3. DESCRIPTION OF EXISTING ENVIRONMENT

This section describes the physical, biological and social environment in which the proposed project will be constructed and operated. The majority of the information presented in this section has been obtained by field survey of the lease area, review of readily available information and discussions with persons having specific knowledge of the region. It should be noted that due to timing constraints field surveys for flora, fauna and biting insects were conducted during the Wet Season only. Consequently the documentation of migratory or seasonally abundant species could not be undertaken.

The following report was previously prepared for the Blackmore River (East) Aquaculture Development and was reviewed as part of this assessment:

- Ullman & Nolan Pty Ltd, Blackmore East Aquaculture Project: Preliminary Geotechnical Investigation, 15 February 1996.

3.1 CLIMATE

The closest meteorological station to the development site with comprehensive climatic data is Darwin Airport, a distance of approximately 25 km to the north-west. The project area is within the monsoon tropics of Northern Australia and experiences two distinct seasons: the Wet Season from November to March: and the Dry Season from May to September. April and October are transition months between the Wet and Dry Seasons (Parkinson, 1996).

The distinct seasonality of the rainfall is the most distinguishing feature of the regional climate. There is a pre-Wet Season transitional period, commonly known as "the build up", during October and November. This period is characterised by thunderstorms occurring at irregular intervals prior to the onset of the more general rain systems associated with the monsoon trough during the Wet Season. Darwin has an average rainfall of 1702 mm (110 rainy days), most of which falls during the Wet Season (Darwin City Council, 1997). Humidity over this period averages 70-80 %. In the Dry Season humidity is often below 40 % and there is virtually no rainfall.

While the maximum temperatures are defined as hot all year round, November is the hottest month with a range of 25°C to 33°C. The lowest monthly temperatures are normally experienced in June and July, when the range is 19°C to 30°C. Darwin has a yearly average of 8.5 sunshine hours per day with the highest monthly average (10.2 hours per day) in August (Darwin City Council, 1997).

Prevailing winds during the Wet Season are light west to north-westerly, freshening in the afternoon due to sea breezes. In the Dry Season, the prevailing winds are the south-easterly trade winds (Parkinson, 1996).

The monsoonal tropics also experience cyclonic activity. The cyclone season in northern Australia extends from October to April (Darwin City Council, 1997). Tropical cyclones cause most damage within a distance of 50 km from the coast. Once a cyclone has passed onto landfall it weakens rapidly, but resultant storm surge can be of concern to coastal developments and flood damage can result from associated squally rains.

Monthly evaporation and precipitation for the Darwin Meteorological Station are presented in **Appendix E**. Values for monthly precipitation (ram) at Darwin Airport are presented in **Table 12**.

Table 12

Monthly & Annual Precipitation and Evaporation (ram) - Darwin Airport

Monthly Precipitation (mm)													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Highest	940	815	1014	357	299	41	10	84	130	339	371	665	2777
Lowest	136	103	88	1	0	0	0	0	0	0	17	19	1025
Mean	428	347	322	99	21	1	1	6	16	72	142	250	1702
Median	389	330	289	78	3	0	0	0	7	54	141	215	1684
Records (yr)	59	59	59	59	59	59	59	59	59	58	58	58	58
Monthly Evaporation (mm)													
Highest	257	273	233	255	260	249	276	338	291	313	303	276	2976
Lowest	161	112	152	156	174	171	189	164	201	217	198	174	2460
Mean	208	186	192	207	223	213	226	239	246	264	237	220	2712
Median	205	189	192	204	223	213	223	236	243	260	237	226	2712
Records (yr)	35	38	34	32	35	34	34	33	33	34	34	36	31

3.2 OCEANOGRAPHY

3.2.1 Regional Tides

The lease area lies within Darwin Harbour. Tidal levels (AHD) and relative to Lowest Astronomical Tide (LAT) at Darwin are presented in **Table 13**.

Table 13

Tide Data – Darwin

Tide	**Australian Height Datum AHD (m)**	**Relative to Lowest Astronomical Tide LAT (m)**
Highest Astronomical Tide	3.9	8.0
Mean High Water Spring	2.8	6.9
Mean High Water Neap	0.9	5.0
Mean Sea Level	0	4.1
Mean Low Water Neap	-0.9	3.2
Mean Low Water Spring	-2.8	1.3

In the Darwin region, AHD is equivalent to Mean Sea Level (4.1m above LAT). Therefore, for example, the Highest Astronomical Tide of 8.0 m above LAT is equivalent to a level of 3.9m AHD. Tide Charts are presented in LAT whereas Peak Sea Level Predictions used for construction design are presented in AHD.

Tides are predominantly semidiurnal (two high waters and two low waters per day), with a slight inequality between tides during a single day. Tidal amplitudes are greatest during equinoctial tides in May and November/December, when the tidal range can reach 8.0 m (Department of Defence 2001).

3.2.2 Cyclone Effects

Between November and April tropical depressions, which may develop into cyclones, pass through the Darwin region, usually in a west to south-west direction but in southerly or easterly directions infrequently (for example, Cyclone Tracy, 1974). Surface wind stress, lowered atmospheric pressure and wave set-up combine to elevate sea levels during the passage of a cyclone.

3.3 TOPOGRAPHY

The proposed Blackmore River (East) Aquaculture development encompasses the following land terrain units:

- Undulating rises and gentle slopes.
- Gently undulating upland surfaces.
- Gently undulating lower slopes.
- Alluvial plains and drainage lines/minor levees.

The 'undulating rises and gentle slopes' terrain unit occurs across the majority of the lease area and includes:

- Low rounded hills, slopes of 0 – 4 %, shallow gravelly lithosols, Eucalypt open woodland to mixed woodland.
- Gentle sideslopes, slopes of 2 – 5 %, moderately deep, gravelly, yellow massive earths, Eucalypt open woodland to woodland.

The 'gently undulating upland surfaces' terrain unit occurs in a thin strip at the north-east of the lease area, and includes flat to gently undulating upland surface, slopes of 1 – 3 %, shallow, very gravelly, yellow massive earths and mixed Eucalypt woodland to open woodland.

The 'gently undulating lower slopes' terrain unit occurs along minor streams and includes gentle lower slopes of 0.5 - 1.5 %, slow drainage, deep mottled lateritic grey earths and *Eucalypt* open woodland to mixed species woodland.

The 'alluvial plains and drainage lines/minor levees' terrain unit occurs along major streams in the area of the proposed Stage 2 freshwater dam and includes:

- Narrow upland alluvial plains, slopes of <1%, hard apedal mottled yellow duplex soils, grassland with scattered trees.
- Drainage lines, incised within upland terrain, slopes of <1%, mottled grey earths and hard mottled yellow duplex soils, mixed open woodland to open shrubland.

3.4 GEOLOGY

The Bynoe 1:100,000 Geological Map Sheet issued by the Department of Mines and Energy (1986) indicates that the Blackmore River is underlain by meta-sediments of the Early Proterozoic Finniss River Group, which generally consists of shale, siltstone, sandstone, greywacke, schist and gneiss.
The Finniss River Group was deposited by turbidity currents in a submarine fan environment. The

member of the Finniss River Group present beneath the lease area is the Burrell Creek Formation. Borehole data (Ref Nos: 279, 287, 280) from drilling conducted approximately 1.5 km to the east of the lease area by the Department of Defence (DoD) in 1944 (compiled by DLPE) indicate the area to be generally underlain by 'slate'.

3.5 SOILS

3.5.1 Soil Types

The Bynoe 1:100,000 Geological Map Sheet (DME 1986) indicates that:

- The majority of the lease area is underlain by unconsolidated sand, ferruginous, clayey, clayey and gravelly soil, common limonite pisolites, or pisolitic and mottled laterites, ferricrete, *in-situ* and reworked remnants of standard laterite profile.

- The lower lying mangrove areas to the west of the lease area are underlain by mud, clay and intertidal marine alluvium.

- The watercourses that drain the upper catchment are underlain by sand, shelly sand, coralline sand and cheniers.

Numerous outcropping quartz dykes exist across the lease area. In addition, there are small occurrences of outcropping shale, siltstone and phyllite, in places colour-banded, fine to very coarse sandstone, quartzite, quartz pebble conglomerate, minor graphic phyllite, quartz-mica schist and gneiss.

Borehole data at three locations 1.5 km to the east of the lease area (DoD 1944) was consistent with that depicted on the geological map for the area.

Preliminary investigative works undertaken by Ullman & Nolan (1996) included the excavation of nine test pits within the lease area. Laboratory testing of a limited number of soil samples was undertaken. A summary of the subsurface soils encountered in test pits completed is presented in **Table 14**, and the complete Ullman and Nolan report is included as **Appendix F**.

Table 14
Summary of Test Pit Logs
(Ullman & Nolan, 1996)

Test Pit	Depth (m)	Material
Production Pond Area		
TP1	0.00-0.45	Silty SAND
	0.45-1.90	Clayey Gravelly SAND
TP2	0.00-0.45	Sandy Silty GRAVEL
	0.45-2.15	Sandy Clayey GRAVEL
TP3	0.00-0.30	Silty Gravelly SAND
	0.30-0.60	Sandy Clayey GRAVEL
	0.60-1.90	Sandy Clayey GRAVEL

Table 14 (continued)

Test Pit	Depth (m)	Material
TP4	0.00-0.20	Silty SAND
	0.20-2.00	Sandy Clayey GRAVEL
	0.70-1.50	Sandy Clayey GRAVEL
TP5	0.0-0.50	Silty Gravelly SAND
	0.50-2.10	Clayey SAND
TP6	0.00-0.20	Clayey SAND
	0.20-0.50	Sandy CLAY
	0.50-1.70	Sandy Clayey GRAVEL
Freshwater Dam Wall (Stage 2)		
TP7	0.00-0.30	Clayey Gravelly SAND
	0.30-2.80	Sandy Clayey GRAVEL
TP8	0.00-0.60	Clayey SAND
	0.60-0.90	Gravelly Sandy CLAY
	0.90-1.80	Clayey SAND
	1.80-3.40	Silty CLAY
TP9	0.00-0.50	Clayey SAND
	0.50-1.30	Gravelly Sandy CLAY
	1.30-2.10	Clayey SAND
	2.10-3.30	Clayey Silty SAND

Cross sections indicating the inferred stratigraphy for the lease area are presented in **Figure 15**.

3.5.2 Acid Sulfate Soils

3.5.2.1 Background

Coastal sediments containing iron sulfides are widespread throughout the northern and eastern seaboard of Australia. The presence of sulfidic sediments, or acid sulfate soils as they are commonly known, have been recognised along the Australian coastline for the last thirty years. However acid sulfate soils have only recently become important in land use planning as the understanding of their potential environmental impact has developed. Thus, techniques for identifying, classifying and treating these sediments are still evolving.

The following terms are used within this report when referring to Acid Sulfate Soils:

- Acid Sulfate Soils (ASS) - this is a generic term that refers to any soil which has an actual and/or potential acidity;

- Potential Acid Sulfate Soils (PASS) - this term refers to a soil that has the potential to generate acid on oxidation, but which has not yet been oxidised. These soils do not pose a significant environmental risk if left in an unoxidised state and typically have a near neutral pH; and
- Actual Acid Sulfate Soils (AASS) - this term refers to ASS that has undergone oxidation and have therefore developed acidity. They typically have a pH less than 4.

Australian ASS is commonly found in Holocene sediments deposited within the past 11,000 years. ASS is generally found below 5 m AHD and may be deeply deposited and covered by other sediments. The ideal environment for development of ASS is in marine sediments in wetlands replenished by tidal flooding or in brackish estuaries. Thus soft, saturated, organic rich, marine clay sediments on coastal floodplains are common deposits of PASS. Pyrite is commonly formed from anaerobic decomposition of organic material in the presence of a source of sulfate (generally from seawater) and iron sourced from terrestrial sediments and is a source of potential acidity. Pyrite often accumulates heterogeneously, which leads to significant variability in sulfuric acid formation in soils that are superficially similar.

The oxidation of PASS releases sulfuric acid that can strip aluminium, iron and other heavy metals from soil. Both the sulfuric acid and the dissolved metals are readily leached to groundwater and transported to local waterways and estuaries with potentially significant environmental consequences.

Potential problems associated with acid sulfate soils derived from the release of harmful volumes of acid include:

- corrosion of steel and concrete structures;
- clogging of aquifers due to iron hydroxide precipitation; disease or death of aquatic life;
- leaching of heavy metals from the soil (especially aluminium); and
- human health risk due to increased aluminium concentrations in water and fish.

The rate of oxidation of exposed PASS depends on the rate at which oxygen can enter the soil. A broad characterisation of oxidation rates for PASS is as follows:

- In fine-grained soils (clays) which do not freely drain, oxidation can take prolonged periods. In *insitu* clay soils which oxidise primarily around old plant root channels and fissure planes the process can take from months to hundreds of years.
- In coarse grained soils (sands) where oxygen moves more rapidly into the soil, oxidation can occur rapidly, often within days, weeks or months. Although they may contain lesser quantities of pyrite overall, sandy soils pose a significant potential for environmental impact,

The magnitude and duration of effects from the oxidation and leaching of PASS depends on the amount of pyrite present in the soil, oxidation and leaching rates, the soil's inherent buffering capacity and other site-specific factors.

3.5.2.2 Impact of Acid Sulfate Soils

No testing for ASS was conducted as part of this PER. Only a small portion of the development area (approximately 1 ha) is underlain by marine clays, namely the proposed salt water supply channel embankment, extending to the jetty on the Blackmore River. It is considered that the mangrove clays in this area may contain ASS, similar to that evident in soils in similar geomorphological zones within the Darwin Harbour.

There will be minimal disturbance to the underlying marine clays as a result of construction of the salt water supply channel and jetty. As such, ASS are not considered a management issue for the Blackmore River (East) aquaculture development.

3.6 GROUNDWATER

The groundwater regime of the Blackmore River (East) Development comprises a near-surface seasonally effected groundwater table, and a deeper groundwater aquifer associated with the underlying Burrell Creek Formation.

3.6.1 Near-Surface Water Table

The weathered soil profile at the lease area can generally be expected to have a high permeability, which will readily facilitate recharge to a shallow watertable. Laterite profiles, which are typical of the area, include porous laterite at shallow depths that will readily accept water infiltration. The laterite profile typically absorbs groundwater recharge during the Wet Season and then gradually releases the stored water during the Dry Season as the water table slowly drains. Near-surface groundwater movement can be expected to flow from the higher ground at the east of the lease area towards Blackmore River.

As the porous laterite profile and the weathered soil profile become saturated, reserves of groundwater may be released in the form of seepage zones along the lower reaches of the hills. The release of groundwater in the form of seepage zones may continue into or through the Dry Season, depending on the storage capacities and release characteristics of the lateritic profile, and may supply base flow for minor freshwater streams into the Dry Season.

The near-surface water table at the lease area is not considered to comprise a significant extractable groundwater resource. Any near-surface groundwater can be expected to be of relatively low yield and be seasonably variable in both quantity and quality.

3.6.2 Burrell Creek Formation

The Burrell Creek Formation that underlies the lease area is generally impermeable, holding limited quantities of water in fractures of defined spatial and vertical extent.

Aquifer testing results from three bores drilled approximately 1.5 km to the east of the lease area (DoD 1944) is presented in **Table 15** and the complete groundwater drilling data is included as **Appendix G**.

Table 15
Aquifer Testing Results
(Department of Defence, 1944)

Bore	Depth intersected water (m)	Standing Water Level (SWL) (m)	Pump Test Yield (L/s)
RN 279	9.2	13.8	1.9
RN 287	-	21.3	<0.25
RN 280	24.4	15.2	2.1

The DLPE Natural Resources Division Provisional Groundwater Supply Prospects of the Litchfield Shire (February 2000) planning map, indicates that the Blackmore River (East) Aquaculture lease area lies within an area having a potential yield of less than 0.5 L/s.

A limited number of pump tests conducted by DLPE, inferred geology of the lease area and discussions with DLPE staff indicates that the occurrence of groundwater may be variable and of limited yield. Groundwater bores with yields of 0.5 L/s to 2.0 L/s may be located on the lease area.

Phelps/Panizza propose to obtain potable (eg. drinking, showering, septic), landscaping and factory production water requirements from the groundwater supply. Initial estimated water requirements include:

Potable Water	Stage 1 (250 L/person/day, 9 staff)	2,250 L/day
	Stage 2 (250 L/person/day, 40 staff)	10,000 L/day
Landscaping	Stage 2	35,000 L/day
Factory Production	Stage 2 (one day/week operation)	160,000 L/week

Factory production water will be required for one day a week, with the majority being supplied from a 100,000 L storage tank that will be progressively filled from the groundwater bores during the week. Multiple bores (minimum two) will be established to guarantee supply in the event of collapse or malfunction of the main supply groundwater bore.

The daily groundwater requirement for Stage 2 of the development is estimated at 70 kL. A groundwater bore with a sustainable yield of 2.0 L/s will provide a daily water supply of 170 kL/day. While the occurrence of sustainable groundwater in the Burrell Creek Formation is anticipated to be variable and of relatively low yield, it is expected that sufficient groundwater supplies will be available for domestic potable useage and possibly for landscaping and commercial requirements. Multiple bores may need to be installed to obtain sufficient reliable yields of groundwater.

3.7 SURFACE HYDROLOGY

3.7.1 Catchment Characteristics

The Blackmore River (East) Aquaculture Development is situated in a water catchment of approximately 2,255 ha. The catchment drains in a westerly direction across the lease area through tidal creeks and into Blackmore River. The catchment area and inferred drainage patterns across the lease area are presented in **Figure 16**.

The generation of stormwater run-off is seasonally dependent with minimal runoff occurring during the Dry Season and the early Wet Season, when the catchment will largely absorb the sporadic rainfall events. Runoff rates will be high during the Wet Season as the ground becomes saturated and the catchment will remain in parts largely waterlogged until the end of the Wet Season. Rainfall during the Wet Season is characterised by high intensity, short duration events that maximise overland flow.

The upper catchment to the east of the lease area encompasses gently sloping gradients through woodland habitats. The area will generally be responsive to stormwater runoff and is expected to have volumetric runoff coefficients between 0.3-0.4, increasing up to 0.9 for high intensity rainfall events during the Wet Season. The upper catchment is generally underlain by shallow soils over a lateritic profile. The laterite will absorb substantial volumes of water during the Wet Season and will release the groundwater during the Dry Season. No permanent freshwater watercourses have been observed on the lease area, however delayed near-surface groundwater release can be expected to contribute to catchment runoff during the late Wet and early Dry Seasons.

There is approximately 310 ha of tidally inundated low-lying land adjacent to the Blackmore River

within the catchment. The area is primarily covered in mangroves with minor salt flat areas adjacent to the boundary of the upper catchment. Tidal channels intersect the low-lying areas.

3.7.2 Hydrological Flow Patterns

Runoff across the elevated areas to the east of the lease area is anticipated to consist of sheet flow draining to minor streams. Inferred drainage characteristics are shown in Figure 16.

The low-lying tidally inundated areas adjacent to Blackmore River receive both saltwater tidal intrusion from the Blackmore River and freshwater drainage from the elevated eastern areas of the catchment.

Tidal inundation of the mangrove areas depends on the tide height and the network of tidal channels through the mangroves. During neap tides only the tidal channels will be inundated. However, during spring tides the tidal waters will inundate the mangrove area. There are small isolated areas of salt flats at the land side of the mangrove areas. The minor salt flat areas may be connected by small channels that will provide preferential movement of tidal waters.

The soils of the mangrove areas and the minor salt flats are typically of low permeability. The soils are generally saturated (from tidal inundation or Wet Season rainfall events) and may dry to a relatively shallow depth below ground level (generally less than 300 mm). Water movement through the mangrove/minor salt flat areas is therefore generally via sheet flow with minimal infiltration.

Freshwater runoff from rainfall events in the upper catchment will inundate the mangrove areas by one of the following mechanisms:

- Sheet flow from areas directly upslope of the mangrove areas.
- Stream flow accumulated in the upper catchment.

Stream flow is anticipated to be greater than 90 % of the freshwater contribution to the low lying mangrove areas. Stream flow from the surrounding catchment will generally be channeled directly into the existing tidal channels and subsequently into Blackmore River. The volume of freshwater that will enter the greater mangrove area is dependent on the following:

- Volume of sheet flow entering the mangrove area directly from adjacent slopes.
- Intensity, duration and sequence of rainfall events and the tide levels. This will determine the volume of freshwater stream flow that will either flow directly to Blackmore River through existing tidal channels or overflow the tidal channels and enter the greater mangrove area.
- Volume of direct rainfall onto the mangrove area.
- Infrequent backwater flooding from Blackmore River.

3.7.3 Watercourses

The following watercourses traverse or are adjacent to the proposed Blackmore River (East) Aquaculture Development:

Blackmore River

The Blackmore River runs along the western boundary of the lease area. All runoff from the lease area will drain to the Blackmore River through tributary tidal creeks.

Middle Creek

Middle Creek is the main tributary for the Blackmore River for the adjacent catchment area. Middle Creek includes a north and south arm. The north arm of Middle Creek is the proposed site for the exchange water discharge outlet and the south arm directly drains the catchment of the proposed Stage 2 dam.

Unnamed Tributary

An unnamed tributary of the Blackmore River collects runoff from the northern areas of the proposed aquaculture development.

3.8 SURFACE WATER QUALITY

On 4 December 2000 and 1 February 2001, surface water samples were collected from seven locations on the lease area and analysed to provide baseline water quality data. Locations sampled are presented in **Figure 17** and laboratory results are presented in **Appendix H**. The following testing was undertaken:

- *In-situ* analysis for physicochemical parameters (pH, salinity, electrical conductivity, turbidity and temperature).

- Laboratory analysis for phosphate (P), sulphate (S) and the metals, aluminium, antimony, arsenic, beryllium, cadmium, chromium, copper, iron (tot), lead, mercury, nickel, selenium, silver and zinc.

The majority of parameters tested were either not detected or were detected at concentrations less than their respective guideline levels (where available) as provided in the Australian Water Quality Guidelines for the Protection of Marine waters (ANZECC 1992). The concentrations of copper and zinc detected in some samples tested were equivalent to or slightly exceeded their respective guideline levels. A significantly elevated concentration of lead was detected in one of the samples tested (SW7: 73 ug/l, guideline level: 5 ug/l).

3.9 FLORA

Aerial photograph interpretation and field surveys were used to describe the vegetation of the lease area between November 2000 and January 2001. A total of 155 plant species from 57 different families were recorded during field surveys. A vegetation map is presented as **Figure 18a** and a full report of the vegetation survey, including methodology, is included as **Appendix I**.

Vegetation was noted to form complex spatial patterns principally determined by local variations in Dry Season moisture supply and Wet Season soil aeration. Vegetation within the proposed aquaculture lease appears to closely reflect the interplay of topography and soils and the influence of temporal fluctuations of salt and freshwater supply. Cyclonic storms and frequent fires also play a major role in determining overall vegetation types in the local area (Wilson & Bowman 1987).

Within the 796 ha lease area, approximately 99 % (794 ha) comprises terrestrial woodland habitats lying above the 4 m AHD contour. The remaining 1 % of the proposed development area (1.1 ha) is

vegetated by mixed and grassy open woodland, mangroves and saltflats. While little of the actual lease area is vegetated by mangroves, most of the eastern margin closely follows the mangrove fringe. The 4 m contour corresponds with the mangrove fringe and marks the upper limit of tidal inundation, reached only by the highest spring tides of around 7.8 m.

A description of the flora in each community within the proposed leasehold area is provided below.

3.9.1 Upland Communities

The majority of upland terrestrial vegetation within the study area comprises extensive *Eucalyptus*–dominated woodlands. The Eucalypt woodlands typically comprise a relatively sparse tree layer over a more or less continuous grass layer, a formation commonly known as "savanna". This vegetation type covers vast areas of northern Australia and the monsoonal tropics generally, where highly seasonal rainfall and annual fire result in the formation of savanna landscapes. Other species assume dominance in areas of higher soil moisture resulting in several distinct upland woodland communities.

3.9.1.1 Mixed Eucalypt woodland

The majority of the hinterland habitat supports *Eucalyptus*-dominated woodlands or open forest communities. The dominant upper stratum species is typically *Eucalyptus tetrodonta* (Darwin Stringybark), with canopy trees up to 10-15 m high. The dominant Eucalypt species varies with changing topographic conditions and associated variations in drainage and soil type. *Eucalyptus tetrodonta* open forests to 20 m high tend to occur in areas of deep, reddish soils with *Eucalyptus miniata* (Darwin Woollybutt) becoming co-dominant to dominant on shallower, yellowish soils of the low plateau surface. In rocky areas and on low crests *Eucalyptus bleeseri* may be locally abundant to dominant with *E. foelsheana, E. polycarpa* and *E. confertiflora* common in low-lying areas.

Common canopy-forming species throughout the upland woodland habitat include *Erythrophleum chlorostachys* (Ironwood) and *Eucalyptus tectifica.* A mid-stratum layer of mixed species, approximately 4-6 m high commonly includes *Planchonia careya, Terminalia ferdinandiana, Cochlospermum fraseri* and *Acacia* spp.

3.9.1.2 Open woodland communities

Open woodland communities dominate the lease area, covering 590 ha and are Eucalypt dominated. Communities are typically dominated by *Eucalyptus miniata* with *E. tetrodonta, E. foelsheana,* and *E. confertiflora* sometimes present.

The upper stratum is predominantly *Eucalyptus* species 8-14 m high over a sparse to medium density middle stratum. Plant species vary in dominance with varying topography, soils and drainage. Secondary tree species include *Buchanania obovata, Terminalia grandiflora, Planchonella pohlmaniana* and *Terminalia ferdinandiana*.

Mid stratum communities are mixed species from 2-8 m high, commonly including *Planchonia careya, Cycas armstrongii, Acacia* spp. and *Pandanas spiralis*. Communities closely reflect highly localised substrate and drainage variations. Rocky shallow soils support *Calytrix exstipulata* (Turkey Bush) and *Petalostigma quadriloculare*, while *Gardenia megasperma* and *Xanthostemon paradoxus* are commonly found on deeper soils. *Terminalia grandiflora* is a mid-stratum species common in poorly drained areas.

The understorey is dominated by dense grass and subshrub species such as *Petalostigma quadriloculare*. There is abundant Eucalypt regrowth from lignotubers, promoted by frequent fire events. Herbs (*Pachynema* sp., *Flemingia trifoliastrum* and *Tephrosia nematophylla*) and vines (*Ampelocissus* spp.) are sometimes locally abundant. *Sorghum* sp. is widespread throughout the lease area but introduced grasses are restricted to roadsides and disturbed areas.

Patches of low open woodland in which dense species of *Grevillea longicuspis* occur are also present in this community within the lease area.

3.9.1.3 Grassland

Grasses are a significant component of the understorey of upland woodland communities in the lease area. The majority of categorised grassland occurs along the mangrove fringe and species present must endure freshwater inundation and waterlogging for several months of the year. Common grasses in this zone include *Ischaeum australe, Imperata cylindrica, Germainia grandiflora, Heteropogan triteceus, Eriachne burkitti* and *Sorghum* spp. Sedges (*Fimbristylis* spp. and *Cyperus* spp.) are abundant in waterlogged areas.

Shrubs associated with these low-lying areas include *Grevillea pteridifolia, G. decurrens, Persoonia falcata, Livistonia humilis* and *Syzgium eucalyptoides* ssp. *bleeseri*. With the exception of *Melaleuca leucadendra* and *M. viridiflora, M. nervosa* and *Pandanus spiralis*, waterlogged conditions prevent the establishment of tree species. Where grassland intergrades with woodland habitats, *Erythrophleum chlorostachys*, *Eucalyptus polycarpa* and *Lophostemon lactifluus* become more common.

3.9.2 Drainage Areas

Drainage areas within the lease area include several distinct habitats that retain or carry water during the Wet Season. Transitional areas (between upland woodlands and lowland mangroves), drainage ways and narrow alluvial plains within upland areas are characterised by seasonal inundation and waterlogging. Drainage lines are typically surrounded by grassy open woodland areas and become waterlogged sometimes but are not prone to lengthy periods of inundation. Generally site drainage is slow with substrates containing clay at depth. Three main vegetation types have been identified in drainage areas: *Eucalyptus polycarpa* open woodland, mixed species woodland and riverine open woodland.

3.9.2.1 *Eucalyptus polycarpa* open woodland

Eucalyptus polycarpa-dominated open woodland typically fringes the main drainage lines and covers approximately 79 ha of the lease area. The tree layer is from 8-12 m high, sparse, and often intergrading with grassland communities. *E. polycarpa* is characteristically found in seasonally inundated alluvial flats and low areas with shallow soils.

Eucalyptus polycarpa is found commonly in transitional zones (between upland and lowland areas) often in association with *Lophostemon lactifluus* (Water gum). *L. lactifluus* is similarly well adapted to waterlogged conditions and can establish monospecific stands under conditions of prolonged seasonal inundation. Patches of *L. lactifluus* were found in alluvial basins and drainage ways, notably towards the eastern boundary of the lease area.

Associated tree species include *Melaleuca nervosa, M. leucadendra* and *Erythrophleum chlorostachys*. Medium to low trees and shrubs associated with this habitat are *Banksia dentata, Pandanus spiralis* and *Grevillea pteridifolia*.

3.9.2.2 Mixed species woodland

The mixed species woodland covers approximately 15 ha of the lease area, forming a broad band in the most upstream sections of the two drainage ways, roughly delineating the extent of the drainage basin.

The headwaters of two major drainage lines within the lease area are heavily vegetated with a mixed species woodland exposed to seasonal inundation and waterlogged soils. Species composition is variable, with dense monospecific stands of *Lophostemon lactifluus* intergrading with areas of *Eucalyptus papuana* (Ghost Gum) and *Erythrophleum chlorostachys* (Ironwood). Dense *L. lactifluus* woodland is present upstream of the high voltage power lines, extending upstream for approximately 500 m.

Monsoonal forest species are found scattered throughout the mixed woodland habitat, including *Ficus virens* (Banyan), *Canarium australianum* and *Alphitonia excelsa*. Mid-stratum layer is sparse or absent but may include species such as *Planchonia careya* and *Exocarpus latifolius*.

3.9.2.3 Riverine open woodland

Two small seasonal tributaries of Middle Creek (north arm and south arm) flow through the lease area and drain into the mangroves at the eastern bank of the Blackmore River. The south arm comprises two major incised channels 1-4 m deep, clearly delineated by dense riparian vegetation.

The riparian (creek bank) vegetation of these three drainage lines typically comprises *Syzygium armstrongii, Acacia auriculiformis, Melaleuca leucadendra, Lophostemon lactifluus, L. grandis* and *Eucalyptus polycarpa*, forming a band of trees 8-14 m high. The dense riparian community merges with sparser fringing vegetation, distinguished as riverine open community. This community, although not extensive, is distinct and was found to have the highest species richness of all defined communities.

Common mid-stratum species include *Pandanus spiralis, Antidesma ghasembila, Brachychiton megaphyllus, Dodonaea platyptera, Breynia cernua* and *Planchonia careya* with *Barringtonia acutangula* (Freshwater Mangrove), *Carallia brachiata* and *Timonius timon* on creek banks. A mid-

dense ground layer includes the subshrub *Petalostigma quariloculare* and vines such as *Tinospora smilacina, Ampelocissus spp.* and *Gymnanthera oblonga.*

3.9.3 Mangrove Communities

Mangrove vegetation is well developed along the coastline of Northern Australia with particularly extensive mangroves in sheltered embankments such as Bynoe and Darwin Harbours. In these areas, mangroves are notable for both their species diversity and extent, despite being relatively species-poor in comparison with terrestrial habitats. Thirty-eight of the forty-eight mangrove species known from the Northern Territory have been recorded in the Darwin region (Wightmann, 1989). Twenty-two mangrove and salt flat species were recorded within the project area.

Mangroves typically show distinct patterns of zonation particularly in areas of macrotidal range and low relief. Mangrove mapping for the DLPE regional mapping program indicates that the Blackmore River, its tributaries and numerous small tidal channels show distinct and predictable patterns of zonation with bands of species aligned roughly parallel to the shore.

The distribution of mangrove species and the predictable pattern of zonation of mangrove vegetation is primarily a result of the interplay of climatic and geomorphological factors, combined with the frequency of tidal inundation and the availability of freshwater. Consequently mangrove communities will have their own individual character, according to the specific local conditions, despite sharing similar basic species composition and zonation patterns.

Mangroves flanking the western boundary of the lease area are typical of upstream mangroves in Darwin Harbour. Two major mangrove zones, the tidal creek bank and tidal flat, have been identified fringing the eastern bank of the Blackmore River. Very little mangrove vegetation actually occurs within the lease area.

3.9.3.1 Tidal creek bank

The tidal creek bank zone is well developed along the main Blackmore River channel and extends along the banks of numerous smaller tributaries and tidal channels. Tidal creeks are generally narrow and steeply sloping, sensitive to erosion and bank slump. This zone is characterised by regular tidal flushing and supports a distinct mangrove assemblage including *Rhizophora stylosa, Camptostemon schultzii* and *Bruguiera parviflora*.

Closer to the proposed development area, minor tidal creeks are characterised by tall *Rhizophora stylosa* and occasional large *Avicennia marina* and *Camptostemon schultzii*. In the transitional zone between the tidal creek banks and tidal flats there is commonly dense stands of *Bruguiera parviflora* which gives way to *Bruguiera exaristata* in the tidal flat zone.

The tidal creek bank has been found to have the highest biomass and be most productive as measured by leaf litter fall (Woodroffe *et.* al 1988; Metcalfe, unpublished 1999).

3.9.3.2 Tidal flat

The tidal flat is the most extensive zone both within the Blackmore River system and along the regional coastal area. It is typically comprised of relatively monospecific closed forest of *Ceriops australis*, often 2-4 m high. Associated species include *Bruguiera exaristata*, scattered *Avicennia marina* and

Exoecaria ovalis. Although the tidal flats are extensive in area, they support very low biomass and low productivity (Woodroffe *et.* al 1988, Metcalfe, unpublished 1999).

Tidal flats typically include numerous hypersaline salt flats due to consolidated substrates that contain high proportions of sand and gravel. Salt flats are a prominent feature of northern Australian mangrove habitats (Semeniuk, 1985). Mangrove zones adjacent to the lease area encompass such salt flats, which due to their hypersaline conditions are generally devoid of vegetation, excepting algal films and patches of samphire.

The hinterland/tidal flat margin is thin and not extensive but can be quite diverse, especially in seepage zones or in areas with abundant seasonal freshwater runoff. *Lumnitzera racemosa* is characteristic of this zone, and is one of only few species that occurs almost exclusively above HWN (high water neap). This mangrove area lies closest to the proposed development.

3.9.4 Rainforest

3.9.4.1 Monsoon vine forest

There are no springs or areas of perennial freshwater (that typically support evergreen monsoon forest or rainforest species) in the lease area. An off-site small rocky hill area of dry rainforest is located within the mangroves, approximately 50 m north of the proposed saltwater supply channel (Figure 18). This hill supports a diverse, non-Eucalypt community with species characteristic of monsoon vine-forest habitats. A number of these 'hinterland islets' occur within Darwin Harbour mangroves (EcoSystems 1993), where the level of the terrain lies above the high tide mark (4 m AHD), creating suitable conditions for the development of coastal monsoon vine forest/thicket assemblages.

Such islets typically have high species richness (34 species were recorded during this survey), supporting abundant vines and mesophyll species not found in other upland woodland habitats. Unlike most of the landscape, these areas are well protected from fire, being completely surrounded by mangroves that do not burn. It follows that these areas may contain a high proportion of fire-sensitive rainforest species and occasionally plant species of botanical or conservation significance.

The dominant upper stratum species in this vine forest is *Brachychiton diversifolius* with *Acacia auriculiformis* and *Mimusops elengi* to 8 m high. Associated tree species include *Vitex glabrata* and *Strychnos lucida,* between 3 m and 5 m high. Common mid-stratum species include *Allophyllus cobbe, Premna acuminata, Canthium* sp., *Drypetes lasiogyna* and *Croton harbrophyllus*. Both evergreen and semi-deciduous species occur in this location. Abundant vines include *Flagellaria indica, Abrus precatorius* and *Adenia heterophylla*.

Habitat degradation in rainforests is common and is often due to disturbances from cyclones, human activity, feral animals and fire (Wilson and Bowman, 1987). However, this site appears to be relatively undisturbed except for the presence of the weed *Hyptis suaveolens* (Horehound).

3.9.5 Weeds

Overall, the flora survey of the lease area found the area to be in relatively natural condition and free from weed infestations. Four introduced species were recorded within the area, three of which are declared noxious weeds Class B; *Hyptis suaveolens* (Horehound), *Sida cordifolia (*Flannel Weed) and *Pennisetum polystachion* (Mission Grass). These species are common and widespread in the region. Within the lease area weeds were most abundant in riverine areas where naturally high soil moisture

levels and disturbance from seasonal flooding encourages weed proliferation. The tall grass *Pennisetum polystachion* (Mission Grass) occurred sporadically on road verges and *Hyptis suaveolens* was widely distributed throughout several habitats within the lease area.

It should be noted that noxious weed species common in the Darwin region were not evident in the lease area. Such weeds include *Lantana camara* (Lantana), *Mimosa pigra* (Prickly Mimosa), *Salvinia molesta* (Salvinia), *Senna alata* (Candlebush), *Leucaena leucocephala* (Coffee Bush), *Andropogon gayanus* (Gamba Grass), *Echinochloa polystachya* (Aleman Grass) and *Hymenachne amplexicaulis* (Olive Hymenachne).

3.9.6 Fire Regime

Similar to tropical savannas throughout the world, fire is an annual event in the landscape of Northern Australia, with up to 50 % of the region burnt each year (Williams, 1995). Consistent with this trend, field surveys of the lease area indicated a pattern of frequent, extensive burning with roughly 60 % of the lease area burnt during the 2000 Dry Season. Such a regime is not planned, but rather a consequence of the *ad hoc* land use and the prevalence of sporadic, deliberately lit fires in the Darwin region.

Fires lit by people visiting the area in the mid to late Dry Season can form large fronts, particularly when fanned by strong south-easterly winds. With little to stop them, such fires consume large tracts of natural vegetation. Intertidal areas do, however, present a definite barrier and consequently the lease area is well protected from the west where mangroves border the lease area.

3.9.7 Conservation Significance

The lease area is in a relatively undisturbed condition, with little physical disturbance and few weed species present. There is no significant degradation by either natural or anthropogenic means including grazing, weed invasion and clearing. There are no registered flora sites of conservation significance in the lease area identified in the Northern Territory Oil Spill Response Atlas, (DLPE 1999).

The conservation significance of vegetation in natural habitats can be considered on different levels (that is, at the level of the individual species, or the plant community) and at several different spatial scales (for example, local, regional or national).

3.9.7.1 Individual species with conservation significance

No endangered species were observed during field surveys, nor were any listed for the lease area.

Six species endemic to the Northern Territory were recorded within the lease area during the field work for the flora survey including, *Eucalyptus porrecta*, *Pachynema* spp. and *Livistona humilus*. These species do not have declared rare status.

Rare Species

Grevillea longicuspis (Holly Leaf Grevillea) occurs within the lease area (**Figure 18b**) and is considered rare, listed as 3RC (Leach *et*. Al, 1992). *G. longicuspis* is restricted in distribution, known only from the Darwin/Litchfield region, but is locally common within its range. This species is distinctive but poorly known. *G. longicuspis'* rare status may be an artifact of under collection.

Botanists from the Northern Territory Herbarium consider that this species no longer warrants rare status and new categorisation should reflect this. Additionally, *G. longicuspis* has been recorded in cleared and drainage areas, suggesting resilience to disturbance. However, its current rare status should still be acknowledged and respected.

Intermittent flooding to 14m AHD resulting from the proposed dam construction will impinge on the habitat of this species. It is anticipated that inundation from the dam will have a minor effect on the overall population, affecting approximately 5-10 % of the population in the local area.

A more comprehensive botanical survey would provide detailed information on the distribution of this species and the precise impact of the proposed development on the local population.

Protected species

Cycas armstrongii (Cycad), is a protected species that is commonly found in the mid stratum of open woodland communities in the lease area, growing to heights of 3-4 m. Although classified as protected this species is widespread and relatively common in the region.

The protected status of cycads prevents collection or removal from bushland unless part of lawful land use. Thus, although cycads are protected, with intrinsic ecological value, their presence does not preclude development in areas with appropriate approval or zoning. The presence of cycads within the proposed development area is unlikely to be of significance.

Undescribed Species

One undescribed species, *Notelaea* sp. nov. (Family: Oleaceae), was collected from within the proposed lease area, but this species, common in sandstone areas, does not have declared conservation status. It was collected from a small off-site rocky outcrop covered with dry rainforest on the western margin of the lease area. Approximately seven other collections of this plant have been made from the Darwin/Shoal Bay area. Its 'undescribed' status is most likely due to limited botanical focus in northern Australia (the Northern Territory and Kimberley region of Western Australia have been much less studied than southern Australia) rather than a case of rarity.

3.9.7.2 Plant communities of significance

A small off-site area of dry rainforest is located approximately 50 m north of the saltwater supply channel. Located within the mangroves, it is protected from fire and supports a diverse, non-Eucalypt community with species characteristic of monsoon vine-forest habitats. Although not within the bounds of the lease area, this rainforest community holds significant ecological value and should be protected from adverse effects of the proposed development.

An extensive and well-developed mangrove community borders the western edge of the lease area. The proposed aquaculture development is largely located within upland areas, impinging on mangrove areas only at locations for the salt water supply pump and the discharge water outlet. The development will impinge on approximately 1 ha of mangroves, representing roughly 0.02 % of the total Middle Arm mangroves. It is anticipated that the proposed development will have a negligible impact on the conservation values of mangrove vegetation in the area. Damage to mangroves including increased siltation from dam construction in adjacent habitats will be avoided.

3.9.7.3 Local conservation significance

The lease area encompasses extensive open woodland with some mangrove, grassland and rainforest habitats with minor drainage lines. The area is currently utilised by local people for off-road motorcycle riding, hunting, and fishing. Its recreational and tourist value is enhanced by its proximity to a major urban centre.

The mangroves of the Blackmore River could be considered to have intrinsic ecological significance at the local scale. The proposed aquaculture development will impinge on a small area of mangroves so is suspected to have minimal direct impact.

The area contains a diversity of habitats with intrinsic conservation significance that is difficult to quantify and sometimes not recognised. The high value of natural, undisturbed ecosystems is widely accepted and believed to greatly enhance our standard of living, contributing to clean air and water, biological diversity and environmental stability.

3.9.7.4 Regional conservation significance

The terrestrial vegetation communities within the proposed development area are typical of Eucalypt forests and woodlands of the Top End, comprising part of an extensive bioregion. Thus, in the regional context, the conservation value of terrestrial flora found on the lease area is not special. Further, 15.8 % of the bioregion is currently reserved predominantly for conservation purposes (Woinarski et al., 1996) so these woodland habitats are well represented in reserves elsewhere in the region.

An extensive and well developed mangrove community borders the western edge of the lease area. The mangroves of the Blackmore River, as part of the extensive Darwin Harbour system, are listed on the 'Directory of Important Wetlands' in Australia (ANCA 1997), but have no declared conservation significance at the regional or national scale. The mangroves of the Blackmore River system are in relatively pristine condition and are broadly similar to assemblages found on tidal rivers across the Top End. The species present and the general zonation patterns are relatively predictable in these tidal systems, although each has its own distinctive features. The proposed aquaculture development is largely located within upland areas, impinging on mangrove areas only at locations for the salt water supply pump and the discharge water outlet. The conservation significance of the mangroves of the Blackmore River should remain unaffected by the development.

3.10 TERRESTRIAL FAUNA

3.10.1 Studies Undertaken

The terrestrial fauna of the Phelps/Panizza project area was assessed through field surveys and reference to existing information on Darwin coastal areas. A detailed report of the fauna investigation, including methodology, is included as **Appendix J**.

The survey encompassed all major habitats occurring on the lease area and quantitative data was collected on fauna of the three broad habitat types, comprising upland communities, drainage areas and mangrove communities. Taxonomy and common name usage generally conformed to the following standard references: reptiles & amphibians - Cogger (1996); birds - Christidis & Boles (1994); and mammals - Strahan (1983).

3.10.2 Reptiles and Amphibians

Nine frog species were recorded during the field survey. Most species were found along the perennial streamlines within the dam area, although frogs were also commonly encountered in the other habitats. As heavy rains had fallen the week previous to the survey, standing water was present in the area, resulting in increased frog activity. Frogs were heard calling from freshwater soaks and creek lines at night.

The most common species encountered were Bicolor Tree Frog (*Litoria bicolour*), Floodplain Toadlet (*Uperoleia inundata*), Bilingual Froglet (*Crinia bilingua*) and Marbled Frog (*Limnodynastes convexiusculus*), all of which were recorded from two or more sites. Bicolor Tree Frogs were found in grassy situations throughout the woodlands and in sedges bordering the mangroves. Species such as *Litoria tornieri*, *Litoria pallida* and *Litoria inermis* were confined to the streams.

Eleven frog species are recorded in the NT Fauna Atlas (PWCNT 2000) for the area. All but one of the species observed during the field survey are listed in the Fauna Atlas.

A total of sixteen reptile species were recorded in the area, including fourteen lizards and two snakes. Small skinks of the genus *Carlia* were abundant throughout the area, with four species being recorded. The commonest species was *Carlia gracilis*, which was found along the streamlines. Northern Water Dragon (*Lophognathus temporalis*) and Merten's Water Monitor (*Varanus mertensi*) were present along the creeks, indicating the presence of semi-permanent aquatic habitats in these areas. Frilled Lizards (*Chlamydosaurus kingi*) were frequently encountered along the roads through woodland habitat.

In the drier, stony woodland habitat, *Carlia triacantha*, *Varanus scalaris* and *Ctenotus borealis* were encountered. Sand monitor (*Varanus panoptes*) diggings were evident in softer soils along the creek lines. The King Brown Snake (*Pseudechis australis*) and Common Tree Snake (*Dendrelaphus punctulatus*) were both observed in riverine areas.

Numerous other species are expected in the area, and the NT Fauna Atlas (PWCNT 2000) lists a further 32 species. Lizards such as the Northern Blue-tongue Skink (*Tiliqua scincoides*), Bynoe's Gecko (*Heteronotia binoei*) and Douglas's Skink (*Glaphromorphus douglasi*) are common in coastal areas near Darwin, as are snakes such as Children's Python (*Bothrochilus childreni*) and Black Whip Snake (*Demansia atra*). Most, if not all of the species listed in the Atlas could be expected to be present in the project area.

Few reptile species inhabit mangrove areas, although the Estuarine Crocodile (*Crocodylus porosus*) is fairly common in the Darwin Harbour estuaries. Four species of water snake are specialised to mangrove habitat and although they were not observed in the current study and do not appear on the NT Fauna Atlas (PWCNT 2000) list, they are very likely to occur in this area. These species are Bockadam (*Cerberus rhynchops*), White-bellied Mangrove Snake (*Fordonia leucobalia*), Richardson's Mangrove Snake (*Myron richardsoni*) and Little File Snake (*Acrochordus granulatus*).

3.10.3 Birds

A total of 49 bird species were recorded during field surveys. Of these, the greatest variety (26 species) was recorded in the woodlands at Site 2, followed by mangroves (22 species) and the woodlands and riverine habitats near the proposed dam (18 and 17 species, respectively).

The most abundant species overall was the Little Friarbird, which was recorded on 37% of all counts, and was recorded from three sites. Rainbow Bee-eater and Bar-shouldered Dove were also commonly

encountered. In the woodland habitats, Rainbow Bee-eater, Little Friarbird, Brown Honeyeater and Golden-headed Cisticola were commonly encountered. Along the streamlines Sulphur-crested Cockatoo, White-gaped Honeyeater, White-throated Honeyeater, Lemon-bellied Flycatcher and Northern Fantail were common. In the mangrove margins Bar-shouldered Dove, Little Friarbird, Helmeted Friarbird, Brown Honeyeater, Dusky Honeyeater, Red-headed Honeyeater and Black Butcherbird were most common. Overall, the mangrove habitat had the highest number of individual birds recorded.

Some bird species recorded in the mangroves are specialised to that habitat. These being Chestnut Rail, Red-headed Honeyeater, Black Butcherbird and Mangrove Golden Whistler. Most of the woodland and riverine birds are unspecialised forms, which are widely distributed in northern Australia.

As the survey was conducted during the Wet Season, it could be expected that if migratory waders were in the area they would have been encountered. As no habitats for wading birds were found, it is considered that the area is not important for migratory birds. The seaward mangrove fringe would provide feeding habitat for migratory waders at low tide. Dry Season species, such as the Fork-tailed Kite, were noticeably absent during the survey.

The NT Fauna Atlas (PWCNT 2000) records 178 bird species for the area. As the database records encompass habitats that are not present on the lease area, such as monsoon forest, freshwater swamp and perennial streams, many of the species listed would not be expected in the project area.

In general, the mangrove habitat appears to be the most important for birds because of the high quality and extensive nature of mangroves in the area. The presence of several specialist birds, such as Chestnut Rail are an indication of good mangrove habitat.

3.10.4 Mammals

Seventeen species of mammal were recorded in the survey, including three introduced species.

A total of 320 trap nights caught eight animals of four species. The Northern Quoll (*Dasyurus hallucatus*) was trapped in woodland and mangrove margins. Three individuals of this species were trapped, all of which were juveniles. One specimen of the Kakadu Dunnart (*Sminthopsis bindi*) was trapped in grassland along the creek near the proposed dam wall. Two rodents, the Grassland Melomys (*Melomys burtoni*) and the Western Chestnut Mouse (*Pseudomys nanus*) were trapped in woodland and creek habitats.

Northern Brown Bandicoots (*Isoodon macrourus*) are abundant in the project area, particularly along the creek lines and in the grassy areas of the mangrove margins. This species was observed several times during night surveys and its distinctive digging marks were obvious in most areas. Agile Wallaby (*Macropus agilis*) tracks were seen along the mangrove margins.

Seven species of microchiropteran bats were detected by Anabat calls. The most commonly recorded species in woodland habitats was the Northern Pipistrelle (*Pipistrellus westralis*), with seven sequences recorded. The Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*) and Little Northern Freetail-bat (*Mormopterus loriae ridei*) were the least commonly recorded species, recorded from single sequences from the open woodland site. Gould's Wattled Bat (*Chalinolobus gouldii*) was recorded in the open woodland habitat.

Tracks of pigs and cattle were present in the wetter parts of the project area, especially along the mangrove margins. A feral cat was also seen along the mangrove margins in the north of the project area.

Twenty-five mammal species (including four introduced) are recorded from the region in the NT Fauna Atlas (PWCNT 2000). Most of these species could be expected to occur in the project area, although it should be noted that the Brush-tailed Tree Rat record is an historical record. This species no longer occurs in the Darwin area.

3.10.5 Conservation Values

Examination of international, national and state lists of threatened species indicate that there is little likelihood of any endangered species occurring in the project area. However, some species, which are known or considered likely to be present in the area, are of some conservation significance and these are described below.

The Partridge Pigeon is classified as Vulnerable (ANZECC 2000; Environment Australia 1999). Internationally, it has been listed in the lower "low risk, near threatened" category (IUCN 2000). Partridge pigeons were formerly widespread across northern Australia, but have suffered a recent decline in the southern parts of their range. Partridge Pigeons are regularly observed in the Berry Springs area and, although they were not recorded during the field surveys, there is a strong likelihood that they are found in woodland habitats in the project area.

The Bush Stone Curlew is listed by IUCN (2000) in the "low-risk, near threatened" category. It was observed during the surveys and is likely to be a resident of the project area. Stone curlews are susceptible to human disturbance.

The Northern Quoll is a species listed by IUCN (2000) in the "low-risk, near threatened" category. Northern Quolls have suffered a recent decline in populations across northern Australia. Three individuals, all juveniles, were trapped in woodland and mangrove margin habitats on the project area. The species is likely to be present throughout the area in moderate numbers.

A total of 44 vertebrate fauna species in the Top End Coastal bioregion have been considered rare or threatened (Connors et al 1996). Of these species, one bird (Partridge Pigeon) and five reptiles are classified as "insufficiently known" are common or expected to occur in the Blackmore River area. The reptiles include the Estuarine Crocodile (a management plan for which is active for Darwin Harbour), three mangrove snakes (Bockadam, Richardson's Mangrove Snake and the Port Darwin Sea-snake - all of which are expected to occur in the mangrove creeks adjacent to the project area), and a small monitor, *Varanus primordius* (known to occur in the Berry Springs area and suitable habitat is present on the project area).

None of the "Specially Protected" species listed under the Territory Parks and Wildlife Conservation Act 1997 are expected in the project area.

The Kakadu Dunnart, a small and poorly known carnivorous marsupial, was trapped during the fauna survey in a grassy situation along a small creek line near the proposed dam location. This species was only discovered in 1989, and was at first thought confined to the stony woodland habitats in Kakadu National Park Stage III. However, it has since been recorded in a number of other locations across the Top End, including Bradshaw Station, Gregory National Park, Litchfield National Park, Coomalie

Creek and the Humpty Doo area (NT Museum register). This species is probably sparsely distributed across the NT, and as it is known in several major conservation reserves its status is probably secure.

McKean & Martin (1986) identified mangrove birds found in Darwin Harbour such as Chestnut Rail, Large-tailed Nightjar, Little Kingfisher, Mangrove Golden Whistler, White-breasted Whistler, Little Shrike-thrush and Mangrove Fantail as being "rare", or of conservation significance. These species are either known or expected in the mangroves adjacent to the lease area.

Other than the mangroves, the area does not support specialist or significant habitats such as monsoon forest, paperbark swamp or wetlands. No significant breeding, roosting or feeding sites for fauna were discovered during the field surveys.

The habitats occurring on the project area are commonly found throughout the Darwin region, and on a local scale, are not regarded as significant for threatened fauna. However, the habitats do not appear to have suffered seriously from degradation by fire or feral animals and are in good condition.

The number and diversity of small mammals trapped in the limited time is an indication of high quality habitat. Feral animals, including pigs and cattle are in low numbers and no non-native rodents were found. Feral cats in the area may be a threat to native small mammal populations.

3.11 FISHERIES RESOURCES

Fisheries production in Northern Territory coastal waters is centred on a small number of species of high unit value, including barramundi (*Lates calcarifer*), prawns (*Penaeidae*) and mud crabs (*Scylla serrata*). These species are all either caught near mangroves or are associated with mangrove areas for significant parts of their life cycles. Production of barramundi and prawns in particular is likely to be very much dependent on conditions in the mangrove and coastal wetland environments (Griffin, 1984).

3.11.1 Barramundi

Barramundi is an important commercial and recreational species in the Northern Territory. The commercial fishery is restricted to inshore waters seaward of river mouths (except within Darwin Harbour and Shoal Bay, where it is excluded) while recreational fishing takes place over the entire range of habitats, although it is concentrated in freshwater and upper tidal waters (Pender & Griffin, 1996). Recent commercial landings of barramundi have been in the vicinity of 600 tonnes per annum, with the 1999/2000 catch worth an estimated $4.5 million (DPI&F, 2000).

Barramundi is the most targeted fish by recreational anglers in the Northern Territory (Coleman, 1998). Near Darwin, barramundi can be caught in the harbour arms, in the creeks and estuaries of Shoal Bay, at Leader's Creek and in Bynoe Harbour.

The life cycle of barramundi is generally known (Moore, 1982; Moore & Reynolds, 1982; Davis, 1985, 1986). Spawning occurs in marine areas at river mouths away from the major influence of fresh water runoff, where the water is relatively clear and the salinity appropriately high. The barramundi stock of Darwin Harbour probably spawn in the vicinity of Lee Point and Shoal Bay with the extensive wetlands fringing much of Shoal Bay providing most of the nursery swamp habitat (Griffin 2000).
Barramundi undergo a prolonged breeding season which starts just before the summer monsoon, with the onset of spawning apparently variable with geographic location. Davis (1985) found larval barramundi in Van Diemen Gulf (to the north-east of Darwin Harbour) from September through to

February. In Leanyer Swamp (outside of Darwin Harbour) the size distribution of larvae collected by Griffin (1985) indicated that, in 1984, significant spawning had occurred as early as August.

The eggs of barramundi are pelagic and hatch in less than 24 hours, therefore it is probably critical that the spawning area is located close to suitable nursery habitats or within the path of currents which will carry the eggs and larvae towards nursery habitats (Garrett, 1987). The nursery habitats occupied by barramundi through the first few months of life are primarily wetland areas at the interface of salt and fresh water, at or near the upper high tide level (Moore, 1982; Russell & Garrett, 1983; Davis, 1985; Griffin, 2000).

In the Darwin region, these supralittoral swamps generally occur where salt water reaches on tides greater than 7.3 m. These swamps are typically vegetated by seasonal plants including the salt water grasses such as *Sporobolus* sp. and various sedges such as *Eleocharis* spp. and *Schoenoplectus littoralis* (Griffin, 2000). While the sedge *Eleocharis* may occur in the grasslands at the upper tidal limit, no areas of supralittoral swamp habitat have been identified within the proposed aquaculture lease.

During the Dry Season the swamp plants are normally dormant and the landscape can have a somewhat barren appearance. When the Wet Season rains commence and the areas are inundated by very high tides the dormant plants rejuvenate and provide cover for aquatic life (Griffin, 2000).

During the late Dry Season or early Wet Season months (September to December) the high tides penetrate into the supralittoral swamps, bringing with them barramundi up to two weeks of age. In some areas, frequently at the very upper reaches of small tidal channels, the tide leaves behind shallow pools when it recedes. The small barramundi remaining in these pools prey upon the coexisting abundant insects, other fish and crustaceans (Makaira, 1999, Griffin, 2000). The pools are also the primary hatching and breeding areas for the saltmarsh mosquito, *Aedes vigilax*, and mosquito larvae probably form a substantial dietary component of small barramundi (Griffin, 2000).

As the Wet Season progresses the supralittoral swamps, which were initially only filled by tidal incursion, fill with fresh water and expand considerably in area, thereby increasing the habitat available to small barramundi. The swamps are very productive, providing barramundi with conditions for rapid growth and with shelter from predators. They also provide important habitat for the early stages of many other species of fish and also for crustaceans, including penaeid prawns. These, along with insects and frogs, form an integral part of the diet of young barramundi (Griffin, 2000).

Towards the end of the Wet Season, before the swamps dry out, the barramundi (up to 25cm long at this time) move out into adjacent rivers or creeks and usually migrate upstream into permanent fresh waters. The period of rapid growth in the supralittoral swamp habitat allows the young barramundi to more successfully compete and survive in the open estuary or river. Young barramundi (1–10cm in length) have rarely been located in large numbers outside of supralittoral swamp habitat, indicating that it may not only be advantageous for them to have access to swamp habitat, it may be essential if they are to flourish (Griffin, 2000). However, Pender & Griffin (1996) suggested that this life cycle may not be obligatory, as their studies provided strong indications that purely marine populations of barramundi may exist in areas remote from fresh water.
After leaving the supralittoral swamps, the barramundi move upstream as far as possible in their first year, generally remaining in the upper fresh water reaches of the rivers until they mature (Griffin, 1985). After three to four years, maturing fish move back to spawning areas adjacent to river mouths during the late Dry Season (Griffin 1987). Adult fish then remain in the estuarine or upper tidal sections of rivers (Davis, 1986; Makaira, 1999).

It is considered that the proposed aquaculture development has no potential to significantly impact upon the Darwin Harbour barramundi population.

3.11.2 Prawns

The fishery for penaeid prawns is the largest and most valuable of all the Northern Territory fisheries. The Northern Prawn Fishery extends from Cape Londonderry (north Kimberley coast, Western Australia) to Cape York, Queensland, and is managed by the Commonwealth through the Australian Fisheries Management Authority (AFMA). The estimated catch in 1999/2000 was 5,600 tonnes, with a production value of $107 million (AFMA website).

The main commercial species are white banana (*Fenneropenaeus merguiensis*), red-legged banana (*F. indicus*), brown tiger (*Penaeus esculentus*), grooved tiger (*P. semisulcatus*), blue endeavour (*Metapenaeus endeavouri*), and red endeavour (*M. ensis*). Units operating out of Darwin mainly target banana prawns, trawling mostly within 30 nautical miles of the coast (S. Bolton, AFMA, pers. comm.).

Banana prawns spawn offshore, with larvae moving inshore and entering the mouths of rivers on flood tides as post-larvae, mainly in November. The juvenile prawns remain in the rivers, where they are distributed according to salinity. When river salinities are decreased by rainfall at the commencement of the Wet Season, the prawns move towards the mouths of the rivers and into adjacent coastal waters (Staples, 1979, 1980a, 1980b; Vance et al., 1983).

It is not expected that the proposed aquaculture development will impact upon the prawn populations of Darwin Harbour. Water quality issues are discussed in **Section 4.6**, and disease management and stock containment in **Section 4.4**.

3.11.3 Mud Crabs

The mud crab fishery is the most valuable wild harvest commercial fishery managed by the Northern Territory. Recent annual commercial landings have been around 500-600 tonnes, with the 1999/2000 catch worth just under $10 million (DPI&F, 2000). The recreational catch in 1995 was estimated at around 50 tonnes. The majority of commercial activity is focussed in the Gulf of Carpentaria, while recreational activity is highest in the southern Gulf and in the vicinity of Darwin (DPI&F website).

The life cycle of the mud crab is similar to that of the banana prawn, with spawning taking place at sea and larvae moving inshore to settle in mangrove areas. Small shallow mangrove creeks provide important habitats for juvenile mud crabs (Hill, 1982). These habitats will experience very little disturbance during the construction and operation of the proposed aquaculture facility (**Section 4.2.1**).

3.12 MOSQUITOS AND OTHER BITING INSECTS

The Medical Entomology Branch of THS undertook an initial assessment of biting insects associated with the proposed Blackmore River (East) Aquaculture Project. Field survey works were undertaken over a three-day period in early December 2000. The potential biting midge breeding sites were assessed from aerial photographs using information on the biology of biting midges. An assessment of the actucal and potential mosquito breeding sites were made from aerial photographs, site inspection, field survey works and an evaluation of the proposed aquaculture development plans.

Outlined below are findings of the report titled *"Biting Insect Survey and Assessment, Blackmore River*

Prawn Farm, December to March 2000-2001" relating to the existing, undeveloped lease area. A complete copy of the report, including all figures, is included as **Appendix K**.

3.12.1 Mosquitoes

3.12.1.1 Species present

There are over 100 species of mosquitoes recorded in the Northern Territory. Over 60 have been recorded from Palmerston (Liehne et al. 1985). In the Fairway Waters study 39 species were recorded from carbon dioxide baited traps. The 17 species recorded in the current survey is a reflection of trapping over a small period when many species may be seasonally absent or not present in sufficient numbers to be recorded. The species recovered however include most of the common or most relevant pest and potential disease vectors in the Top End of the NT (Whelan 1988a).

Aedes vigilax and *Culex annulirostris* are the most important potential vectors and pests in the development area and are discussed below.

3.12.1.2 Breeding sites

Aedes vigilax

The topography of the coastal margin in the study area is relatively steep, with no extensive breeding areas of *Ae. Vigilax*, such as the large coastal marshes east of Darwin. However there were a number of potential productive breeding sites associated with the creek lines entering the mangrove margin, and disturbed areas at the mangrove margin. The most extensive and productive site will be the upper tidal section of the creek, down stream from the proposed fresh water dam. The other significant breeding site is located in an extensive *Eleocharis* reed habitat.

There is also likely to be smaller, localized breeding sites around the mangrove margin. The smaller breeding sites will be relatively small depressions, vehicle disturbed areas or small drainage lines at the upper high tide mark. Brackish water reeds or salt tolerant grasses indicate small depressions at the end of drainage lines. Other breeding sites will be in residual pools in the beds of the larger creek lines that are flooded only by the highest tides of the month in the late Dry Season. Any disturbance of the mangrove landward margin that creates tidal pooling will produce additional breeding sites.

Culex annulirostris

Potential breeding sites include the seasonally rain flooded low lying areas around the mangrove margin and small creeks, as well as the seasonally flooded grass floodways associated with the two arms of the largest creek. These creeks are relatively well defined and well drained, and do not contain any large areas of persistent or perennial swamps. They are intermittent and cease flowing soon after the Wet Season. The present *Cx. annulirostris* productivity of these sites appears limited.

3.12.1.3 Seasonal abundance

Aedes vigilax is a major pest species in the Palmerston and Darwin South area, where the coastal topography is similar to that of the lease area. This species is likely to be most abundant in the late Dry Season and the early Wet Season (August to January). Generally the numbers increase after each succeeding spring tide from August to December and reach their highest numbers after the early heavy rains in December or January. The pattern and levels of abundance can vary from one year to another,

due to the variable height of the spring tides each year and the amount and timing of rain in relation to the tides.

Culex annulirostris

The topography of the lease area is similar to that of a previous study undertaken at the Weddell site near Elizabeth River, and hence the seasonal abundance pattern is expected to be similar. The Weddell pattern of abundance indicates seasonal breeding in temporary Wet Season filled depressions, followed by breeding in longer lasting creeks and floodways as grass growth and receding water levels hinder the impact of aquatic mosquito predators. Abundance is expected to increase coinciding with the start of the Wet Season, followed by a steady post Wet Season rise to a peak in July.
The highest numbers of *Cx. annulirostris* trapped in the western-most section of the lease area and on the power line easement in the north-east corner. It is considered that floodways associated with flooded areas of grass, Paperbark and *Pandanus* are likely to provide mosquito breeding habitats in the Wet Season. They are unlikely to be the sources of mosquitoes by the mid Dry Season in June or July, as they would either be dry or the water restricted to narrow channels, with fish populations limiting the number of mosquito larvae.

3.12.2 Biting Midges

3.12.2.1 Species present

Eight species of *Culicoides* were collected during this study. Thirty-three (33) species of *Culicoides* have been recorded in the Darwin area (A. Dyce pers. comm.) and nearer to the present study area there were 11 species recorded in the Weddell study (Whelan et al 1988). In the light of these previous collections, additional species are likely to be present in the lease area. However they are not likely to include any additional species that will pose a significant human pest problem for this development.

C. ornatus, collected during this study, is by far the main potential human pest species of biting midge in the Top End of the Northern Territory. This is the species that is most likely to cause a pest problem in this area.

It is possible that both *Culicoides flumineus* and *C. immaculatus*? could exist in relatively high numbers within the nearby mangroves. They could pose pest problems for development immediately adjacent to or inside extensive mangrove areas. However, as these two species very rarely occur in high numbers outside of mangrove areas, they will not be of pest importance in most of the proposed development area.

Culicoides undescribed species (Ornatus gp.) No. 6, while occurring in very high numbers in other areas of Darwin Harbour, rarely bites humans, and is not likely to pose any problems at the proposed development.

3.12.2.2 Breeding sites

In the proposed development area, the main *C. ornatus* Dry Season breeding sites are likely to be on the small tidal branches of Blackmore River, particularly the tributaries nearest to the Middle Arm boat ramp and the proposed salt water pump jetty. Breeding sites also include the extensive mangrove tributaries further north and on the opposite side of the Blackmore River. The frontal *Sonneratia* zone along the Blackmore River is also a probable *C. ornatus* breeding site. The back edge of the mangroves around the Blackmore River mangrove margin would offer significant Wet Season breeding sites.

This evaluation is supported by the current trapping results, which confirm that a major breeding site for *C. ornatus* is present in the vicinity the vicinity of the Blackmore River boat ramp. However relatively high numbers were present at all other sites, indicating that there are appreciable breeding sites around the entire mangrove margin of the development.

Culicoides flumineus and *C. immaculatus*? are thought to breed inside the mangroves in the neap tide zone with the adults not dispersing far from the mangroves (M. Shivas pers. comm.). *Culicoides immaculatus* ? appears to be more common in the lower reaches of larger creeks and hence breeding sites are probably present in the larger creek south of the pond development and relatively close to the saltwater pump jetty.

3.12.2.3 Spatial abundance and dispersal

The highest collections of *Culicoides ornatus* in the study area were from the vicinity of the Blackmore River boat ramp and nearest to the most extensive dendritic area of mangroves north of the boat ramp, and at the head of the tidal creek in the western-most portion of the lease area. Other relatively high numbers occurred at the tidal headwaters of the other mangrove creeks in the area. The high numbers of midges recorded near the proposed residence on the slope of the escarpment facing Blackmore River boat ramp, indicates that the midges recorded at in the mangrove fringe are capable of dispersing in high numbers in a broad area into the northern section of the development.

3.13 ARCHAEOLOGY

3.13.1 Ethnographic Background

Blackmore River falls within the traditional territory of the Larrakia people (Tindale, 1974). The tribal boundaries of this group apparently extended from the Finniss River and Fogg Bay in the south-west to Middle Arm, Darwin Harbour in the north-east.

The Larrakia people were heavily dependent on marine resources such as fish, crabs, and shellfish (Foelsche, 1881; Curr, 1886; Basedow, 1907). Dugout canoes were used to hunt large marine animals including turtle, dugong and crocodile (Brown, 1906). Parkhouse (1895) mentioned that beaches were favoured places for camping and such places were likely to contain midden deposits.

Permanent sources of freshwater, particularly waterholes, were important camping areas for the inhabitants of the region (Foelsche, 1881). Ducks, geese, crustaceans and water lilies were obtained at waterholes, while kangaroos and wallabies could be ambushed on animal tracks leading to these features (Foelsche, 1881, Wildey, 1876). Fish were poisoned at waterholes through the use of the bark from certain trees (Foelsche, 1881; Curr, 1886). Other food resources included snakes, emus, lizards, roots, fruits, honey and insect larvae (Basedow, 1907, Foelsche, 1881; Curr, 1886; Wildey, 1876).

Documented items of material culture have included shells and sharp stones used for cutting and carving, red ochre, and ground stone hatchets (Foelsche, 1881; Curr, 1886). Small nets and bags were manufactured from tree bark fibre, while bark paintings, fighting sticks and message sticks have also been recorded. Large trumpet and bailer shells were used as drinking cups, water vessels and canoe bailers (Basedow, 1907). Spears included two pronged fishing spears, wooden spears with a carved barbed head, short reed spears and wooden spears tipped with a sharp stone spear head (Basedow, 1907).

Items of Larrakia material culture likely to be preserved in the archaeological record include stone

spearheads, stone hatchets and hearths made from stone or lumps of termites nest. Shell tools used for cutting and scraping activities and for pressure flaking stone may also be preserved (Foelsche, 1881, 1885; Basedow, 1907).

Foelsche (1881) recorded that the Larrakia buried their dead in shallow graves, and it is therefore possible that prehistoric skeletons may be found in sandy areas such as beach ridges adjacent to the coast. While the Larrakia are also known to have deposited their dead in tree burials (Wildey, 1876), archaeological remnants of such activities are less likely to have survived.
Ethnographic data highlights a number of elements within the landscape which appear to have been focal points for hunter-gatherers living in the Darwin region. As such, permanent sources of water and the coastline could be considered particularly likely to contain archaeological materials. In the Blackmore River area the coastline and the adjacent higher ground might be expected to be particularly archaeologically sensitive.

3.13.2 Archaeological Sites

Archaeological investigations of the project area were undertaken by Heritage Surveys in November 2000. The investigations included identification and assessment of the archaeological significance of all sites likely to be impacted by the proposed development. All identified archaeological sites are shown in **Figure 19**. A report on the findings of the investigations is included as **Appendix L**.

3.13.2.1 Previously Recorded Sites

A search of the Northern Territory Museum Site Register (now held by DLPE) revealed that no archaeological sites have previously been recorded within a 5 km radius of the proposed Blackmore River aquaculture lease area.

3.13.2.2 Archaeological surveys

A survey of the entire lease area was undertaken as part of the archaeological investigations. Across the study area as a whole, ground surface visibility ranged between 90% and 0% and was greater than 30% across approximately two thirds of the surveyed area. In general, ground surface visibility was lowest in the centre of the study area where vegetation had not been burned off for some time and a thick grass cover obscured the ground.

For the purposes of this survey an archaeological "site" was defined as a concentration of "artefactual materials with a high density relative to the background scatter of similar types of cultural debris at those or similar points in the landscape" (Hiscock 1995:3). In particular, clusters of shell and/or stone were defined as “sites” if the following criteria could be met (after Hiscock 1995:3):

- more than ten shells or artefacts;
- an area of at least 2m²; or
- an average density of artefacts or shells at least five times that of the background scatter.

A total of six archaeological sites, three shell scatters and three stone artefact scatters, were identified during the archaeological survey. The location and characteristics of these sites are summarised in **Table 16** and shown in Figure 19. The three shell scatters are distributed along the mangrove/hinterland boundary on the western side of the study area and the three artefact scatters are located close to watercourses in the study area’s south-east corner. All sites consisted of small, low density, surface

scatters of archaeological material. Each of the archaeological sites is described in greater detail in Appendix L.

Table 16

Characteristics of Archeological Sites in the Proposed Project Lease

Name	Type	Easting*	Northing*	Size (m)	Contents
BR1	Shell scatter	715012	8601234	15 x 10	Quartz flakes, *T. telescopium*
BR2	Shell scatter	714924	8601111	20 x 20	Quartz retouched flake, *T. telescopium*
BR3	Shell scatter	714710	8600833	70 x 10	T. telescopium, Nerita *sp*.
BR4	Artefact scatter	717101	8598924	50 x 5	Quartz flakes and cores, *T. telescopium*
BR5	Artefact scatter	718107	8598522	10 x 10	Quartz flakes and bifacial points
BR6	Artefact Scatter	717234	8599086	10 x 10	Quartz flakes

Note: * GPS reading, WGS84

In addition, a total of 60 isolated artefacts were identified during the archaeological survey (**Tables 17** and **18**). These included flakes, retouched flakes, cores, unifacial and bifacial points made almost exclusively from quartz, which as noted above, crops out extensively across the area. A single chert flake was also identified as part of the background scatter. Isolated artefacts were generally found either on the mangrove/hinterland boundary or along creek banks.

Table 17

Isolated Artefacts identified within the Study Area

Easting[1 & 2]	Northing[1 & 2]	Artefacts
715150	8601200	1 quartz flake
714850	8600200	6 quartz flakes, 1 quartz bifacial point
716100	8600300	2 quartz flakes, 1 quartz bifacial point
716250	8599250	4 quartz flakes, 2 quartz cores
717700	8599800	2 quartz flakes
716250	8598350	1 quartz flake, 1 quartz unifacial point
71750	8598700	7 quartz flakes, 1 quartz core

Table 17 (Continued)

716950	8598700	2 quartz cores
717200	8598850	6 quartz flakes, 2 quartz bifacial points
717400	8598600	1 chert flake, 1 quartz core, 3 quartz flakes
717500	8598550	8 quartz flakes, 2 quartz cores, 2 quartz retouched flakes
718150	8598350	1 quartz bifacial point
718400	8598400	2 quartz flakes, 1 quartz bifacial point

Notes: [1] GPS reading, WGS84

[2] Accuracy within 200 m radius

Table 18

Summary of Isolated Artefacts

Artefact type	Quartz (n)	Chert (n)	Total (n)	Total (%)
Flake	42	1	43	71.7
Retouched flake	2	0	2	3.3
Bifacial point	6	0	6	10
Unifacial point	1	0	1	1.7
Core	8	0	8	13.3
Total (n)	59	1	60	-
Total (%)	98.3	1.7	-	-

3.14 RECREATIONAL ACCESS

The lease area is used by the public for recreational purposes on an irregular basis. The main apparent use of the lease area, mainly around the mangrove fringe, is for off road motorcycle riding. Future access for off road motorcycle riding will not be possible.

Adjacent waters are used by recreational fisherman, who launch their boats from the Middle Arm boat ramp, which is approximately 2 km by road from the western boundary of the lease area. The project area is and will remain out of view of fishermen passing along the Blackmore River by craft. The pump jetty will be the only visible part of the farm from the river.

The lease area contains no permanent freshwater habitat, limiting the recreational use of the lease area for many activities.