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Lower Robe River ecological values and issues

Looking after all our water needs

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Contents

Summary v

1 Introduction 1

2 Biophysical setting 2

2.1 Climate 2
2.2 Physiography and geomorphology 5
2.3 Hydrogeology 6
Aquifers 6
Groundwater 7
River flow and aquifer recharge 8
2.4 Land use and cultural values 11

3 Identification and description of groundwater-dependent ecosystems 12

3.1 Defining groundwater dependent ecosystems 12
3.2 Riverine ecosystems 12
Pool Permanency 12
Conceptual link to groundwater 15
Ecology 18
Sensitivity and conservation significance 21
3.3 Riparian ecosystems 23
Vegetation 23
Conceptual link to groundwater 25
Ecology 27
Conservation significance 30
3.4 Aquifer ecosystems 30
Conservation significance 31
3.5 Summary of ecological values 31
Riverine ecosystems 32
Riparian ecosystems 32
Aquifers 33

4 Ecological management objectives 34

4.1 Background and overall objective 34
4.2 Objectives for riverine and riparian ecosystems 35
4.3 Ecological water requirements 36

Shortened forms 37

References 38

Figures

Figure 1 Robe River study area 3
Figure 2 Long-term annual rainfall for Robe River measured at Pannawonica 4
Figure 3 Mean monthly rainfall and pan evaporation measured at Pannawonica 4
Figure 4 Cross-section of the lower Robe River (Haig, 2009) 6
Figure 5 Monitoring bore hydrographs (1983 –2009) 7
Figure 6 Groundwater level response to recharge events at bore 1A (upstream) and 9A and 11A (downstream) 8

Figure 7 Average monthly flow and rainfall (±SE) Yarraloola (Station 707002) and Pannawonica (Station 5069) 9
Figure 8 River flow analysis showing months when flow was present and years of low flow (total annual flow < 10% average annual flow) 10
Figure 9 River flow at Yarraloola and Bore 1A hydrograph 11
Figure 10 Location and permanence of Robe River pools 14
Figure 11 Conceptual diagram of a longitudinal cross-section of the Robe River during a river flow event 16
Figure 12 Conceptual diagram of a longitudinal cross-section of the Robe River during a period of no river flow 17
Figure 13 Conceptual diagram of a longitudinal cross-section of the Robe River during a drought period 17
Figure 14 Vegetation map of lower Robe River 24
Figure 15 Conceptual groundwater dependence of riparian vegetation of the Robe River 26
Figure 16 E. camaldulensis on the banks of the Robe River access groundwater during periods of no river flow. Recruitment of these species occurs during flood periods. 26
Figure 17 Occurrences of dense, moderate and sparse E. camaldulensis woodlands with associated depth to groundwater 29

Tables

Table 1 Stratigraphic units of the lower Robe River (from Commander 1994) 5
Table 2 Pool permanency data for the Robe River 13
Table 3 Fish species recorded in the Robe River 18
Table 4 Bird species identified at Yarraloola Pool on the Robe River 19
Table 5 Fauna of conservation significance recorded from, or likely to occur within, pools of study area 21
Table 6 Vegetation communities of the Robe River and their groundwater dependence based on local groundwater conditions 28

Summary

The Robe River alluvial aquifer has been identified as a potential water source in the Pilbara regional water plan and previous regional hydrogeological assessments. The Department of Water is currently assessing the sustainable yield of the resource as part of water management planning for the region. This will include identification of the groundwater dependent ecosystems and estimation of their ecological water requirements.

This document summarises the groundwater dependent values associated with the Robe River alluvial aquifer and describes the links between these ecosystems and the aquifer.

The Robe River, like most Pilbara rivers is ephemeral, with a highly variable flow regime reliant on summer cyclones and autumn thunderstorms. The alluvial aquifer is recharged from direct infiltration through the riverbed during these unpredictable river flow events.

River pools, riparian vegetation and aquifer ecosystems are identified as being sustained, at least in part, by water from the alluvial aquifer, particularly during periods of no river flow.

The river and riparian ecosystems are of conservation significance at the local scale and provide valuable habitat for several priority fauna species, two federally protected migratory birds and a potentially new fish species. The aquifer ecosystem with its distinct stygofauna species is expected to be of high conservation value.

Conceptual models have been used to describe the links between the ecosystems and the aquifer. Key links have been identified as objectives for estimating ecological water requirements for the system.

The ecological water requirements will be a key input into the determination of a sustainable yield and an allocation limit for the system. Social and cultural water requirements and consumptive demand for water will also be considered during this determination.

An allocation plan covering Pilbara coastal aquifers, including the Robe River alluvial aquifer is scheduled to be completed in 2012. This plan will include allocation limits and management and monitoring frameworks for each resource.

1 Introduction

The lower Robe River alluvial aquifer was assessed as a potential potable water supply in 1985 by the *Geological Survey of Western Australia* (Commander 1994) and more recently in the *Pilbara coast water study* (Haig 2009).

These hydrogeological assessments do not include any consideration of existing demands for water that may be present within the lower Robe River alluvium. These demands include groundwater-dependent ecosystems, cultural values and existing use (stock, domestic and mining).

In this report we identify and describe groundwater-dependent ecosystems in the lower Robe River area using available information supplemented by the results of field studies. The key challenge is to understand ecosystem dependence on groundwater in an environment of highly variable aquifer recharge and water availability.

Conceptual models have been used to identify the key linkages between these ecosystems and the hydrogeology of the lower Robe River. Key links have been identified as objectives for estimating ecological water requirements for the system.

The outcomes of this work will set the framework for development of ecological water requirements and ultimately inform the determination of an allocation limit for the lower Robe River.

2 Biophysical setting

The lower Robe River alluvium is located 80 km east of Onslow and 50 km west of Pannawonnica in the Pilbara region. The study area extends approximately 40 km along the Robe River, downstream of where it crosses the North West Coastal Highway (Figure 1).

2.1 Climate

The Pilbara region's climate is classified as semi-arid to arid with low variable annual rainfall and hot dry conditions most of the year.

The nearest weather station located at Pannawonica has recorded an average annual rainfall of 410 mm (Station 5069, 1971–2009) with totals ranging from 700 mm in 2006 to 113 mm in 2002 (Figure 2). This high annual variability is due to the episodic nature of tropical cyclones which occur between December and March and account for 70% of total annual rainfall.

Recorded temperatures at Pannawonica show January has generally been the hottest month with a mean maximum of 41.0 ^{o}C and a mean minimum of 27.7 ^{o}C. July is the coolest month with a mean maximum of 26.7 ^{o}C and a mean minimum of 24.6 ^{o}C.

Due to the high temperatures and solar radiation, annual evaporation is above 3000 mm and far exceeds the annual rainfall (Figure 3). These high evaporation rates and low rainfall cause an extreme moisture deficit across the region.

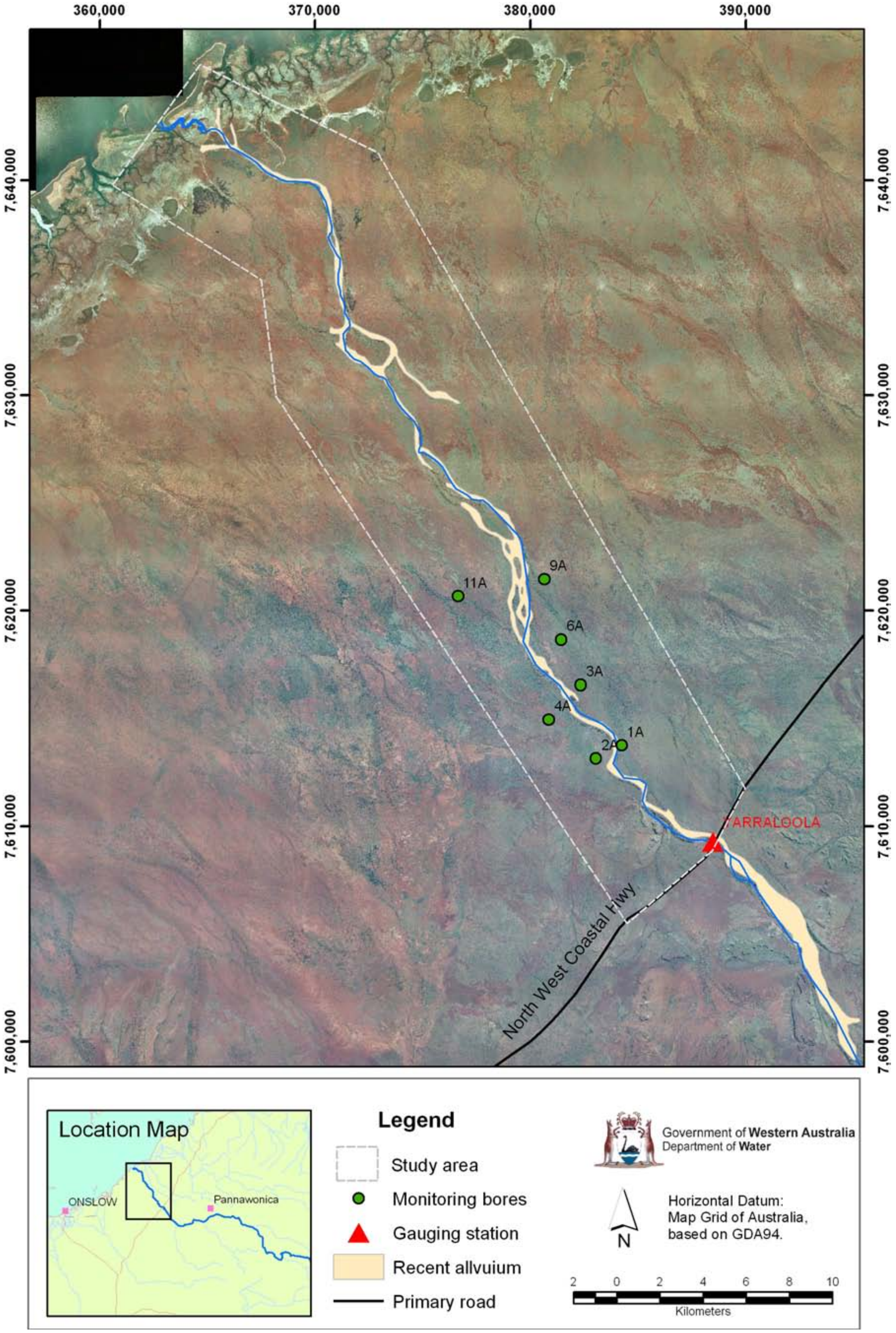

Figure 1 Robe River study area

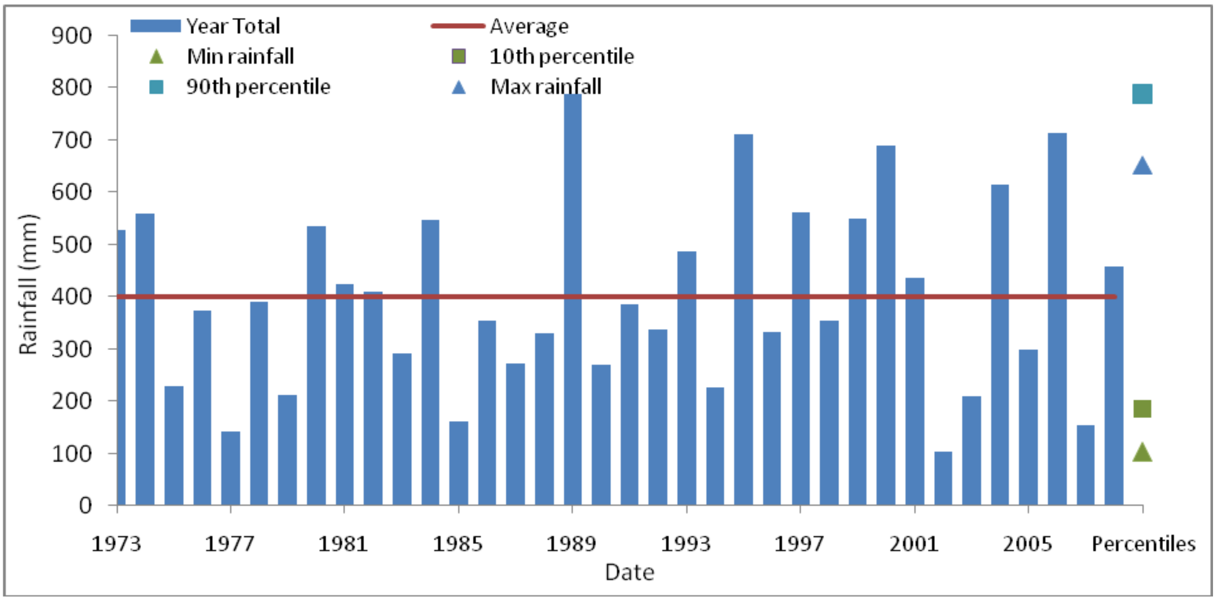

Figure 2 Long-term annual rainfall for Robe River measured at Pannawonica

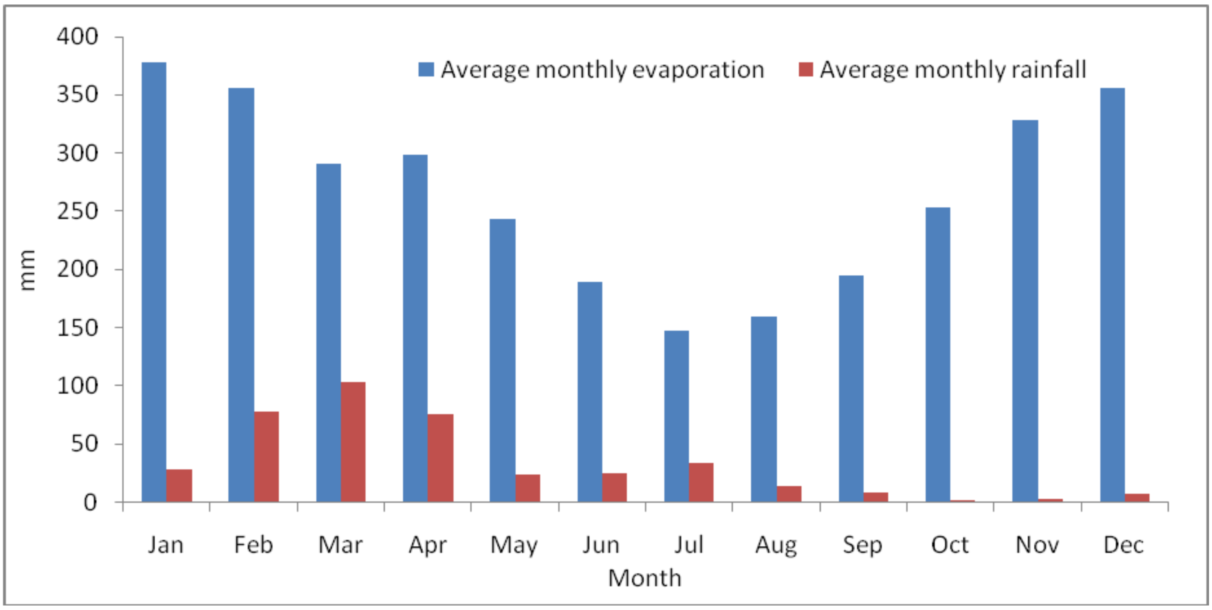

Figure 3 Mean monthly rainfall and pan evaporation measured at Pannawonica

2.2 Physiography and geomorphology

The lower Robe River lies on the Ashburton Plain which rises gently from the Cane-Robe Tidal Flats at the coast to about 50 m above sea level at the foot of an escarpment bordering the Nanutarra region. The Robe River passes through a gap in the scarp and crosses the coastal plain which is a flat mosaic of stony plains and intervening areas of cracking clay soils. The river then flows in a north-westerly direction along a narrow channel that is incised as much as 5 m below the general level of the plain.

Alluvial sediments to maximum depths of 30 m cover the coastal plain. These sediments are mainly overbank deposits of clay and silt. Gravel deposits outcrop along the riverbed and occur in the subsurface extending out about 5 km from the river channel. These deposits have a maximum thickness of 15 m, and generally thin with distance from the river and with distance downstream (Table 1).

Trealla Limestone unconformably underlies the alluvium with thicknesses ranging from 17 m to about 10 m. This formation is similar in lithology to the Millstream Dolomite in the Millstream aquifer of the Upper Fortescue River (Commander 1994).

Robe Pisolite which is found along the present course of the Robe River unconformably underlies the Trealla Limestone. Underlying the Robe Pisolite is up to 45 m of Cretaceous sediments made up of either Windalia Radiolarite or Muderong Shale and then Toolonga Calcilutite overlying Yarraloola Conglomerate.

The basement rock of the lower Robe River alluvium consists of the Proterozoic Ashburton Formation which outcrops in low hills on either side of the river.

Table 1 Stratigraphic units of the lower Robe River (from Commander 1994)

Period	Rock unit	Lithology	Thickness m*
Quaternary	Alluvium	Clay, gravel (calcrete close to watertable)	30
		unconformity	
Tertiary	Trealla Limestone	Alluvium, pisolite and calcrete	17
		unconformity	
	Robe Pisolite	Pisolitic iron stone, silcrete, clay	6
		unconformity	
Cretaceous	Toolonga Calcilutite	Clay, claystone	6
		disconformity	
	Windalia radiolarite	Siltstone	8
	Muderong Shale	Shale	8
	Yarraloola Conglomerate	Conglomerate, sand,clay	23
		unconformity	
Proterozoic	Ashburton Formation	Schist	22

*maximum thickness intersected during drilling

2.3 Hydrogeology

The Geological Survey of Western Australia investigated alluvial sediments in 1983 and 1984 (Commander 1994). Twenty-two exploration bores were drilled into the alluvium and underlying bedrock to delineate the aquifer. Four pumping tests were conducted and completed bores were lithologically logged.

This and subsequent investigations have lead to the development of a conceptual understanding of the Robe River's hydrogeology. This conceptual understanding was tested by the Department of Water using a numerical model recently completed for the study area (Sinclair Knight Merz 2010).

Aquifers

The major aquifer underlying the lower Robe River consists of the gravel beds of the alluvium (Figure 4). The gravel has a maximum saturated thickness of 15 m adjacent to the Robe River and extends out approximately 5 km. The aquifer thins away from the river and towards the downstream end of the study area. Calcrete is also present in the alluvial gravels often occurring at or up to 5 m below the watertable.

The underlying Trealla Limestone generally acts as a confining layer but may be considered an aquifer on a local scale in situations where secondary porosity has been developed (Haig 2009).

The Robe Pisolite can be a highly transmissive aquifer, however it has low permeability in the study area. This formation along with the underlying Cretaceous sediments forms an impermeable base to the alluvial aquifer with leakage into the underlying Yarraloola Conglomerate likely to be low.

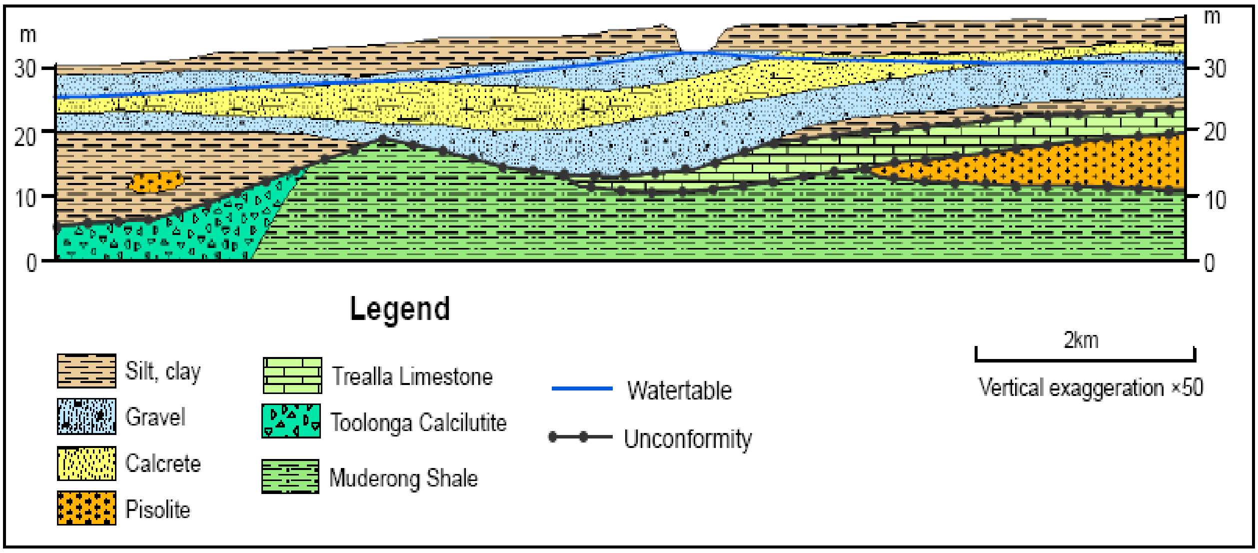

Figure 4 Cross-section of the lower Robe River (Haig 2009)

Groundwater

Groundwater levels at seven bores situated along the course of the river have been monitored annually in the study area since 1983. Their location is shown in Figure 1.

The depth to groundwater (dtgw) in lower Robe River ranges between 4.075 m and 9.792 m with an average of 6.627m (Figure 5).

Bore 1A is the most upstream bore in the study area, and is situated closest to the river channel at a distance of 180 m. This bore has the most variable hydrograph with historical maximum, minimum and average depth to groundwater of 8.964 m, 4.594 m and 6.837 m respectively (range 4.370 m).

The two most downstream bores, 11A and 9A, have the least variable hydrographs with depths to groundwater ranging from 4.186 m to 7.205 m and 4.075 m to 7.035 m respectively (range 2.839 m and 2.96 m). Monitoring data suggests that upstream groundwater levels are more responsive to recharge events (Figure 6).

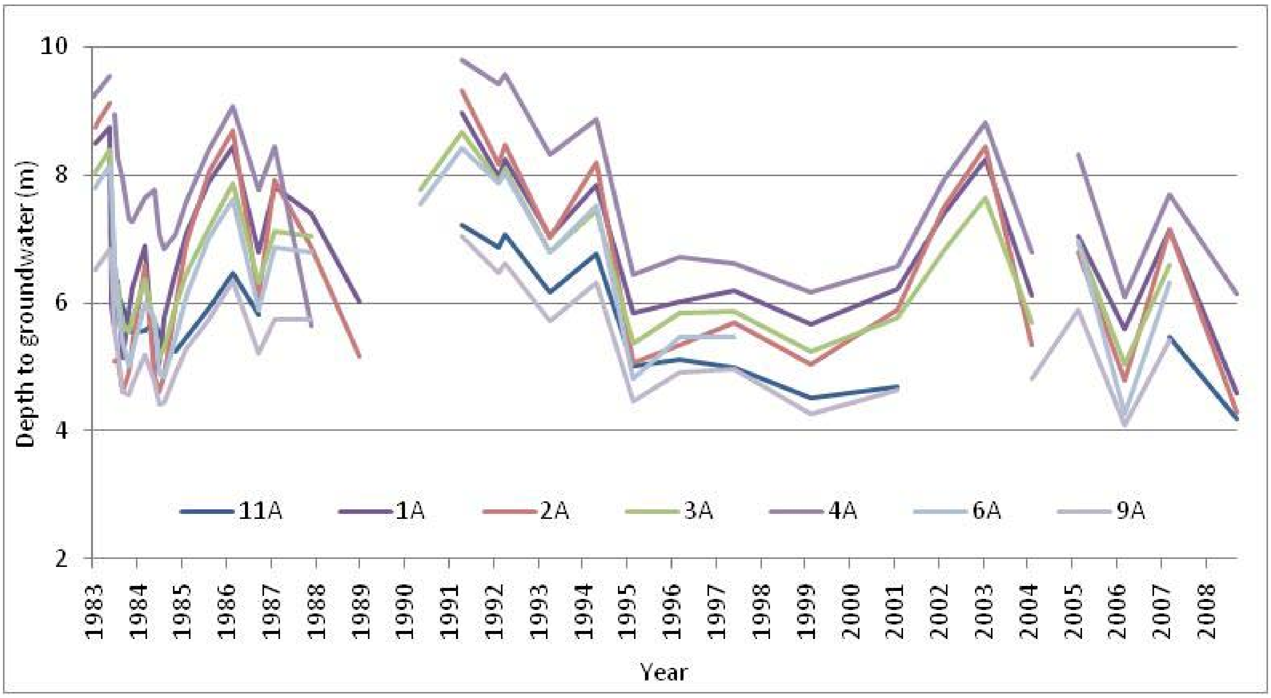

Figure 5 *Monitoring bore hydrographs (1983 –2009)*

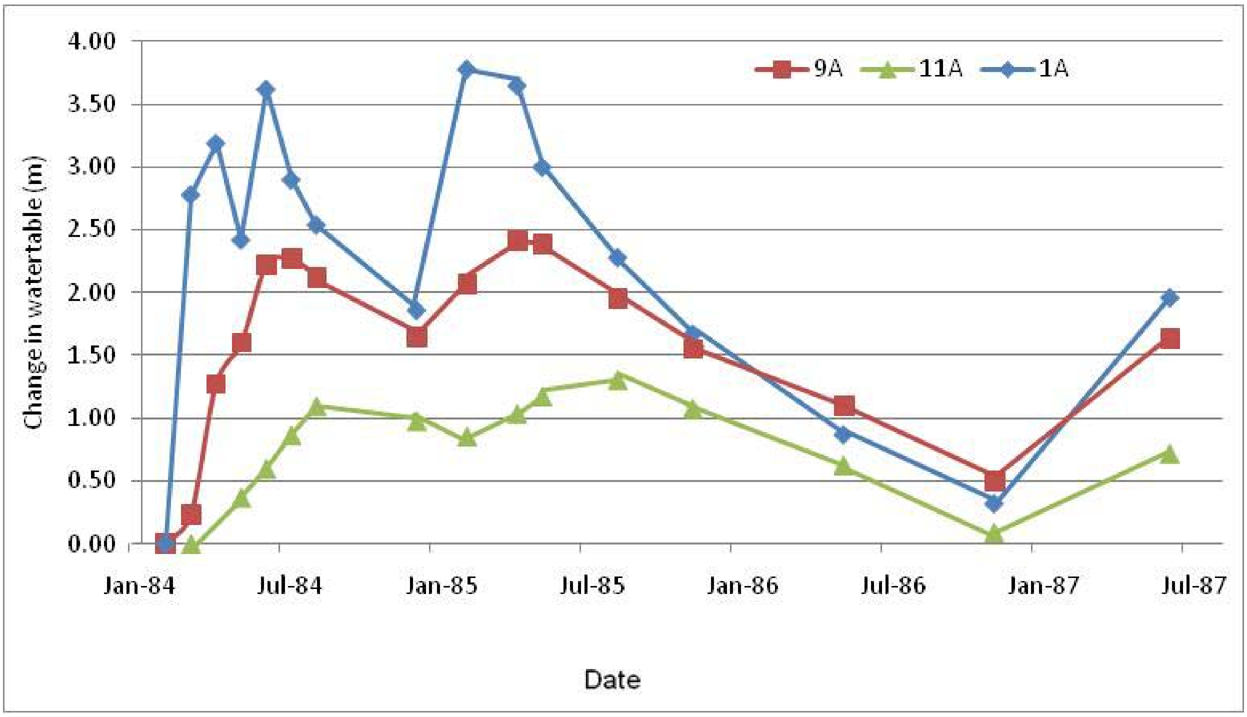

Figure 6 *Groundwater level response to recharge events at bore 1A (upstream) and 9A and 11A (downstream)*

River flow and aquifer recharge

The lower Robe River gauging station is located immediately upstream of the study area where the North West Coastal Highway crosses the river. The period of record is 37 years, from 1972 to the present.

Robe River has a catchment area of 7104 km^2. Records indicate that over the period of record, mean annual flow has been 108 GL (± SE 30). The river is ephemeral with flow occurring after heavy rainfall and continuing for 1 to 2 months. River flows events are likely to occur during January to April, peaking in March. Low or no flow is typically experienced from July to December (Figure 7).

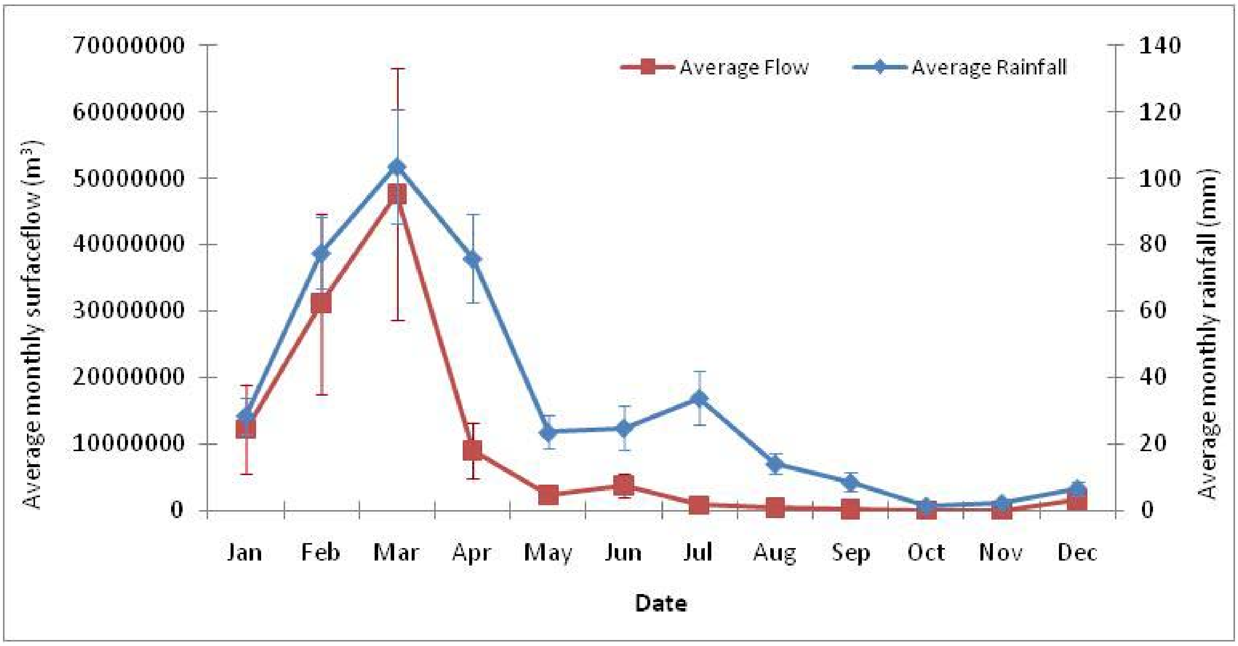

Figure 7 Average monthly flow and rainfall (±SE) Yarraloola (Station 707002) and Pannawonica (Station 5069)

Recharge of the alluvial aquifer occurs primarily through river recharge. The aquifer has the potential to absorb a significant percentage of river flow, with the amount of recharge controlled by the frequency, size and duration of flows. For example in 1984 river flows of 102 GL over a 5 month period resulted in an estimated recharge of 24 GL. In 1985 similar flows of 80 GL over a three-month period resulted in an estimated recharge of only 10 GL (Haig 2009). In the first instance aquifer storage would have been low due to the proceeding two years of low or no flow, whilst the second recharge event was following a year of high river flow and high aquifer levels (Figure 8).

A monthly flow analysis shows that Robe River is characterised by a flow regime that is highly variable and unpredictable (Figure 8). Over the 37 years of record, nine years have recorded no flow and another eight years recorded total flows less than 10 percent of the mean annual flow. This indicates that in two out of five years recharge to the lower Robe River alluvial aquifer is very low.

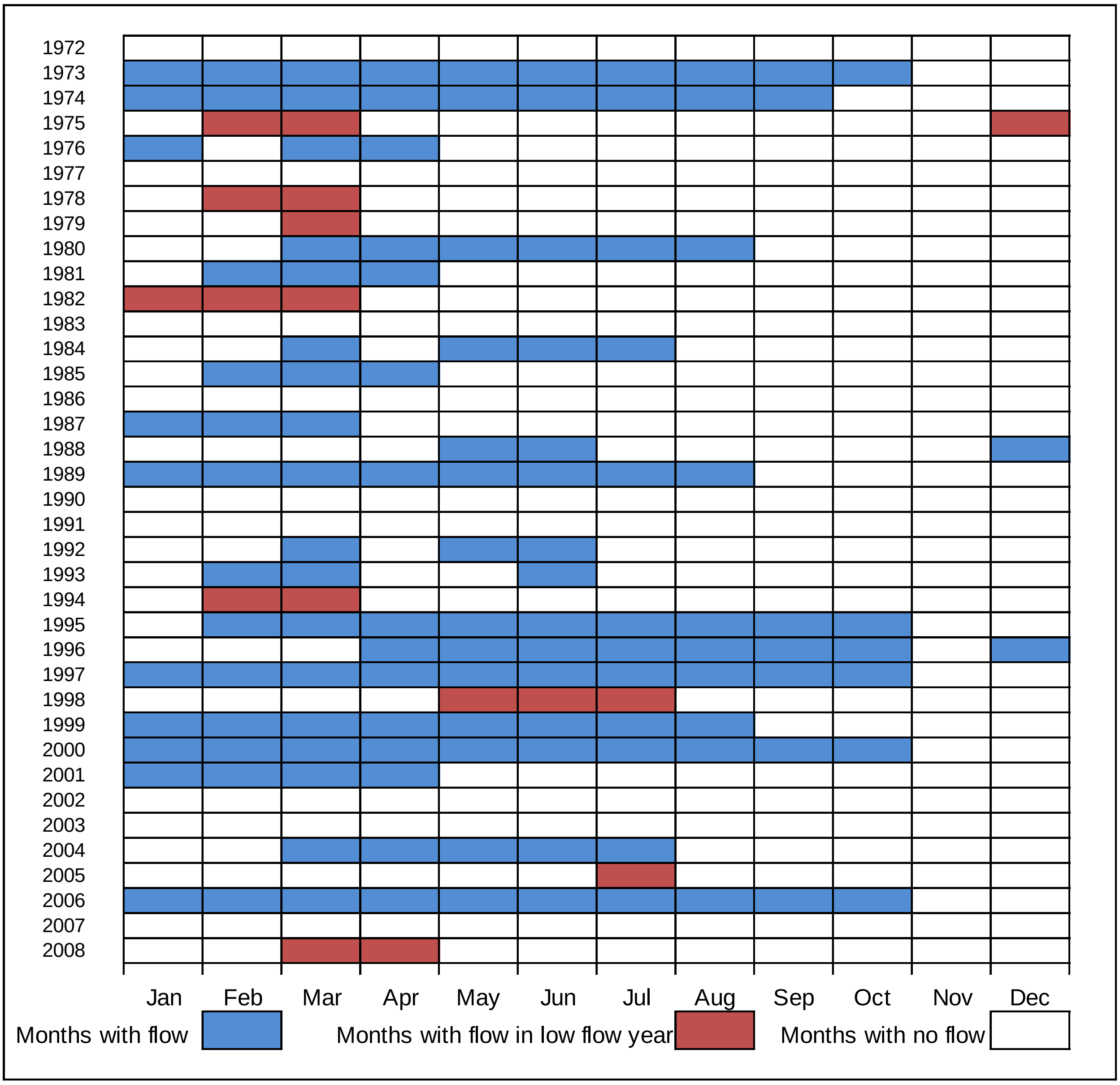

Figure 8 *River flow analysis showing months when flow was present and years of low flow (total annual flow <10% average annual flow)*

The longest duration of no flow was 34 months, between May 2001 and March 2004 and resulted in the second lowest recorded groundwater levels (Figure 9). The lowest groundwater levels were experienced in January 1991 after a no flow period of 29 months (the second longest on record).

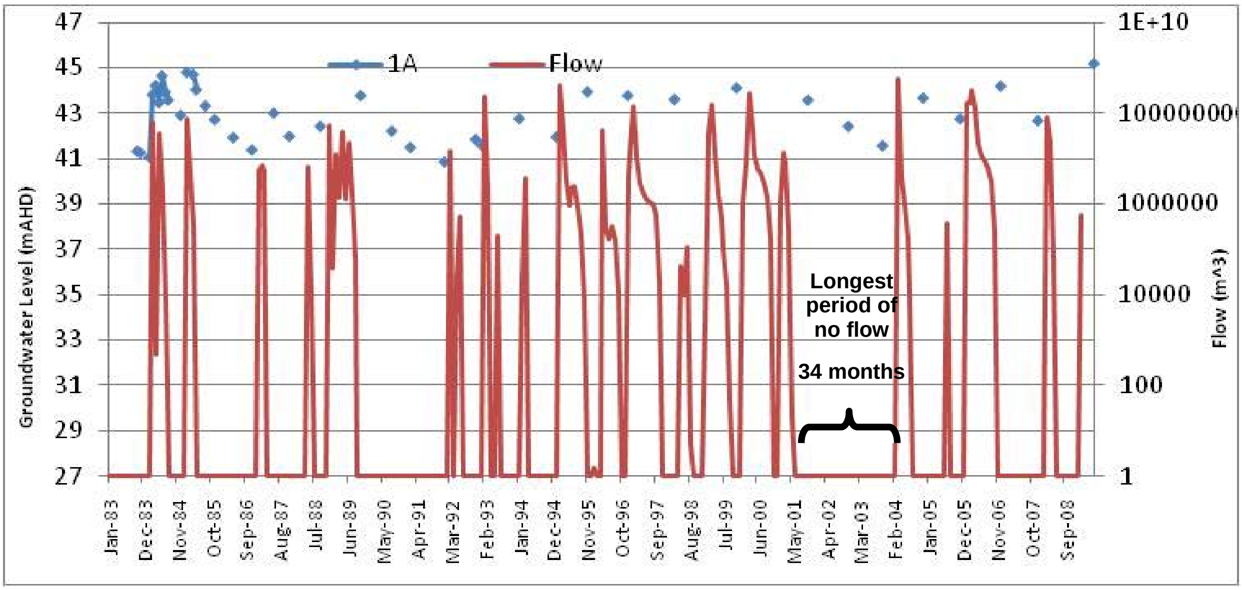

Figure 9 *River flow at Yarraloola and Bore 1A hydrograph*

2.4 Land use and cultural values

Two working pastoral stations (Yarraloola Station and Mardie Station) cover the study area. Robe River Iron Associates also holds several exploration and mining leases across the study area with mining being undertaken at Mesa A and Warramboo in the lower southwest corner of the study area.

Water supply for the mining operations is being abstracted from several deep bores intercepting the Yarraloola Conglomerate approximately 8 km from the Robe River. The current licence for this borefield is 3 GL/annum with production currently around 2 GL.

The Kuruma Marthudunera people are the Traditional Owners of the land around the lower Robe River. Ethnographic heritage values of the area have been documented through partnership with the Department of Water and the Kuruma Marthudunera people. Through this process it has been determined that the pools and surrounds hold very high value for the Traditional Owners (Pilbara Native Title Service 2009).

3 Identification and description of groundwater-dependent ecosystems

3.1 Defining groundwater dependent ecosystems

To manage potential impacts of groundwater abstraction the department has identified those ecosystems that have some degree of groundwater dependence and determined the type and level of that dependence.

Three types of ecosystems have been identified as being reliant, at least in part, on groundwater in the lower Robe River:

- riverine ecosystems – sustained by aquifer discharge or surface expressions of groundwater
- riparian ecosystems – phreatophytic vegetation accessing groundwater
- aquifer ecosystems – stygofaunal assemblages using the aquifer as habitat.

The degree of dependence of these ecosystems on groundwater may vary from high dependence (such as permanent river pools), to opportunistic dependence in times of drought (such as some areas of terrestrial vegetation) (Hyde 2006).

An ecosystem's groundwater dependence is based on one or more of four basic groundwater attributes (Sinclair Knight Merz 2001):

- flow or flux – the rate and volume of supply of groundwater
- level – for unconfined aquifers, the depth below surface of the watertable
- pressure – for confined aquifers, the potentiometric head of the aquifer and its expression in groundwater discharge areas
- quality – the chemical quality of groundwater expressed in terms of pH, salinity and/or other possible constituents, including nutrients and contaminants.

For riparian ecosystems, depth to groundwater (level) and quality are the most important attributes, whereas for riverine ecosystems, permanency of inundation (flow and flux) is most important with groundwater level being important in terms of maintaining the hydraulic gradient and flow towards the river (Eamus et al 2006).

Conceptual models have been developed to illustrate the type and behaviour of interactions between groundwater and dependent ecosystems, and support the identification of the potential response to declining groundwater availability.

3.2 Riverine ecosystems

Pool Permanency

The Robe River is an ephemeral system with intermittent surface flows. In between flows the river is reduced to a series of isolated pools (Table 2 and Figure 10). The number and permanence of these pools depends on the antecedent river flow events and groundwater levels.

Remote mapping of pools, conducted by the Department of Water, has identified five permanent pools, five semi-permanent pools and fourteen intermittent pools (Department of Water 2009).

The mapping made use of satellite imagery spanning six years, to characterise the permanency of pools across the Pilbara. Pools which have been identified as permanent were present throughout the entire time-series, including a no flow period of 21 months leading up to February 2003. Semi-permanent pools are defined as those present in 60 – 90% of image sets and intermittent pools are defined as those pools present in <60% of image sets.

Table 2 Pool permanency data for the Robe River

Pool name	Nov-99	Feb-02	Feb-03	Oct-04	Jun-04	Feb-05	Defined perm.
	Estimated inundation area m^2						
Unknown	104 834	40 864	2 530	48 949	98 614	52 699	Permanent
Unknown	4 430	1 270	3 155	1 900	635	2 525	Permanent
Unknown	6 930	1 895	10 690	8 180	3 790	17 000	Permanent
Unknown	11 340	5 045	13 220	8 185	24 554	11 320	Permanent
Yarraloola	19 450	13 195	635	16 320	50 229	32 620	Permanent
Unknown	11 330	1 900	0	0	35 189	2 525	Semi-perm
Multhuwarra	0	0	2 525	45 190	5 675	42 715	Semi-perm
Unknown	3 160	635	0	0	20 119	635	Semi-perm
Unknown	4 420	0	0	3 155	11 975	6 920	Semi-perm
Unknown	2 525	3 155	0	6 290	24 554	5 665	Semi-perm
Unknown	0	0	2 525	0	0	1 900	Intermittent
Unknown	62 184	0	0	0	0	77 799	Intermittent
Unknown	3 785	0	635	0	0	0	Intermittent
Unknown	2 530	0	0	0	635	0	Intermittent
Unknown	1 895	0	0	0	12 590	0	Intermittent
Unknown	4 435	0	0	0	15 114	0	Intermittent
Unknown	0	1 270	0	0	0	635	Intermittent
Unknown	26 365	0	0	0	37 650	0	Intermittent
Unknown	1 270	0	0	0	14 490	0	Intermittent
Unknown	1 265	0	0	0	14 490	0	Intermittent
Unknown	0	0	0	1 265	0	1 900	Intermittent
Unknown	0	0	3 785	0	0	635	Intermittent
Unknown	0	0	5 035	0	0	3 150	Intermittent
Unknown	0	0	0	1 265	0	15 764	Intermittent

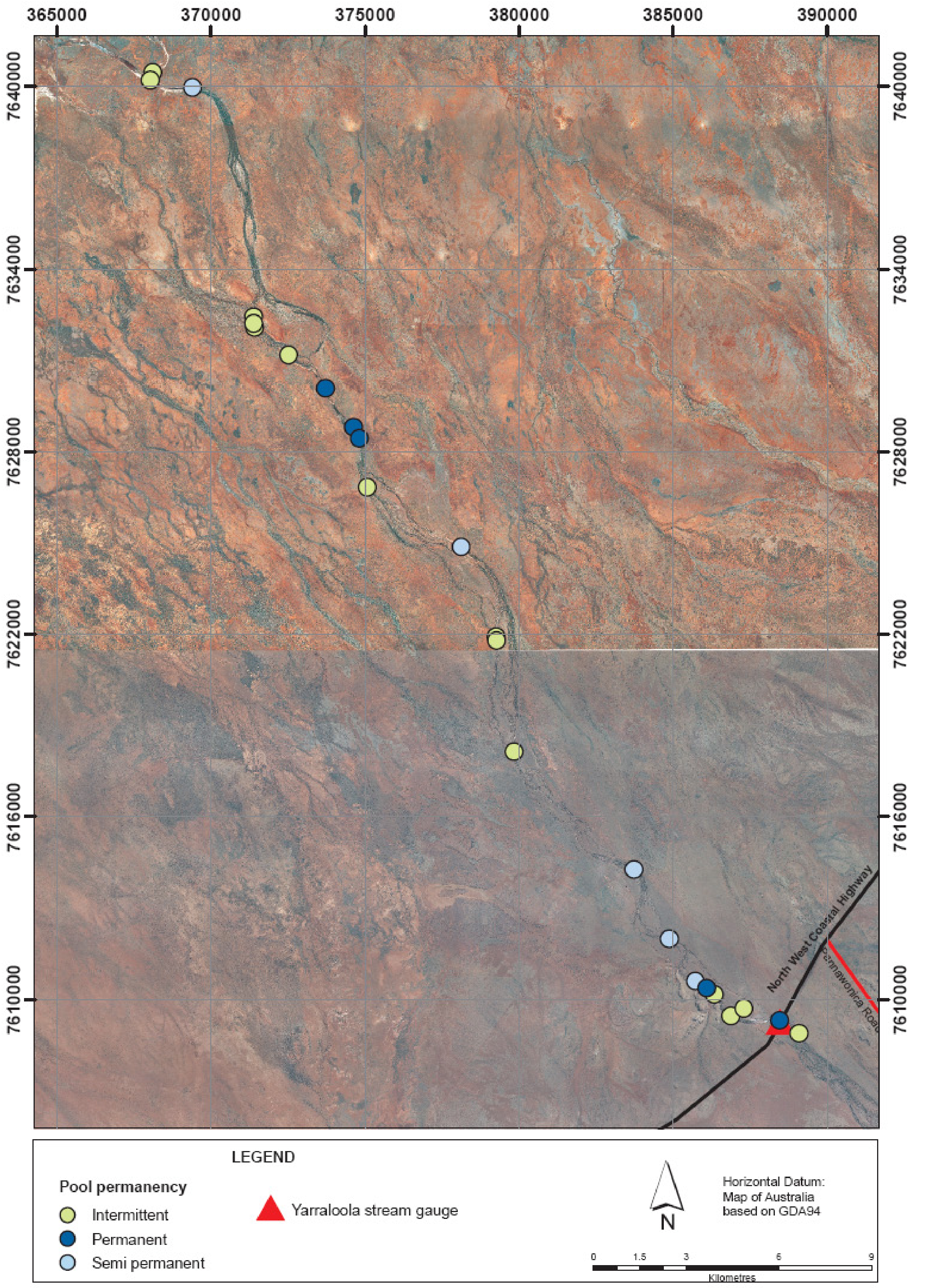

Figure 10 Location and permanence of Robe River pools

Conceptual link to groundwater

There is strong connectivity and interaction between the Robe River surface water and the underlying aquifer. The direction of interaction changes seasonally in response to flooding, evaporation from pools or transpiration of groundwater by riparian vegetation.

When the river is in flood there is connectivity between pools, the floodplains and the riparian zone (Figure 11). This hydrological connectivity replenishes river pools, allows biota, nutrients and carbon to disperse or migrate through the system and triggers recruitment of riparian vegetation and aquatic flora and fauna.

River flow events also recharge groundwater, causing the watertable to rise. As floodwaters recede large areas remain inundated resulting in a spike in productivity and provision of large areas of temporary habitat.

After a period of no flow (Figure 12) the hydraulic gradient between the groundwater and the pools reverse and groundwater discharges into the pools. At high groundwater levels discharge into the pools can be enough to sustain river baseflow between pools. Groundwater eventually becomes disconnected from intermittent pools and as surface water evaporates these pools will disappear.

Drought conditions and declining groundwater levels result in shallower pool depths and semi-permanent pools becoming disconnected from the groundwater (Figure 13). This greatly reduces the area of aquatic habitat available for macroinvertebrates, fish and macrophytes. Aquatic flora and fauna are either lost from the system, avoid the drought by life-cycle adaptations (such as drought resistant propagules or aestivate) or become concentrated in permanent pools sustained by groundwater.

Permanent pools provide critical habitat and are an important refuge for aquatic flora and fauna during drought periods. In addition they facilitate relatively high ‘in pool’ productivity during droughts and support productivity in surrounding areas (Douglas et al. 2005). These pools typically have long-term connectivity to the groundwater and are expected to be maintained by groundwater discharge during drought periods.

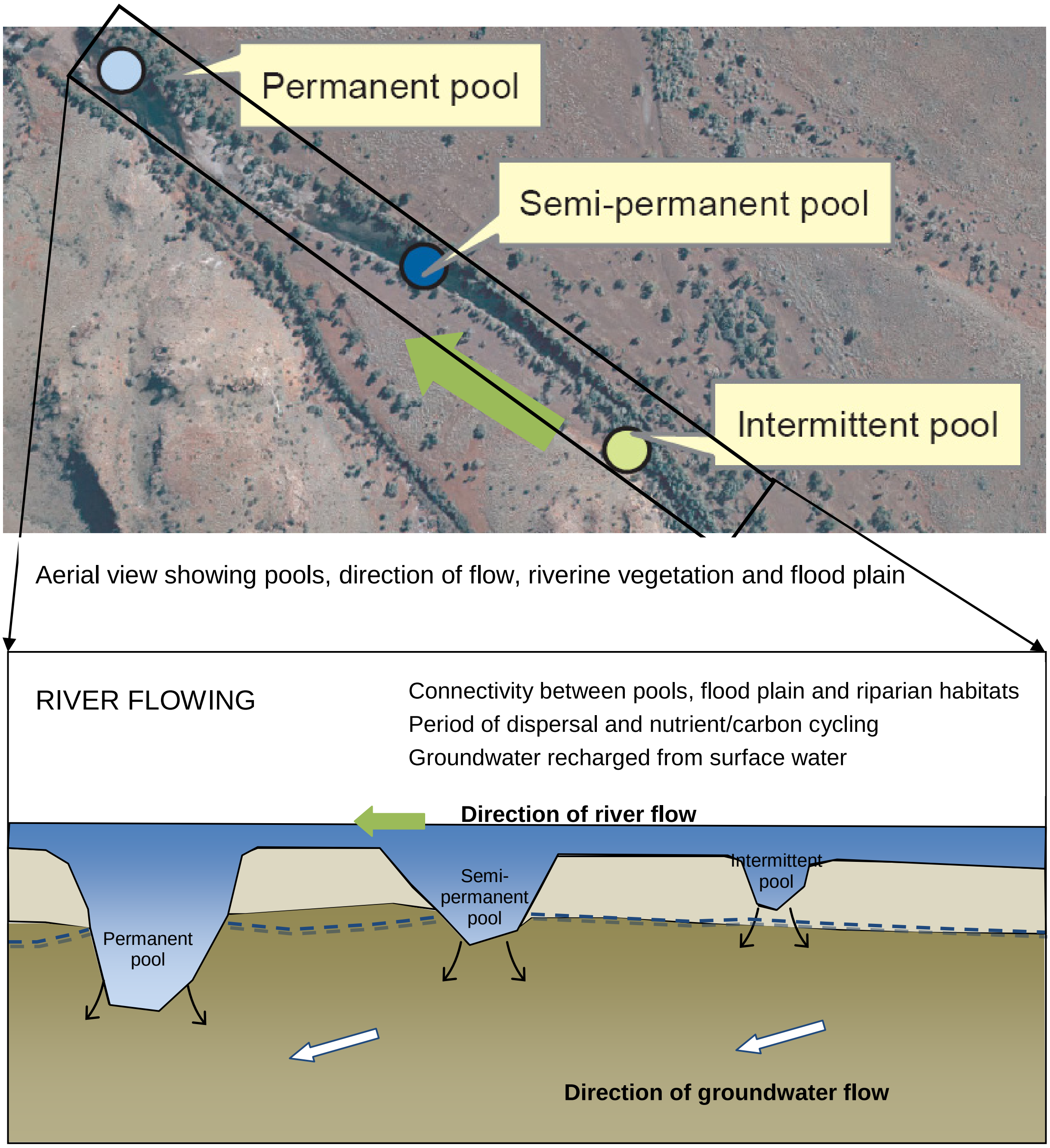

Figure 11 Conceptual diagram of a longitudinal cross-section of the Robe River during a river flow event

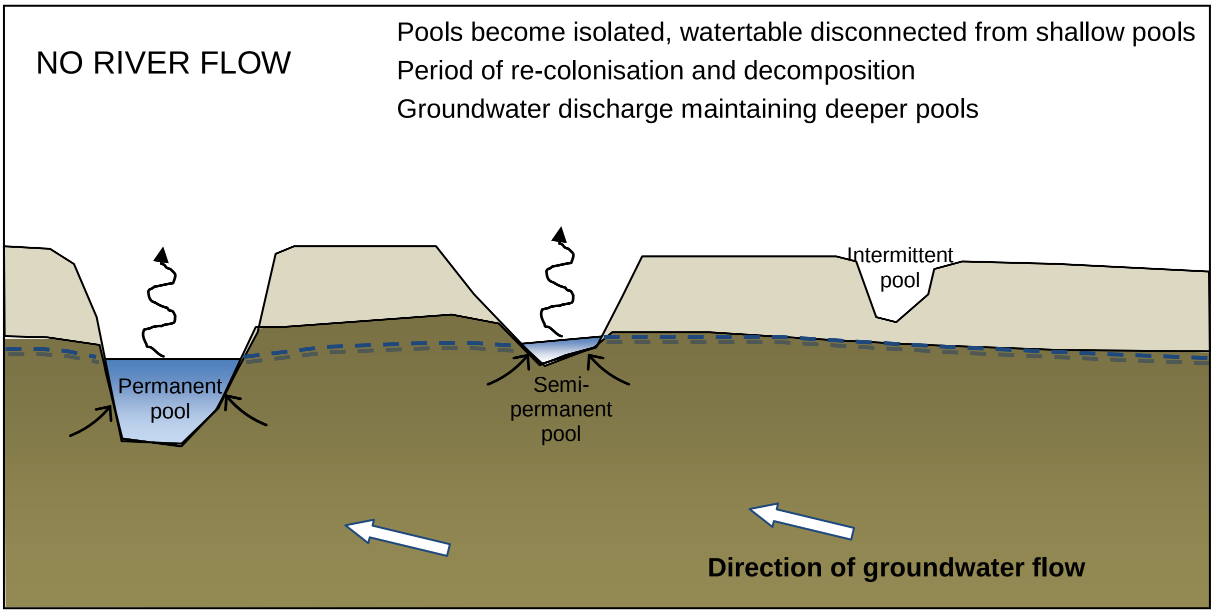

Figure 12 *Conceptual diagram of a longitudinal cross-section of the Robe River during a period of no river flow*

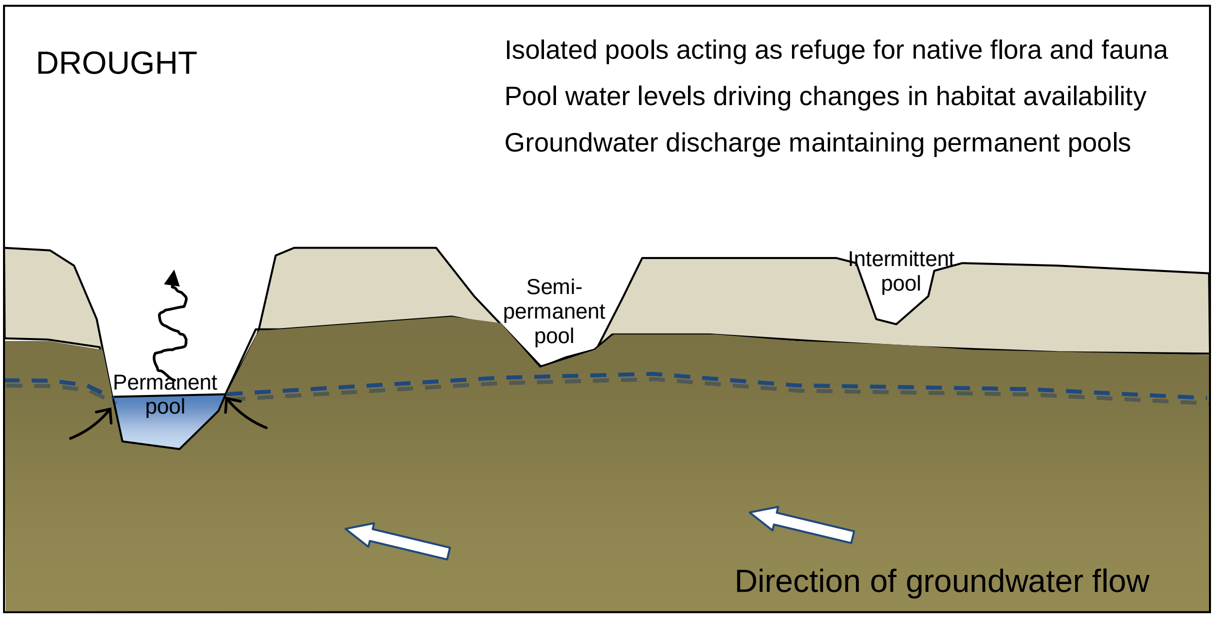

Figure 13 Conceptual diagram of a longitudinal cross-section of the Robe River during a drought period

Ecology

Fish fauna

Surveys of the lower Robe River and representative upstream pools have recorded 12 species of fish (Biota Environmental Services 2006, Dobbs and Davies 2009). This includes a previously unidentified species of catfish that has recently also been recorded in the lower Fortescue River (Morgan et al. 2009).

Of the 12 species recorded, seven species spend their entire lives in fresh water, and five are marine species which occasionally venture into freshwater environments (Table 3).

Table 3 Fish species recorded in the Robe River

Species	Common Name	Morgan (2003)	Biota (2005)	Dobbs & Davies (2009)
Freshwater				
Amniataba percoides	Barred Grunter	X	X	X
Leiopotherapon aheneus	Fortescue Grunter	X		X
Leiopotherapon unicolor	Spangled Perch	X	X	X
Melanotaenia australis	Western Rainbowfish	X	X	X
Nematalosa erebi	Bony Bream	X		X
Neosilurus hyrtlii	Catfish		X	X
Neosilurus sp.	Unnamed	X		
Marine				
Megalops cyprinoides	Oxeye Herring		X	X
Selenotoca multifasciata	Striped Butterfish			X
Gerres filamentus	Threadfin Silver-biddy		X	X
Lutjanus argentimaculatus	Mangrove Jack			X
Scatophagus multifacsicatus	Banded Scat		X	
Total number of species	12	6	7	10

Of these, the larger bodied species *Nematalosa erebi, and Neosilurus hyrtlii* have a known preference for deep permanent pools (Dames and Moore 1984, Morgan et al. 2003). Larger permanent pools, particularly in the lower reaches close to the coast were also the preferred habitat of marine species with their occurrence diminishing with distance from the coast (Dobbs and Davies 2009, Morgan et al. 2003).

The highest diversity of species was found in the more stable pools (defined by permanence and variability of maximum depth). These pools were also found to have a greater stability in species composition, suggesting that they act as refuge habitats during droughts and source pools when connectivity is re-established (Dobbs and Davies 2009). This is similar to trends in other Pilbara rivers where pool stability was found to be the most direct determinant of diversity, with habitat diversity also being an important factor (Beesley 2006).

The tolerance of fish to lower water quality, including levels of dissolved oxygen differs between species. Buffering of extremes in levels of dissolved oxygen, temperature and salinity through connection to or contribution of groundwater is considered to be vital in maintaining fish populations, particularly for those species less tolerant to low DO levels (Morgan et al. 2009).

Macroinvertebrates

The wetland fauna of the Robe River 20 km upstream of the study area have been the subject of a long-term ecological research program and have been sampled annually since 1991 (Dobbs and Davies 2009). In their review of results from this program, Dobbs and Davies (2009) assessed the relationships between species richness, flow and other habitat variables.

Since this program began, annual sampling of macroinvertebrate communities, water quality and pool morphology has been conducted within eight pools. This sampling has yield 112 macroinvertebrate taxa from 64 families.

Species richness was found to be highly dependent on flow events. High flow events are a major disturbance as they scour fauna from the pools and remove structural habitats. Following on from the initial high flow disturbance, extended periods of flow become important for recovery as they provide more time for species to recolonise as well as increasing habitat size and type.

During drier years, important parameters were found to be pool size (particularly maximum depth) and habitat. Recent findings of Pinder and Leung (2009) also concluded that pool depth, size, permanency and habitat diversity were correlated to macroinvertebrate communities.

The Robe River macroinvertebrate communities are dominated by insects, especially mobile bugs (Hemiptera), beetles (Coleoptera) and flies (Diptera) with no species considered rare or restricted in distribution (Dobbs and Davies 2009).

Birds

Biota Environmental Services (2006) undertook an avifauna survey as part of the *Robe River Iron Associates Mesa A transport corridor project*. This included a single 40-minute avifauna census conducted within the study area at Yarraloola Pool. This survey yielded 159 individual birds from 25 species (Table 4).

Table 4 Bird species identified at Yarraloola Pool on the Robe River

Common name	Species	Total individuals
Red-backed kingfisher	*Todiramphus pyrrhopygia*	2
Rainbow bee-eater	*Merops ornatus*	1
Brown honeyeater	*Lichmera indistincta*	2
White-plumed honeyeater	*Lichenstomus penicillatus*	9
Magpie-lark	*Grallina cyanoleuca*	1
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	1

Common name		Species	Total individuals
Fairy martin		*Hirundo ariel*	100
Rufous songlark		*Cincloramphus mathewsi*	1
Zebra finch		*Neochmia ruficauda*	2
Star finch*		*Neochmia ruficauda*	1
Pacific Black duck*		*Anas superciliosa*	4
Darter*		*Anhinga melanogaster*	1
Little Black cormorant*		*Phalacrocorax sulcirostris*	1
Little Pied cormorant*		*Phalacrocorax melanoleucos*	4
Australian pelican*		*Pelecanus conspicillatus*	3
Great egret*		*Ardea alba modesta*	1
Little egret*		*Ardea garzetta*	1
Black-necked stork*		*Ephippiorhynchus asiaticus*	1
Black kite		*Milvus migrans*	1
Whistling kite		*Haliastur sphenurus*	1
Eurasian coot*		*Fulica atra*	13
Australian bustard		*Ardeolis australis*	1
Black-fronted Dotterel*		*Charadrius melanops*	4
Peaceful dove		*Geopelia striata*	2
Little corella		*Cacatua sanguinea*	1
Night parrot**		*Pezoporus occidentalis*	
Total species	26	Total individuals	159

* *Based on their dependence on river pools and associated habitats, these species have been identified as having high sensitivity to groundwater declines (Outback Ecology Services 2004).*

** *Record from the threatened and priority fauna database (Department of Environment and Conservation 2010)*

The avifauna survey undertaken by Biota Environmental Services included 32 sites and yielded a total of 93 avifauna species. The richest sites were all close to the Robe River or its tributaries. This is considered to be due to the availability of surface water and associated higher productivity and greater structural diversity often associated with river channels (Biota Environmental Services 2006).

Water Quality

Long term water chemistry analysis in the Robe River (Dobbs and Davies 2009) indicate that the pools are fresh (<1200 µS/cm) slightly alkaline (pH ranging from 7.45 to 8.26) with low levels of turbidity (<8 NTU) during the dry season becoming elevated immediately following flood events (>70 NTU).

Long term quarterly monitoring indicates there is no significant seasonal difference in conductivity within sampled pools despite high evaporation rates. This is likely due to the continual input of low salinity groundwater.

Monitoring of dissolved oxygen (DO) shows significant spatial and temporal variation. Smaller, shallower pools showed the greatest variations falling to night time concentrations < 2 mg/L. This is below the recommended critical threshold at which respiration becomes difficult for many fish (ARMCANZ/ANZECC 2000).

Levels of total nitrogen and total phosphorous have also exceeded ANZECC guideline levels. These elevated nutrient levels are likely to be due to inputs from cattle. Guidelines used here were developed for tropical low land rivers and should be applied with caution to arid coastal rivers.

Declines in groundwater would likely result in falling pool levels and increasing salinity. Shallow pools have also been shown to be more susceptible to night time anoxia. Maintenance of water levels and pool water quality is important to ensure oxygen levels remain sufficient for aquatic biota and to facilitate nutrient cycling associated with primary productivity and decomposition of organic carbon for food webs.

Sensitivity and conservation significance

Native birds and fish considered to be of conservation significance are detailed in Table 5. Those species considered to be rare, threatened with extinction, or of high conservation value are specially protected by law under the Western Australian *Wildlife Conservation Act 1950*. Additionally, many of these species are listed under the federal *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).*

Table 5 Fauna of conservation significance recorded from, or likely to occur within, pools of study area

Common name		**Conservation status**	
		State level	**Federal level**
Night parrot	*Pezoporus occidentalis*	Schedule 1	Endangered
Star finch	*Neochmia ruficauda*	Priority 4	
Australian bustard	*Ardeotis australis*	Priority 4	
Fortescue grunter	*Leiopotherapon aheneus*	Priority 4	
Undescribed	Neosilurus sp.	To be determined	
Rainbow bee-eater	*Merop ornatus*		Protected marine species (EPBC Act) Listed migratory species – JAMBA
Great egret	*Ardea alba modesta*		Protected marine species (EPBC Act) Listed migratory species – CAMBA and JAMBA

Note: CAMBA China – Australia Migratory Bird Agreement. JAMBA Japan – Australia Migratory Bird Agreement

Night parrot

The Night parrot is a nocturnal bird species listed as endangered under the EPBC Act and as a Schedule 1 under the Wildlife Conservation Notice 2005. The species was recorded near Yarraloola Pool in 1967 and has not been recorded since. It is known to inhabit treeless or sparsely wooded spinifex (*Triodia* spp.) near water. Many records have come from waterholes, and almost all reports from areas of *Triodia* have noted the presence of nearby water (Biota Environmental Services 2006).

This species has experienced a decline in number in recent years. Several reasons have been proposed such as habitat loss, reduced availability of pools or surrounding suitable food plants, and predation by feral animals.

Star finch

Star finch is a nomadic bird species assigned a priority 4 rating, in need of monitoring. This species is found from the Pilbara to south-eastern Australia. Its known habitat is grasslands and eucalypt woodlands near water. In the Pilbara this species is typically confined to reed beds and adjacent vegetation communities along permanent waterways (Biota Environmental Services 2006).

The main threat to the species is considered to be overgrazing by stock along waterways, which destroys the riparian vegetation on which they depend (Garnett and Crowley 2000)

Australian bustard

Australian bustard has been assigned a priority 4 rating, in need of monitoring.

It occurs over much of Western Australia, preferring an open or lightly wooded grassland including *Triodia* sand plains. This species is not considered to be sensitive to groundwater declines (Outback Ecology Services 2004).

Fortescue grunter

Fortescue grunter is a fish species endemic to the Pilbara, only known to occur in the Fortescue, Ashburton and Robe Rivers (Morgan et al. 2003). Within the Robe River this species can be considered highly dependent on pools and highly sensitive to groundwater decline.

Undescribed species

One specimen of an undescribed fish species was collected in the Robe River (Morgan et al. 2003). The single specimen is thought to be a member of the genus *Neosilurus*, morphologically different from the N*. hyrtlii.*

Rainbow bee-eater

Rainbow bee-eater is a marine and migratory species under the EPBC Act. This species is distributed across better watered parts of Western Australia where it inhabits lightly wooded, sandy country near water. This species has been assessed as being moderately sensitive to groundwater decline due to its habitation of riverine vegetation (Outback Ecology Services 2004).

Great-white egret

Great-white egret is listed as a protected marine species under EPBC Act and a migratory species under CAMBA and JAMBA. It is a wader that mainly inhabits shallow freshwaters, including river pools. This species is considered highly sensitive to groundwater decline (Outback Ecology Services 2004).

Outback Ecology (2004) conducted a desk-based sensitivity assessment of fauna species of the lower De Grey River, taking into account potential impacts of groundwater decline on river pools and riparian vegetation. Each species was assigned to one of three categories as described in Bamford (2003). Eleven bird species that are considered to be highly sensitive to groundwater decline on the De Grey River were also identified on the Robe River (Table 4).

3.3 Riparian ecosystems

Vegetation

The Robe River study area lies within the Fortescue Botanical District of the Eremaean Botanical Province (Beard 1975). The vegetation of this province is typically open, and frequently dominated by spinifex, wattles and occasional Eucalypts.

Within the study area the active floodplain and major river support eucalypt woodlands, shrublands and tussock grasslands with the sandy-surfaces alluvial plains supporting soft (and occasionally hard) spinifex grasslands (Biota Environmental Sciences 2006c).

In 2009 Department of Water conducted a vegetation survey to define the vegetation and flora of the study area. Five main vegetation communities were found to occur within the riparian zone (Figure 14).

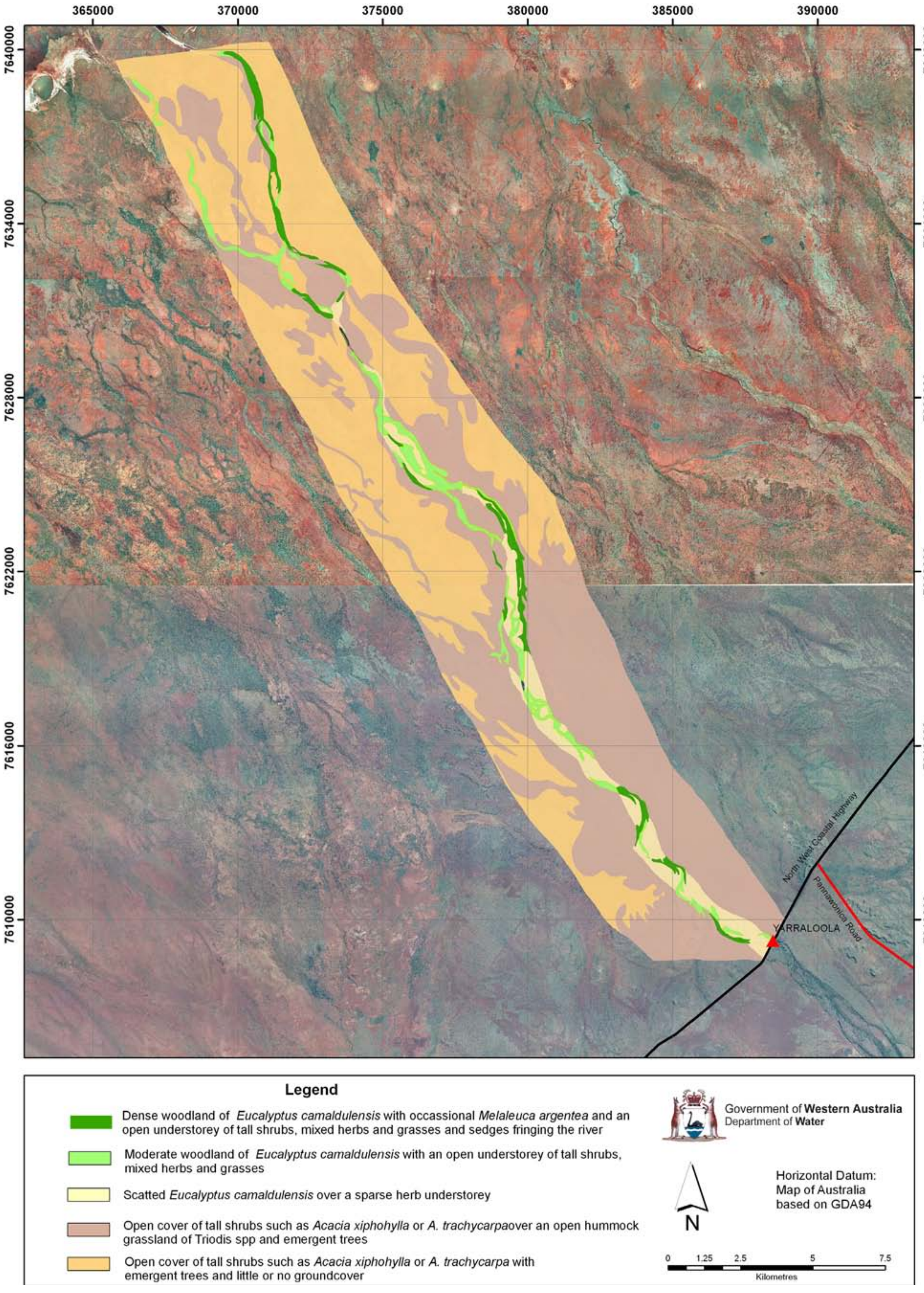

Figure 14 Vegetation map of lower Robe River

Conceptual link to groundwater

A conceptual model of groundwater dependency of riparian vegetation along the Robe River study area has been developed using vegetation mapping, groundwater mapping and analysis of antecedent hydrological conditions (Figure 15).

The distribution of riparian plant communities generally reflects the depth to groundwater and area inundated during flooding. The shallow depth to groundwater in the alluvium and especially along the river, provide areas where deep rooted vegetation can access groundwater. Whilst plants will use surface and soil water when available, during sustained drought, riparian vegetation is reliant on groundwater to meets its water requirements.

During flood events surface water replenishes soil and bank storage and distributes nutrients and carbons throughout the system. Flood events are also important triggers for recruitment and ensure effective seed dispersal and moist sediments to support seed germination. The recharge of groundwater from surface flows results in groundwater mounding under the river channel.

Average depths to groundwater along the course of the lower Robe River are typically in the range of 2.0 to 4.0m. Inter-annual fluctuations are in the order of 2.0m, with maximum declines from average groundwater level being approximately 2.5m (i.e. maximum depth to groundwater approximately 6.5m).

At these shallow depths to groundwater, riparian species such as *Eucalyptus camaldulenis* (Figure 16) is likely to be highly groundwater dependent. As groundwater levels gradually decline the trees ability to adapt depends upon their physiology and adaptations to cope with water stress. For example how quickly their roots will grow, the maximum depths to which they will grow, and/or morphological adaptations that reduce water use.

During sustained drought when soil water becomes unavailable, riparian vegetation is reliant entirely on groundwater to meet its water requirements. During these periods groundwater continues to decline. The duration, frequency and magnitude of droughts (or periods of low groundwater levels) are important factors affecting the vigour of riparian ecosystems.

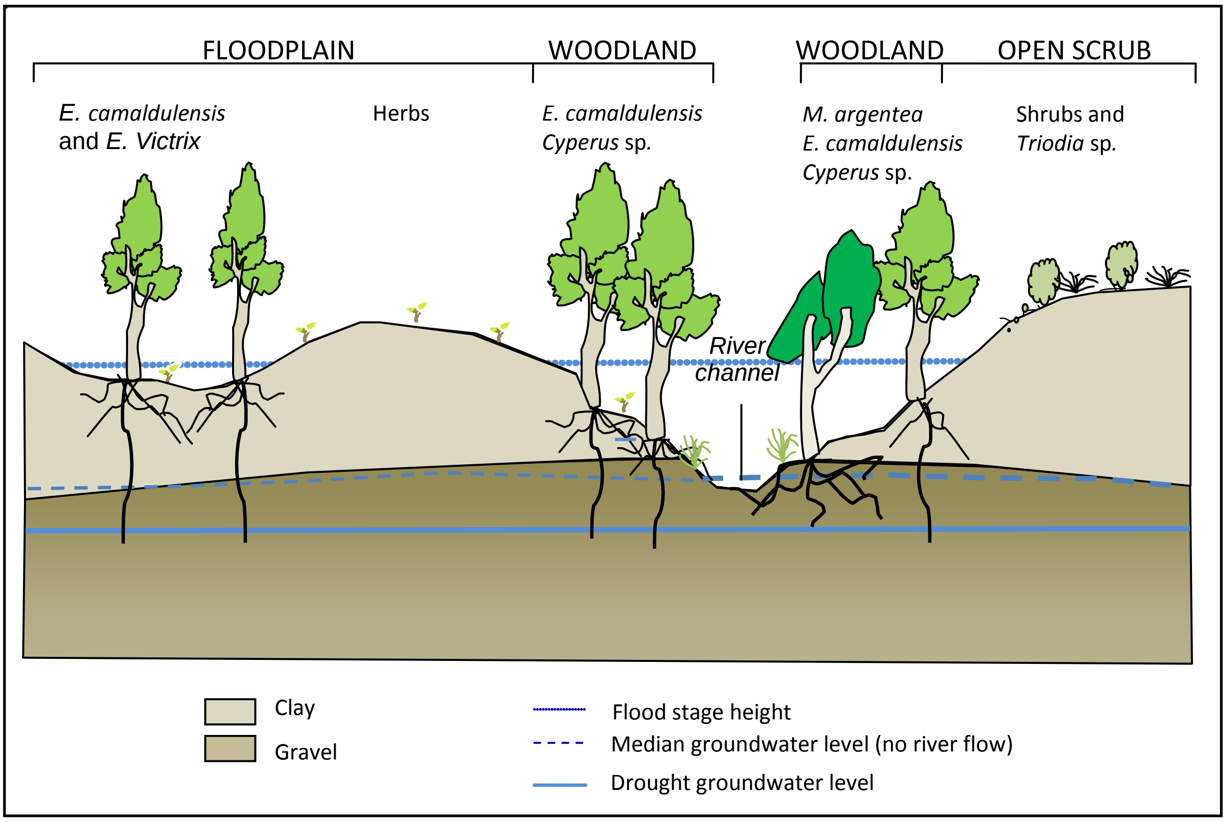

Figure 15 Conceptual groundwater dependence of riparian vegetation of the Robe River

Figure 16 E. camaldulensis on the banks of the Robe River access groundwater during periods of no river flow. Recruitment of these species occurs during flood periods.

Ecology

Groundwater-dependent vegetation

For the purposes of management of the ecological values associated with the Robe River, the Department of Water identifies groundwater-dependent communities based on the riparian vegetation having:

- direct access to groundwater or groundwater derived discharge (i.e. where depth to groundwater is <10 to 15 m the possibility of use by deep rooted vegetation increases), and/or
- presence of vegetation known to draw on groundwater or be groundwater dependent. These include *Melaleuca argentea, Eucalyptus camaldulensis* and *E. victrix* as discussed in following sections.

Melaleuca argentea, *Eucalyptus camaldulensis* and *E. victrix* are tree species common to riparian zones in the Pilbara and often referred to as groundwater dependent. They are the most studied of the Pilbara riparian species in terms of plant water requirements and are useful indicator species.

The degree of dependence varies across species based on their physiology and within species depending on antecedent local conditions.

Eucalyptus camaldulensis and *Melaleuca argentea* are restricted in distribution to riparian wetland areas. During droughts they rely solely on groundwater (Muir Environmental 1995) however they will also draw on surface water and soil water when present (O'Grady et al. 2002).

The shallow planform root system of *M. argentea* is adapted to areas where surface water is present or groundwater is very shallow (maximum 2 to 3 m below ground level (mbgl)). A recently developed database of water level ranges of Pilbara riparian species describes a similar mean water level range for this species between 0.92 and 3.87 mbgl (Loomes 2010).

At these shallow depths to groundwater the species is likely to be highly groundwater dependent and will have difficulty adjusting to short periods of dry conditions or reductions in water availability (Graham 2001, Strategen 2006).

Eucalyptus camaldulensis is also commonly associated with shallow depths to groundwater of 2 to 5 mbgl (Strategen 2006, Loomes 2010), although it has been recorded where groundwater is up to 21 mbgl (Landman 2001). The bimorphic root system (surface lateral roots and a tap root) of this species enables it to use both groundwater and water held in the unsaturated, vadose zone above the watertable.

Although *E. camaldulensis* is reported to be capable of sinking new tap roots in response to groundwater decline, drawdown of >10 m over a prolonged period may cause irreversible stress (Woodward-Clyde 1997).

Eucalyptus victrix tends to be found higher in the landscape than *E. camaldulensis* and *M. argentea* (Muir Environmental 1995). Consequently, it is more tolerant of long periods of drought, is less susceptible to declining groundwater levels and is sensitive to prolonged inundation (Strategen 2006).

It is generally accepted that the shallower the depth to groundwater, the greater is the reliance of vegetation on the watertable as a water source (Hyde 2006, Eamus et al. 2006). In order to determine the degree of groundwater dependence of the communities on the lower Robe River a depth to groundwater map was produced and overlaid with the vegetation mapping (*Figure 17*).

Communities dominated by dense *E. camaldulensis* woodland are restricted to areas where average depth to groundwater is less than 4 m, whilst communities of moderate and scattered *E. camaldulensis* woodland are largely restricted to areas where average depth to groundwater is less than 6 m (although the latter also occurs at depths of 10 m upstream). *M. argentea* was present in *E. camaldulensis* woodlands but only where depth to groundwater was very shallow or adjacent to river pools.

Table 6 summarises these results and includes determinations of groundwater dependence for each of the communities identified based on the presence of known groundwater dependent species and shallow groundwater.

Table 6 Vegetation communities of the Robe River and their groundwater dependence based on local groundwater conditions

Community description	Groundwater dependent vegetation	Average depth to groundwater	Groundwater dependence
Dense woodland of *Eucalyptus camaldulensis* and occasional *Melaleuce argentea* with an open understorey of tall shrubs, mixed herbs and grasses and sedges such as *Cyperus vaginatus* fringing the river	*E. camaldulensis* *M. argentea*	0 to 4 m (annual fluctuations ~2 m)	High
Moderate woodland of *Eucalyptus camaldulensis* with an open understorey of tall shrubs, mixed herbs and grasses	*E. camaldulensis*	0 to 6 m (annual fluctuations ~2 m)	High
Scattered *Eucalyptus camaldulensis* over a sparse herb understorey occurring along the course of the riverbed.	*E. camaldulensis*	2 to 8 m (annual fluctuations ~2 m)	Medium
Open cover of tall shrubs such as *Acacia xiphophylla* or *A. trachycarpa* over an open hummock grassland of Triodia spp. and emergent trees	*E. victrix*	>6 m	Low
Open cover of tall shrubs such as *Acacia xiphophylla* or *A. trachycarpa* with emergent trees and little or no groundcover	*E. victrix*	>6 m	Low

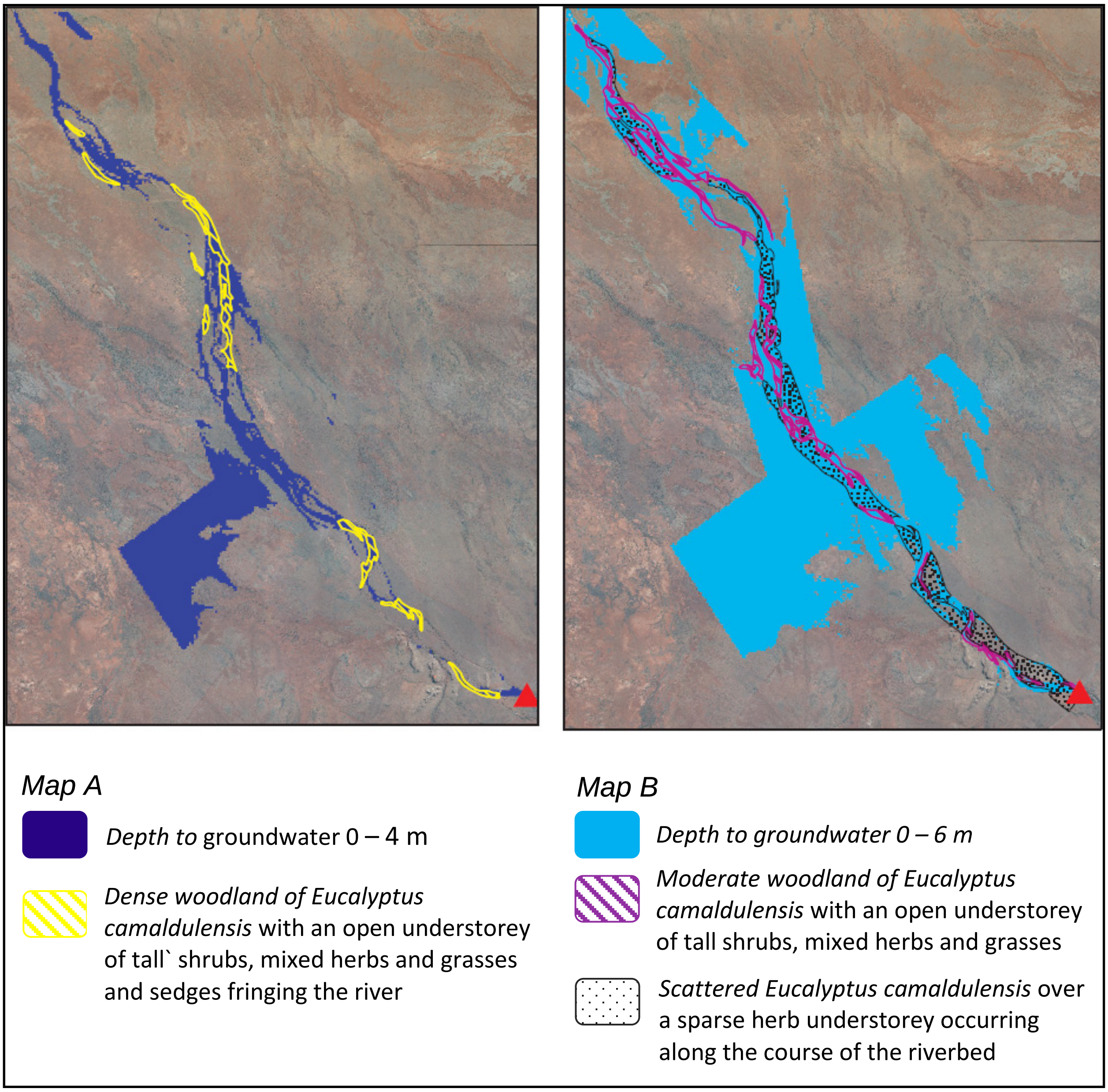

Figure 17 Occurrences of dense, moderate and sparse E. camaldulensis woodlands with associated depth to groundwater

Fauna

Riparian woodlands and forests fringing the Robe River provide habitat for terrestrial fauna, including reptiles, mammals and avifauna. Although most species would not be directly affected by groundwater decline, any loss of habitat may have an indirect impact.

A targeted survey for the Northern quoll (*Dasycerous hallucatus*) has determined that this species may occur within the study area (How and Hamilton 2005). To date no intensive survey has been conducted to identify other species which do inhabit these riparian forests, but it is likely that many of the species recorded at river pools also utilise the riparian woodland habitat.

Conservation significance

Vegetation communities may be of conservation significance because they are uncommon, support unique assemblages, support flora or fauna of special conservation significance or any combination of these three.

At the landscape scale the vegetation communities described for the Robe River are good examples of riparian ecosystems of the region. They are relatively uncommon, only occurring along major drainage lines thereby providing important habitat and connectivity between habitats.

The riparian vegetation also maintains key ecosystem processes by maintaining water quality through biofiltration and bank stabilisation during flooding to reduce erosion and excessive sediment loads. The vegetation also provides shading to river pools and carbon inputs into the system to support aquatic food webs.

A search of the Department of Environment and Conservation's threatened (declared rare) flora database has identified no known priority flora species in the general area. However, the riparian communities support several schedule and priority fauna species (Table 5) including the Northern quoll (discussed below) and a high diversity of local and migratory avifauna (Table 4).

Northern quoll

Northern quoll (*Dasycerous hallucatus*) is a medium sized marsupial, listed as endangered at the federal level. It is known to occur along mesa edges along the Robe River and has been recorded in areas adjacent to the study area (How and Hamilton 2005).

In previous surveys most sightings occurred in dense vegetation in drainage areas, primarily where in contact with rocky mesas.

The Northern quoll is a short lived mammal with discrete male cohorts that arise within populations, making the quolls vulnerable to extinction. Therefore, any factor that results in significant increases in mortality rates of female and juvenile quolls could cause local extinction of quoll populations.

3.4 Aquifer ecosystems

Aquifers in the Pilbara region have been associated with diverse subterranean fauna. These subterranean fauna often represent relicts, descendents from ancient pre-Gondwanan lineages. They tend to be highly specialised, and obligate dwellers of, subterranean groundwater habitats (Humphreys 2000).

True subterranean fauna may be divided into two main categories (Humphreys 2000);

- stygofauna: obligate groundwater dwelling, aquatic fauna

- troglofauna: obligate cave or karst dwelling, terrestrial subterranean fauna occurring above the watertable.

Stygofauna are those fauna that inhabit groundwater, sometimes occurring very close to the surface. Extraction of groundwater has the potential to affect any stygofauna communities which may be present.

The possible affect of development on subterranean fauna has become a major issue for several new developments in Western Australia, as relatively localised impacts such as mining have the potential to significantly change the conservation status of locally endemic species (Eberhard and Humphreys 1999, Biota Environmental Sciences 2001).

Stygofauna sampling was conducted by Biota Environmental Sciences (2006a) for Robe River Iron Associates at Mesa A and Warramboo in 2004. Twenty-eight bores were sampled within the study area, 15 within the alluvial aquifer and a further 13 outside the known extent of the aquifer. Of the 15 alluvial bores 11 yielded stygofauna. A further three of the non-alluvial bores also yielded stygofauna.

Conservation significance

Survey results to date indicate that the lower Robe River contains five distinct genetic groups and several species that are currently only known to occur within this study area (Biota Environmental Sciences 2006b).

The Department of Environment and Conservation has recently completed the Pilbara Biological Survey which includes regional sampling of stygofauna. It is anticipated that more thorough consideration of the significance of stygofaunal assemblages along Robe River in a Pilbara regional context will be possible when the final results of the this survey become available. It is likely that the results will demonstrate that the aquifer contains additional endemic stygofaunal species.

3.5 Summary of ecological values

This study has identified three groundwater-dependent ecosystems in the lower Robe River study area. The components of these ecosystems, their conservation significance and their links to the groundwater of the alluvial aquifer have been described. Their ecological values are summarised in this section using the categories defined by Horwitz and Rogan (2003):

- biotic – key species and/or communities (including rare or threatened biota)
- functional – ecosystem services that maintain habitat for dependent populations or species.
- landscape and waterscape – contributions to landscape connectivity, habitat provision, representativeness and ecosystem resilience to disturbance.

Cultural values will be discussed in a separate report.

Riverine ecosystems

Recent pool mapping has identified five permanent, five semi-permanent and 13 intermittent pools. These pools are of varying size and depth, providing a myriad of habitats.

Biotic values

The lower Robe pools are known or thought to support the following flora and fauna:

- > 100 macroinvertebrate taxa (based on upstream pools)
- 12 fish species
- 25 bird species

Functional values

The pools maintain key ecological processes important to habitat provision including:

- water quality
- nutrient cycling associated with productivity
- decomposition of organic carbon required for food webs.

Landscape and waterscape values

The pools hold a number of broader scale and regional values. These include:

- connectivity – hydrological linking of pools plays an important role in the natural functioning of a major wetland system
- habitat provision – pools act as a drought refuge for native flora and fauna
- representativeness – the wetlands are an unique in the region in terms of their hydrology and scale
- resilience – the health and condition of the wetlands allow them to absorb seasonal changes (including droughts and floods).

Riparian ecosystems

The pools and shallow groundwater adjacent to the lower Robe River support numerous riparian vegetation community types.

Biotic values

Riparian vegetation supports the following fauna:

- birds
- reptiles
- mammals.

Functional values

Riparian vegetation maintains key ecological processes important to habitat provision including:

- maintenance of water quality through biofiltration
- soil and bank stabilisation
- supporting complex food webs.

Landscape values

Riparian vegetation of the lower Robe River supports the following landscape values:

- connectivity – vegetation provides corridors allowing fauna to move between habitats (e.g. pools)
- habitat provision – vegetation provides both direct habitat and refuge habitat during drought
- representativeness – vegetation communities are good examples of riparian ecosystems of the region
- resilience – the health and condition of vegetation allow it to absorb seasonal changes (including droughts and floods).

Aquifers

Biotic values

Aquifers in the Pilbara region have been associated with diverse subterranean fauna and are recognised as being important for the conservation of subterranean biodiversity(Eberhard et al. 2005). The lower Robe River with its interesting and relatively abundant stygofauna population is likely to be considered of high value.

4 Ecological management objectives

4.1 Background and overall objective

Formulating management objectives for a water resource system is an integral component of the allocation planning process. Objectives presented in this report are based solely on ecological values and issues identified during the review of ecological information. These objectives will frame the development of ecological water requirements. In developing an allocation plan, management objectives will also consider social, cultural and economic values.

This review has identified groundwater-dependent ecosystems of three different types associated with the lower Robe River – riverine pools, riparian vegetation and aquifers. Management objectives are required to ensure these values are maintained and considered in future water resource planning.

The overall objective to guide the determination of ecological water requirements for the lower Robe River has been developed with the variable climate and the role of the river and groundwater system as a refuge in mind.

This overall objective is to:

> maintain the extent and condition of groundwater-dependent ecosystems in the context of a naturally variable climate.

In order to make sure this objective is met, the ecological water requirements will need to include practical objectives and parameters against which water requirements will be set and then measured. The objectives have been developed based on the conceptual links between hydrology and ecology summarised in this report as conceptual models. The objectives have focused on the parts of the hydrological regime we have identified as most important to maintain ecosystem function and values.

Due to a lack of knowledge on the habitat requirements of stygofauna they will not be included in the determination of ecological water requirements for the lower Robe River. It is anticipated that the water requirements determined for other dependent ecosystems will, by maintaining aquifer levels within the range of tolerance of riparian vegetation and pools, also maintain adequate habitat for stygofauna within the aquifer.

The objectives and assessment parameters have focused on the parts of the hydrological regime that can be managed through water resource management and in particular through the management of groundwater abstraction. Consequently objectives to maintain high flow events have not been developed even though they are important to Pilbara river systems in a number of ways including:

- recharging groundwater
- triggering recruitment of riparian vegetation and movement of aquatic fauna

- redistributing carbon and nutrients within and around river and floodplain systems
- geomorphological processes in river channels.

4.2 Objectives for riverine and riparian ecosystems

Riverine ecosystems

The riverine ecosystems have been demonstrated to support a diverse aquatic biota with specific habitat requirements. River pools are also considered important in terms of supporting avifauna and other terrestrial fauna that is associated with this habitat. The role of permanent pools as a refuge for aquatic and terrestrial biota particularly during drought periods is considered particularly important in terms of maintaining ecosystem processes and systems.

Groundwater contributions to the river pools are considered to be most critical during drought periods when surface water inputs are negligible.

To maintain the extent and diversity of river pool habitats the following objectives need to be met within the context of a dynamic climate.

1 *Maintain areas of permanent pools consistent with regional seasonality to maintain pool stability and pool refuges for fish and other fauna.*

    Parameters:

    a. minimum aquifer level in the vicinity of river pools to maintain discharge/surface expression of groundwater

2 *Sufficient areas of inundated shallow macrophyte habitat available for macroinvertebrates, small-bodied fish and juveniles of large-bodied fish*

    Parameters:

    a. minimum pool depth and area to provide macrophyte habitat

    b. minimum aquifer level to ensure sufficient contribution to pools

3 *Sufficient deeper habitat permanently inundated and available for mature and large-bodied fish.*

    Parameters

    a. minimum pool depth and area to provide deep pool habitat

    b. minimum aquifer level to ensure sufficient contribution to pools

4 *Sufficient depth in deeper pools to ensure dissolved oxygen levels do not reduce to anoxia.*

Riparian vegetation

Riparian vegetation provides habitat and habitat corridors for avifauna and other terrestrial fauna. It is also important in maintaining waterway condition and functionality. Riparian vegetation also contains species and represents a habitat type that is typically restricted in distribution across the region.

Based on the conceptual model discussed previously the water requirements of the riparian vegetation are met at least in part by access to groundwater through maintenance of local watertables or soil moisture. During drought periods groundwater contributions to maintenance of vegetation is critical as it is likely to be the only source of water available. Access to groundwater is likely to be maintained for deep rooted vegetation so long as the depth to groundwater does not exceed maximum rooting depths of the vegetation and that groundwater levels decline at rates that roots can follow.

To maintain the extent and diversity of riparian habitats the following objective needs to be met within the context of a dynamic climate/consistent with regional seasonality.

5 *Sufficient water provided for phreatophytic vegetation by maintenance of accessible watertable levels during periods of no surface water inputs*

Parameters

a. minimum depth to water table in areas of phreatophytic riparian vegetation
b. rate of change in groundwater levels
c. frequency and duration of periods of 'low' groundwater levels

4.3 Ecological water requirements

The ecological management objectives described here, as well as the social and cultural values to be addressed in the future, will inform the development of ecological water requirements for the lower Robe River. In this process they will be used to frame estimates of water requirements specifically related to those that may be affected by groundwater abstraction. In addition, they will provide the basis for a future ecological monitoring program.

Shortened forms

CAMBA	China–Australia Migratory Birds Agreement
GIS	Geographic information system
JAMBA	Japan–Australia Migratory Birds Agreement
LiDAR	Light detection and ranging
mbgl	metres below ground level

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