allen 1997, Stead 1963). Individuals less than two and a half metres in length are more common in coastal waters, as well as estuaries and river mouths, but do not venture into freshwater. Larger individuals greater than two and a half metres in length are found in both inshore and offshore waters (Thorburn and Morgan 2004). The majority of capture locations are between Karratha and One Arm Point, with very few specimens recorded in King Sound (Morgan *et al.* 2011).	King Sound (south) not considered a biologically important area for this species (DOTE, 2013).

Species	EPBC Act status	Habitat	Comment
Rhincodon typhus Whale Shark	Vulnerable	**Unlikely to occur.** The Whale Shark is oceanic and coastal, tropical to warm-temperate, often seen far offshore but can also come close inshore to enter lagoons or coral atolls (DOTE, 2013). In Australia, the Whale Shark is known from NSW, Queensland, Northern Territory, Western Australia and occasionally Victoria and South Australia, but it is most commonly seen in waters off northern Western Australia, Northern Territory and Queensland	Unlikely to occur in Doctor's Creek.
Marine Mammals			
Balaenoptera musculus Blue Whale [36]	Endangered and Migratory	**Unlikely to occur.** The Blue Whale is found in oceanic waters north of 55°S, and is largely confined to the tropical waters of the Indian Ocean, southern Australia and east to New Zealand (DEWHA, 2010d). Three known areas of significance for the species are summer foraging grounds located at: the Perth Canyon, 22 km west of Rottnest Island, WA; the Bonney Upwelling, South Australia and Victoria; and the Duntroon Basin, South Australia (Department of Environment and Heritage (DEH), 2005).	Known areas of significance for this species is a long distance from Doctor's Creek. Unlikely to inhabit the Creek due to its shallow nature.
Megaptera novaeangliae Humpback Whale [38]	Vulnerable and Migratory	**Unlikely to occur**. Humpback Whales annually migrate between their summer feeding grounds in Antarctica to their tropical breeding grounds in winter. The Kimberley region is considered particularly important for the WA population of Humpback Whales whose breeding and calving grounds are thought to be in the northern end of Camden Sound. There is an important Humpback Whale calving and resting area between the Lacepede Islands and Beagle Bay in the south and Camden Sound in the north.	Whales tend to migrate in water depths of 20 to 500 m with the majority of whales within the 50 to 200 m isobaths. Although Humpback Whales calve in nearby Camden Sound, they are unlikely to enter King Sound.

Species	EPBC Act status	Habitat	Comment
Dugong dugon Dugong	Migratory	**Unlikely to occur**. Dugongs inhabit both shallow and deep water habitats (Lanyon *et al* 1989) although they generally frequent coastal waters, particularly areas with favourable seagrass beds. Major concentrations of dugongs tend to occur in wide shallow bays and mangrove channels and in the lee of large inshore islands (Marsh *et al* 2003a). Generally, shallow waters such as tidal sandbanks and estuaries are used for calving (Hughes and Oxley-Oxland, 1971; Marsh *et al*, 1984). Small concentrations of dugongs have been observed in seagrass between Cape Bossut and King Sound.	It is likely that dugongs occasionally utilise suitable seagrass habitats within the region of King Sound. The water in Doctor's Creek is turbid and does not support seagrasses.
Orcaella heinsohni Australian Snubfin Dolphin [45]	Migratory	**Possible**. The Australian Snubnosed Dolphin occurs in shallow waters up to 23km from the coast and up to 20km from the nearest river mouth (DSEWPAC, 2012). They have been recorded around mangroves, sandy bottom estuaries and embayments, as well as rock and/or coral reefs and shallow areas with seagrass.	King Sound is considered an important area for breeding, calving and foraging year round (DSEWPAC, 2012, DOTE 2013). No Australian Snubfin Dolphins have been recorded in Doctor's Creek.
Sousa chinensis Indo-Pacific Humpback Dolphin [50]	Migratory	**Possible.** The Indo-Pacific dolphin occurs along the northern Australian coastline, extending to Exmouth Gulf on the west coast (25°S), and the Queensland/NSW border region on the east coast (34°S). From mangroves to sandy bottom estuaries and embayments, to rock and/or coral reefs. These dolphins feed primarily in shallow waters (less than 20m).	The north of King Sound is considered likely breeding grounds while the southern sector supports important foraging habitat (DSEWPAC, 2012; DOTE, 2013). Sightings have not been recorded in Doctor's Creek.
Tursiops aduncus Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]	Migratory	**Likely to occur**. The Spotted Bottlenose Dolphins are found in inshore areas such as bays and estuaries, nearshore waters, open coast environments, and shallow offshore waters including coastal areas around oceanic islands.	According to DPW, Bottlenose Dolphins are reported to be the most common dolphin species seen in the King Sound area. King Sound considered an important foraging, breeding and calving area (DOTE, 2013).

Species	EPBC Act status	Habitat	Comment
Balaenoptera edeni Bryde's Whale [35]	Migratory	**Unlikely to occur**. The Bryde's Whale is typically found in tropical and warm temperate waters between 40°N and 40°S, in both oceanic and inshore waters (Bannister *et al*., 1996; DEWHA, 2010e). The species is the least migratory of the baleen whales, and is considered a tropical water specialist (Mustoe and Edmunds, 2008). The Bryde's Whale concentrates its feeding in areas of high productivity over the continental shelf (Mustoe and Edmunds, 2008).	The species is typically found in deep water.
Orcinus orca Killer Whale, Orca [46]	Migratory	**Unlikely to occur**. Killer Whales have been recorded from all states in Australia, showing particular concentration around Tasmania and in the Antarctic south of 60^{o} S (DOTE, 2013). They have been seen in all marine regions throughout all oceans and can enter river systems (DOTE, 2013).	Wide species distribution, usually found further South.
Marine Reptiles			
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	**Unlikely to occur.** Endemic to the North-west Bioregion and recorded from Exmouth Gulf and the reefs of the Sahul Shelf. Prefers reef flats, therefore is unlikely to be impacted by the project.	
Caretta caretta Loggerhead Turtle [1763]	Endangered	**Possible.** Loggerhead turtle rookeries in WA generally occur between Shark Bay and Ningaloo (Dutton *et al*. 2002), and occasional records as far north as Ashmore Reef (DEWHA 2008a). Shark Bay contains the largest breeding population of loggerhead turtles in Australia and the third largest in the world. Loggerheads are known to forage across a wide range of habitats including rocky and coral reefs, seagrass patches and estuaries (DEWHA 2008a).	Their entry into Doctor's Creek is considered unlikely as they are not known to be associated with intertidal flats. King Sound (south) is not recognised as a biologically important area (DOTE, 2013).

Species	EPBC Act status	Habitat	Comment
Chelonia mydas Green Turtle [1765]	Vulnerable and Migratory	**Unlikely to occur.** Green Turtles spend their first five to ten years drifting on ocean currents. During this pelagic (ocean-going) phase, they are often found in association with driftlines and rafts of *Sargassum* (a floating marine plant that is also carried by currents) (DSEWPAC, 2012). Once Green Turtles reach 30 to 40 cm curved carapace length, they settle in shallow benthic foraging habitats such as tropical tidal and sub-tidal coral and rocky reef habitat or inshore seagrass beds. The shallow foraging habitat of adults contains seagrass beds or algae mats on which Green Turtles mainly feed (DSEWPAC, 2012).	Green turtles have not been recorded in the area however they potentially use nearby islands for breeding. King Sound (south) is not recognised as a biologically important area (DOTE, 2013).
Dermochelys coriacea Leatherback Turtle [1768]	Endangered	**Unlikely to occur**. The Leatherback turtle is associated with tropical, sub-tropical and temperate waters throughout the world (DOTE, 2013). This species has the widest distribution of any marine turtle, occurring from the North Sea and the Gulf of Alaska in the Northern Hemisphere, to Chile and New Zealand in the Southern Hemisphere. They feed on gelatinous material and pelagic feeding opportunities.	No major nesting sites have been found in Australia, with only isolated nesting in southern Queensland and the NT. It is unlikely to be using King Sound as a breeding area.
Eretmochelys imbricate Hawksbill Turtle [1766]	Vulnerable and Migratory	**Unlikely to occur.** The hawksbill turtle breeds predominantly in WA from North West Cape to the Dampier Archipelago (Moritz *et al*, 2002, Dutton *et al*, 2002). The major rookeries for Hawksbill Turtles are in the Dampier Archipelago, the Montebello Islands and the Lowendal Islands (Limpus, 2004). The feeding areas of hawksbill turtles in WA are largely unknown, however, it has been suggested that they commonly feed on the reefs adjacent to the mainland Kimberley coast (Prince, 1994), and may migrate up to 2400km between their nesting and foraging grounds (DEWHA, 2008a).	Lack of reefs present in Doctor's Creek indicates that it is unlikely that this species is present within Doctor's Creek. King Sound (south) is not recognised as a biologically important area (DOTE, 2013).

Species	EPBC Act status	Habitat	Comment
Natator depressus Flatback Turtle [59257]	Vulnerable and Migratory	**Unlikely to occur**. The flatback turtle is known to have major nesting rookeries in northern WA. Breeding has been recorded from Exmouth in the Pilbara to Cape Domett on the Kimberley Coast and represents one of the four genetic stocks in Australia (Limpus, 2007). They feed on Halophyta seagrasses and soft invertebrates including sea pens, whips, gorgonians, sea cucumbers, spiny soft corals, jellyfish and gelatinous plankton.	Known breeding sites are 580km northeast of Doctor's Creek, near the NT border. Species may enter King Sound but it is unlikely to be significant habitat. King Sound (south) is not recognised as a biologically important area (DOTE, 2013).
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]	Migratory	**Known to occur**. The Salt-water Crocodile is found in Australian coastal waters, estuaries, freshwater sections of lakes, inland swamps and marshes. In Western Australia the species is found in most major river systems of the Kimberley. The largest populations occur in the rivers draining into the Cambridge Gulf, the Prince Regent and Roe River systems. They have also been recorded in isolated rivers of the Pilbara region, around Derby near Broome and as far south as Carnarvon on the mid-west coast (DEC, 2009a).	More than two dozen crocodiles were sighted in the creeks during the 1997 fauna survey.
Terrestrial Species			
Dasyurus hallacatus Northern Quoll	Endangered	**Unlikely to occur**. The Northern Quoll occurs in the Pilbara and further north through to the Kimberley (DOTE, 2013a). The species occupies wide range of habitats including, rocky areas, eucalypt forest and woodlands, sandy lowlands and beaches, shrubland, grassland and desert (DOTE, 2013a).	There are no listed records of Northern Quoll in the search completed in the area.
Macrotis lagotis Greater Bilby	Vulnerable	**Unlikely to occur**. In WA, the Greater Bilby occurs in disjunct populations in the Gibson Desert, southwestern Kimberley, inland areas of the Pilbara and northern Great Sandy Desert (DSEWPAC, 2011b). The Bilby occupies three distinct habitat types; open tussock grassland on hills, mulga woodlands and shrublands on ridges and rises and hummock grassland on plains and alluvial areas (DOTE, 2013a).	There have been eight records between 1963 and 2001 in the Kimberley with two records located 95 and 98km south of Derby.
Notorcyctes caurinus Karrkarratul, Northern Marsupial mole	Endangered	**Unlikely to occur.** The Karkarratul lives underground, primarily in sand dunes and sandy soils along river flats. Records are inland mostly in the Great Sandy Desert.	This species is considered unlikely to be at risk due to a lack of suitable habitat in the vicinity of the project area (sand dunes and river flats).

Species	EPBC Act status	Habitat	Comment
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheathtail Bat	Critically Endangered	**Unlikely to occur**. Records are from two distinct populations in the Northern Territory and in Queensland.	Records are from two distinct populations in the Northern Territory and in Queensland. Unlikely to be impacted by the project.
Xeromys myoides Water Mouse	Vulnerable	**Unlikely to occur**. The Water Mouse occurs in three discrete populations on the eastern and northern Australian coastline. It is known to occur in Queensland and the Northern Territory and may occur in Western Australia due to the proximity of records near the WA/NT border. Preferred habitat for this species includes mangroves and the associated saltmarsh, sedgelands, clay pans, heathlands and freshwater wetlands (DSEWPAC 2012).	There were no records of this species near the project area.
Avifauna			
Erthrotriorchis radiates Red Goshawk [942]	Vulnerable	**Possible.** Species is widely distributed across Australia, preferring taller woodlands and open forests. The species nests in tall trees, often near permanent water.	Species is likely to be an occasional visitor to the project area, however unlikely to directly use habitat within the project area.
Erythrura gouldiae Gouldian Finch [413]	Endangered and migratory	**Unlikely to occur.** Known breeding habitats occur in association with rocky hills, hollow bearing eucalypts and permanent fresh water. Gouldian's are the only Australian finch species that nests exclusively in tree hollows or in termite mounds. This species usually feeds on a range of seeding grasses. They are partly migratory, following grass seeding patterns.	No suitable habitat is present in the project area.
Rostratula australis Australian Painted Snipe [77037]	Endangered and migratory	**Unlikely to occur**. The Australian painted snipe generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. Breeding habitat requirements may be quite specific: shallow wetlands with areas of bare wet mud and both upper and canopy cover nearby.	Nest records are all, or nearly all, from or near small islands in freshwater wetlands. Doctor's Creek is unlikely to be a significant habitat for this species.
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	**Unlikely to occur**. This subspecies typically occurs in the north and north western Kimberley coast where they usually occur in heavier forested eucalypt country, roosting in large tree hollows or crevices in cliffs and occasionally caves (Biota 2009).	There is no heavily forested eucalypt country or large trees with hollows in the project area.

Species	EPBC Act status	Habitat	Comment
Apus pacificus Fork-tailed Swift [678]	Migratory	**Unlikely to occur**. The Fork-tailed Swift (Marine and Migratory (EPBC)) is a regular summer migrant to Australia, arriving in October and leaving by mid-April. It is generally observed flying high overhead, over open country, semi-arid deserts to coasts and forests (Pizzey & Knight 2007).	Given the mobile nature of this species and linear corridor of impact, there are unlikely to be any impacts on this species.
Ardea alba (modesta) Great Egret, White Egret [59541]	Migratory	**Known to occur**. The Great Egret occupies a wide variety of wet habitats including freshwater wetlands, dams, flooded pastures, estuarine mudflats, mangroves and reefs (Morcombe, 2003). This species is also known to visit shallows of rivers, sewage ponds and irrigation areas (Pizzey and Knight, 2007).	Species is known to occur in the project area (recorded during shorebird survey in November 1997).
Ardea ibis Cattle Egret [59542]	Migratory	**Known to occur**. The Cattle Egret is a small egret weighing only 390g and standing 70cm tall. The heaviest distribution of this species in WA is in the north east, and into the Northern Territory. In the non-breeding season, it can be found throughout most of Australia (DSEWPAC, 2012).	Species is known to occur in the project area (recorded in project area during shorebird survey in November 1997)
Charadrius veredus Oriental Plover, Oriental Dotterel [882]	Migratory	**Possible.** The Oriental Plover breeds in Mongolia and Manchuria before migrating to Australia where it is a regular visitor. Most common in coastal and northern inland Australia, this species can venture far from water and has been observed frequenting ploughed land, bare claypans, margins of coastal margins and open plains (Pizzey and Knight, 2007).	Doctor's Creek supports foraging habitat.
Haliaeetus leucogaster White-bellied Sea-Eagle [943]	Marine and migratory	**Known to occur**. The White-bellied Sea Eagle is a large raptor that is widespread throughout coastal Australia. The White Bellied Sea-Eagle occupies a wide range of habitats, usually in close proximity to a large body of water (including the ocean). Breeding usually occurs in tall open woodlands overlooking bodies of water (DSEWPAC, 2012). These habitats are not present in the project area.	Recorded in project area during the shorebird survey in November 1997.
Glareola maldivarum Oriental Pratincole [840]	Migratory	**Possible**. In non-breeding grounds in Australia, this species is known to inhabit marine areas, terrestrial wetlands, floodplains and grasslands (DSEWPAC, 2011). The Oriental Pratincole is particularly widespread along the Pilbara and Kimberly Coasts where its population is counted in the millions.	Doctor's Creek supports foraging habitat.

Species	EPBC Act status	Habitat	Comment
Hirundo rustica Barn Swallow [662]	Migratory	**Unlikely to occur**. The Barn Swallow is widespread in northern Australia during the summer months (Knight and Pizzey, 2007). Habitat includes open country, agricultural land, especially near water, railyards and towns (Knight and Pizzey, 2007).	The Barn Swallow is insectivorous and is unlikely to be impacted by the Proposal.
Merops ornatus Rainbow Bee-eater [670]	Migratory	**Known to occur**. The Rainbow Bee-eater is a common species which occupies numerous habitats including open woodlands with sandy loamy soil, sand ridges, sandpits, riverbanks, road cuttings, beaches, dunes, cliffs, mangroves and rainforests. The Rainbow Bee-eater avoids heavy forest that would hinder its pursuit of its insect prey (Morcombe, 2003).	Recorded in project area during shorebird survey in November 1997.
Poecilodryas superciliosa cerviniventris Derby White-browed Robin [26190]	Migratory	**Likely to occur**. Inhabits mangrove forests in northern Australia, including Derby.	
Sterna albifrons Little Tern	Migratory	**Possible.** The Little Tern inhabits sheltered coastal environments, but are not recorded from wetlands greater than one kilometre from the coast (DOTE, 2013)	The species is generally confined to coastal habitat, but was not recorded in site surveys.

5.0 Social and Economic Considerations

The International Energy Agency (IEA) projects that the world's primary energy demand will grow by more than one-third over the period to 2035 in the New Policies Scenario, with China, India and the Middle East accounting for 60% of the increase. Energy demand barely rises in OECD countries, although there is a pronounced shift away from oil, coal (and, in some countries, nuclear) towards natural gas and renewables (International Energy Agency, press release, World Energy Outlook, 2012).

Despite the growth in low carbon sources of energy, fossil fuels remain dominant in the global energy mix, supported by subsidies that amounted to $523 billion in 2011, up almost 30% on 2010 and six times more than subsidies to renewables.

5.1 Regional Considerations

The current lack of a suitable power supply is limiting development in the wider region, thereby also limiting employment and continued growth of small local communities. Industry in the surrounding Derby area would benefit from the Project as power becomes more readily available and cheaper. The Project may also encourage other industry and development in the wider region which would improve job opportunities, the local economy, and growth of nearby rural towns.

5.2 Local Considerations

The Project is located some 14km from the Derby township which supports numerous businesses and industry, including tourism and recreation (hotels, lodges, cruises), as well as common services found in most towns such as mechanics, petrol stations, restaurants and supermarkets. In addition to the township, nearby local industry includes:

- The Kimberley Prawn Farm
- RAAF Curtin Airbase
- Curtin Immigration Detention Centre
- Birdwood Downs Company
- Derby base hospital.

The Project is expected to benefit local industry by providing cheaper power. Tidal power will reduce the cost of power to 30c/Kw from Tidal Power. The reduction in price below this would depend on the extent of government support to new industry.

Horizon Power purchases its energy from Energy Developments Limited (EDL) at a price in excess of 50 cents per KWh, which it onsells to the general public at the uniform tariff in WA of 22.62 c/KWh. Horizon Power actively discourages industrial development as each extra KWh sold increases their loss. Large contestable customers (users requiring > 0.5 MW) and government departments have to pay the full cost of generation.

The Kimberley Prawn Farm is located in the low basin tidal flat, with its north operations located in the same footprint as the Project footprint. The Prawn Farm has successfully obtained approval for its operations (1998, EPA Bulletin 918). It is in the interest of the prawn farm operators for the Project to be successful. The availability of cheaper power at close proximity would dramatically reduce the cost of power necessary for aeration pumps in the prawn farm ponds. It is likely that the Kimberley Prawn Farm would purchase power to support the aeration systems for the prawn ponds. That company has delayed expansion of their prawn farm due to rising costs.

Social benefits include both direct and indirect employment opportunities. The Project would employ up to 200 people during construction. Furthermore, cheap power would encourage other projects to commence in the area, potentially providing more employment opportunities.

Recreational use of Doctor's Creek would still be possible during the operation of the Project.

5.3 Project Interactions with Others

The Project is located in the Shire of Derby/West Kimberley. The statistics for this section are from the 2011 census for the State suburb of Derby. This area was chosen because it includes the town of Derby and surrounds, including the Doctor's Creek area.

In the 2011 Census, there were 4,865 people in Derby. Of these 65.6% were male and 34.4% were female. Aboriginal and Torres Strait Islander people made up 25.2% of the population (Table 11).

Table 11 Demographics of the population of Derby, Western Australia, and Australia

People	Derby (WA)	%	Western Australia	%	Australia	%
Total	4,865		2,239,170		21,507,717	
Male	3,191	65.6	1,126,178	50.3	10,634,013	49.4
Female	1,674	34.4	1,112,992	49.7	10,873,704	50.6
Aboriginal and Torres Strait Islander	1,225	25.2	69,664	3.1	548,369	2.5

Future demand may arise in the area due to the expansion in mining developments in the region. Mining companies are projected to utilise 120GW while the Curtin Immigration Detention Centre and RAAF Curtin Air Base would use 20GW. Additional market demand may arise from Derby, Broome and Fitzroy in the future as towns expand.

The power station will become a tourist attraction and it is proposed that the local traditional owners could operate this side of the project. For example La Rance attracts 200,000 visitors per year and generates substantial income from tourism.

5.4 Economic Sustainability

Reliance on fossil fuels will have to decrease if Australia is to meet Kyoto Protocol standards by 2020. The only options are to seek alternative sources of fuel that do not emit greenhouse gases and can provide energy to the local and regional communities in a sustainable manner. The Project is expected to have a net positive impact on the environment by reducing our dependency on fossil fuels, reducing greenhouse gas emissions produced from energy generation in the Derby area and reducing transmission loss costs by generating energy for local use.

The lifespan of the Project is estimated at 120 years. For the duration of this time the local and regional area would be able to purchase cheap and clean power.