Pit Dewatering and Vegetation Monitoring Plan

Iron Ore Mine and Downstream Processing, Cape Preston, Western Australia

Mineralogy Pty Ltd

September 2006

MAUNSELL | AECOM

MINERALOGY PTY LTD

A.B.N. 65 010 582 680

Pit Dewatering and Vegetation Monitoring Plan

Prepared for

Mineralogy Pty Ltd

Prepared by

Maunsell Australia Pty Ltd
Level 1, 629 Newcastle Street, PO Box 81, Leederville 6902, Western Australia
T +61 8 9281 6100 F +61 8 9281 6295 www.maunsell.com
ABN 20 093 846 925

September 2006

74500300.02

Quality Information

Document	Pit Dewatering and Vegetation Monitoring Plan
Ref	74500300.02
Date	September 2006
Prepared by	Kellie Honczar/Johanna Thompson
Reviewed by	Paul Holmes

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
F	12/09/2006	Final	Paul Holmes Manager Environment	

Table of Contents

Tables

Figures

1.0 Introduction

1.1 Background

Mineralogy Pty Ltd (the proponent), proposes the development of an iron ore mine and downstream processing facilities at Cape Preston, 80km south west of Karratha.

In response to project environmental impact assessment requirements as determined by the Environmental Protection Authority (EPA), a Public Environmental Review (PER) was submitted to the Authority in December 2000 (HGM, 2000). The PER was supplemented with a Supplementary Environmental Review (SER) in February 2002 to address changes to the project design being sought by the proponent (HGM, 2002). Under the proposal assessed by the EPA pursuant to the PER and SER, and a subsequent successful application for a non-substantial change to the assessed project pursuant to Section 45(c) of the *Environmental Protection Act 1986,* the project would entail an annual mining rate of approximately 67.4 Mt and annual production of the following:

- Concentrate – approximately 19.6 Mt;
- Pellets – approximately 13.8 Mt; and
- Direct reduced/hot briquetted iron – approximately 4.7 Mt.

Through the Section 45 (C) process seeking Ministerial approval for a non-substantial change to the assessed project, it was made clear that the stockpiling and export of concentrate was intended and in this regard, it should be noted that the Minister's approval of the proposed change was unconditional.

The Ministerial Statement for the project was issued in October 2003, subject to a number of Conditions and the Proponent's Commitments. One of these Commitments was for the preparation of a Pit Dewatering and Vegetation Monitoring Plan for operational (mining and pit dewatering) phase of the project.

1.2 Relevant Legislation & Guidelines

State Government Legislation	Application
Environmental Protection Act 1986	PER Assessment and Ministerial Approval Process
Iron Ore Processing (Mineralogy Pty Ltd) Agreement Act, 2002	Act under which the project is developed
Mining Act 1978 and Regulations 1981	Regulation of mining operations
Mine Safety and Inspection Act 1994 and Regulations 1995	Protection of mine personnel
Rights in Water and Irrigation Act 1914	Regulation of draw on groundwater

1.3 Purpose of this Document

The purpose of this document is to satisfy the conditions set down by the Minister for the Environment in Condition 6 of Ministerial Statement No. 000635 (Minister for the Environment, 2003). Ministerial Condition 6 requires that:

Prior to the commencement of pit dewatering, the proponent shall prepare a Pit Dewatering and Vegetation Monitoring Plan for the pit and its surrounding groundwater depletion zone, to the requirements of the Minister for the Environment on advice of the Environmental Protection Authority.

The objective of this plan is to allow deep-rooted vegetation, by extending their root systems, the maximum opportunity to adjust to dropping water regime by dewatering the pit as slowly as possible, commensurate with the requirements of mining.

This plan shall include monitoring of representative stands of creekline vegetation and other areas of conservation significance within the zone of groundwater depletion, to determine the extent of effects of groundwater drawdown on this vegetation.

1.4 Objectives of this Document

This Pit Dewatering and Vegetation Monitoring Plan (PDVMP) is to be read in conjunction with the project Environmental Management System and Construction Environmental Management Plan. The objectives of the PDVMP are:

- identify the groundwater drawdown zone ("cone of depression") that will result from pit dewatering activities;
- identify groundwater dependent ecosystems (GDEs) which fall within this zone; and
- define a programme for monitoring the effects of groundwater drawdown on GDEs identified.

1.5 Responsibilities & Reporting

Overall responsibility for ensuring that site environmental monitoring requirements are met will rest with the Proponent's Environmental Manager. In respect of this Pit Dewatering and Vegetation Monitoring Plan, this responsibility will include:

- ensuring that all mine personnel, both the proponent's workforce and contract personnel, conform with requirements pursuant to the Management Plan;
- ensuring that contract personnel are fully inducted and aware of their environmental responsibilities and contractual obligations; and
- ensuring that monitoring requirements are met.

Contractors undertaking site works will be required to appoint an environmental representative. The key responsibilities of the representative will be to:

- maintain routine contact with the proponent's Environmental Manager to ensure that environmental objectives of this plan are met;
- provide monthly reports to the Proponent's Environmental Manager on environmental issues and conduct regular audits; and
- ensure that all management aims and monitoring requirements of this Pit Dewatering & Vegetation Monitoring Plan are met.

1.6 Consultation

Pursuant to Environmental Impact Assessment requirements under the *Environmental Protection Act (1986)*, Comprehensive consultation with stakeholders and members of the community has been undertaken. The outcomes of these negotiations were used to develop the commitments provided by Mineralogy and presented in the Public and Supplementary Environmental Review documents (HGM 2000, 2002) and, ultimately, in the development of this environmental management plan.

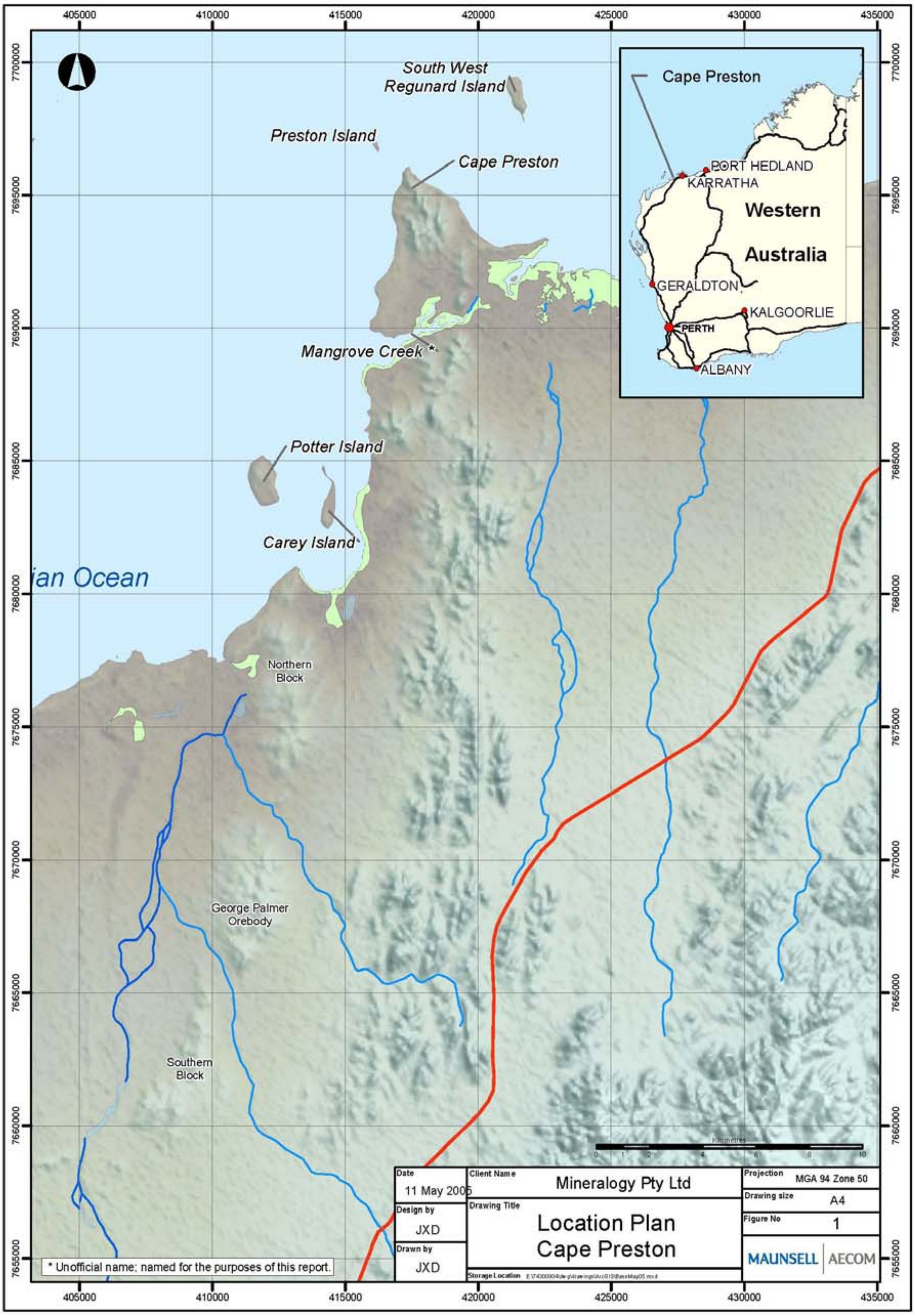
2.0 Project Description

2.1 Project Outline

The proponent plans to mine the George Palmer Orebody, which is located approximately 80km south west of Karratha and 25 km south of Cape Preston in the Pilbara region of Western Australia. A stockyard and laydown area will be constructed at Cape Preston. Preston Island is the intended location for the port facilities. Figure 1 depicts the location of the site in a regional context. The major components of the project are:

- open pit mine;
- desalination plant;
- HBI (Hot Briquetted Iron) plant;
- DRI (Direct Reduced Iron) plant;
- pellet plant;
- concentrator plant;
- tailings dam;
- waste dumps;
- system of conveyors and a service road to Cape Preston;
- product stockpile (HBI, DRI, pellets, concentrate) and adjacent general laydown areas at Cape Preston;
- causeway to Preston Island;
- jetty to the load out / port facilities;
- port facilities; and
- accommodation for employees and construction staff.

Figure 2.1 - Regional Setting



2.2 Existing Environment

2.2.1 Climate

The climate of the Pilbara is classified as arid tropical with two distinct seasons: a hot summer extending from October to April and a mild winter from May to September. High evaporation rates are largely responsible for the arid climate with rates of evaporation often exceeding mean annual rainfall figures.

Rainfall in the Pilbara region is spatially and temporally variable, largely due to the random nature of tropical cyclones passing through the region and, to a lesser extent, localised thunderstorms. The majority of rainfall occurs between December and March as a result of tropical cyclones originating from the north. A lesser proportion of rainfall occurs between May and June from cold fronts moving across the south of the state in an easterly direction, which occasionally extend into the Pilbara. Droughts, or long periods of low rainfall are common in the Pilbara and may be localised in one area. Rainfall occurrence, wind strength and wind direction have direct impacts on dust issues and hence, have been canvassed within this section.

Meteorological data sourced from the recording station located at Mardie Homestead (Met. Stn 005008), situated approximately 20km south of the George Palmer Ore Body, is summarised in Figure 2.1.

Rainfall records have been collected at Mardie Homestead for 115 years, and temperature for the past 46. Mean annual rainfall is 271.2mm from an average of 22 rain days, with the majority of rainfall experienced between January and June. Large temperature ranges typical of the Pilbara region occur at Mardie where mean monthly temperatures range from 27.7°C in July to 38.1°C in March (mean 33.9°C), whilst mean monthly minimum temperatures range from 11.7°C in July to 25.2°C in February (BOM 2005). Records indicate temperature ranges from a record July low of 2.9°C to a February high 50.5°C.

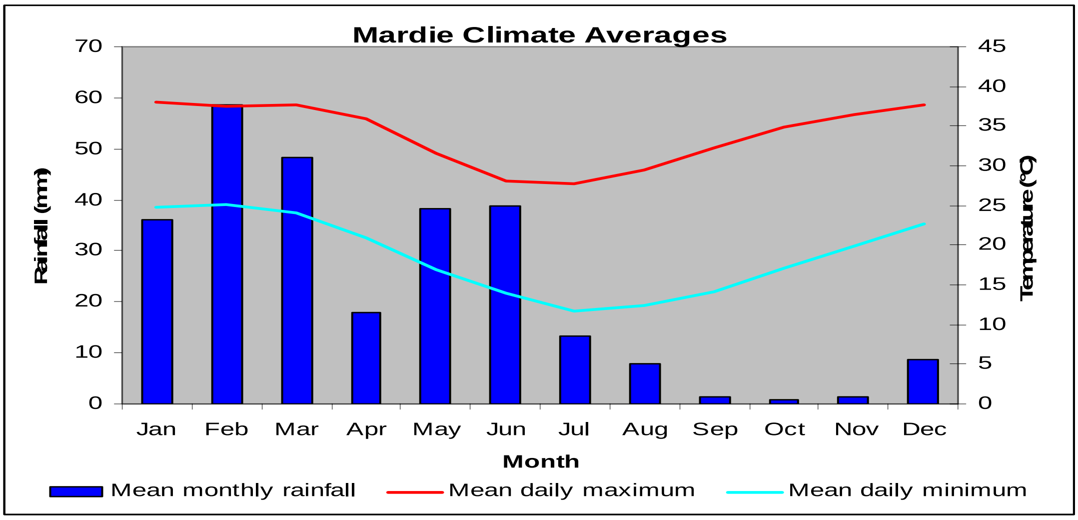


Figure 2.2 - Mean monthly rainfall and temperatures for Mardie Homestead (Station No. 005008)

(Bureau of Meteorology 2005).

2.2.2 Geology & Soils

Figure 2.2 shows surface geology within the Project Area. The eastern part of the area is characterised by 2 series of north-northeasterly trending ridges of outcropping Lower Proterozoic aged rocks of the Mount Bruce Supergroup, which form part of the Hamersley Basin (Aquaterra, 2000), the Kylena and Maddina Volcanics form The highest eastern series of ridges. The western series of ridges are made up of banded iron formation (BIF), cherts, shales and breccias of the Brockman Iron Formation, and to a lesser extent the underlying Mount MaCrae Shale-Mount Sylvia Formation. Three main orebodies have been identified within the Project Area; the Central, Northern and Southern Blocks, which are described as high-grade magnetite which have developed within the Joffre Member of Brockman Iron Formation. A thin veneer of Quaternary aged alluvial, colluvium and residual soils overlies the basement rocks in low lying area, with some creek bed alluvium along drainage courses (Aquaterra, 2000).

The western part of the Project Area lies on part of the Fortescue River floodplain. This area is underlain by a sequence of sediments. The lower most unit is the Cretaceous aged Yarraloola Conglomerate, which is comprised of rounded gravels and minor sands and clays.

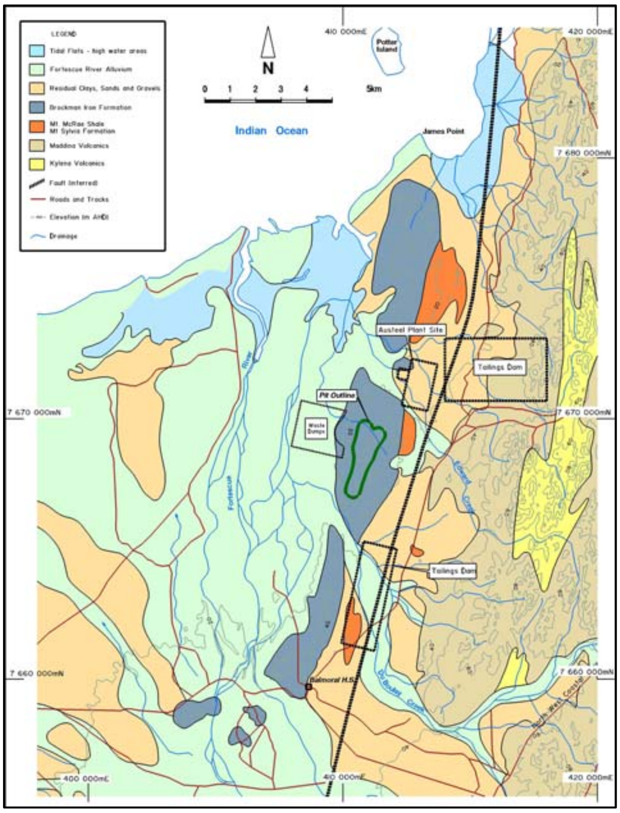


Figure 2.3 - Surface Geology of the Cape Preston project area.

This unit forms part of the Carnarvon Basin and unconformably overlies units of the Mount Bruce Supergroup that are younger than the Brockman Iron Formation, and occupies buried channels incised into Precambrian rocks. The Yarraloola Conglomerate is unconformably overlain by the Tertiary aged Trealla Limestone, which comprises clays, maris and crystalline limestone. This is unconformably overlain by the Fortescue River Alluvium, which is comprised of gravel bed-load deposits; silty clay, sand and gravel overbank deposits; colluvial deposits; and calcrete within the zone of water table fluctuation. The Trealla limestone forms a confining bed between the Yarraloola Conglomerate and the Alluvium (Commander, 1993; Aquaterra, 2000).

2.2.3 Soils

Soils of the Pilbara region are described at a scale of 1:2,000,000 (Bettenay et. al., 1967). Mapping units are associations of soils generally delineated by landscapes. Although this scale is too broad to provide a detailed description of the soils across the site, it is useful in describing the predominant soils present. In general terms, the project area comprises:

- Gf 1 – friable loamy soils; brown, shallow and porous loamy soils;
- Sv 8 – loamy soils of minimal development; calcareous and silicious loamy soils; and
- Oc 72 – hard setting loamy soils with red clayey subsoils; sporadically bleached A_2 horizon; pedal subsoils.

2.2.4 Hydrogeology

A summary of the hydrogeological properties of various geological units, discussed in Section 2.2.2, is shown in Table 2.1. Regional groundwater flow is generally from the south-east to the north-west towards the ocean, while local flows are generally influenced by topography, and recharge and discharge zones (Aquaterra, 2000). Depth to water table varies seasonally between 4 to 12 m over the Project Area (Commander, 1993; Aquaterra, 2000).

The major aquifer within the Project Area is the Fortescue River Alluvium and to a lesser extent the Yarraloola Conglomerate (Aquaterra, 2000).

AGE	UNIT	CHARACTERISTICS
Quaternary	Fortescue River Alluvium	Gravels form aquifer with high permeability. Aquifer covers extensive area beneath floodplain. Groundwater is fresh (<1000 mg/L TDS) in most of floodplain area. Groundwater is marginal to brackish (1000 to 2000 mg/L TDS) on edge of floodplain, where mixing with basement rock throughflow occurs. Groundwater is brackish to saline (>5000 mg/L TDS) at depth near "salt water wedge" near coast.
	Eluvium-Residual Soils	Mostly above the water table. Forms local aquifer where saturated, connected to alluvium.
Tertiary	Trealla Limestone	Forms a confining layer (acts as an aquitard) to Yarraloola Conglomerate. Forms base of overlying alluvial aquifer.
Cretaceous	Yarraloola Conglomerate	Confined aquifer with moderate to low permeability. Forms narrow channel aquifer in old river course. Groundwater reported as fresh in 3 bores.
Proterozoic	Weeli Wolli Formation Brockman Iron Formation Mt McRae-Mt Sylvia Formation Maddina Volcanics	Indurated rocks with no primary porosity of permeability. Some minor fracture induced secondary aquifer properties. Not aquifers in Project Area. Groundwater is marginal to brackish (1000 to 2000 mg/L) in Project Area.

Table 2.1 - Hydrogeological Properties of Geological Units within the Cape Preston Area (after Aquaterra, 2000)

The Fortescue River Alluvium is up to 30 m thick and forms a 5 to 15 m thick shallow aquifer in the area (Commander, 1993). Fortescue River alluvium aquifer permeabilities are reported to be in excess of 50 m/day and bore yields up to 900 kL/day, while Yarraloola Conglomerate aquifer permeabilities are reported to be less than 2 m/day (Aquaterra, 2000). Mineral exploration drill holes in the Central and Northern Blocks have indicated very slow groundwater level recovery rates, which indicates low bulk aquifer permeability (Aquaterra, 2000).

Surface water to groundwater interaction in the Pilbara region is significant. This recharge is thought to be the most significant on the coastal plain where there is significant recharge from rivers to alluvial groundwater systems, during streamflow events. For coastal alluvial aquifers a range (based on streamflow frequency, volume and duration) of 150 000 to 1 350 000 m^3/year/km (length of river) has been estimated (Wright, 1997).

Primary recharge of the Fortescue River Alluvium within the Project Area occurs via infiltration of streamflow. Minor recharge occurs via direct rainfall and some throughflow from flanking Proterozoic aquifers. Aquifer discharge occurs via baseflow to the Fortescue River during times when water table levels exceed riverbed and river water levels (Skidmore, 1996). Additional discharge occurs via evapotranspiration from vegetation on the floodplain and direct evaporation from nearshore tidal flats where fresh groundwaters flow to the surface above a saline (denser) interface (Aquaterra, 2000). Recharge per year for the Fortescue River Alluvium has been estimated at 16 x 10^6 m^3/year (Wright, 1997). Groundwater throughflow is estimated to be up to 9.2 GL/yr (Commander, 1993). Fortescue River Alluvium aquifer (and other coastal alluvial aquifers) properties are presented in Table 2.2.

Proterozoic basement rock aquifers within the Project Area are recharged by the infiltration of rainfall and local runoff in areas of outcrop and via leakage from overlying residual soils and sediments in areas of subcrop. Aquifer discharge occurs via baseflow to local drainage and by throughflow to Fortescue River Alluvium and coastal sediments (Skidmore, 1996; Aquaterra, 2000). Volume of water recharged annually is variable and will dependent on the frequency, flow volume and duration of surface water flows and aquifer permeability (Skidmore, 1996).

River	**Saturated Thickness** (m)	**Approximate Area** (x 10^6 m^2)	**Approximate Storage** (x 10^6 m^3)	**Recharge** (x 10^6 m^3/ yr)	**Approximate Bore Yield** ($m^{3/}$day)
Ashburton River	12	151 (2527)	272 (1050)	15	500 to 1000
Cane River	10	215 (1798)	108 (697)	4	< 500
Warramboo Creek	5	31 (761)	8 (190)	1	< 50
Robe River	12	132 (494)	240 (442)	15	1000 to 1500
Peter Creek	6	200 (2539)	60 (762)	5	< 100
Fortescue River	19	190 (461)	357 (514)	16	500 to 1000
Pewah-Harding River	4	(720)	(230)	7	< 500
Yule River	17	361 (929)	1008 (1282)	14	1000 to 2000
Turner River	12	182 (488)	232 (380)	3	500 to 1000
Tabba Tabba Creek	4	79 (457)	16 (92)	1	< 100
Shaw River	15	1140 (2148)	1926 (2295)	12	< 1000
DeGrey River	30	1030 (3259)	2084 (4547)	13	1000 to 2000

Note: Salinity < mg/L TDS

Brackets denote total irrespective of salinity.

Table 2.2 - A Summary of Groundwater Resources of the Coastal Alluvial Aquifer (after Wright 1997)

Groundwater quality is fresh, close to areas of groundwater recharge. Salinity generally increases with increasing distance from areas of recharge; in areas of low permeability; increasing depth below natural surface; by evapotranspiration; and/or dissolution of salts stored in geological strata. Concentration of salts may also occur in discharge areas by evaporation (Skidmore, 1996).

Groundwater salinities will vary seasonally and will increase slowly during dry periods due to evapotranspiration and decrease following influx of freshwater during recharge events. Measured groundwater salinities within the Fortescue River Catchment generally range 90 to 35 000 mg/L TDS (Skidmore, 1996).

2.2.5 Surface Hydrology

Pilbara Region

There are five drainage basins in the Pilbara Region: the Ashburton River Basin, Onslow Coast Basin, Fortescue River Basin, Port Hedland Coast Basin and the De Grey River Basin. The major rivers are the De Grey, Yule, Shaw and Turner in the north and the Ashburton, Fortescue and Robe in the south.

These rivers drain the uplands of the Ophthalmia, Chichester, Hamersley and associated ranges (Ruprecht, 1996).

Streamflow in the Pilbara region is highly seasonal and variable with flows occurring as a direct response to rainfall. Streamflow is typically highest in February followed by March and January and follows cyclonic rainfall events. Winter streamflow may occur for rivers in the southern and western Pilbara, however for the northern rivers streamflow is generally dominated by summer rainfall (Ruprecht & Ivanescu, 2000). Figures 2.3 and 2.4 present stream gauge data and nearby rain gauge data for Bilanoo Pool (located within the Fortescue River Basin) and illustrates a relationship between rainfall and streamflow in the Pilbara.

For most of the year the riverbeds are dry, with the exception of numerous chains of large pools along the main river channels. Such pools last for considerable periods of time and are spring fed by groundwater aquifers. Following heavy rains the rivers flood, often overflowing and inundating the coastal plain. Pilbara Rivers are characterised by broad alluvial sands or zones of unconsolidated rock saturated with groundwater (Ruprecht, 1996).

Project Area

The Project Area is situated adjacent to lower Fortescue River, which has an effective catchment area of 20,000 km^2. The total Fortescue River Basin has a catchment area of approximately 50,000 km^2, however the upper portion of the basin only drains to the Fortescue Marsh Area (350 km from the coast), and does not contribute to the lower Fortescue River (Wright, 1997; Water & Rivers Commission, 2000). The Edward and Du Boulay creeks flow in a north-westerly direction through the Project Area and discharge into the Fortescue River, and have catchment areas of approximately 30 km^2 and 210 km^2 respectively (Aquaterra, 2000).

The Fortescue River has flowed 22 times in a 25 year period 1968 to 1992 and has a mean annual flow volume of 95 x 10^6 m^3 (Skidmore, 1996).

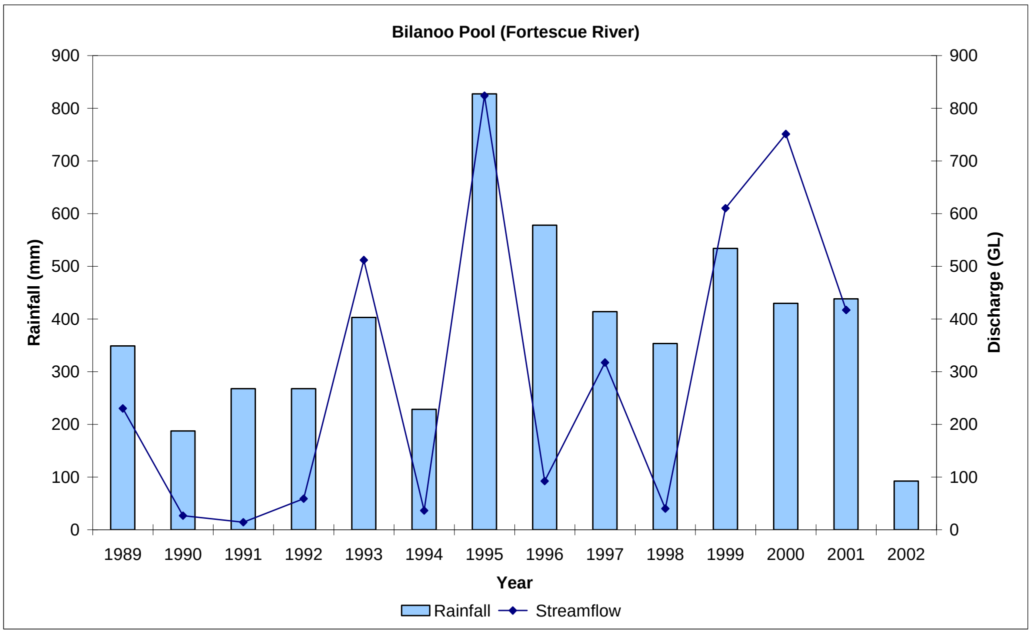


Figure 2.4 - Total Annual Rainfall versus Total Annual Streamflow (1989 – 2002) for Bilanoo Pool (Fortescue River) (Data Source: Department of Environment, 2004)

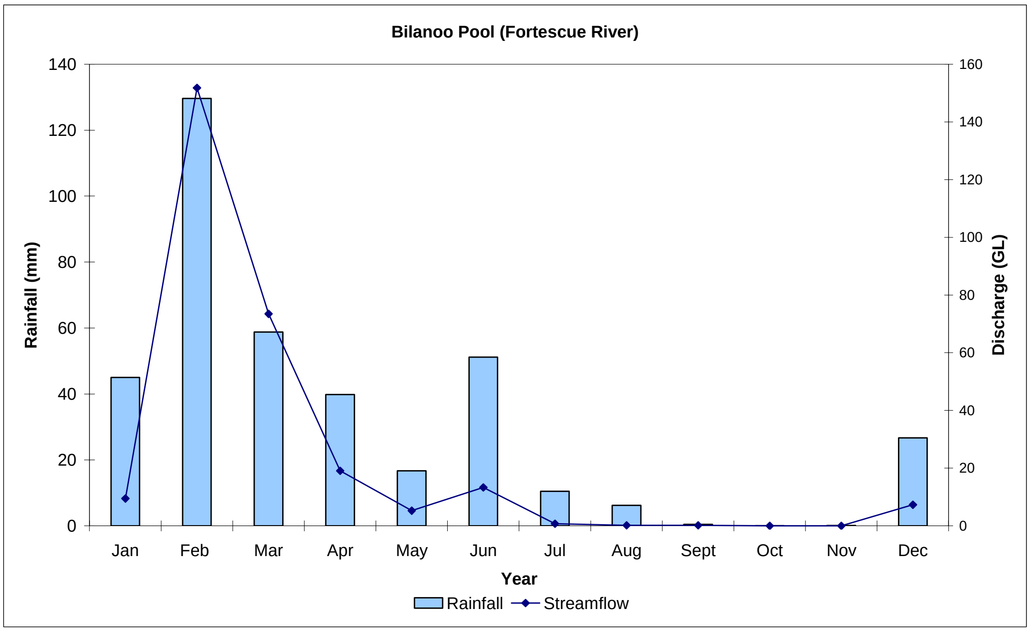


Figure 2.5 - Mean monthly rainfall versus mean monthly streamflow (1989 – 2002) for Bilanoo Pool (Fortescue River) (Data Source: Department of Environment, 2004)

2.2.6 Land Systems

Land System data was obtained and used as a basis for description of vegetation communities in the initial biological survey of the project area (Halpern Glick Maunsell, 2001). The Project Area includes the following 9 Land Systems:

Littoral bare coastal mudflats flanked by mangroves and samphire flats; minor sandy islands, narrow sandy plains, coastal dunes and beaches;

Horseflats extensive gilgaied clay plains with tussock grasslands;

Newman rugged jaspilite plateaux and ridges with hard spinifex grasslands;

Rocklea rugged basalt hills and plateau remnants with hard spinifex grasslands;

Paraburdoo stony plains derived from basalt, supporting snakewood shrublands and spinifex grasslands;

Macroy stony plains with hard and soft spinifex hummock grasslands;

Boolgeeda stony lower slopes and plains found below hill systems, supporting hard spinifex grasslands;

River active floodplains and terraces flanking major rivers and creeks, supporting riverine woodlands and tussock and hummock grasslands; and

Yamerina floodplains and deltaic deposits supporting tussock grasslands with chenopod low shrubs and soft spinifex grasses.

2.2.7 Vegetation Mapping

In anticipation of future impacts, based on proposed mining and associated dewatering activities, a baseline biological survey of the Cape Preston Project Area was undertaken in 2001 (Halpern Glick Maunsell, 2001). The survey described and documented vegetation associations and fauna habitats, compiled an inventory of flora and fauna species from the area and identified threatened or otherwise significant species. The survey covered terrestrial flora and vegetation, with a specific emphasis on Mangrove Communities and vertebrate fauna.

Sixty-four Terrestrial Vegetation Units (communities) were described from the 9 Land Systems during the 2000 biological survey (Halpern Glick Maunsell, 2001). The most widespread Land Systems were the Rocklea, Newman, Paraburdoo and Horseflats systems with 14, 13, 10 and 5 vegetation units described for these respectively. Given the diversity of vegetation units described and the relatively good condition of vegetation, the area was considered to have conservation value.

For the reasons indicated, the following vegetation units are considered to be particularly important:

- Coastal dune vegetation
  - small representation in area; high species richness of one vegetation unit; susceptibility to erosion and weed invasion following physical disturbance.
- Riverine vegetation
  - high species richness; habitat specific flora, including Priority species; susceptible to weed invasion.
- Rockpile vegetation
  - very limited representation in area; variable composition; habitat restricted flora.
- Minor creeklines
  - small representation in area; relatively species rich; habitat specific flora, including Priority species; susceptible to weed invasion.

The implications of pit dewatering operations are greatest for the riparian or groundwater dependent vegetation units, such as the Riverine and Creekline units.

2.2.8 Riparian Ecosystems

The riparian vegetation most sensitive to change in hydrological regime and therefore of greatest importance to this study are obligate phreatophytes. Phreatophytes are species that rely on groundwater sources for water uptake (Busch *et al.*, 1992; Halpern Glick Maunsell 1999). Phreatophytic vegetation often shows low tolerance to extended water stress due to a lack of physiological and/or morphological adaptation to drought (Smith *et al.*, 1998; Graham, 2001). Phreatophytes respond to significant and/or rapid groundwater drawdown by a decline in health and eventual death (Halpern Glick Maunsell, 1999; BHP, 1997).

Table 2.3 lists the vegetation communities within the Project Area which support phreatophytic species. These communities are regarded as the GDEs present within the Survey Area.

<table>
<tr><th>Land System</th><th>Vegetation Community</th><th>Phreatophytic species present</th><th>Common Name</th></tr>
<tr><td rowspan="4">Paraburdoo</td><td>Pc1</td><td>Eucalyptus camaldulensis, Eucalyptus victrix</td><td>River Red Gum, Coolibah</td></tr>
<tr><td>Pc2</td><td>Eucalyptus victrix</td><td>Coolibah</td></tr>
<tr><td>Pc3</td><td>Eucalyptus victrix</td><td>Coolibah</td></tr>
<tr><td>Pc4</td><td>Eucalyptus victrix</td><td>Coolibah</td></tr>
<tr><td rowspan="5">Riverland</td><td>Rc1</td><td>Eucalyptus camaldulensis, Eucalyptus victrix</td><td>River Red Gum, Coolibah</td></tr>
<tr><td>Rc2</td><td>Eucalyptus camaldulensis, Melaleuca argentea</td><td>River Red Gum, Cajeput</td></tr>
<tr><td>Rc3</td><td>Eucalyptus camaldulensis</td><td>River Red Gum</td></tr>
<tr><td>Rc4</td><td>Eucalyptus camaldulensis, Eucalyptus victrix</td><td>River Red Gum, Coolibah</td></tr>
<tr><td>Rf1</td><td>Eucalyptus victrix</td><td>Coolibah</td></tr>
</table>

Table 2.3 - Locations of Phreatophytic species within vegetation communities identified within the Austeel survey area

The three phreatophytic species that occur within the Project Area, (*E. camaldulensis*, *M. argentea* and *E. victrix*) have been demonstrated / reported to source water from the phreatic zone (Halpern Glick Maunsell, 1999; Thorburn *et al.,* 1992; BHP, 1997; Weston & Trudgen, 1995; Landman, 1994; Mensforth *et al.*, 1994; Muir Environmental, 1995). These are considered key indicator species for groundwater dependent ecosystems within the Project Area. These species are also the dominant over-storey species of the riparian zone within the Project Area and are therefore of ecological significance on a local scale. A brief summary of hydrological tolerances of these species is provided below.

2.2.9 *Melaleuca argentea*

This species is restricted to creeklines and is referred to as an obligate phreatophyte (BHP, 1997; Halpern Glick Maunsell, 1999). BHP (1997) suggests that the species is an indicator of shallow water tables, unlikely to occur where depth to groundwater exceeds 2 to 3m.

Dames & Moore (1984) have reported increased stress and/or deaths of this species attributable to drought and increased depth to groundwater. Dames & Moore (1984) report that a decline in groundwater levels for an extended period below 2 m from the natural surface may lead to the death of *Melaleuca argentea.* BHP (1997) also provides an indication of tolerance to changes in groundwater level for *M. argentea,* suggesting that a decline in water level of 0.5 m may result in decreased vigour and that a decline of 1m may result in death.

Studies by Graham (2001) using stable isotope and sap flow techniques indicate that *M. argentea* is predominantly shallow rooted. That is, the majority of its root system (75%) comprises surface lateral roots. This species is characteristically known as a “water spender” and evades drought conditions by ensuring access to perennial water supplies (Graham, 2001).

Given the conditions prevalent within the Project Area (eg. surface/creek water available only at limited locations) it has been assumed for the purposes of the current study that *M. argentea* depends on groundwater during the dry season and times of drought.

2.2.10 *Eucalyptus camaldulensis*

E. camaldulensis is typically described as a vadophyte and/or a facultative phreatophyte and during phases of its life and/or periods of drought, it is reported to be dependent on groundwater (Halpern Glick Maunsell, 1999; Thorburn *et al.,* 1992; BHP 1997; Weston & Trudgen, 1995).

The tolerance of *E. camaldulensis* to changes in groundwater levels is not known with certainty. *E. camaldulensis* has been reported to access water up to a depth of 21m (Landman, 2001). Generally however, *E. camaldulensis* is closely associated with riparian systems and is typically found where the depth to groundwater varies between 1 to 3m (Dames & Moore, 1984).

Various research on the response of *E. camaldulensis* to falls in groundwater levels (shown in Table 2.4) suggest that a drawdown rate limit of 4 m/year can be tolerated by *E. camaldulensis.* However, since initial groundwater levels are not specified and visual signs of stress only become evident late in tree decline, this study is of limited application in determining the effects of groundwater drawdown on *E. camaldulensis*.

No. of Years	**Water Level Drop** (m)	**Approximate Rate of Water Level Drop**[1] (m/yr)	**Reported Tree Health**	**Source**
1	4	4.0	No visual sign of stress.	BHP (1997)[2]
2	10	5.0	Visual signs of stress.	BHP (1997)[2]
4	8	2.0	No visual sign of stress.	BHP (1997)[2]
4	17	4.3	Visual signs of stress.	BHP (1997)[2]
6	8	1.3	No visual sign of stress.	BHP (1997)[2]
Not specified	5	Not calculated	Impacts observed	Dames & Moore (1984)
Not specified	0.5 to 1	Not calculated	Stress to individual trees and long-term changes to community structure.	BHP (1987)
Not specified	1	Not calculated	Selective deaths of individuals	BHP (1987)
Not specified	2	Not calculated	Significant deaths	BHP (1987)

Note: 1 - Calculated by Maunsell Pty Ltd

2 - Studies are not designed to be interpreted this way

Table 2.4 - **Response of *Eucalyptus camaldulensis* to various rates of ground water level drop**

2.2.11 *Eucalyptus victrix*

While not a true phreatophyte, *E. victrix* (Coolibah) has been described, like *E. camaldulensis,* as a vadophyte, relatively drought tolerant, but likely to exhibit signs of stress with decreased access to groundwater (Muir, 1995). Occurrence of this species within the vegetation survey area (Halpern Glick Maunsell, 2001) is reported to be independent from the occurrence of *E. camaldulensis* and *M. argentea* within 4 vegetation communities (see Table 2.3).

Little information about the tolerances of Coolibahs to changes in groundwater levels is available. However, while vadophytes are considered to be relatively drought tolerant, they are likely to experience stress if the watertable falls to a level where the capillary fringe of the vadose layer was no longer accessible. A gradual decline of the watertable would probably not affect Coolibahs, although the effects of a long-term decline in the groundwater level would depend on the adaptive ability of individuals and their dependence on the vadose zone (Muir, 1995).

3.0 Predicted Impacts of Pit Dewatering

To carry out proposed mining operations, the proposed open pit is to extend 250 m to 300 m below natural surface, or 220 m to 270 m below the local and regional groundwater table. Associated pit dewatering is expected to result in creation of a steep "cone of depression" around the pit area.

Dewatering operations are expected to intercept 4 to 8% of estimated groundwater throughflow in the Fortescue River Alluvium and interception of most of the groundwater throughflow in basement rock aquifers within the vicinity of the pit. The range of natural variations in groundwater throughflow, as a result of variations in river flow however, is expected to greatly exceed this volume (Aquaterra, 2000; Halpern Glick Maunsell, 2002).

The PER (Halpern Glick Maunsell, 2002) anticipates the loss of approximately 63 ha of creekline vegetation as a result of direct disturbance by development of mine infrastructure, and approximately 75 ha of phreatophytic vegetation in Edward and Du Boulay creeks as an indirect impact of pit dewatering drawdown.

These impacts are addressed below.

3.1 Predicted Impacts of Pit Dewatering

Pit dewatering is expected to result in a regional drawdown of the water table. A simple groundwater model was developed to assess potential groundwater impacts resulting from dewatering operations. The model was set up as a 2 layer (aquifer) system, the upper layer of which represents the Fortescue River Alluvium and the shallower parts of the Brockman Iron Formation and basement rocks, where water flows into the model from inland areas and discharges to the sea (Aquaterra, 2001). The model was calibrated to steady-state conditions using measured groundwater levels sourced from Geological Survey of Western Australia and Aquaterra (modelled steady-state groundwater level contours are shown in Figure 3.1, 3.2, 3.3) (Aquaterra, 2001). No recharge (from rainfall or infiltration of streamflow) was specified in the model. In this regard, the modelling approach was conservative especially with respect to the Fortescue River Alluvium, where infiltration from streamflow is the primary recharge mechanism. As a consequence model predictions tend to over estimate long-term drawdowns in both the basement and alluvium (Aquaterra, 2001; Halpern Glick Maunsell, 2002).

Prediction of dewatering impacts were based on the proposed mine plan after years 5, 10 and 20 as presented in the PER (Halpern Glick Maunsell, 2002). Results of modelling indicated that inflows into the open pit are likely to be between 600 and 1,000 m^3/d which equates to a total volume of approximately 5.5 GL over the 20 year mining period. It should be noted, however, that sensitivity analysis indicates that this rate could be as high as 1,600 m^3/d. Modelling further revealed that the major source of inflow, approximately 4.75×10^6 m^3/yr, is via the Fortescue River Alluvium (Aquaterra, 2001; Halpern Glick Maunsell, 2002).

Figures 3.1 to 3.3 show modelled groundwater levels after 5 years, 10 years and 20 years and the extent of impact on vegetation communities following commencement of pit dewatering. Drawdown impacts extend elliptically in a north-south direction from the George Palmer Orebody. Significant drawdown impacts do not extend into the alluvial aquifer. At the end of the 20 year mining period, the total drawdown impact extends approximately 25 km to the north-south and 8 km to the west-east of the George Palmer Orebody. Table 3.1 shows predicted drawdown (and drawdown rates) at a number of wells and locations along drainage paths in the vicinity of the Orebody for modelled years 5, 10 and 20. Significant drawdowns are shown to occur at creek locations 2 and 5 (on Du Boulay and Edwards Creeks).

Location	Predicted Drawdown (m)					
	Year 5	Estimated Drawdown Rate 0 – 5 years (m/yr)	**Year 10**	Estimated Drawdown Rate 5 – 10 years (m/yr)	**Year 20**	Estimated Drawdown Rate 10 – 20 years (m/yr)
Violet Well	0.0	0	0.1	0.1	0.4	0.39
Balmoral H.S.	5.8	1.16	13	11.84	24	22.7
Tarquin Well	0.0	0	1.2	1.2	7.5	7.38
Marda Well	0.0	0	0.2	0.2	2.9	2.88
Creek Location 1	0.1	0.02	0.1	0.08	0.2	0.19
Creek Location 2	51	10.2	87	76.8	103	94.3
Creek Location 3	0.1	0.02	1.4	1.38	7.2	7.06
Creek Location 4	0.2	0.04	0.9	0.86	1.9	1.81
Creek Location 5	16	3.2	31	27.8	46	42.9
Creek Location 6	0.0	0	0.1	0.1	3.3	3.29

Table 3.1 - Predicted drawdown (Data Source: Aquaterra 2001; Halpern Glick Maunsell 2002)

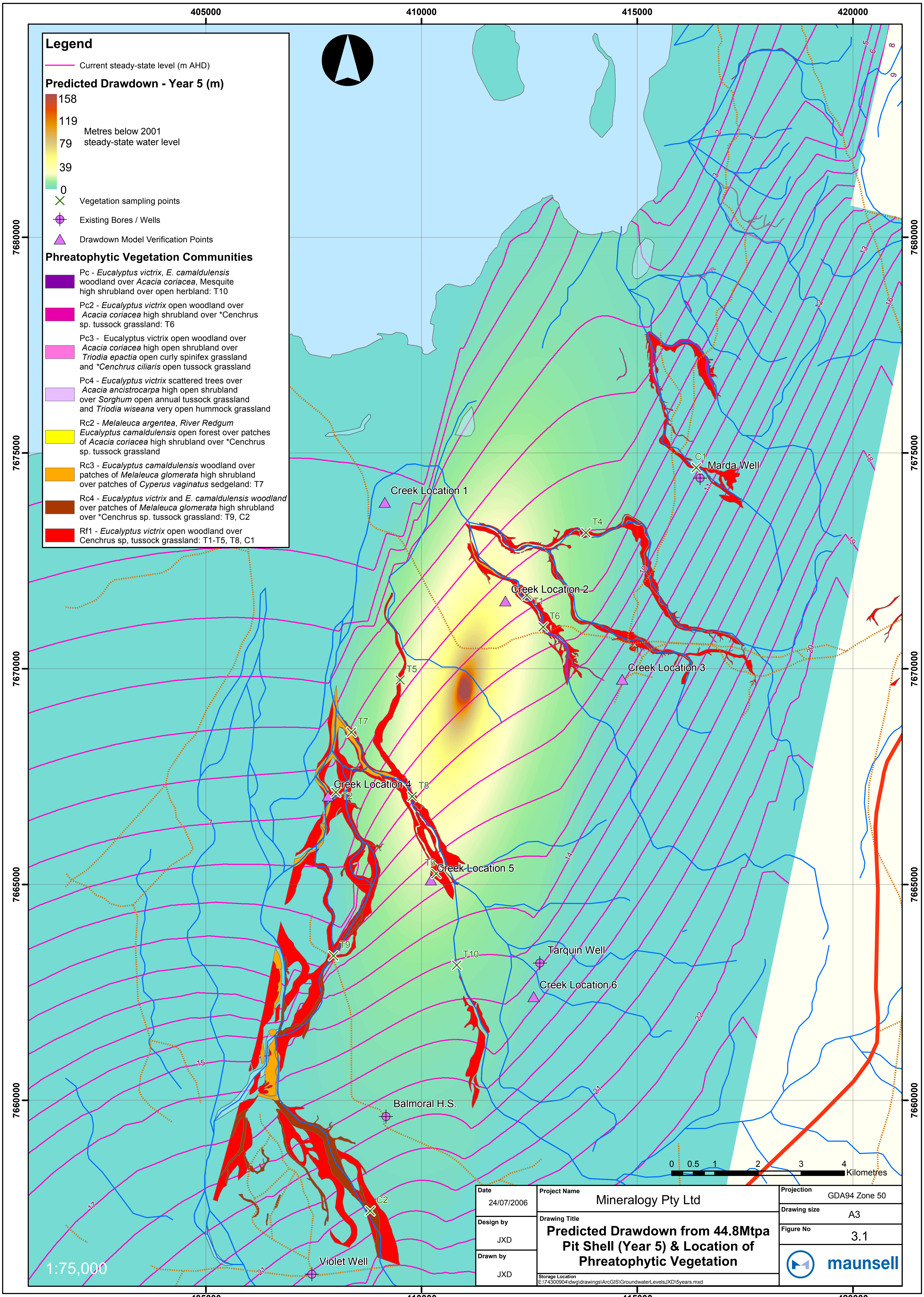
Groundwater drawdown is expected to cause extended drying of water pools, thereby impacting on Riverine Environments and GDEs such as phreatophytic vegetation. Shallow-rooted species are not likely to be directly affected by dewatering and consequently some vegetation cover may be retained. However, as a result of the permanent loss of phreatophytic vegetation, understorey species may also be lost depending on the extent of drawdown, drawdown level and drawdown rate.

Based on the anticipated extent of groundwater drawdown, it is evident that phreatophytic species within the survey area will be adversely affected by pit dewatering associated groundwater level drawdown. The limited data on maximum root growth rates related to groundwater drawdown rates, and root growth depths of *Eucalyptus victrix* (Coolibah) and *Melaleuca argentea* (Cajeput), does not allow for quantitative calculation of temporal and spatial impacts of dewatering on phreatophytic vegetation.

Information and data available on the tolerance of River Red Gums to changes in groundwater levels suggest that this species may be adversely affected by pit dewatering associated groundwater drawdown. However, because only limited information regrading the maximum rate of root extension and depth for *E. victrix* (Coolibah) and *M. argentea* (Cajeput) compared worth the extent of drawdown, quantitative calculation of temporal and spatial impacts of dewatering on these phreatophytic species is not possible.

Information on the tolerance of River Red Gums to changes in groundwater levels suggests that this species may be adversely affected if there is an overall fall in groundwater levels in excess of 8m, but that it is likely to tolerate reductions of up to 8m at a rate of up to 4 m/year. Evidence of stress has been seen in River Red Gums where the groundwater has fallen 17 m over 4 years, but with a drop of 10m in the first two years (BHP, 1997).

Figure 3.1 - Predicted drawdown from 44.8 Mtpa pit shell (Year 5) and phreatophytic vegetation location.



Date: 24/07/2006

Project Name: Mineralogy Pty Ltd

Projection: GDA94 Zone 50

Design by: JXD

Drawing Title: **Predicted Drawdown from 44.8Mtpa Pit Shell (Year 5) & Location of Phreatophytic Vegetation**

Drawing size: A3

Figure No: 3.1

Drawn by: JXD

Storage Location: E:\74300904\dwg\drawings\ArcGIS\GroundwaterLevelsJXD\5years.mxd

maunsell

Figure 3.2 - Predicted drawdown from 44.8 Mtpa pit shell (Year 10) and phreatophytic vegetation location

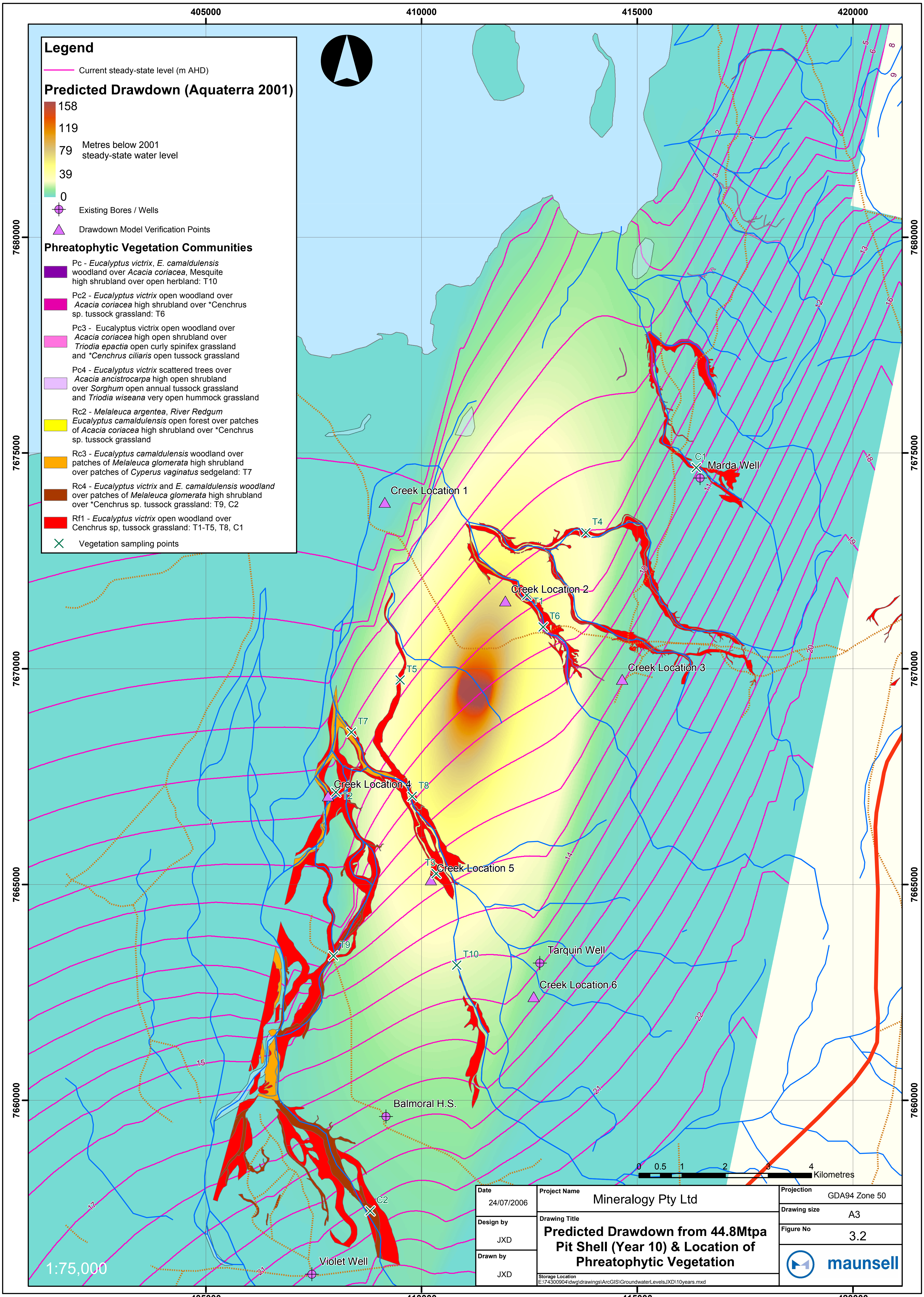
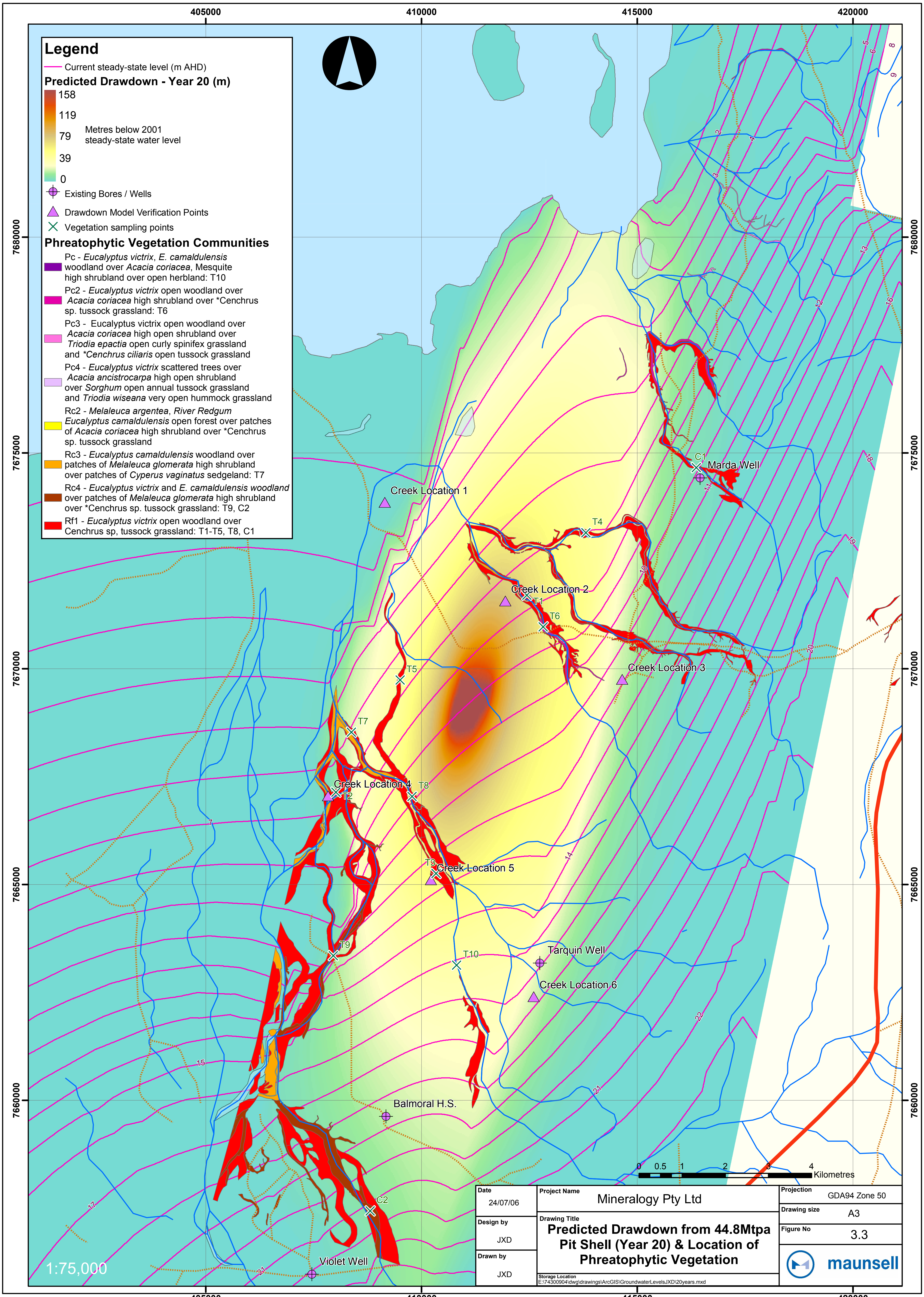

Legend
Current steady-state level (m AHD)
Predicted Drawdown (Aquaterra 2001)
158
119
79
39
0
Metres below 2001 steady-state water level
Existing Bores / Wells
Drawdown Model Verification Points
Phreatophytic Vegetation Communities
Pc - Eucalyptus victrix, E. camaldulensis woodland over Acacia coriacea, Mesquite high shrubland over open herbland: T10
Pc2 - Eucalyptus victrix open woodland over Acacia coriacea high shrubland over *Cenchrus sp. tussock grassland: T6
Pc3 - Eucalyptus victrix open woodland over Acacia coriacea high open shrubland over Triodia epactia open curly spinifex grassland and *Cenchrus ciliaris open tussock grassland
Pc4 - Eucalyptus victrix scattered trees over Acacia ancistrocarpa high open shrubland over Sorghum open annual tussock grassland and Triodia wiseana very open hummock grassland
Rc2 - Melaleuca argentea, River Redgum Eucalyptus camaldulensis open forest over patches of Acacia coriacea high shrubland over *Cenchrus sp. tussock grassland
Rc3 - Eucalyptus camaldulensis woodland over patches of Melaleuca glomerata high shrubland over patches of Cyperus vaginatus sedgeland: T7
Rc4 - Eucalyptus victrix and E. camaldulensis woodland over patches of Melaleuca glomerata high shrubland over *Cenchrus sp. tussock grassland: T9, C2
Rf1 - Eucalyptus victrix open woodland over Cenchrus sp, tussock grassland: T1-T5, T8, C1
Vegetation sampling points
405000
410000
415000
420000
7680000
7675000
7670000
7665000
7660000
Creek Location 1
Creek Location 2
Creek Location 3
Creek Location 4
Creek Location 5
Creek Location 6
Marda Well
Tarquin Well
Balmoral H.S.
Violet Well
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
C1
C2
0 0.5 1 2 3 4 Kilometres
1:75,000
Date
24/07/2006
Project Name
Mineralogy Pty Ltd
Projection
GDA94 Zone 50
Drawing size
A3
Design by
JXD
Drawing Title
Predicted Drawdown from 44.8Mtpa Pit Shell (Year 10) & Location of Phreatophytic Vegetation
Figure No
3.2
Drawn by
JXD
Storage Location
E:\74300904\dwg\drawings\ArcGIS\GroundwaterLevelsJXD\10years.mxd
maunsell

Figure 3.3 - Predicted drawdown from 44.8 Mtpa pit shell (Year 20) and phreatophytic vegetation location.


Legend
Current steady-state level (m AHD)
Predicted Drawdown - Year 20 (m)
158
119
79
39
0
Metres below 2001 steady-state water level
Existing Bores / Wells
Drawdown Model Verification Points
Vegetation sampling points
Phreatophytic Vegetation Communities
Pc - Eucalyptus victrix, E. camaldulensis woodland over Acacia coriacea, Mesquite high shrubland over open herbland: T10
Pc2 - Eucalyptus victrix open woodland over Acacia coriacea high shrubland over *Cenchrus sp. tussock grassland: T6
Pc3 - Eucalyptus victrix open woodland over Acacia coriacea high open shrubland over Triodia epactia open curly spinifex grassland and *Cenchrus ciliaris open tussock grassland
Pc4 - Eucalyptus victrix scattered trees over Acacia ancistrocarpa high open shrubland over Sorghum open annual tussock grassland and Triodia wiseana very open hummock grassland
Rc2 - Melaleuca argentea, River Redgum Eucalyptus camaldulensis open forest over patches of Acacia coriacea high shrubland over *Cenchrus sp. tussock grassland
Rc3 - Eucalyptus camaldulensis woodland over patches of Melaleuca glomerata high shrubland over patches of Cyperus vaginatus sedgeland: T7
Rc4 - Eucalyptus victrix and E. camaldulensis woodland over patches of Melaleuca glomerata high shrubland over *Cenchrus sp. tussock grassland: T9, C2
Rf1 - Eucalyptus victrix open woodland over Cenchrus sp, tussock grassland: T1-T5, T8, C1
405000
410000
415000
420000
7680000
7675000
7670000
7665000
7660000
Creek Location 1
Creek Location 2
Creek Location 3
Creek Location 4
Creek Location 5
Creek Location 6
Marda Well
Tarquin Well
Balmoral H.S.
Violet Well
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
C1
C2
0 0.5 1 2 3 4 Kilometres
1:75,000
Date
24/07/06
Design by
JXD
Drawn by
JXD
Project Name
Mineralogy Pty Ltd
Drawing Title
Predicted Drawdown from 44.8Mtpa Pit Shell (Year 20) & Location of Phreatophytic Vegetation
Storage Location
E:\74300904\dwg\drawings\ArcGIS\GroundwaterLevelsJXD\20years.mxd
Projection
GDA94 Zone 50
Drawing size
A3
Figure No
3.3
maunsell

4.0 Monitoring Plan Objectives and Investigation Methods

The key objectives of the proposed pit dewatering and related vegetation monitoring program are to:

- monitor the health and response of Groundwater Dependent Ecosystems (GDEs) to mine dewatering operations;
- verify water source requirements of key indicator species *E. camaldulensis*, *M. argentea* and *E. victrix*; and
- collect data that enables the continual review of EWR criteria thereby encouraging sustainable management and enabling protection of identified ecological values.

To fulfil these objectives, tasks as canvassed in the following section will be undertaken.

4.1 Determination of Ecological and Other Water Use Water Requirements

The identification of Ecological Water Requirements (EWRs), potential Other Water User Requirements (OWURs), the quantity and rate of dewatering proposed and the balance between these, form a basis for decisions concerning the level and rate of sustainable dewatering practices.

EWRs will be determined as described below with an emphasis on documented responses of GDEs (in similar environments) to changes in their water table regime. The proposed methodology has been adapted from *Environmental Water Requirements to Maintain Groundwater Dependant Ecosystems* (Sinclair Knight Merz, 2001) and provides a logical and adaptable framework for the identification of GDEs and the determination of their respective EWRs. The key components of the framework are:

- identification of GDEs;
- assessment of conservation significance/ecological value and condition of GDEs;
- analysis of ecosystem groundwater dependency;
- assessment of hydrological regime in which dependency operates;
- determination of EWRs; and
- implementation of ongoing monitoring programme.

OWURs for the proposed pit dewatering will be determined by:

- identification of commercial/industrial values relating to the groundwater system;
- description of water requirements for proposed pit dewatering (as detailed in SER); and
- determination of impact of optimum rate of dewatering to maintain proposed mining activities (as described in the SER) on GDE function.

4.2 Determination of EWRs

4.2.1 Identification of GDEs

A desktop investigation, supplemented by field observations and data, will be undertaken to identify GDEs within the Project Area, specifically:

- biological studies conducted within the Project Area (HGM, 2001);
- field observations of ecosystem groundwater dependence; and

- detailed literature review of previous EWR studies conducted.

4.2.2 Groundwater Dependency Analysis

A dependency analysis to describe the nature of ecosystem dependence on groundwater will be undertaken. This will comprise:

- Identification of groundwater dependent elements of the ecosystem - i.e. species that may be directly dependent on groundwater;
- Identification of key groundwater attributes (Sinclair Knight Merz, 2001) - these include flow/flux, level, pressure and quality (Appendix A, Table A1); and
- Determination of groundwater dependency type - e.g. entirely dependent, highly dependent, proportional dependence, limited or opportunistic dependence and no apparent dependence (Appendix A, Table A2).

The dependency analysis will draw on using existing information from previous research. If necessary, inferences will be drawn based on the best available information, with a conservative approach is to be adopted where information is limited.

4.2.3 Assessment of Existing Hydrologic Regime

The assessment of the existing hydrologic regime will use historical groundwater (water level and quality) monitoring data.

4.2.4 Ecological Water Requirements (EWRs)

GDE water sources will be determined using meteorological, streamflow and hydrogeological information and data from previous research. The requirements of ecosystems for groundwater will be grouped as follows:

- Consumptive use

  eg. evapotranspiration by phreatophytic vegetation;
- Habitat

  eg. aquatic and aquifer ecosystems occupying groundwater; and
- *Biophysical processes* **-** groundwater facilitates important ecological or physical processes, i.e.

  recruitment and succession, salt balance, nutrient balance or geomorphological processes.

GDEs water usage patterns will be determined by the following methods:

- Threshold Values for Groundwater Attributes;
- Analysis of historical groundwater monitoring data, anecdotal evidence and historical information, which is supplemented by previous research conducted in similar environments, to characterise long-term fluctuations in groundwater attributes which support the identified GDEs;
- Rates of Use;
- This factor applies primarily to consumptive uses. Rates of water use over time will be based on information drawn from previous similar research and data obtained from the monitoring programme described in the following section; and
- Temporal Distribution of Use.

Patterns of water use may change with time and/or season and accordingly, the following temporal distribution of groundwater use will be considered:

- *Timing* - refers to the seasonality of a hydrologic regime and/or groundwater use;
- *Duration* - key ecosystem processes (eg. breeding) may rely on certain duration of events within a hydrologic regime; and
- *Frequency & Episodicity* - refers to the pattern or time interval at which hydrological events occur. (Episodicity generally refers to the periodic occurrence of hydrological events)

5.0 Vegetation and Groundwater Monitoring

A monitoring programme, based on the Before/After/Control/Impact (BACI) Design (Green, 1976), will be established to review the rate and degree of groundwater drawdown and investigate the effects of draw down on phreatophytic vegetation located within the “zone of impact”.

5.1 Vegetation Monitoring

Monitoring of GDEs will entail the assessment of tree health and tree water use at a range of monitoring sites.

Monitoring sites will be established across the drawdown zone. Two control sites will be established, one each upstream and downstream from the centre of groundwater drawdown (the pit). A total of ten impact sites will be established at varying distances from the centre of groundwater drawdown and within the range of various riparian vegetation communities present within the drawdown zone. Three of the ten impact sites will be located adjacent to previously established groundwater modelling sites (Aquaterra, 2000), to enable relationships between changes in vegetation health and groundwater levels to be drawn. Although the remaining sites are removed from existing bores their establishment in selected locations will benefit interpretation of tree health data. The location of the monitoring sites (shown in Figures 3.1, 3.2, 3.3) is preliminary and alterations may be necessary during initial field studies, for example, due to access limitations.

At each monitoring site, permanent transects 10 metres wide and 50 metres long, will be established, pegged and labelled. Within each of the $500m^2$ transects, all phreatophytic trees (*Eucalyptus camaldulensis, Eucalyptus victrix* and *Melaleuca argentea*) will be numbered, tagged and measured for parameters summarised in Table 4.1 and detailed in Appendix B. In order to obtain sufficient data for statistical analysis, a minimum of 20 trees will be measured at each site. In the event that the $500m^2$ transect does not encompass at least 20 phreatophytic tree species, transects will be extended accordingly.

Within each of the 10m x 50m tree transects, two 10m x 10m understorey quadrats will be established at each end. Monitoring of understorey vegetation within the riparian zone is intended to monitor the effects of groundwater drawdown and other impacts on non phreatophytic species occurring within phreatophytic vegetation communities, as a subsequent result of potential impacts on canopy species. Understorey species will be measured for parameters outlined in Table 5.1 and detailed in Appendix C.

As for all components of the Vegetation Monitoring Plan, sampling will be carried out under the BACI (Before After Control Impact) Sampling Design (Green, 1979). If possible, two sampling events will take place over a twelve month period to establish baseline data for both wet and dry season conditions, prior to the commencement of operations.

Table 5.1 - Predicted Impacts and Associated Monitoring Programs to be implemented to Assess Vegetation Health Decline, Cape Preston Development (from Vegetation Monitoring Plan, Maunsell 2006)

Impact	Vegetation/ Area	Monitoring Program	Plot dimensions	Parameters to be monitored
Groundwater drawdown from pit dewatering	Riparian Vegetation	Transects at a range of sites selected for their vegetation type and distance for the centre of the "cone of groundwater drawdown"	Tree plots: 10m wide x 50m long	• species • height • DBH • % alive canopy • health score • photograph (for visual health) • site conditions including; site photograph, erosion, visible dust deposits, cattle degradation and weed presence (if significant)
Ground water drawdown from pit dewatering	Riparian Vegetation	Quadrats within transects as above	Understorey plots (at each end of each tree plot): 10m x 10m	• species (including weeds) • height • no. alive plants (ea sp.) • no. dead plants (ea sp.) • % cover alive plants (ea sp.) • % cover dead plants (ea sp.)

5.1.1 Tree Health

Tree health monitoring will be conducted quarterly to represent wet (summer) and dry (winter) seasons and intermediate periods. The monitoring programme will entail the collection of baseline data prior to commencement of pit dewatering. In order to achieve effective representation of species' populations within each monitoring site, trees selected for analysis will be chosen based on their age, stress, vigour and location. Selected trees (*E. camaldulensis, E. victrix* and *M. argentea*) at each monitoring site will be numbered and tagged to enable sampling repetition and ensure data consistency over the duration of the monitoring programme.

The following parameters will be monitored as a measure of tree health:

- Visual health - to be assessed via established photo points;
- Health ranking - to be derived from visual assessment, based on a range of heaths, ranging from healthy to dead with various degrees of stress as intermediates;
- Alive canopy foliage cover (%) - to be used as a visual measure of tree stress;
- Height (m) - to be used as a measure of growth;
- Diameter at Breast Height (DBH) - to be used as a measure of growth; and
- Isotopic analysis - to be used as a quantitative measure of tree stress.

Isotopic analysis uses relative concentrations of 13C and 18O of leaf organic matter to determine the physiological responses (e.g. changes in photosynthetic capacity, stomatal conductance, humidity, rate of evapotranspiration) of plants to water stress. Analysis of naturally occurring gradients in stable isotopes in water can determine the baseline proportion of groundwater, soil water and rain water in plant water (via xylem sap) (Thorburn, *et al.* 1992; Landman, 1994; Busch *et al.*, 1992). Error associated with the sampling, extraction and analysis is generally <5%.

Other benefits of this technique include:

- it is an established International Standard (IS Standard VPDB);
- it is a quantitative technique, which results in greater result confidence and therefore a better baseline on which to assess impacts of mine dewatering and assist application of Best Management Practices (BMPs);
- it provides an early indication of tree stress;
- it is an indicator of water stress, not factors such as leaf pests or disease; and
- research conducted in the Pilbara supports the use of this technique for the monitoring of water-stress in *E. camaldulensis* and *M. argentea* (Landman *pers. comm.* 2002).

In conjunction with the above monitoring, aerial surveys, using Digital Multi-Spectral Video (DMSV) system, will be conducted to assist assessment of tree health. This method allows detection of any changes in vegetation health before such would be apparent to through ground observations, and will be used to assist in the determination of tree health prior to and following (on an annual basis) the commencement of pit dewatering.

Additional monitoring of site conditions including erosion, weed invasion, extent of stock disturbance and pathogen attack is to be conducted in at each monitoring site in association with tree health monitoring.

5.1.2 Tree Water Use

Marcam Environmental (Marshall, 2000) has carried out water use of creekline Eucalypts to detect the effects of dewatering near Newman. Water use by *Eucalyptus camaldulensis* and *Eucalyptus victrix* was measured using the heat-pulse technique. In this technique, heat is used as a tracer for the movement of water. The sap velocity of the tree is measured by inserting a heat probe and sensors into the trunk and this data is multiplied by the conducting wood area of the tree, to give tree water use – typically as litres per day (L/d). These measurements can continue for years unless interrupted by problems caused by heat, cattle, floods or human interference. This method will be used during the monitoring programme to measure the amount of water being used by representative trees at selected sites.

5.1.3 Other Monitoring

Other data related to changes in groundwater due to dewatering will also be collected as part of the Pit Dewatering and Vegetation Monitoring Plan. These parameters include:

- groundwater levels;
- groundwater quality;
- streamflow;
- meteorological data; and
- tree irrigation rates.

Details of these parameters and the methods of collection of them are outlined in the Pit Dewatering and Vegetation Monitoring Plan (Maunsell, 2005).

5.2 Groundwater Monitoring

Effective monitoring of water table drawdown over the life of the mine will require the establishment of a network of groundwater monitoring bores. These bores will be used to:

- confirm predicted regional drawdown and to identify impacts on groundwater quality (pH, salinity) resulting from dewatering operations;
- provide data for refinement of predicted future impacts.

It should also be noted that although the study described here includes investigation of the effects of local groundwater abstraction on tree health and groundwater levels, it is only intended to observe broad-scale trends (spatial and temporal) across the predicted pit dewatering impact zone.

DoW's WIN Database of Western Australian hydrogeological and borehole monitoring data has been interrogated to compile information on shallow aquifer bores within a 30km radius of the proposed pit. This information has been reconciled with additional monitoring bore data previously used to model pit dewatering effects and water table drawdown (Halpern Glick Maunsell, 2002). The data shown in Table 5.1 includes information from these datasets (both within and beyond the "zone of impact") that will assist monitoring of drawdown effects in the shallow aquifer. Further interrogation of the DoW WIN Database, and liaison with appropriate authorities, is required to identify bores suitable for monitoring drawdown effects in the deeper aquifer. Field inspection is also required to determine bore condition, to ensure accuracy and reliability of data collected.

In addition to those bores that are found to be suitable for shallow aquifer monitoring (as recommended in Aquaterra, 2001 and indicated in Figures 3.1, 3.2 & 3.3) consultation with DoW and DEC will be undertaken to determine the most appropriate locations for the installation of further monitoring bores (in basement rock and alluvium). In this regard, it is suggested that monitoring bores be established in the following general locations:

- around the margin of the pit (4 bores);
- between the pit and potentially affected station wells (3 bores);
- between the pit and Fortescue River - 1 bore into the basement rock and in the alluvium at the edge of the floodplain on 2 transects (4 bores);
- adjacent to Control Site 2 and Impact Sites 4 – 10; and
- near the southern extremity of the predicted extent of groundwater drawdown.

Prior to commencement of pit development, collation and compilation of all historical rain gauge, stream gauge, water level and water quality (pH, salinity) data for existing bores will be undertaken. The monitoring bores will be installed 12 months prior to commencement of mining, once formal approval to commence construction has been granted and the various required licences have been granted. Monthly groundwater monitoring will commence immediately after the bores are installed to ensure collection of sufficient baseline data.

Stream gauges will be established at sites to be determined in consultation with DEC. Ideally, they will be positioned alongside riparian vegetation monitoring sites. The stream gauges will be established at least twelve months prior to the commencement of pit development to ensure the availability of adequate baseline flow data. Flow data will be used in conjunction with rainfall data collected from the meteorological station installed pursuant to Ministerial Condition 10-1 to assist with interpretation of vegetation monitoring data.

Bore	Custodian	Date Drilled	Easting (m MGA94)	Northing (m MGA94)	Total Depth (mBNS)	Aquifer	Status	WL Records (years)
Marda Well	Private	01/1900	416457	7674421	9.50	-	Production	1900, 1974, 2000
Neera Well	Private	5/11/1996	415438	7677655	-	-	Production	1996
Fortescue Mill	Private	01/1900	407728	766457	10.06	Quaternary	Production	1900
Fortescue River Coastal Plain 32B	DoE	4/7/1985	407438	7653055	12.70	Quaternary	Monitoring	1985, 1987-1996, 1998-2003
Fortescue River Coastal Plain 7B	DoE	30/8/1983	401638	7659655	14.50	Quaternary	Ex Monitoring	1983-1991
Balmoral Station No. 11	Private	4/8/1965	407300	7663807	9.14	Quaternary	-	1965
Fortescue Bore	Private	5/11/1996	408118	7666495	-	Floodplain Delta	-	1996
Dubaulay Well	Private	01/1900	409730	7656217	10.00	Quaternary	Production	1900, 1974, 1996
Carrawan Mill	Private	01/1900	416324	7657204	14.55	Quaternary	Production	1900, 1974
Diorite Well 14B	Private	01/1900	412499	7658443	14.90	-	Production	1900
Woolie Paddick Well	Private	01/1900	407199	7658287	8.70	Quaternary	Production	1900, 1974, 1996
Violet Well	Private	01/1900	407457	7655968	11.15	Quaternary	Production	1900, 1974, 1996
Balmoral Station No. 11	Private	4/8/1965	407300	7663807	9.14	Quaternary	Production	1965
Fortescue River Coastal Plain 15A	DoE	2/8/1983	406838	7662955	20.00	Quaternary	Ex Monitoring	1983-1991
Nooria	Private	01/1900	416008	7677873	3.96	Quaternary	Production	1900, 1974
Warralee Well 38M	Private	01/1900	404323	7655282	12.8	Quaternary	Production	1900, 1974, 1996
N.3. Wealumba Well 29M	Private	01/1900	395161	7664489	5.95	Quaternary	Production	1900, 1974
Helda Well	Private	01/1900	393213	7664128	5.65	Quaternary	Production	1900, 1974
Lawns Mill 27M	Private	01/1900	391357	7659199	6.20	Quaternary	Production	1900, 1974
Two Mile Well 35M	Private	01/1900	395661	7659810	6.20	Quaternary	Production	1900, 1974
Mardie Woolshed Well	Private	01/1900	390807	7656871	6.20	Quaternary	Production	1900, 1974
Can (COW) Paddock Well	Private	01/1900	392326	7656715	5.75	Quaternary	Production	1900, 1974
Homestead Wekk	Private	01/1900	394186	7656879	8.40	Quaternary	Production	1900, 1974
Camp Well (Native Camp Well)	Private	01/1900	393604	7656545	7.25	Quaternary	Production	1900
Garden Well	Private	01/1900	394088	7655315	11.55	Quaternary	Production	1900, 1974
Flyns Well	Private	01/1900	391141	7654141	8.80	Quaternary	Production	1900, 1974, 1996
Six Mile Well	Private	01/1900	390250	7646900	8.30	Quaternary	Production	1900, 1974, 1996
Govt Well (Eramurra W)	-	01/1900	422777	7671639	8.76	Quaternary	-	1900, 1974. 1996
Monkey Well	Private	01/1900	398151	7646339	5.30	Quaternary	Ex Production	1900, 1974, 1996
Wearawandie Well	Private	01/1900	400385	7646676	5.95	Quaternary	Production	1900, 1974, 1996
Campbell Well	Private	01/1900	399629	7640616	22.95	Quaternary	Production	1900, 1974, 1996
Landing Well	Private	01/1900	405171	7673063	5.18	Flood silt	Production	1900, 1974
Coonga Well	Private	01/1900	400841	7671582	5.79	Quaternary	Production	1900, 1974
Toondy Mill/ Toondy Well	Private	01/1900	397011	7667321	5.49	Quaternary	Production	1900, 1974
Pilling Well	Private	01/1900	400077	7665675	7.95	Quaternary	Production	1900, 1974
Woolawandowoolana Well	Private	01/1900	400167	7662601	9.30	Quaternary	Production	1900, 1974
Corner Well	Private	01/1900	398517	7659179	10.15	Quaternary	Production	1900, 1974, 1996
Jellin Jellin Well M45	Private	01/1900	403818	7659860	12.80	Quaternary	Production	1900, 1974
Secret Well	Private	01/1900	401031	7657380	13.55	Quaternary	Production	1900, 1974, 1996
Warralee Well 38M	Private	01/1900	404323	7655282	12.80	Quaternary	Production	1900, 1974, 1996
Coolanarra Well	Private	01/1900	405687	7657527	13.10	Quaternary	Production	1900, 1974
Yabberoo Well	-	01/1900	401267	7654298	10.25	Quaternary	-	1900, 1974
Currangyry Mill	Private	01/1900	408651	3651992	12.50	Quaternary	Production	1900, 1974, 2000
Mulyering Mill	Private	01/1900	404655	7650856	12.35	Quaternary	Production	1900, 1974, 1996

Note: mBNS – Metres Below Natural Surface
DoE – Department of Environment

Table 5.2 - Existing Monitoring Bore Inventory (July 2004)

6.0 Reporting Requirements

Following each quarterly assessment of tree health, a brief report will be prepared for submission to regulatory authorities as applicable. The report will present the data and summarise changes in tree health, growth, function (water use) and results of groundwater monitoring.

At the completion of each monitoring year, a detailed Pit Dewatering and Vegetation Monitoring Annual Report will be prepared for the client and submission to regulatory authorities as applicable. This document will analyse the available monitoring data and identify both spatial and temporal trends in the information based on correlation with baseline data (historical and collected). The report will also assess whether the adopted EWR criteria are being achieved. If it is concluded that ecosystem health and ecological values are being sustained (i.e. no significant impacts to key indicator species are reported) then no change to EWR criteria will be required. Trends in groundwater drawdown will also be identified and compared with those predicted by modelling.

In the event that monitoring results indicate any of the following, mitigation strategies will be implemented as outlined in Section 7.2, or alternatively as agreed with the appropriate regulatory authorities:

- failure to achieve EWR criteria commensurate with the requirements of mining;
- unanticipated extent of adverse impacts on GDEs; and / or
- variation from predicted drawdown.

Reporting of monitoring results will continue over the life of the mine, unless otherwise determined by the relevant regulatory authorities.

7.0 Conclusions and Mitigation Strategies

7.1 Conclusions

The objective of the Pit Dewatering and Vegetation Monitoring Plan is to qualitatively and quantitatively assess pit dewatering related impacts within the Project Area. The key components of the Plan in this regard are:

- quarterly monitoring of health of key indicator (phreatophytic) species and other site conditions at pre-selected permanent control and impact sites;
- annual aerial photography (DMSV);
- investigation of water requirements of key indicator species by collection of meteorological data over duration of study and use of the heat-pulse technique;
- monthly groundwater level and quality monitoring;
- collection of streamflow and meteorological data; and
- collection and collation of historical groundwater, streamflow and meteorological data for collation with monitoring programme data.

As indicated in the Plan, it is anticipated that the rate and degree of groundwater drawdown from pit dewatering will result in a significant loss of phreatophytic vegetation. Accordingly, the need for remedial action is also anticipated. Any remedial measures implemented will need to be agreed with relevant regulatory authorities, however possible initiatives in this regard are discussed below.

The Plan highlights limits in the available information relating to the response of phreatophytic vegetation to declining water levels, and options for maintaining tree health. It is therefore evident that the exchange of information and increased communication between relevant project stakeholders and liaison with regulatory authorities is desirable.

7.2 Rehabilitation

If deemed appropriate on consultation with the relevant regulatory authorities, in the event of major riverine tree species loss, a rehabilitation plan will be prepared and implemented. Taking into account the potential for phreatophytic vegetation to re-establish under the new groundwater regime, this will involve the removal and replacement of phreatophytic tree species in areas of significant death. Depending on the extent of degradation and vegetation loss, understorey species may also require replacement.

8.0 References

Aquaterra Consulting Pty Ltd (2000), *Fortescue Iron Ore Projects, Assessment of Minesite Surface Water and Groundwater Issues, June 2000*, Report prepared for Halpern Glick Maunsell.

Aquaterra Consulting Pty Ltd (2001), *Austeel Iron Ore Project – Prediction of Groundwater Level Drawdown*, Report prepared for Halpern Glick Maunsell.

Bettenay, E. H.M. Churchward and W.M. McArthur (1967). *Atlas of Australian Soils, Explanatory Data for Sheet 6, Meekatharra – Hamersley Range Area.* CSIRO and Melbourne University Press.

BHP Iron Ore (1997), *Newman Satellite Development Mining of Orebody 23 below the water table, Consultative Environmental Review*, Unpublished Report.

Bureau of Meteorology (2005), *Climate Averages for Australian Sites*, [Online], Available from: http:www.bom.gov.au [May 2005].

Busch D.E., Ingraham N.L. & Smith S.D. (1992), 'Water Uptake in Woody Riparian Phreatophytes of the Southwestern United States: A Stable Isotope Study', *Ecological Applications*, Vol 2 (4), pp 450-459.

Commander D.P. (1993), 'Hydrogeology of the Fortescue River Alluvium', *Hydrogeology Report No. 1993/*14, Geological Survey of Western Australia, Perth.

Dames & Moore (1984), *West Pilbara Water Supply – Millstream Aquifer Environmental Water Management Program (Draft)*, Unpublished report prepared for Public Works Department of Western Australia

Green, R.H. (1976), *Sampling Design and Statistical Methods for Environmental Biologists* John Wiley & Sons, New York.

Graham J. (2001), *The root hydraulic architecture of Melaleuca argentea*, PhD thesis, The University of Western Australia.

Halpern Glick Maunsell Pty Ltd (1999), *Marillana Creek Tree Stress Monitoring Summer 1998-1999,* Unpublished report for BHP Iron Ore Pty Ltd.

Halpern Glick Maunsell Pty Ltd (2000), *Iron Ore Mine and Downstream Processing, Cape Preston, WA, Public Environmental Review, December 2000,* Unpublished report prepared for Mineralogy Pty Ltd.

Halpern Glick Maunsell Pty Ltd (2001), *Austeel Biological Survey – Phase 1,* Unpublished report prepared for Mineralogy Pty Ltd.

Halpern Glick Pty Ltd (2002), *Iron Ore Mine and Downstream Processing, Cape Preston, WA, Supplementary Environmental Review, February 2002*, Unpublished report prepared for Mineralogy Pty Ltd.

Landman, P.A. (1994), 'Root Architecture and Sources of Water used by Riparian Vegetation Growing in the Pilbara Region', in *Management of Groundwater Dependent Vegetation in the Central Pilbara Iron Ore Mining Province,* The University of Western Australia.

Landman P.A. (2001), *The ecology and physiology of acacias and eucalypts in the Pilbara region of Western Australia*, PhD thesis, The University of Western Australia.

Maunsell Australia Pty Ltd (2006) *Vegetation Monitoring Plan - Iron Ore Mine and Downstream Processing, Cape Preston, Western Australia* Unpublished report prepared for Mineralogy Pty Ltd, February 2005

Mensforth L.J., Thorburn P.J., Tyerman S.D. & Walker G.R. (1994), *Sources of water used by riparian Eucalyptus camaldulensis overlying saline groundwater*, Unpublished paper.

Minister for the Environment (2003). *Statement that a proposal may be implemented (Pursuant to the provisions of the Environmental Protection Act 1986).* Statement No 00635. October 2003.

Muir, B. (1995), 'Field Monitoring of Vegetation Health', in *Management of Groundwater Dependent Vegetation in the Central Pilbara Iron Ore Mining Province*, ed. The University of Western Australia.

Ruprecht J. (1996) *Arid Zone Hydrology: Pilbara Region of Western Australia*, Presented at the 23rd Hydrology and Water Resources Symposium 21 – 24 May 1996, Hobart, Australia.

Ruprecht J. & Ivanescu S. (2000), *Surface Hydrology of the Pilbara Region Summary Report*, Unpublished report prepared on behalf of Water & Rivers Commission, Perth.

Sinclair Knight Merz (2001), 'Environmental Water Requirements to Maintain Groundwater Dependent Ecosystems', *Environmental Flows Initiative Technical Report No. 2*, Prepared for Natural Heritage Trust & Environment Australia.

Skidmore, D.J.P. (1996), 'Groundwater Resources of Major Catchments in the Pilbara Region, Western Australia', *Hydrogeology Report No. 35*, Water & Rivers Commission, Perth.

Smith S.D., Devitt D.A., Sala A.., Cleverly J.R. & Busch D.E. (1998), 'Water relations of riparian plants from warm desert regions', *Wetlands*, Vol 18, pp 687-696.

Thorburn P.J., Walker G.R., Hatton T.J. (1992), 'Are River Red Gums taking water from soil, groundwater or streams?', in *Proceedings of the Catchment of Green: A National Conference on Vegetation and Water Management*, Adelaide, pp 63-68.

Water & Rivers Commission (2000b), *Surface Hydrology of the Pilbara Region*, Unpublished report SWH32/2000.

Weston A. & Trudgen M. (1995), *Vegetation and Flora Survey Marillana / Weeli Wolli Creeks and Palaeochannels*, Unpublished report for BHPIO.

Woodward-Clyde Pty Ltd (1999), *Orebody 23 Tree Monitoring Programme, July 1999*, Unpublished report prepared for BHP Iron Ore.

Wright A (1997), ‘Groundwater Resources of the Pilbara Region, Western Australia’, *Hydrology Report No. HR 61,* Water & Rivers Commission, Perth.

Wright A. (2000), ‘Introduction’, in *Management of Groundwater Dependent Vegetation in the Central Pilbara Iron Ore Mining Province Conference Papers,* ed. The University of Western Australia, Perth, pp. 1-3.

Appendix A - Groundwater Dependency Analysis

Appendix A - Groundwater Dependency Analysis

Table A1: Forms of Ecosystem Dependency on Groundwater (After Hatton & Evans 1998)

Type	**Definition**
Entirely Dependent	Communities where only slight changes in key groundwater attributes below or above a threshold value result in their demise.
Highly Dependent	Communities where moderate changes in groundwater discharge or water tables would result in a substantial change in their distribution, composition and/or health.
Proportional Dependence	Groundwater that exhibit subdued, proportional responses to changes in groundwater attributes.
Limited or Opportunistic Dependence	Groundwater appears only to play a significant role in the water balance of such ecosystems at the end of a dry season or during extreme drought.
No Apparent Dependency	Communities that appear to be entirely rain fed or dependent on surface water.

Table A2: Definition of Key Groundwater Attributes (After SKM 2001)

Attribute	Definition & Description
Flux	Groundwater flux (flow) is the rate of surface or subsurface discharge on an aquifer. It is relevant to the provision of an adequate quantity of water to sustain an ecosystem *per se* or of a sufficient quantity to dilute more saline water (in estuarine, marine or wetland systems) to allow an ecosystem to function. The former case applies to ecosystems that occupy discharged groundwater (eg. cave systems, aquatic ecosystems in base flow dependent streams and many groundwater-fed wetlands) or whose sole or principal source of water is groundwater (eg. mound springs.
Level	Groundwater level is the depth of the water table. It is relevant to a broad range of ecosystems including wetlands fed by unconfined aquifers, terrestrial vegetation, many coastal lake and estuarine ecosystems, some cave and aquifer ecosystems and baseflow dependent ecosystems. The ecosystems' occupation or usage of groundwater depends on the water table level (above or below) the surface remaining within a certain range.
Pressure	Pressure has a similar role in ecosystems fed by confined aquifers to that of level in systems fed by unconfined systems. It applies, for example, to Great Artesian Basin mound springs.
Quality	Groundwater quality is typically measured in term of electrical conductivity (or salinity), nutrient content and/or contaminant concentrations (eg. heavy metals, pesticides). Ecosystems and their component species would typically function adequately over certain ranges in water quality. Outside these ranges the composition and health of the ecosystem is likely to decline. This groundwater attribute becomes important to ecosystems in circumstances where there is a sustained change in quality or trend away from the natural water quality state.

Appendix B - Tree Transects - Riparian Vegetation (Data Sheet)

Appendix B - Tree Transects - Riparian Vegetation (Data Sheet)

Appendix B: Tree Transects - Riparian Vegetation (10m x 50m)

Field Data Sheet

Site No.: RT………… Date: ……/………/……… Recorder: …………….. Photo No.: ………….

GPS: ………………………mE ……..……………..mN Bearing of Transect from start: …….. °

Landform: FLAT SLOPE RIDGE
OTHER: ……………..

Erosion: NONE LO MED HI V HI

Dust: NONE LO MED HI V HI

Weed inf'n: NONE LO MED HI V HI

Cattle Deg'n: NONE LO MED HI V HI

Weeds:

Sp.	%CA	%CD

Site Comments: …………………………………

……………………………………………………

……………………………………………………

Tree health scores: Healthy =H Slightly Stressed =SS Stressed =S Died Recently =DR Dead (long time) Old =DO

Tree No.	Species	Ht (cm)	DBH	%A cnpy	Health	Photo	Comment

Appendix C - Understorey Quadrats - Riparian Vegetation (Data Sheet)

Appendix C - Understorey Quadrats - Riparian Vegetation (Data Sheet)

Appendix C: Understory Quadrats - Riparian Vegetation (10m x 10m)

Field Data Sheet

Site No.: RU………… Date: ……/………/……… Recorder: …………….. Photo No.: ………….

GPS: ……………………….mE …………………..mN

Landform: FLAT SLOPE RIDGE
OTHER: ……………..

Erosion: NONE LO MED HI V HI

Dust: NONE LO MED HI V HI

Weed inf'n: NONE LO MED HI V HI

Cattle Deg'n: NONE LO MED HI V HI

Site Comments: ………..…………………………….

………..

Coll No.	Species/Field Name	Ht (cm)	No. A	%CA	No. D	%CD	Comment