Water and Environment

# JIMBLEBAR BOREFIELD GROUNDWATER IMPACT ASSESSMENT

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| Prepared for | BHP Billiton Iron Ore |
| Date of Issue | 14 May 2009 |
| Our Reference | 1008/600/001g.doc |

aquaterra

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| | Date | Revision Description |
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| **Revision A** | 19/11/08 | Draft For Client Review |
| **Revision B** | 05/01/09 | Inclusion of Client Comments |
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| | Name | Position | Signature | Date |
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# EXECUTIVE SUMMARY

## BACKGROUND

The Jimblebar borefield supplies water to the Wheelarra Hill Mine, for dust suppression, mineral ore processing and potable water supply purposes. The current Groundwater Borefield License (GWL) at Jimblebar, GWL 158795(3), limits abstraction to an annual allocation of 1,650,000kL. This was increased from 650,000kL per annum in May 2008 to cover an increased allocation of 4,500kL/d.

BHP Billiton Iron Ore Pty Ltd (BHPBIO) is planning to increase iron ore production at the Wheelarra Hill Mine to up to 45 million tonnes per annum (Mtpa), which will increase the water demand to up to 11,800kL/day.

BHPBIO is seeking approval for this change under the *Environmental Protection Act, 1986.* Aquaterra has been commissioned by BHPBIO to undertake a groundwater impact assessment of the proposed changes that will be appended to the approval document as supporting information.

The Jimblebar Groundwater model developed by Aquaterra in 2007 has recently been updated and calibrated incorporating data from July 2006 to June 2008. The updated calibrated model has been used to:

- Assess the capacity of the existing Jimblebar borefield to supply the proposed increase in water demand; and
- Assess the impact of this increased abstraction.

## GEOLOGY AND HYDROGEOLOGY

The main aquifers in the Jimblebar area are the semi-confined weathered dolomite of the Wittenoom Formation (Paraburdoo Member), weathered Marra Mamba Formation and the Tertiary alluvial aquifer. The unweathered bedrock is regionally considered to be of low permeability. The regional groundwater flow direction is from south to north with the water table more than 50m below ground surface. Water quality is fresh with Total Dissolved Solids (TDS) ranging from 250mg/L to 1100mg/L. The aquifer system is recharged by rainfall runoff infiltration over the valley via infiltration through the creek during flood events and direct recharge to basement rock aquifers.

## GROUNDWATER MODEL

Predicted Groundwater Drawdown Depth (Numerical Model)

The groundwater model was developed as a transient, MODFLOW 96, finite difference model using the Processing Modflow Pro Graphical User Interface (IES Inc, 2005). A steady state model was produced using historical data and the resultant heads were used as the initial heads in the transient model. The transient or time varying model ran from March 1994 to June 2008. The hydrogeology was represented as three layers with grid squares of 100m as shown below in Table ES1.

**Table ES1: Model layers**

| Layer | Description | Thickness |
|---|---|---|
| Layer 1 (L1) | Tertiary Formation aquifer, silt to gravel grade alluvium and weathered Marra Mamba formation surrounded by relatively impermeable bedrock | Up to 172m thick, base at 400mAHD |
| Layer 2 (L2) | Wittenoom Dolomite aquifer and weathered Marra Mamba formation surrounded by relatively impermeable bedrock | 100m thick, base at 300mAHD |
| Layer 3 (L3) | relatively impermeable competent bedrock | 50 metres, base at 250mAHD |

Following a consideration of available data, aquifer properties were assigned to areas of the model that were considered typical of the geological unit. The majority of data was derived from bulk permeability testing of the on site abstraction boreholes.

Predicted Groundwater Drawdown Extent (Analytical Model)

To determine the extent of maximum drawdown in this 'strip aquifer' the Dupuit Equation (Charbeneau, 2000) for steady state flow for unconfined aquifer was used. The assumptions to this equation are, the flow is mainly horizontal and the flow is proportional to the slope of water table. The Dupuit's Equation is one dimensional steady state equation. The parameters used in the Dupuit's equation (viz., *K, W, Hd and Hm*) were derived from the results of the numerical model.

**PREDICTION SCENARIOS**

It is planned that a water demand between 2,700kL/d (minimum) to 11,800kL/d (maximum) will be required for a period of 14 years from the Jimblebar borefield. It is anticipated that the demand will be drawn from bores Geo5, Geo6R, Geo7, Geo9, Geo10 and Geo11 initially, (up to 2 years), when the demand is anticipated to be 2,700kL/d, with further addition of two new bores to meet the higher demand in future years. For the prediction runs the abstraction rates from each bore were the same, and in proportion to the required demand. In addition these rates were also in accordance with Source Reliable Output (SRO) analysis results for each bore. The calibrated groundwater model was used to assess the capacity of the existing borefield to supply the increased water demand.

**CONCLUSIONS AND RECOMMENDATIONS**

The numerical modelling indicated that the aquifers at Jimblebar can deliver the required demand for the proposed increase in water demand at the Wheelarra Hill Mine.

Over the 14 year modelled period water levels are predicted to drawdown up to 45 m close to the centre of the borefield. The predicted drawdown is not expected to draw groundwater levels below the top of the Wittenoom Dolomite aquifer.

The cone of depression (impact area) would be an elongated shape reflecting more transmissive characteristics of the weathered Wittenoom Dolomite formation. The result of the analytical model indicates that the maximum extent of drawdown would be encountered at approximately 10.7 km from the 45m drawdown contour in both the east and west directions. However, the extent of drawdown to the west may be restricted by the intervening geology (i.e. Marra Mamba Iron Formation).

The predicted drawdown as a result of the continued and proposed increased abstraction from the Jimblebar borefield, is not expected to have any additional significant impacts on local and regional water resources, to those which have already been observed to date.

Continuation of the monthly water level monitoring programme at the observation bores JM1, JM3, JM7 and JM8 is recommended to monitor the water supply and to provide a better estimate of aquifer parameters as the borefield is developed.

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# 1 INTRODUCTION

## 1.1 BACKGROUND

The Jimblebar borefield (located approximately 50km east of Newman, WA, Figure 1.1) supplies water to the Wheelarra Hill Mine, for dust suppression, mineral ore processing and potable water supply purposes. The current Groundwater Wellfield Licence (GWL) at Jimblebar, GWL 158795(3) limits abstraction to an annual allocation of 1,650,000kL. This was increased from 650,000kL per annum in May 2008 to cover an increased allocation of 4,500kL/d.

The borefield draws groundwater from the semi-confined weathered dolomite of the Wittenoom Formation (Paraburdoo Member), weathered Marra Mamba Formation and the Tertiary alluvial aquifer.

## 1.2 SCOPE OF WORK

BHP Billiton Iron Ore Pty Ltd (BHPBIO) is planning to increase iron ore production at the Wheelarra Hill Mine to up to 45 Million tonnes per annum (Mtpa), which would increase the water demand to up to 11,800 KL/day.

BHPBIO is seeking approval for this change under Section 45C of the Environmental Protection Act, 1986. Aquaterra has been commissioned by BHPBIO to undertake a groundwater impact assessment of the proposed changes.

The scope of this groundwater impact assessment is as outlined below:

- Describe the existing groundwater environment in the vicinity of the Jimblebar borefield including geology, hydrogeology and the presence of non-BHPBIO groundwater users or groundwater dependent;
- Describe the existing Jimblebar borefield including relevant licences and groundwater operating strategy and a summary of monitoring results;
- Assess the predicted impacts of the planned increase in water-demand from the Jimblebar borefield associated with the proposed modification by undertaking the following groundwater modelling;
  - Updating the model calibration data set to include groundwater monitoring data (groundwater pumping and water levels) to include data collected between July 2006 and June 2008;
  - Using the calibrated model to assess the sustainability of the proposed water demand;
  - Modelling predictions to assess the potential impacts of the proposed increases in groundwater abstraction to the local aquifers.

## 1.3 PREDICTED GROUNDWATER ABSTRACTION

Table 1.1 presents the predicted daily water demand that would be required from the Jimblebar borefield under the proposed modification to the Wheelarra Hill Mine.

**Figure 1.1: Location Map Jimblebar Mine Operation**

**Table 1.1: Predicted Daily Water Demand**

| Year | Demand (KL/day) |
|---|---|
| 2008-2009 | 2000* |
| 2009-2010 | 2,700 |
| 2010-2011 | 7,200 |
| 2011-2012 | 11,800 |
| 2012-2013 | 11,800 |
| 2013-2014 | 11,800 |
| 2014-2015 | 11,800 |
| 2015-2016 | 11,800 |
| 2016-2017 | 11,800 |
| 2017-2018 | 11,800 |
| 2018-2019 | 11,800 |
| 2019-2020 | 11,800 |
| 2020-2021 | 11,800 |
| 2021-2022 | 11,800 |

*yearly average based on recorded months July to October 2008

# 2 EXISTING GROUNDWATER ENVIRONMENT

## 2.1 GEOLOGY

### 2.1.1 REGIONAL GEOLOGY

The geological history of Australia began early in the Archaean era, around 3,500 million years ago, with the formation of rocks which now underlie much of the Pilbara region (Pilbara Craton). Between 3,450 and 3,000 million years ago they were folded, severely metamorphosed and uplifted to form mountain ranges interspersed with scattered volcanos.

The Pilbara Craton is overlain by Proterozoic rocks deposited in the Hamersley and Bangemall Basins. The Hamersley Basin which occupies most of the southern part of the Pilbara Craton can be divided into three stratigraphic groups: the Fortescue, Hamersley and Turee Creek Groups (Beard, 1975).

Of the three groups, the Hamersley Group is the most relevant to the study area where it is approximately 2.5 km thick. It contains both the Brockman Iron Formation and the Marra Mamba Iron Formation, which together provide the most of the known major ore deposits in the Pilbara region.

The earliest rocks of the Pilbara consisted of silts, sands and iron-rich sediments and chert overlain and intruded by basic volcanic rocks.

### 2.1.2 LOCAL GEOLOGY

The geology of the region around Jimblebar has been mapped and described in detail by Tyler et al. (1991), Tyler (1994) and BHPBIO (2005). The area of study lies within the Ophthalmia Fold Belt which unconformably overlies Archaean basement rocks and abuts the Sylvania Inlier, an exposed portion of the cratonic basement.

A summary of the main geological elements, which are important to both the development of the landscape and the vegetation, is outlined below in chronological sequence:

- Wheelarra Hill is comprised of units from Brockman Iron Formation. This is economically the most important iron formation in the Hamersley Group and forms prominent strike ridges rising 200-400m. The formation is composed of chert, ferruginous chert and minor shale bands;
- The Weeli Wolli Formation outcrops to the north of Wheelarra Hill. It consists of interbedded Banded Iron Formation (BIF), chert and shale. Associated with this formation are rocks of the Woongarra Volcanics, which consist of partially metamorphosed igneous rhyolite and rhyodacite;
- South of Wheelarra Hill, Cainozoic in valley-fill deposits are found comprising consolidated and cemented colluvium. These deposits are derived from dissection of the Proterozoic rocks;
- Quaternary deposits occur as scree slopes, in drainage channels and associated floodplains that lie at the base of the Wheelarra Hill range.

## 2.2 HYDROLOGY

The southern side of the Wheelarra Hill ridge drains into Copper Creek. The creek is an ephemeral watercourse that runs for 10km in a north-easterly direction towards Jimblebar Creek. The land on the northern side of the Wheelarra Hill ridge comprises numerous small channels and valleys that initially drain to the north, before running in an easterly direction to Jimblebar Creek.

## 2.3 HYDROGEOLOGY OF THE JIMBLEBAR AREA

The main aquifers in the Jimblebar area are the semi-confined weathered dolomite of the Wittenoom Formation (Paraburdoo Member), weathered Marra Mamba Formation and the Tertiary alluvial aquifer. The unweathered bedrock is regionally considered to be of low permeability as are the formations to the north and south (Mount McRae Shale, Brockman Iron Formation, and the Jeerinah Formation).

The regional groundwater flow direction is from South to North with the water table more than 50m below ground surface. Water quality is fresh with Total Dissolved Solids (TDS) ranging from 200mg/L to 1100mg/L. The aquifer system is recharged by rainfall runoff infiltration over the valley via infiltration through the creek during flood events.

A brief description of the local aquifer system is discussed below:

### 2.3.1 WEATHERED DOLOMITE AQUIFER OF WITTENOOM FORMATION

The regional aquifer is the semi-confined weathered dolomite of the Wittenoom Formation (Paraburdoo Member). The dolomite sub-crops south of the Jimblebar mine, striking east-west and forming the southern limb of a westerly plunging syncline. The Wittenoom Formation is steeply dipping, forming a low–lying valley between the more resistant hills of Marra Mamba Formation (to the south) and Brockman Formation (to the north).

From bore logs, the thickness of weathered dolomite appears to be around 100m. The aquifer is considered heterogeneous and transmissivity varies across the aquifer. Aquifer transmissivity values of 80m2/d, 100m2/d and 190m2/d have been derived for Bores Geo6R, Geo10, and Geo11 respectively (Aquaterra, 2004).

Water samples analysed from Bores Geo6R, Geo10, and Geo11 indicate that the water is slightly alkaline, bicarbonate dominated groundwater, which is fresh with respect to TDS. The water exceeds the aesthetic limits of the Australian Drinking Water Guidelines (NHMRC, 2004) for TDS and hardness, but is of suitable quality for process / dust suppression water or even short-term potable water if required.

### 2.3.2 TERTIARY ALLUVIAL AQUIFER

The Tertiary alluvial aquifer overlies the weathered Wittenoom Formation. At the Jimblebar borefield, the aquifer is 80m to 120m thick and consists of layers of calcrete, gravels, sand, silt and clays. Water supply potential exists in the calcrete and gravels that form the aquifer. Most of the silts and clays also present act as a regional aquitard.

From the test pumping of Bore Geo9 the transmissivity of the Tertiary alluvial aquifer ranged between 12m2/d to 40m2/d. The recent hydrochemistry data for Bore Geo9 indicates the water from the alluvial aquifer is of similar quality to that from the Bores Geo6R, Geo10, and Geo11 suggesting hydraulic connection between the alluvial aquifer and the Wittenoom Dolomite. It should be noted, however, that one sample taken from Bore Geo9 in June 2002 had a TDS concentration of 2,300mg/L, This value appears anomalous when compared with concentrations taken both before and subsequent to this sample. Levels of sodium, chloride and manganese, however, have exceeded aesthetic guideline limits from time to time (Aquaterra, 2004).

### 2.3.3 WEATHERED MARRA MAMBA AQUIFER

Although there is no geological information for Bores Geo5 and Geo7, from their locations, it is believed the bores intersect weathered or fractured Marra Mamba Formation. No hydraulic testing has been undertaken on these bores. They are however low yielding indicating a much lower transmissivity when compared to the other aquifers.

The water quality for Bore Geo5 is comparable to that of bores Geo6R, Geo10, and Geo11 as they are within the same valley and probably in hydraulic contact with the weathered dolomite aquifer. The water from Bore Geo7, however, is more alkaline (pH of 8.5) and much fresher (TDS of 230mg/L). This is likely to be due to the bore being sited on a tributary creek which feeds into the main Jimblebar valley.

## 2.4 GROUNDWATER IMPACTS ON OTHER USERS

### 2.4.1 GROUNDWATER LICENCE HOLDERS

There are no licensed non-BHPBIO groundwater licence holders within the groundwater model catchment boundaries of the Jimblebar Borefield. The nearest non-BHPBIO groundwater licence holder within 30km of Jimblebar Borefiled is a bore owned by Pilbara Chromite Pty Ltd. It is located 17.6km to the south east of the Jimblebar borefield. The licence groundwater allocation is 500,000kL per year (GWL 107191).

### 2.4.2 BORE SOURCES

Within the study area there are two bores, Mindoona Bore and Cubana Well, they are not licensed and their operational status is unknown. Their distance from the borefield is more than 6 km south-east and south respectively. Predicted drawdown impact on these bores is discussed in section 5.9.2, however the influence of the borefield at these distances on these sources is considered to be negligible.

### 2.4.3 SETTLEMENTS

It unlikely that the Jigalong Aboriginal Settlement will be impacted by groundwater abstraction from the Jimblebar borefield since this the settlement is located 20km to the South-east of the Jimblebar borefield.

### 2.4.4 GROUNDWATER DEPENDENT VEGETATION

There are no groundwater dependent vegetation in the vicinity of the Jimblebar borefield as the current rest water level is approximately in excess of 50m below ground level (bgl).

# 3 EXISTING JIMBLEBAR BOREFIELD

The Jimblebar borefield is used to supply water for the Wheelarra Hill Mine. The current borefield comprises 6 production bores: Geo 5, Geo6R, Geo7, Geo9, Geo10 and Geo11, and nine observation bores: JM1, JM3, JM4, JM5, JM6, JM7, JM8, JM9 and JM10.

Geo5 has not been used since November 2006. Geo6 was damaged in September 2001, and is no longer in use. Bores Geo6R (replacement for Geo6) and Geo11 were installed in April and May 2004. Bore Geo7 supplies potable water to the mine, while the remaining production bores supply water for dust suppression and processing.

Bores Geo6R, Geo9, Geo10, and Geo11 are located near the middle of the valley and abstract water from the alluvial sequence and (apart from Geo9) also from the underlying weathered basement (believed to be weathered dolomite of the Wittenoom Formation). Bores Geo5 and Geo7 are situated closer to a low ridge to the south of the main valley and intersect the Marra Mamba and Jeerinah Formations respectively. The Brockman Iron Formation forms the ridge to the north where the current Wheelarra Hill Mine operations are sited.

Current hydrogeological information indicates that the local groundwater flow in the area of the existing borefield is sympathetic to the surface hydrology with minor flow coming in from the north and south and the main flow direction being to the east beneath the valley. The aquifer systems are recharged by rainfall runoff infiltration over the valley and associated ridges and via infiltration through the creek during flood events.

A schematic cross-section of the aquifer system is presented in Figure 3.1.

Details of the bore location Figure 3.2 and construction are presented in the following Tables 3.1 and Table 3.2.

## 3.1 GROUNDWATER LICENCES

There are currently two GWLs at Jimblebar, GWL 158795(3) and GWL 166329(1) for the tenement property reference AM70/266 – Jimblebar Operation.

GWL 166329 (1) was issued in April 2008 and expires on April 2010. The licence has been issued for the purposes of supplying water to exploratory drilling operations, the license has an annual allocation of 5,000kL.

GWL 158795(3) was issued in May 2008 and expires on the 11th May 2010. The licence was issued for the purposes of dust suppression, mineral ore processing and potable water supply purposes and has an annual abstraction allocation of 1,650,000kL. A copy of the current groundwater licence is presented in Appendix A

As a condition of licence GWL 158795(3) on Annual Aquifer Review must be submitted to the Department of Water (DoW). The Annual Aquifer Review is to include comparisons of actual drawdown figures against modelled drawdowns; details on abstraction history, water use, water level, water quality, aquifer performance and wellfield performance.

## 3.2 GROUNDWATER LEVELS

Groundwater levels from the Jimblebar borefield are tabulated in Appendix B (Figure B1).

In general terms the water levels at observation bores adjacent to production bores (ie JM1, JM3, JM7 and JM8) have remained relatively unchanged over the review period, except for a small decline at the start of the reporting period in JM8 which now appears to have stabilised.

**Figure 3.1: A Schematic Cross-Section of the Aquifer System**

**Figure 3.2: Location of Jimblebar Borefield**

**Table 3.1: Jimblebar Production Bores Construction Details**

| Bore | Location Data | | | | | Drilling Data | | | | | | Construction Data | | | Geology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AMG84 Northing (m) | AMG84 Easting (m) | Mine Northing (m) | Mine Easting (m) | Top of Casing (mAHD) | Date Drilled | | Drilled Depth (mbgl) | Water Level (mbgl) | Date of WL Reading | Max Airlift Yield*2 (L/s) | Total Cased Depth (m) | PVC slots (mbgl) | PVC plain (mbgl) | Screened Units |
| | | | | | | Started | Finished | | | | | | | | |
| **Geo5** | 7409494 | 205987 | 9496 | 5987 | 529.16 | | | | | | | | | | Marra Mamba |
| **Geo6R** | 7409927.94 | 208700.07 | 9929.25 | 8698.63 | 520.61 | 12/05/04 | 24/05/04 | 172 | 54.43 | 05/07/04 | 14 | 165.5 | 57.5 – 165.5 | 0 – 57.5 | Tertiary alluvium and Dolomite |
| **Geo7** | 7409538 | 208755 | 9540 | 8754 | 521.77 | | | | | | | | | | Jeerinah |
| **Geo9** | 7409737 | 207839 | 9738 | 7838 | 522.79 | 17/10/89 | 25/10/89 | 110 | 57.85 | 26/10/89 | 2 | 104 | 62-104 | 0-62 | Tertiary alluvium |
| **Geo10** | 7409763 | 206864 | 9764 | 6864 | 524.26 | 1/2/98 | 10/2/98 | 155 | | | | 154.8 | 50-56; 78-95.8; 107.6-154.8 | 0-50; 56-78 95.8-107.6 | Tertiary alluvium and Dolomite |
| **Geo11** | 7410004.76 | 205812.58 | 10006.04 | 5812.79 | 527.34 | 24/04/04 | 03/05/04 | 171 | 65.59 | 09/07/04 | 10 | 167 | 102 - 167 | 0 - 65 | Tertiary alluvium and Dolomite |

**Table 3.2: Jimblebar Observation Bore Construction Details**

| Bore | Location Data | | | | | Drilling Data | | | | | | Construction Data | | | Geology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AMG84 Northing (m) | AMG84 Easting (m) | Mine Northing (m) | Mine Easting (m) | Top of Casing (mAHD) | Date Drilled: Started | Date Drilled: Finished | Drilled Depth (mbgl) | Water Level (mbgl) | Date of WL Reading | Max Airlift Yield*2 (L/s) | Total Cased Depth (m) | PVC slots (mbgl) | PVC plain (mbgl) | Screened Units |
| JEX1 | 7410002.12 | 205799.10 | 10003.4 | 5799.32 | 527.49 | 20/04/04 | 23/04/04 | 150 | 65.235 | 29/04/04 | 10 | Hole collapsed - uncased | | | - |
| JEX2 | 7410143.60 | 204894.99 | 10144.81 | 4895.74 | 529.63 | 06/05/04 | 08/05/04 | 168 | - | - | 1.0 | Hole collapsed - uncased | | | - |
| JEX3 | 7410185.64 | 204903.04 | 10186.83 | 4903.78 | 529.84 | 09/05/04 | 11/05/04 | 150 | - | - | 2.8 | Hole collapsed - uncased | | | - |
| JM1 | 7409654 | 206009 | 9655 | 6009 | 526.52 | | | 93 | | | | 93 | 87-93 | 0-87 | |
| JM2 | 7409931 | 207778 | 9932 | 7777 | 522.86 | | | 82 | | | | 82 | 76-82 | 0-76 | |
| JM3 | 7409719 | 208706 | 9720 | 8705 | 520.22 | | | 82 | | | | 82 | 76-82 | 0-72 | |
| JM6 | 7408502.97 | 207489.79 | 8505.094 | 7489.022 | 529.19 | | | 77 | | | | 77 | 64-76 | 0-64 | |
| JM7 | 7409489.29 | 206485.62 | 9490.863 | 6485.438 | 526.92 | | | 85 | | | | 84.6 | - | - | |
| JM8 | 7409946.28 | 207777.14 | 9947.581 | 7776.224 | 523.24 | | | 83 | | | | 83 | 71-83 | 0-71 | |

### 3.3 GROUNDWATER QUALITY

Field EC and pH for all operational production bores, with the exception of Geo11, from February 1997 to June 2008 are presented in Appendix B (Table B1).

Field pH readings indicate groundwater to be neutral to weakly alkaline, and have remained fairly stable

Field EC values and trends vary between the operational boreholes. Geo5 EC values ranged from 1320-2240µS/cm (although typically the levels have been between 1500µS/cm-1600µS/cm 2240 µS/cm was only recorded once in August 2006 and a subsequent value in October 2006 showed the EC to have decreased back to 1320µS/cm). Geo6 from 1300-1400µS/cm (decommissioned in September 2002), Geo6R 1060-1350µS/cm, Geo7 from 320-470µS/cm, Geo9 from 360-4200µS/cm and Geo10 from 1200-1750. EC values were relatively stable for Geo5, Geo6/6R and Geo10, although there was a very slight downward trend for Geo6R, Geo7 and Geo10 over the last two years. EC values for Geo9 seem to be quite stable between January 1998 and June 2005 with an average value of 1800µS/cm between July 2005 and April 2006. values are approximately 400µS/cm. During 2007 and 2008 EC values for Geo9 decrease from 2270µS/cm in July 2007 to 1380 in June 2008. Geo7 values are low in comparison to the other EC measurements recorded in the Geo bores, this is due to surface water influences from the creek bed located approximately 50m to the east of the bore.

The results of the laboratory analyses carried out during the reporting period are presented in Appendix B (Table B2). These results show groundwater in the Jimblebar area to be fresh (TDS general trend ranging from 150 and 1200mg/L).

According to the Australian Drinking Water Guideline health standards (NHMRC, 2004) there were occasional exceedances for the following parameters: Nitrate (No3) Cadmium (Cd), Chromium (Cr), and Nickel (Ni). These were:

- Nitrate (No3) – Bores Geo5 (June 2001) and Geo10 (June 2001);
- Cadmium (Cd) - Geo5 ( February 2007) and Geo6 (March 2008);
- Chromium (Cr) - Geo7 (February 1997);
- Nickel (Ni); Geo6 (March 2007).

Aesthetic values for the following parameters are exceeded (marginally) during the course of the review period.

- Total Dissolved Solids (TDS) and Hardness; Geo5, Geo6R, Geo9, Geo10, Geo11.(All samples between 1997 to 2008);
- Chlorine (Cl); Geo9 (Feb Dec 00, Jun 02, Dec 02, May 05, June Sept Dec 06, Apr 07 and Apr 08) and Geo10 (Apr 08);
- Sulphate (SO4); Geo9 (Jun 02 and Apr 07);
- Sodium (Na); Geo6R (Mar 08) Geo9 (Jan 98, Dec 00, June 02, Sept, Dec 06, Apr 07, Apr 08);
- Manganese (Mn); Geo6R (Mar Nov 97, Jan 98 to Jun 01, Apr 07 to Apr 08) Geo9 (Jan 98 to Jun 00, Dec 01 and Dec 02) and Geo10 (Apr 08);
- Aluminium (Al); Geo5 (Mar 98) Geo6 (Feb 00) and Geo9 (Mar 98).

### 3.4 PERFORMANCE

There are no available pumping water level data for the production bores, but monthly production rates are shown in Appendix B (Figure B2).

There have been no reported pump failures due to burnt out motors caused by excessive groundwater drawdown. Assuming no decline in bore efficiencies, it is considered that the borefield can also sustain current and even higher production rates into the future.

# 4 CURRENT JIMBLEBAR OPERATING STRATEGY

## 4.1 INTRODUCTION

Groundwater abstraction at the Jimblebar borefield is conducted in accordance with the GWL operating strategy for Jimblebar. The duration of this operating strategy is dependent on the mine plans. At present it is estimated that the strategy will be in use for approximately 14 years.

The GWL Operating Strategy for Jimblebar includes the following:

- general groundwater licence information;
- a description of the groundwater abstraction methods used;
- a description of the general and site-specific administrative requirements;
- operating rules for the Borefield;
- monitoring requirements (including data collection, data verification and management, data review, use of data and reporting);
- the principles of water use efficiency that are applied during the operation of the borefield.

As discussed in section 3.1 BHPBIO is required to submit a monitoring report (Aquifer Review) to the DoW by the 30th September each year. The report details the results of the monitoring for that water year (1st July to 30th June). Three years of data are presented graphically and the current year's data are presented in tabular format. The report text focuses on the current water year, however, comments are made of apparent trends over the three year report period. A triennial report is also submitted every 3 years (due 30th July 2010). Data are presented graphically in the triennial report with the previous three year's data also presented in tabular format. The report text focuses on the current triennial period, however, comment is made to any apparent long term trends.

## 4.2 OPERATING RULES

BHPBIO currently has a groundwater allocation of 1,650,000 kL per annum.

Table 4.1 presents the maximum recommended pumping rates for each bore and the average expected monthly / annual abstraction. Water meters are required to be re-calibrated every 3 years.

**Table 4.1: Pumping Rates**

| Bore | Maximum Recommended Pumping Rate (kL/d) | Planned Monthly Maximum Abstraction (kL) | Planned Annual Abstraction (kL) |
|---|---|---|---|
| Geo 5 | 470 | 0** | 0 |
| Geo6R | 2,000 | 60,000 | 720,000 |
| Geo 7 | 270 | 830 | 9,960 |
| Geo 9 | 350 | 3,000 | 36,000 |
| Geo 10 | 2000 | 15,000* | 180,000 |
| Geo11 | 2,000 | 58,670 | 704,040 |
| Total | 7,090 | 137,500 | 1,650,000 |

* Factored down from maximum recommended rate to allow for operational factors.

** Standby bore

## 4.3 MONITORING

Groundwater monitoring is currently carried out and reported to the DoW annually, in accordance with the following monitoring programme (Tables 4.2 and 4.3).

**Table 4.2: Current Monitoring Programme**

| Parameter | Monitoring / Sampling Site | Frequency | Monitored By | Reported To |
|---|---|---|---|---|
| Abstraction | Geo5, Geo6R, Geo7, Geo9, Geo10 and Geo11 | Monthly with annual total | Macmahons | HSEC DMS |
| Water Use | Flow Meters#: WCR001 | Monthly | Macmahons | HSEC DMS |
| Water Levels | Geo5, Geo6R, Geo7, Geo9, Geo10 and Geo11<br>JM1, JM3, JM6, JM7 and JM8 | Monthly | Macmahons | HSEC DMS |
| Salinity (EC) and pH | Geo5, Geo6R, Geo7, Geo9, Geo10 and Geo11 | Monthly | Macmahons | HSEC DMS |
| Hydrochemistry* | Geo7 | Quarterly | Macmahons | HSEC DMS |
| Hydrochemistry* | Geo5, Geo6R, Geo9, Geo10 and Geo11 | Annually | Macmahons | HSEC DMS |

# Total volumes for categories of water use reported to DoW, not actual meter readings.
*pH, EC, TDS, Na, Ca, Mg, K, Cl, SO4, HCO3, NO3, Pb, Cu, Mn, Zn and Fe.

In addition, the following monitoring is conducted as background data for geotechnical dewatering purposes.

**Table 4.3: Production Monitoring Programme**

| Parameter | Monitoring / Sampling Site | Frequency | Monitored By | Reported To |
|---|---|---|---|---|
| Water Levels | JM9 and JM10 | Monthly | Macmahons | HSEC DMS |

## 4.4 DATA COLLECTION

Macmahons is responsible for the collection of monthly water level, abstraction and pH/EC data.

pH and EC meters are calibrated before each monitoring round and water samples for these readings are taken when the pump is operational. If a bore is not operational at the time of the round (but is generally operational), it will be returned to later.

All flow meters are re-calibrated every two years.

Water samples for hydrochemical analysis are collected quarterly from the potable water supply bore(s) and annually from all other operational production / dewatering bores. The annual samples and final quarterly samples are collected between March and May to allow sufficient time for analyses and reporting.

### 4.4.1 DATA VERIFICATION & MANAGEMENT

All monthly monitoring data are entered directly in to into the BHPBIO Health, Safety, Environment and Community Data Management System (HSEC DMS) on a monthly basis (by the Macmahons Environment Officer). Readings that appear erroneous are re-measured by Macmahons. Should there be any unexpected data trends, Macmahons informs the Hydro Group immediately. The data are reviewed on a quarterly basis by the Newman Hydrogeologist.

Macmahons reports the hydrochemical analysis results to the Hydro Group as soon as they are received for verification. If the analyses appear erroneous, the bore(s) in question is re-sampled. Monthly rainfall totals (July to June) are forwarded to the Hydro Group in the first week of July each year, together with all Jimblebar monitoring data for the water period (July to June).

#### 4.4.2 DATA REVIEW

The Hydro Group reviews all site data quarterly and at the end of the water period (July each year). The nominated monitoring sites and monitoring frequencies listed in Table 4.2 are reassessed and confirmed as part of each annual review.

#### 4.4.3 USE OF DATA / REPORTING

The data are used for the preparation of the Annual or Triennial Aquifer Review (prepared by BHPBIO).

### 4.5 ENVIRONMENTAL WATER PROVISIONS

There are no environmental conditions, limits or requirements associated with GWL158795(3) with respect to groundwater abstraction.

### 4.6 CONTINGENCY PLANS

Data to date has shown that groundwater abstraction has only a very minor and local impact on the aquifers. As such, there is no requirement for a contingency plan to cover a declining resource.

Should individual bores fail or decline in yield (eg due to collapse, decline in efficiency etc), they will be replaced or redeveloped as required. Before any bore is replaced an application for a Section 26D CAW will be submitted to DoW for approval.

### 4.7 WATER USE EFFICIENCY

Appendix C presents the current water circuit diagram for Jimblebar. The abstracted water is used for dust suppression, ore handling and, after treatment at an RO plant, the workshop. No excess water is pumped or discharged. Regular checks are made along the water supply system for leaks.

The water balance (in total annual volumes) is presented each year in the Annual Aquifer Review. This water balance is assessed by the Hydro Group and any opportunities for maximising water efficiency and reducing overall water consumption will are identified and implemented where practical.

BHPBIO has set a company wide target to achieve a 10 percent improvement in the ratio of water recycled/reused to high quality water consumed by 30 June 2012. The BHP Billiton Sustainability Policy has been developed to improve water use efficiency at all port and inland sites in order to achieve this target. A full water use audit is completed at the Jimblebar site every six months, with data collected used to identify losses and areas for improvement.

Storm water runoff at the site is collected into turkeys nests and sediment traps and is used on site. In addition, new facilities are being constructed on site that will allow the capture of runoff from the crushing and screening plant to enable that water to be recycled back into the water circuit.

### 4.8 COMMITMENTS

Table 4.4 summaries BHPBIO's current commitments associated with groundwater abstraction at the Jimblebar borefield.

**Table 4.4: Summary of BHPBIO's Commitments**

| Jimblebar Commitments | |
|---|---|
| 1 | BHPBIO will review the Operating Strategy on an annual basis and revise it if necessary. If revised, a copy will be submitted to the DoE. |
| 2 | BHPBIO will submit a monitoring report (Aquifer Review) to the DoE by the 30th September each year. The report will detail the results of the monitoring for that water year (1st July to 30th June). Three years of data will be presented graphically whilst only the current year's data will be presented in tabular format. The report text will focus on the current water year, however, comment will be made of any apparent trends over the three year period. Every three years a Triennial Aquifer Review will be submitted. This will present and comment on the previous three years of monitoring data. |
| 3 | BHPBIO will not exceed the maximum draw of 1,650,000 kL per annum from the Jimblebar Wellfield. |
| 4 | BHPBIO will monitor the following:<br>water levels in the production / dewatering bores and nominated observation bores on a monthly basis;<br>abstraction rates from each production / dewatering bore and/or sump on a monthly basis;<br>water use on a monthly basis (ie potable, mine processing, dust suppression, discharge);<br>salinity (EC) and pH levels at operational production / dewatering bores and/or sumps on a monthly basis;<br>water quality at operating production / dewatering bores (ie hydrochemical analyses of water samples from these bores) on an annual basis (quarterly for potable bores). |
| 5 | BHPBIO will maintain a structured data collection and management system with an on-going verification and review process. |
| 6 | BHPBIO will maintain a current water circuit diagram for Jimblebar which will be included in the Annual / Triennial Aquifer Review. |
| 7 | Regular checks will be made along the water supply system for leaks etc |
| 8 | The water balance will be assessed on an annual basis and any improvements to water efficiency will be investigated. |

## 4.9 WATER MANAGEMENT PLAN

Ministerial Statement of Approval No. 683 requires BHPBIO to prepare and implement a Water management Plan at the Wheelarra Hill Mine. The current Version of the Water Management Plan was approved in 2006. It includes the following:

- Jimblebar borefield licensing arrangements;
- baseline monitoring data on groundwater levels and quality within the Jimblebar Borefield;
- the monitoring programme for the Jimblebar borefield and mine project areas (including ground and surface water measurement criteria, quality of groundwater; measurement sites, parameters, frequency; data verification and management procedures; data review/interpretation procedures; data reporting mechanism);
- effects of drawdown on vegetation communities and stygofauna within the project area, and remedial action if impacts are detected;
- the principles of water use efficiency to be applied at the mine during operation of the borefield;
- the effects of climate change on the borefield.

# 5 ASSESSMENT OF THE PLANNED GROUNDWATER ABSTRACTION INCREASE

## 5.1 INTRODUCTION

BHPBIO has forecasted a predicted water demand varying from between 2000kL/d to 11800kL/d over the next 14 years of mining operations at the Wheelarra Hill Mine. This includes a predicted demand of 25kL/day as a potable supply for camp purposes. It is anticipated that the demand will initially be drawn from bores Geo5, Geo6R, Geo7, Geo9, Geo10 and Geo11, with two new proposed bores constructed and developed to meet the higher demands in the later years. To ascertain the sustainability of the aquifer at Jimblebar, numerical groundwater modelling has been undertaken.

## 5.2 GROUNDWATER MODELLING SCOPE OF WORK

To assess the predicted impacts of the planned increase in water demand from the Jimblebar borefield, the following was undertaken:

- The model calibration data set was updated to include groundwater monitoring data (groundwater pumping and water levels) collected between July 2006 and June 2008;
- The calibrated model was used to assess the sustainability of the proposed water demand;
- Model predictions were used to assess the potential impact of the proposed increases in groundwater abstraction on both local and regional groundwater systems.

## 5.3 GROUNDWATER DRAWDOWN MODEL

Groundwater models were developed to predict the groundwater drawdown depth and extent. The models used are described below.

Predicted Groundwater Drawdown Depth (Numerical Model)

The groundwater model was developed as a transient, MODFLOW 96, finite difference model using the Processing Modflow Pro Graphical User Interface (IES Inc, 2005). A steady state model was produced using historical data and the resultant heads were used as the initial heads in the transient model. The transient model ran from March 1994 to June 2006. The hydrogeology was represented as three layers with grid squares of 100m. The layers are shown below in Table 5.1.

The top of the groundwater model was set at 572m AHD. The base of layers 1 and 2 were assigned consistent with hydrogeological drilling data from the site. The base of bed rock (layer 3) was set at 250mAHD as below that depth the bedrock is not thought to be part of the effective aquifer system. The boundaries of the model were based on the extent of the surface water catchments. The model set up is shown schematically in Figure 5.1.

Following a consideration of available data, aquifer properties were assigned to areas of the model that were considered typical of the geological unit. The majority of data was derived from bulk permeability testing of the on site abstraction boreholes.

**Figure 5.1: Schematic Model Set-up**

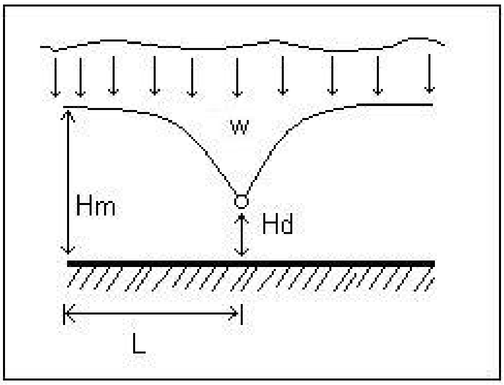
**Table 5.1: Model layers**

| Layer | Description | Thickness |
|---|---|---|
| Layer 1 (L1) | Tertiary Formation aquifer, silt to gravel grade alluvium and weathered Marra Mamba formation surrounded by relatively impermeable bedrock | Up to 172m thick, base at 400mAHD |
| Layer 2 (L2) | Wittenoom Dolomite aquifer and weathered Marra Mamba formation surrounded by relatively impermeable bedrock | 100m thick, base at 300mAHD |
| Layer 3 (L3) | relatively impermeable competent bedrock | 50 metres, base at 250mAHD |

**Predicted Groundwater Drawdown Extent (Analytical Model)**

The weathered Wittenoom Dolomite is considered a sub-vertical geological unit of relatively higher permeability. The unit is bounded to the north and south by low permeability basement rocks (i.e. Brockman Iron Formation and Marra Mamba Formation). As such, conceptually, this can be described as a 'strip aquifer', where by a pumping bore will initially experience radial flow until it hits the impermeable boundaries and flow then essentially coming from the east and west (Figure 5.2).

To determine the extent of maximum drawdown in this 'strip aquifer' the Dupuit Equation (Charbeneau, 2000) for steady state flow for unconfined aquifer was used. The assumptions to this equation are, the flow is mainly horizontal and the flow is proportional to the slope of water table. The Dupuit's Equation is one dimensional steady state equation and thus, the solution to the equation is considered to give an over estimation result because of the steady state solution. According to the Dupuit's equation the distance (L) from the bore field, where the maximum drawdown extent (i.e. 0 m drawdown) would be encountered can be estimated by the equation as:




$$L = \frac{1}{2}\sqrt{\frac{4K}{W}\left(Hm^2 - Hd^2\right)}$$

*L* = is the distance from the bore field.

*Hm* = is the head at a distance L from bore field.

*Hd* = is the head at bore filed.

*K* is the hydraulic conductivity

*W* is the distributed recharge flux.

The parameters used in the Dupuit's equation (viz., *K, W, Hd and Hm*) were derived from the results of the numerical model.

## 5.4 MODEL SET UP

The model developed for Jimblebar includes features to simulate:

- Rainfall recharge to the aquifer system;
- Groundwater inflow to and outflow from the modelled area;
- Groundwater pumping from the Wittenoom Dolomite, Tertiary and Mineralised Marra Mamba aquifers.

**Figure 5.2: Conceptual Model of Weathered Wittenoom Dolomite Aquifer**

## 5.5 MODEL EXTENT AND GRID

The model domain extends 22,200m east to west; and 20,000m north to south. The model and all associated data have been plotted using the GDA 94 Zone 51 coordinate system. Coordinates for the four corners of the rectangular model domain are detailed in Table 5.2 below.

The extent, boundary conditions and general features of the groundwater model are shown in Figure 5.3. The model has a uniform grid size of 100m distributed over 222 columns and 200 rows.

**Table 5.2: Model Domain**

| | **Easting*<br>(m)** | **Northing*<br>(m)** |
|---|---|---|
| Top left | 199000 | 7416000 |
| Top right | 221200 | 7416000 |
| Bottom left | 199000 | 7396000 |
| Bottom right | 221200 | 7396000 |

*GDA 94 Zone 51

## 5.6 DATA SUMMARY

A summary of the key data used to set up the numerical model is provided in Table 5.3.

**Table 5.3: Data Summary**

| **Parameter** | **Data source** |
|---|---|
| Topographic levels | Ground elevation data from topographic maps |
| Potential aquifer horizons | In situ deduced from boreholes (Aquaterra , 2006) |
| Water levels | Measured data (Aquaterra, 2006) |
| Rainfall | Rainfall data from Newman and Jimblebar stations |
| Recharge | Best estimate from model calibration |

**Figure 5.3: Model Extent and Boundary Conditions**

## 5.7 GROUNDWATER INFLOW AND OUTFLOW

### 5.7.1 RAINFALL RECHARGE

Rainfall recharge to the model was applied as a proportion of average annual rainfall (310 mm per year for Newman Station) for the steady state model. The long term average annual rainfall data from Newman Meteorological Station (located 50km west of Jimblebar), was used as rainfall data for Jimblebar station is available only from July 1995. Recharge to the model domain was applied as follows:

- 25.5mm/year to the Tertiary Alluvium and Marra Mamba Formations;
- 0.1mm/year to the rest of model domain.

The modelled rainfall recharge distribution is shown in Figure 5.4.

The transient or time variant model used the same proportion as the steady state model of recorded monthly rainfall (from Jimblebar station) as recharge. Where monthly rainfall record for Jimblebar Station does not exist (from early 1994 to mid 1995), monthly rainfall data were used from the Newman Station for the transient calibration.

### 5.7.2 GROUNDWATER INFLOW

All model boundaries were set consistent with catchment boundaries and assigned as the no flow type (as shown in Figure 5.1). Apart from the incident rainfall, groundwater inflow occurs in the upper reaches of the catchment located to the south of the model domain. This inflow has been modelled as a fixed inflow to the model and was derived from the steady state calibration by specifying a head value of 572mAHD. This head value of 572mAHD was based on a bore which is located close to the boundary and recorded water level of 571.4mAHD.

### 5.7.3 GROUNDWATER OUTFLOW

Groundwater outflow occurs to the north of the modelled area. This is also modelled as a fixed outflow. The amount of out flow was derived from the steady state calibration by specifying a head value of 450mAHD, based on the regional gradient at the downstream model boundary (refer Figure 5.3).

## 5.8 MODEL CALIBRATION

### 5.8.1 INTRODUCTION

Model calibration is the process by which the independent variables of a model are adjusted, within realistic limits, to produce the best match between simulated and measured data (usually obtained from groundwater level monitoring). This process typically involves refining the aquifer properties and boundary conditions of the model to achieve the desired degree of correlation between the observed data and model simulation.

### 5.8.2 STEADY STATE CALIBRATION

During steady state model calibration, aquifer parameters (horizontal and vertical hydraulic conductivity) were specified consistent with available data and the applied aquifer recharge was varied until a satisfactory match was obtained between water levels measured in the model domain and those predicted by the model. This was completed to provide initial conditions for the transient model.

The calibrated steady state water balance is presented below in Table 5.4

**Figure 5.4: Modelled Recharge Distribution**

**Table 5.4: Calibrated Steady State Water Balance (kL/d)**

| Water Balance Component | In | Out |
|---|---|---|
| Recharge | 2180 | 0 |
| Groundwater Inflow | 30 | 0 |
| Groundwater Outflow | 0 | 2210 |
| Total | 2210 | 2210 |

### 5.8.3 TRANSIENT CALIBRATION

As the Jimblebar borefield has been operated since early 1995, operational data (groundwater pumping and water level monitoring data) are available to allow a transient or time varying model calibration. The groundwater model is calibrated against groundwater monitoring data collected between March 1994 and June 2008. During the transient calibration process aquifer hydraulic conductivity and storage parameters were varied until a satisfactory match was achieved between measured and modelled monitoring data.

Calibrated aquifer parameters are presented in Table 5.5. Aquifer parameter distributions for model Layers 1, 2 and 3 are presented in Figures 5.5 to 5.7.

**Table 5.5: Calibrated Aquifer Parameters**

| Aquifer Unit | Horizontal Hydraulic Conductivity (m/d) | Vertical Hydraulic Conductivity (m/d) | Specific Yield | Storage Coefficient |
|---|---|---|---|---|
| Tertiary Formation (Layer 1) | 2 | 0.2 | 0.05 | $1\times10^{-4}$ |
| Marra Mamba Formation (Layers 1 and 2) | 2 | 2 | 0.05 | $1\times10^{-4}$ |
| Wittenoom Dolomite (Layer 2) | 4 | 4 | 0.05 | $1\times10^{-4}$ |
| Wittenoom Formation (Layer 3) | 0.01 | 0.01 | 0.001 | $1\times10^{-4}$ |
| Jeerinah Formation (all layers) | 0.03 | 0.03 | 0.001 | $1\times10^{-4}$ |
| McRae Shale (all layers) | 0.01 | 0.01 | 0.001 | $1\times10^{-4}$ |
| Rest of the bedrock | 0.001 | 0.001 | 0.001 | $1\times10^{-4}$ |

**Figure 5.5: Aquifer Parameter Distribution Layer 1**

**Figure 5.6: Aquifer Parameter Distribution Layer 2**

**Figure 5.7: Aquifer Parameter Distribution Layer 3**

The locations of the monitoring bores used for the model calibration are shown in Figure 5.4. Calibration hydrographs showing measured and modelled water level responses are shown in Figure 5.8. Measured water level trends are generally reasonably well simulated. A good match between measured and observed water levels is predicted at observation bores JM1, JM7 and JM8 (Figure 5.8) for the duration of the calibration period. The water level trend is reasonably well matched at JM3 (Figure 5.8) until the end of 2000 however the model under predicts water levels by approximately 5 metres between mid 1995 and the end of 2000. From 2001 onwards the model continues to under predict water levels. Measured water levels at JM3 increase from 2000 to the end of the calibration period (mid 2008) by 1 metre, while modelled water levels decrease by around 3 metres. Hydrogeological features which cannot be justified on the basis of current understanding have not been included in the model to force model calibration at JM3. Furthermore the under prediction of water levels adds a degree of conservatism to model predictions.

The model predicted water balance for June 2008 is presented in Table 5.6.

**Table 5.6: Calibrated Transient Water Balance for June 2008 (kL/d)**

| Water Balance Component | In | Out |
|---|---|---|
| Storage | 847 | 466 |
| Recharge | 3410 | 0 |
| Groundwater Inflow | 29 | 0 |
| Groundwater Outflow | 0 | 2082 |
| Pumping | 0 | 1738 |
| Total | 4286 | 4286 |

## 5.9 MODEL PREDICTION SCENARIOS

### 5.9.1 PREDICTION RUNS

It is planned that a water demand varying between 2000kL/d to 11800kL/d will be required for a period of 14 years from the Jimblebar borefield. It is anticipated that the demand will initially be drawn from bores Geo5, Geo6R , Geo7, Geo9, Geo10 and Geo11,) with two new proposed bores constructed and developed to meet the higher demands in the later years. The rates (Table 5.7) for each bore used in the prediction runs were in proposition with demand and were in accordance with Source Reliable Output (SRO) analysis for each bore.

**Table 5.7: Pumping Abstraction and Bore Rates for Year 2008 to 2020 (kL/d)**

| Year | Demand | Pumping rate for Bore Geo7 | Pumping rates for all other Bores |
|---|---|---|---|
| 2008 - 2009 | 2,000* | 333 | 333 |
| 2009 - 2010 | 2,700 | 450 | 450 |
| 2010 - 2011 | 7,200 | 900 | 900 |
| 2011 - 2012 | 11,800 | 1000 | 1543 |
| 2012 - 2013 | 11,800 | 1000 | 1543 |
| 2013 - 2014 | 11,800 | 1000 | 1543 |
| 2014 - 2015 | 11,800 | 1000 | 1543 |

| Year | Demand | Pumping rate for Bore Geo7 | Pumping rates for all other Bores |
|---|---|---|---|
| 2015 - 2016 | 11,800 | 1000 | 1543 |
| 2016 - 2017 | 11,800 | 1000 | 1543 |
| 2017 - 2018 | 11,800 | 1000 | 1543 |
| 2018 - 2019 | 11,800 | 1000 | 1543 |
| 2019 - 2020 | 11,800 | 1000 | 1543 |

* yearly average based on recorded months July to October 2008

The calibrated groundwater model was used to assess the capacity of the existing borefield to supply the increased water demand. Groundwater pumping from the Jimblebar borefield was modelled using the evapo-transpiration package in Modflow to incorporate constraints consistent with an operational borefield. This package allows maximum groundwater abstraction from a bore if the modelled water level is above a specified depth. Pumping decreases if there is a significant water level decrease. For the current prediction it was assumed that if modelled water levels decrease to less than 350mAHD (i.e. 50 % depletion of the Wittenoom Dolomite aquifer) pumping decreases, reducing to zero if water levels are reduced a further 5 metres (i.e. to 345mAHD).

For the prediction run it was assumed that recharge to the aquifer system was applied at proportions consistent with the transient calibration, assuming average annual rainfall of 310mm per year (long term annual average for Newman). This provides an element of conservatism to model predictions as no high rainfall/recharge events are assumed to occur over the 14 year prediction period.

### 5.9.2 RESULTS

#### Predicted Groundwater Drawdown Depth (Numerical Model)

Pumping the existing 6 bores and two new bore as mentioned above, to provide a total abstraction varying between 2000kL/d and 11800kL/d, is predicted to be sustainable for the 14 year demand period. A graph showing predicted drawdown over the 14 year mine life at monitoring bores JM1, JM2, and JM7 is presented in Figure 5.9. Over the 14 year prediction period water levels are predicted to drawdown to a maximum of 45 m close to the centre of the borefield. The predicted drawdown is not expected to draw water levels below the top of the Wittenoom Dolomite aquifer.

#### Predicted Groundwater Drawdown Extent (Analytical Model)

The parameters used in the analytical model (i.e. Dupuit's equation) were determined by the numerical model; where $K$ = 4m/d, $W$ = 25.5mm/d $Hd$ = 0m and $Hm$ = 45m (i.e. predicted drawdown depth).

The result of analytical model indicates that the maximum extent of the zero drawdown contour would be encountered at approximately 10.7 km from the 45m drawdown contour in both the east and west directions. The extent of drawdown to the west may be restricted by the intervening geology (i.e. Marra Mamba Iron Formation). Drawdown would be restricted north and south of the Jimblebar borefield by the geological boundaries of the Brockman Iron Formation (north – Wheelarra Hill) and Granite Formation (located approximately 2km and 1km to the north and south respectively). Figure 5.10 shows the conceptual groundwater drawdown extent.

Potential Impacts on Surface Hydrology

Local surface water flows drain along Copper Creek in a north easterly direction into Jimblebar Creek. Copper Creek and Jimblebar Creek are emphemeral watercourses which only flow following large rain events.

The local groundwater table is located more than 50m below the ground surface and is not considered to support surface water flow in the area. As a result, the potential groundwater drawdown impacts as a result of the additional groundwater abstraction at the Wheelarra Hill Mine would not affect surface water flows in Copper Creek or Jimblebar Creek.

**Figure 5.8: Transient Calibration Hydrographs**

**Figure 5.9: Base Case Predicted Water Levels**

**Figure 5.10: Conceptual Maximum Drawdown Contour**

## 5.10 SENSITIVITY ANALYSIS

A sensitivity analysis was performed to assess the potential variability in borefield performance under a range of conditions that may be expected but not necessarily supported by the calibrated model. The sensitivity analysis can be used to provide some confidence limits about the predictions. The parameter values for the sensitivity analysis are lower than those adopted for the base case prediction run and provide further conservatism in water supply predictions. The following sensitivity runs were carried out for predicted groundwater inflows assuming the base case recharge conditions:

**Sensitivity Run 1**

- Horizontal and vertical hydraulic conductivity of the Wittenoom Dolomite in layer 2 decreased by half from 4m/d to 2m/d.

**Sensitivity Run 2**

- Horizontal hydraulic conductivity of the Tertiary Formation in layer 1 decreased by half from 2m/d to 1m/d.

**Sensitivity Run 3**

- Specific yield of Wittenoom Dolomite in layer 2 decreased by half from 0.05 to 0.025.

**Sensitivity Run 4**

- Specific yield of the Tertiary Formation in layer 1 decreased by half from 0.05 to 0.025.

**Sensitivity Run 5**

- Storage coefficient of the Wittenoom Dolomite in layer 2 decreased by half from $1x10^{-4}$ to $5\times10^{-5}$.

Predicted water levels at monitoring bores JM1 and JM8 for all sensitivity runs considered are presented in Figure 5.11. The results are summarised as follows:

**Run 1**

- A reduction in horizontal and vertical hydraulic conductivity of the Wittenoom Dolomite aquifer (layer 2) from 4m/d to 2 m/d is predicted to result in an increased drawdown of close to 5.5 metres at JM1 and about 10 meters at JM8.

**Run 2**

- A reduction in horizontal hydraulic conductivity of the alluvium from 2m/d to 1m/d is not predicted to have significant impact on the results with predicted water levels at JM1 and close to 1 meter increase in drawdown at JM8.

**Run 3**

- A reduction in unconfined storage (or specific yield) for the Wittenoom Dolomite of layer 2 is not predicted to have any significant impact on model results as the aquifer remains confined during the 14 year projected demand period.

**Run 4**

- A reduction in the unconfined storage (or specific yield) of the Tertiary alluvium is predicted to have the greatest impact on model results. Predicted drawdown increase to approximately 18 metres for both observation points considered, with water levels falling below the top of the Wittenoom Dolomite aquifer by about 10 meters at JM8. The water level at JM1 is just at the top of the aquifer, with modelled results indicating water levels to be approximately 3 metre below the top of Wittenoom Dolomite.

**Run 5**

- A reduction in the confined storage of the Wittenoom Dolomite is not predicted to have any significant impact on model results.

In all sensitivity runs considered the projected water demand is still sustainable over the 14 year prediction period.

**Figure 5.11: Sensitivity Analysis**

# 6 CONCLUSIONS

A review of the observation bore hydrographs and groundwater salinity data shows that the current approved groundwater abstraction from the Jimblebar borefield has had no significant impact on local aquifer systems and non-BHPBIO groundwater users.

The numerical modelling indicated that the aquifers at Jimblebar can deliver the required demand for the proposed increase in water demand at the Wheelarra Hill Mine.

Over the 14 year modelled period water levels are predicted to drawdown up to 45 m close to the centre of the borefield. The predicted drawdown is not expected to draw groundwater levels below the top of the Wittenoom Dolomite aquifer.

The cone of depression (impact area) would be an elongated shape reflecting more transmissive characteristics of the weathered Wittenoom Dolomite formation. The result of analytical model indicates that the maximum extent of the zero drawdown contour would be encountered at approximately 10.7km from the 45m drawdown contour in both the east and west directions. The extent of drawdown to the west may be restricted by the intervening geology (i.e. Marra Mamba Iron Formation). Drawdown would be restricted to the north and south of the Jimblebar borefield by the geological boundaries of the Brockman Iron Formation (Wheelarra hill) and granite formation (located approximately 2km and 1km to the north and south, respectively).

The predicted drawdown as a result of the continued and proposed increased abstraction from the Jimblebar borefield, is not expected to have any additional significant impacts on local and regional water resources, to those which have already been observed to date.

Furthermore the current rest water level is approximately in excess of 50m bgl. It is therefore considered highly unlikely that their will be any groundwater dependent vegetation nor surface water flows in Copper Creek or Jimblebar Creek adversely affected by current and future groundwater abstractions.

Continuation of the monthly water level monitoring programme at the observation bores JM1, JM3, JM7 and JM8 is recommended to monitor the water supply and to provide a better estimate of aquifer parameters as the borefield is developed.

# 7 REFERENCES

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## APPENDIX A GROUNDWATER LICENCE

# APPENDIX B WATER LEVEL, WATER QUALITY AND ABSTRACTION DATA

## APPENDIX C JIMBLEBAR WATER CIRCUIT DIAGRAM



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