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BALMORAL SOUTH IRON ORE PROJECT

GROUNDWATER MANAGEMENT PLAN



Prepared for: International Minerals Ltd

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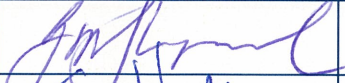
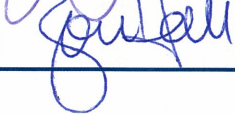
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GROUNDWATER MANAGEMENT PLAN

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EXECUTIVE SUMMARY

Background

International Mineral Ltd (IM) propose to develop the Balmoral South Iron Ore Project (Balmoral), an iron ore mining and processing operation located some 80km southwest of Karratha on the Northwest Pilbara coast (Figure 1). The project is one of three major magnetite orebodies, known as the Northern Block, George Palmer Orebody (Central Block) and Southern Block (Balmoral South). This report covers the development of the Balmoral South project only; development of the George Palmer Orebody is being undertaken independently by CP Mining.

The proposed open pit at Balmoral South is planned to go some 300 m below ground level over a mine life of approximately 24 years with an average mining rate of around 40 Mtpa of ore. This will put the final base of the pit approximately 290 m below the local and regional water table.

Dewatering of the orebody will be required with average dewatering rates in the order of 1,300 to 1,800 kL/day (15 to 21 L/s) over the life of the mine with peak dewatering requirements in the order of 2,500 kL/d (30 L/s). This equates to a total estimated dewatering volume of approximately 15 GL over the 24 year mining period.

The preferred water supply option is the development of a borefield to be installed in the Fortescue River alluvial aquifers adjacent to the Project, supplemented by dewatering discharge. An investigation programme is currently under way to determine the sustainable yield of the aquifer system, the results of which will be known later this year. It is currently planned to make any shortfall in supply (between Project demand and sustainable borefield/aquifer yield) by seawater desalination. However, prior to the development of a fallback seawater desalination system, other sources of water supply and water supply augmentation (wet season surface water harvesting, enhanced aquifer recharge etc) will also be assessed.

Potential Groundwater Impacts

Dewatering

The main pit will be excavated to around -280 mRL. Dewatering and depressurisation will be a critical component of mining. Dewatering is likely to be achieved via sump pumping and possible opportunistic construction of dewatering bores. Horizontal drain holes may be required to reduce pit wall pressures.

Dewatering of Balmoral South will induce drawdowns in groundwater levels around the pit. The lateral and vertical extent of the a "cone of depression" in groundwater levels will be dependent on the nature of local and regional aquifers, the depth of the pit and the "interference" effects of dewatering at the nearby Central Block. The results of groundwater modelling indicate that the cumulative impacts of both dewatering operations will result in one large elongate cone of depression.

Groundwater level drawdowns in close proximity to the mine will be at, or close to the deepest section of the pit (approx 300 mbgl). Predicted drawdowns extend 21 km northwards to the coast, 12 km southwards to the intersection with the Fortescue River and the upper reaches of the Fortescue River alluvial aquifer, 3.5 km to the west to the margin of the Fortescue River alluvial aquifers and 7 km to the east within the basement rock aquifers. Predicted drawdowns within the adjacent Fortescue River alluvial aquifers are minimal.

It should be noted that the model used predicts drawdowns within the basement rock aquifers around the mine sites and within the main Fortescue River alluvial aquifers. There are also minor (and largely seasonally intermittent) aquifers associated with shallow alluvium within several creeks that drain westwards through the mine areas towards the Fortescue River. While the drawdowns in the basement rock aquifers will induce some leakage from these shallow alluvial aquifers (depending on local aquifer properties), these aquifers will be recharged seasonally and will maintain some perched groundwater levels.

The dewatering induced drawdowns in groundwater levels will have some potential impacts on nearby groundwater users, predominantly pastoral wells as well as impacts on phreatophytic vegetation and other groundwater dependant ecosystems as follows:

- Other groundwater users: Bores and wells which tap the basement rock aquifers will experience interference drawdowns and some shallow wells close to the pit may dry up.
- Phreatophytic vegetation: There is the potential for the loss of vegetation within the cone of depression of groundwater level drawdowns. However, the vegetation risk assessments have been based on the predicted drawdowns in the basement rock aquifers and take no account of seasonal creek flows and perched water tables within the main creeks which support much of the vegetation at risk. Actual impacts on phreatophytic vegetation are expected to be significantly less than predicted.
- Subterranean Fauna: There is the potential for the localised impact on stygofauna, through the loss of habitat due to groundwater level drawdowns in both the basement rock aquifers and in the creek alluvium. However, as outlined above (phreatophytic vegetation), the actual groundwater level drawdowns in some areas are expected to be less than predicted. As a result, the loss of stygofauna habitat during mining is also expected to be less than predicted.

Pit Void

The final pit void will act as a groundwater sink in the long term with a pit lake level at around -230 mRL (some 240 m below the pre-mining water table, and some 40 m above the pit base). The potential impacts on groundwater levels will therefore be slightly less than during active dewatering. There will be some long term salinity build-up within the pit lake as a result of evaporative concentration. However, as the pit will remain a groundwater sink, this saline water will largely remain confined to the immediate pit area. There is the possibility of some very long-term density driven flow of hypersaline water at very low rates downwards out of the bottom of the pit. However, any such flow will be well below regional water tables and the major aquifer in the area (Fortescue River alluvium) and there will be no impact on useable groundwater resources.

TSF

It is not expected that the TSF will have any adverse impact on local or regional groundwater. In fact seepage from the TSF will likely result in the development of a local groundwater mound which would have the effect of reducing the potential drawdown impacts of pit dewatering on the two nearby station wells. TSF seepage is also likely to be of similar or better quality than local groundwater in the vicinity of the TSF.

Impact Management

Groundwater Level Monitoring

Comprehensive groundwater monitoring programmes will be implemented to measure the extent of drawdowns and to provide input to the assessment of impacts on other groundwater users, phreatophytic vegetation and stygofauna. Appropriate trigger levels have been developed for more detailed monitoring and analysis.

Maintenance of Supply

In the case of pastoral wells affected by dewatering it is proposed to ensure continuation of water supply to running small diameter feed line to water troughs at effected wells. In cases where water levels drawdowns are not too great the installation of deeper replacement wells may be an option.

Phreatophytic Vegetation

There will likely be some unavoidable loss of vegetation within the cone of depression in groundwater levels. Management strategies have been developed to minimise drawdown impacts including:

- Minimising the rates of drawdowns by the adoption of a steady vertical (ie depth) development progression in the mine plan.
- Monitoring vegetation and vegetation stress to assess actual versus predicted impacts in high drawdown areas.
- Establishment of trigger levels (in consultation with DEC) to identify and quantify impacts.
- Determining (in consultation with DEC and others) appropriate offset strategies to compensate for losses in phreatophytic vegetation.

Stygofauna

It is proposed to develop a Project specific Stygofauna Monitoring and Assessment Programme in conjunction with the DEC, which will include such things as:

- Continued monitoring of existing sampling bores (and others as agreed) to increase the current knowledge base on the distribution and diversity of stygofauna communities and habitat conditions (water quality etc).
- Research into the biology of the species involved to increase the knowledge base.
- Ongoing reporting to DEC and other stakeholders of results.
- Implementation of remedial actions to reduce impacts, should monitoring indicate a risk to stygofauna.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	ES-1
SECTION 1 - INTRODUCTION	1
SECTION 2 - EXISTING HYDROGEOLOGICAL REGIME.....	3
2.1 Geology	3
2.2 Regional Hydrogeology	4
2.3 Groundwater Investigations.....	5
2.4 Groundwater Flow.....	6
2.5 Groundwater Quality	6
2.6 Groundwater Users.....	7
2.6.1 Existing Groundwater Users	7
2.6.2 Future Groundwater Users	8
2.7 Groundwater Dependant Ecosystems.....	8
2.7.1 Phreatophytic Vegetation.....	8
2.7.2 Subterranean Fauna	10
SECTION 3 - MINE DEWATERING	12
3.1 Groundwater Modelling	12
3.1.1 Previous Work	12
3.1.2 Current Work	13
3.1.3 Modifications to Model Set Up	13
3.1.4 Model Calibration	14
3.1.5 Model Predictions	15
3.1.6 Results.....	15
3.2 Pit Dewatering.....	16
3.2.1 Inflow Results and Dewatering Options	16
3.2.2 Potential Inflow from Du Boulay Creek Alluvium	16
3.2.3 Impact on Local and Regional Groundwater Levels.....	17
3.3 Final Voids	18
3.3.1 Pit Lake Level	18
3.3.2 Impact on Groundwater Flows	18
3.3.3 Impact on Groundwater Quality	18
3.4 Impacts on other groundwater users.....	19
3.4.1 Existing Groundwater Users	19
3.4.2 Future Groundwater Users	19
3.5 Impacts on Groundwater Dependent Ecosystems	19
3.5.1 Phreatophytic Vegetation.....	19
3.5.2 Stygofauna.....	20
SECTION 4 - TAILINGS STORAGE FACILITY	21
SECTION 5 - IMPACT MANAGEMENT STRATEGIES.....	22
5.1 Groundwater Management	22
5.1.1 Dewatering Discharge.....	22
5.1.2 Pit Dewatering	22
5.1.3 Pit Void	23
5.1.4 Tailings Storage Facility.....	23
5.1.5 Groundwater Monitoring	24
5.1.6 Trigger Levels	25
5.1.7 Maintenance of Existing Supplies	26
5.2 Phreatophytic Vegetation Management	26
5.2.1 Impact Management	26
5.2.2 Monitoring and Trigger Levels.....	26
5.3 Stygofauna Management	27
5.3.1 Impact Management	27
5.3.2 Monitoring and Trigger Levels.....	27
5.4 Groundwater Operating Strategy	27
SECTION 6 - REFERENCES	28

TABLES

Table 1	Summary of Hydrogeological Properties	4
Table 2	Estimates of Bulk Permeability	5
Table 3	Calibrated Aquifer Parameters	14
Table 4	Model Predicted Water Balance (Steady State Calibration)	15
Table 5	Summary of Pastoral Wells Affected by Dewatering.....	22
Table 6	Proposed Groundwater Monitoring Programme	25

FIGURES

Figure 1	Site Location Plan
Figure 2	Geology
Figure 3	Schematic Cross Section
Figure 4	Groundwater Level Contour Map
Figure 5	Groundwater Salinity Contour Map
Figure 6	Durov Plot
Figure 7	Model Grid and Boundary Conditions
Figure 8	Model Calibration
Figure 9	Predicted Groundwater Inflows and Bench Heights
Figure 10	Drawdown Contour Map
Figure 11	Proposed Monitoring Bore Locations

APPENDICES

Appendix A	Permeability Testing
Appendix B	Laboratory Reports

SECTION 1 - INTRODUCTION

International Mineral Ltd (IM) propose to develop the Balmoral South Iron Ore Project (Balmoral South), an iron ore mining and processing operation located some 80km southwest of Karratha on the Northwest Pilbara coast (Figure 1). The project is one of three major magnetite orebodies, known as the Northern Block, George Palmer Orebody (Central Block) and Southern Block (Balmoral South). This report covers the development of the Balmoral project only; development of the Central Block is being undertaken independently by CP Mining.

The three orebodies are contained within the Brockman Iron Formation that outcrops as a series of basement ridges flanking the Fortescue River floodplain, extending from Balmoral north-northeastwards to Point James on the coast. The proposed open pit at Balmoral South is planned to go some 300 m below ground level over a mine life of around 20 years with an average mining rate of around 40 Mtpa of ore to produce 12 Mtpa product. This will put the base of the pit approximately 290 m below the local and regional water table and there will be groundwater inflows to the pit that will require some form of pit dewatering.

Ore will be processed on site and a port facility will be constructed at Cape Preston in conjunction with CP Mining from which to ship the concentrate, processed pellets and hot-briquetted iron. The preferred water supply option is the development of a borefield to be installed in the Fortescue River alluvial aquifers adjacent to the Project, supplemented by dewatering discharge. An investigation programme is currently under way to determine the sustainable yield of the aquifer system, the results of which will be known later this year. It is currently planned to make any shortfall in supply (between Project demand and sustainable borefield/aquifer yield) by seawater desalination.

This report presents an assessment of the potential impacts of mine activities (largely pit dewatering) on local and regional groundwater resources and any consequent impacts on groundwater dependent ecosystems, and presents impact management strategies. The report has been prepared in the format of a Groundwater Management Plan and includes the following:

- Outline of local and regional hydrogeology.
- Assessment of the site specific hydrogeological properties of the Southern Block Orebody.
- Prediction of groundwater inflows to the proposed mine throughout the life of the mine.
- Prediction of groundwater level drawdowns around the mine in response to dewatering at both Balmoral South and the Central Block.
- Assessment of the potential impacts of the mining and dewatering operations on groundwater quantity and quality.
- Assessment of the potential impacts of mining and dewatering operations on other groundwater users and Groundwater Dependent Ecosystems (GDE's).
- Prediction of the final pit void water levels and assessment of the potential impacts on groundwater flow and quality.
- Assess the cumulative impacts of dewatering operations from both Balmoral and Central Block operations.

- Groundwater and GDE management strategies including monitoring programmes, identification of trigger levels for further action and some impact management measures.

The above assessment does not consider the Balmoral South Project in isolation, but takes account of the cumulative impacts of both the Balmoral South and Central Block projects.

A more detailed Operating Strategy will be prepared at a later date to accompany future application for a 5C Groundwater licence for dewatering operations.

Please note that this report does not provide any assessment of the potential water supply borefield. This will be the subject of a later report, once ongoing investigations are completed. Assessment of the fallback water supply option (seawater desalination) is covered in the referral document for the overall project (Maunsell, 2007).

SECTION 2 - EXISTING HYDROGEOLOGICAL REGIME

2.1 GEOLOGY

Figure 2 shows the surface geology in the general project area. The eastern part of the area is characterised by two series of north-northeasterly trending ridges of outcropping Lower Proterozoic aged rocks of the Mount Bruce Supergroup, which are part of the Hamersley Basin. These rocks dip steeply to the west-northwest and become generally younger from east to west, although there are numerous minor faults in the area that have resulted in some repeats of stratigraphic horizons. There is also one major fault parallel to the regional strike, and located between the two series of ridges, that has resulted in the absence of several major stratigraphic units.

The eastern and highest series of ridges are formed by the Kylenea and Maddina Volcanics which comprise basalts and tuffs. 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 McRae Shale-Mount Sylvia Formation). Three main orebodies have been identified; the George Palmer Orebody and the Northern and Southern Blocks. The Southern Block Orebody is located within the southern most occurrence of Brockman Iron Formation. The orebodies are high-grade magnetites that have developed within the Joffre Member of the Brockman Iron Formation. A thin veneer of Quaternary aged alluvial, colluvial and residual soils overlies the basement rocks in low lying areas, with some creek bed alluvium along drainage courses.

Basement stratigraphy within the project area, from youngest to oldest, is summarised as follows:

- Breccia - which appears to be the local equivalent of the Yandicoogina Shale
- Joffre Member- in which the magnetite orebodies have developed
- Whaleback Shale
- Dales Gorge Member- BIF, chert and shales
- Shales - shales, breccia and BIF which appear to be a local equivalent to lower units of the Dales Gorge Member
- Mount McRae Shale-Mount Sylvia Formation- shales and BIF

Numerous faults exist (both strike-slip and dip-slip) and significant strike slip displacement has resulted in the several repeats of the Joffre Member across the mine site area. Many of the fault planes have been intruded with dolerites.

The western part of the project area lies on part of the Fortescue River floodplain. This is underlain by a sequence of sediments. The lower most unit is the Cretaceous aged Yarraloola Conglomerate, which comprises rounded gravels with minor sands and clays. This unit forms part of the Carnarvon Basin and unconformably overlies units of the Mount Bruce Supergroup that are stratigraphically higher (younger) than the Brockman Iron Formation (Weeli Wollie Formation and possibly others). The Yarraloola Conglomerate is unconformably overlain by the Tertiary aged Trealla Limestone, which comprises clays, marls and crystalline limestone. This is unconformably overlain by the Quaternary aged Fortescue River alluvium, which forms an alluvial fan extending from basement outcrops that border the coastal plain to the coast. The alluvium includes gravel bed-load deposits in the present and past riverbeds and overbank deposits of silty clays with

some sands and gravels. There are also calcrete deposits over the zone of water table fluctuation and some colluvial deposits on the flanks of the major ridges.

A schematic geological section through the project area is presented in Figure 3.

2.2 REGIONAL HYDROGEOLOGY

A summary of the hydrogeological properties of the various geological units outlined above is presented in Table 1.

**Table 1
Summary of Hydrogeological Properties**

Age	Unit	Comments
Quaternary	Fortescue River Alluvium	<ul style="list-style-type: none"> Gravels form major aquifer with high permeability. Aquifer covers extensive area beneath floodplain. Groundwater is fresh in most of floodplain area. Groundwater is marginal to brackish on edge of floodplain. Groundwater is brackish to saline at depth near coast.
	Eluvium-Residual Soils	<ul style="list-style-type: none"> Mostly above the water table. Forms local aquifer where saturated, connected to alluvium.
Tertiary	Trealla Limestone	<ul style="list-style-type: none"> Aquitard. Forms confining layer to Yarraloola Conglomerate. Forms base of overlying alluvial aquifer.
Cretaceous	Yarraloola Conglomerate	<ul style="list-style-type: none"> Confined aquifer with moderate to low permeability. Forms narrow channel aquifer in old river course. Intersected in three GSWA bores. Groundwater is fresh in these bores.
Proterozoic	Weeli Wollie Formation	<ul style="list-style-type: none"> Indurated rocks with no primary porosity or permeability. Some minor fracture induced secondary aquifer properties. Not aquifers in project area. Groundwater is marginal to brackish in mine area.
	Brockman Iron Formation	
	Mt McRae-Mt Sylvia Formation	
	Maddina Volcanics	

The major aquifers in the project area are the gravels of the Fortescue River alluvium and to a lesser extent the Yaraloola Conglomerate. Previous investigations (Commander, 1993 and Bradberry Associates, 1965) indicate that the alluvium is potentially a major source of fresh water and could support substantial pumping. Aquifer permeabilities in excess of 50 m/d and bore yields of up to 900 kL/d each have been demonstrated. Sustainable abstraction of around 10,000 ML per year has been estimated and the DoW has earmarked the aquifer system as a potential area for future development. Numerous station wells and bores in the area also tap this aquifer.

The Yarraloola Conglomerate is much less extensive than the shallower alluvium in the project area and appears to be limited to a narrow channel. Permeabilities of less than 2 m/d have been indicated, although the water quality, where tested, appears to be as good, if not better than in the alluvium.

As outlined in Table 1, there are only minor secondary aquifer properties in the Proterozoic basement rocks, associated with fracturing. There are some station wells and bores in areas of sub-cropping basement, although much of the water yielded by these is likely derived from the overlying eluvium (residual soils).

2.3 GROUNDWATER INVESTIGATIONS

From examination of the exploration drilling database it became apparent that a number of holes particularly in the northern part of the Southern Block orebody reported drilling difficulties due to groundwater inflow. One hole, (SB022) located to the north of the orebody, has been utilised as a temporary drilling water supply bore. SB022 has been pumped at 2.9 L/s for 60 minutes with a resulting 2.7 m drawdown. A programme of hydrogeological investigations was undertaken to assess the bulk permeability across the orebody for input into the groundwater model and assessment of potential inflows to mining operations.

The hydrogeological investigations at the Southern Block orebody comprised airlift testing of numerous mineral exploration drill holes and a water level survey of all available drill holes. Dependant on the water returns from airlifting and the duration of airlifting, the measured water level recovery allowed for either rising-head permeability testing or airlift pumping recovery testing procedures to be applied.

The results of these tests (refer Appendix A) provide some quantitative estimates of bulk permeability and transmissivity. Test results indicate an average permeability for the orebody in the order of 0.6 m/d for the holes tested. Given the depths of the holes tested (in the order of 290 m), these data indicate a fairly high transmissivity of around 150 m²/d. Earlier testing at the Central Block orebody indicated permeabilities in the order of 0.01 m/d. The results of the permeability testing are summarised in Table 2.

**Table 2
Estimates of Bulk Permeability**

Hole ID	Bulk K (m/d)
AR029	3.1E-07
SB003A	3.5E-01
SB005A	2.1E-02
SB006	2.8E-02
SB008A	6.9E-03
SB009	8.1E-08
SB012	1.1E-08
SB022	4.0E-01
SB025	5.8E+00
SB027	1.4E-02
SB030	4.5E-03
SB034	4.1E-01
SB035	1.1E-01

2.4 GROUNDWATER FLOW

Figure 4 shows regional water table contours based on field survey data and historical records. Groundwater flow in the region is generally from southeast to northwest towards the ocean, with local groundwater flows being influenced by topography, recharge and discharge zones.

Proterozoic Basement Rocks

These aquifers 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. These aquifers discharge by baseflow to local drainages and by throughflow to the Fortescue River alluvium and coastal sediments. As such groundwater flow in the basement rock aquifers is generally from topographic highs towards the Fortescue River and the coast, with some local convergence about creeks during non-flood periods.

Fortescue River Alluvium

This aquifer, and deeper sediments on the main floodplain, are mostly recharged by the infiltration of river flow, although there is some minor direct infiltration of rainfall and some throughflow from flanking basement rock aquifers. These aquifers discharge by baseflow to the Fortescue River during periods when the water table is above the riverbed and above river water levels, and by evapotranspiration. The latter occurs via vegetation on the floodplain and also as direct evaporation from the near shore tidal flats where the fresh groundwater flows up to the surface above a saline water interface (refer next section). As such, groundwater level contours tend to be parallel to the coast with flow in a northwesterly direction, although there will be local divergence of groundwater flow away from the main River channels at times of river flow and local convergence of groundwater flow about the river channels in periods of little to no flow. The groundwater throughflow in the main aquifer (gravels) in the alluvium has been estimated (Commander, 1993) at between 2.3 and 9.2 GL/yr.

2.5 GROUNDWATER QUALITY

Appendix B presents the laboratory reports for water samples collected from Central Block drill-holes and some nearby station wells in April 2000, and from Central Block drill-holes in September 1993. Appendix B also includes tabulated results of analyses of water samples collected from drill-holes in the Central and Northern Blocks in 1992. The results of analyses of water samples from bores in the Fortescue River alluvium (Commander, 1993) were also reviewed.

The distribution of groundwater quality is best illustrated by salinity. Figure 5 shows groundwater salinity contours based on the April 2000 field survey results and earlier (pre-1993) results for the Fortescue River alluvium bores. There are basically three groundwater quality types in the region:

- Fresh groundwater (<1,000 mg/L TDS) in the central part of the Fortescue River alluvium. This fresh water forms a "lobe" elongated along the main channels of the River as a result of recharge.
- Marginal to brackish groundwater (1,000 to around 2,000 mg/L TDS) in the basement rock aquifers and on the flanks of the Fortescue River alluvium where throughflow from the basement rocks mixes with the fresh water in the alluvium. This is supported by recent field EC testing during the airlift testing programme in the Southern Block, which indicates groundwater in the Southern Block orebody to have a salinity of around 1,500 mg/L TDS.

- Brackish to saline groundwater (greater than 5,000 mg/L TDS) adjacent to the coast, where there is a saline water interface between the fresh groundwater flowing northwards and seawater. This interface dips to the south (i.e. inland) forming a “salt water wedge” and groundwater salinity would increase with depth in the near coastal and tidal flats areas.

Groundwater quality data from the Basement Rock aquifers (from 1993 and 2000) is graphically plotted (Expanded Durov Plots) on Figure 6. These plots indicate the groundwater to be a predominantly sodium chloride type water typical of mature groundwater with long residence times and little influence from recharging groundwater. Analysis of the data shows no obvious correlation between reported salinity and depth of drill-hole.

Comparison of the reported laboratory data with the Australian Water Quality Guidelines for Fresh and Marine Waters in relation to drinking water and livestock water guidelines indicates the following:

Fortescue River Alluvium

Apart from at the flanks of the floodplain and in the near coastal zone, the groundwater quality conforms to the drinking water guidelines.

Basement Rocks

Apart from one drill-hole in the Central Block (A11), the groundwater sampled from the basement rock bores and wells does not meet drinking water guidelines, mostly in relation to salinity (TDS) and chloride. However some of the samples collected in 1993 and 1992 also reported elevated (with respect to the guidelines) values for sulphate (M7, CB1, CB2, NB2, NB2A, NB3 and NB4), manganese (M7, M15, M16, M23, CB1, CB2, PHD10, NB2, NB2A, NB4 and BAL17), barium (M9), nickel (M11), boron (M11) and cadmium (M7).

Apart from several exceptions, all the groundwater sampled are within the guidelines for stock water usage. The exceptions are some of the GSWA monitor bores located on or adjacent to the tidal flats, and basement rock bores M7 (salinity, magnesium and calcium), M9 (cadmium), M23 (salinity) and NB4 (magnesium). However, we believe that the water quality results for drill-holes M7 and M23 are likely to be a reflection of contamination by drilling fluids rather than in-situ groundwater quality, especially given that nearby drill-holes report much lower salinities.

It should also be noted that the NB prefix drill-holes are in the Northern Block area and, while we do not have precise locations, reports (Ypma, 1992, 1993) indicate that these drill-holes are very close to the coast and tidal flats.

2.6 GROUNDWATER USERS

2.6.1 Existing Groundwater Users

The only other uses of groundwater in the area are pastoral wells and mine dewatering operations at the Central Block. The 1:50,000 scale topographic map series indicate 13 pastoral wells in the project area. These wells are shown on Figure 4. The majority of these wells are assumed to be equipped with wind-mill driven pumps with at least one (De Boulay Well) indicated as being equipped with a solar powered electric pump.

The pit dewatering requirements of the Central Block have been assessed at between approximately 8 and 12L/s (Aquaterra, 2007-a). The impacts of dewatering at both the Balmoral South mine and Central Block operations are discussed in Section 3.

2.6.2 Future Groundwater Users

It is recognised that additional groundwater users may occur in the future and that mining operations will continue to impact on local groundwater long after mining has ceased. Long term impacts of the pit void are discussed in Section 3.3. Likewise the long term impacts of borefield operations will also be assessed for other potential water resource users as a part of the upcoming borefield investigations.

2.7 GROUNDWATER DEPENDANT ECOSYSTEMS

Detailed descriptions of local and regional flora and fauna are included in project baseline environmental report (Maunsell, 2007). These baseline studies identified that there were potential risks to both local phreatophytic vegetation and to local stygofauna communities as a result of dewatering induced groundwater level drawdowns. Please note that the references in the summaries below can be found in the original Maunsell document referred to above.

2.7.1 Phreatophytic Vegetation

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).

Use of groundwater by phreatophytes is highest during the driest season of the year when alternative water sources become depleted and transpirational demand is highest (Eamus & Froend, 2006). Populations of phreatophytic vegetation within the project area are presented on Figure 10.

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.

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 3 m.

Dames & Moore (1984) 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.

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 21 m (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 3 m (Dames & Moore, 1984).

Various research on the response of *E. camaldulensis* to falls in groundwater levels suggest that a drawdown rate limit of 4m/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*.

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).

2.7.2 Subterranean Fauna

Two stygofauna surveys were conducted for the Mineralogy proposal in 2001. A range of Stygofauna was located in the orebody which was dominated by Copepoda. Nineteen individuals in the Isopoda group and three individuals in the Oligochaeta group were also recorded. The isopod was identified as an Oniscid (Peter Seroy, pers. comm.), and it is believed to be the first subterranean Oniscid ever recorded. The most notable specimen found outside of the orebody was a significant species of Thermosbaenacea, which have predominantly been recorded from the Mediterranean coast and the Caribbean.

Stygofauna are aquatic subterranean animals found in a variety of groundwater systems. Recently, the Western Australian Museum has demonstrated that the Pilbara and Yilgarn regions contain stygofaunal communities in calcrete and alluvial aquifers (Scanlon et al. 2006).

A stygofauna survey was conducted between 26 and 31 March, 2001 for the Central Block Orebody, located immediately north of the Balmoral South Project. A total of 46 bores were inspected from the Orebody, the proposed concentrator / HBI plant site and the alluvials of Mardie Station. All of the bores in the ore body were located within the steeply dipping Joffre Member of the Brockman Iron Formation. No karst or calcrete formations were intersected by the drill holes. Most of these bores were over 100 m deep and unslotted. By contrast, the plant site and Mardie Station bores were relatively shallow and located in the Maddina Volcanics and Fortescue River Alluvium, respectively.

Further fieldwork was conducted on 2nd to 8th October, 2001 in order to gather more information on the distribution of the isopod species in the orebody. All bores previously sampled in March were re-sampled using the same methodology.

Of the 46 bores sampled, only 27 contained specimens. The majority of the collected specimens were stygofauna. They were dominated by crustaceans including amphipods, a thermosbaenacean, isopods, copepods (cyclopoid and harpacticoid) and ostracods. The other aquatic fauna consisted of turbellarian and oligochaete worms, and an acarine. The two remaining non-stygofaunal specimens were a beetle and a Diplura (insect relative).

Stygofauna diversity collected included:

- Amphipoda (4 species, 39 individuals);
- Isopoda (1 species, 19 individuals);
- Thermosbaenacea (1 species, 78 individuals);
- Copepoda (2 species, >400 individuals);
- Ostracoda (2 species, 13 individuals);
- Acarina (1 species, 2 individuals);
- Oligochaeta (3 species, 9 specimens); and
- Turbellaria (2 specimens).

Stygofauna in the orebody was dominated by Copepoda. Nineteen individuals in the Isopoda group and three individuals in the Oligochaeta group were also recorded. The Isopoda were found exclusively in the A10 bore hole and specimens were also collected from the A34 and A6 bores during the October surveys. The isopod was identified as an Oniscid (Peter Seroy, pers. comm.), and it is believed to be the first subterranean Oniscid ever recorded.

The most notable specimen found outside of the orebody was a significant species of Thermosbenacea, which have predominantly been recorded from the Mediterranean coast and the Caribbean.

SECTION 3 - MINE DEWATERING

Previous investigations at the Central Block orebody indicated that the basement rocks which make up the ore host sequence, the footwall and hanging wall are indurated and have little to no primary porosity and permeability. There were some minor secondary aquifer properties associated with faults and fractures; however, mineral exploration drilling in the area has not intersected significant water. Most holes were reported to be “dry”, with very slow recovery of water levels at the completion of drilling and limited hydraulic testing indicated low aquifer permeability and transmissivity.

Drilling and testing at the Southern Block (Balmoral South) indicate that the orebody at this location has significantly higher permeability as outlined in Section 2.3. However, while the orebody is of greater permeability the surrounding basement rocks are expected to retain the same low permeability characteristics as previously found for the Central Block. Thus while initial inflows may be quite high as the orebody itself drains, the limited extent of permeable aquifer means that long term inflows will be much smaller.

The majority of the pit will be developed within the basement rocks; however, the western-most and northeastern most margins of the pit extend onto the floodplains of the Fortescue River and Du Boulay Creeks respectively. While the encroachment on to the floodplain of the Fortescue River is quite elevated and no saturated sediments are expected to be encountered, limited drilling information along Du Boulay Creek indicates that saturated sediments will be intersected by the pit. Potential for groundwater inflows from the alluvial deposits are discussed further in Section 3.2.2.

For the current mine plan of 40 Mtpa, an open pit will be developed down to approximately 300 m depth below surface, which equates to around 290 m below the current water table. As such, even with low permeability basement rocks surrounding the orebody low, there is the potential for significant pit inflows of groundwater.

Groundwater modelling has been undertaken to assess groundwater inflows to the pit as it is developed and also to assess the impacts that mine dewatering will have on local groundwater levels, groundwater dependent ecosystems and other groundwater users, including the cumulative effects with dewatering operations from the nearby Central Block mine.

3.1 GROUNDWATER MODELLING

3.1.1 Previous Work

The groundwater model was originally developed by Aquaterra in 2001. The groundwater flow model, developed using Modflow, was set up to predict groundwater level drawdowns resulting from the development of the Central Block Project. The model was also used to assess final mine void groundwater levels after the cessation of mining.

The model included features to simulate:

- The hydrogeological features of the system (Fortescue River Alluvium and shallower parts of the Brockman Iron Formation and basement rocks).
- Regional groundwater throughflow.

- Dewatering of the Central Block pit.

The model was originally calibrated to steady state conditions, which allows for calibration to aquifer permeabilities and boundary conditions. There were no time varying data available to allow from transient model calibration to dynamic (seasonal and annual) aquifer responses and to aquifer storativity. Aquifer storage parameters were assigned consistent with similar hydrogeological environments. Model predictions suggested that:

- Groundwater inflows to the Central Block would be between 600 and 1000 kL/d over the life of the mine.
- Drawdown impacts extended mainly to the north and south of the Central Block due to the nature of the hydrogeological setting. Drawdown of 0.5 metres was predicted 3.5 km to the west, 5 km to the east and 15 km north and south of the Central Block.
- No significant drawdown impact was predicted in the Fortescue Alluvium.

Details of the model set up, calibration and predictions are provided in the Aquaterra 2001 report (Aquaterra, 2001).

3.1.2 Current Work

The existing groundwater model was updated and used to assess dewatering requirements and impacts for the Central Block (Balmoral South) Project. The work was completed in three phases:

- Updating the existing groundwater model to include mine plans for the Southern Block and recent hydraulic testing data, and to confirm model calibration performance.
- Using the refined/updated groundwater model to predict groundwater inflows to the proposed Balmoral South development.
- Using the groundwater model to predict the drawdown impact of simultaneous development of the Central Block and the Balmoral South Project.

3.1.3 Modifications to Model Set Up

The extent of the groundwater model was increased to include an additional area of approximately 10 km by 10 km upstream of the original south east model boundary. This area was included to accommodate any additional drawdown that may extend further to the south east due to the inclusion of dewatering of the Balmoral South Orebody. The revised model extent and associated boundary conditions are shown in Figure 1. The model boundary conditions are unchanged from the previous model set up (see below).

Aquifer hydraulic conductivity (horizontal and vertical) specified for the Balmoral South Orebody was increased to 0.6 m/d, from the value of 0.01 m/d specified in the original model. This revised value is consistent with recent testing results.

The model includes the extensive Fortescue Alluvium Aquifer, which is located to the west of the project area. Two model layers were included, one representative of the alluvium of the Fortescue floodplain and the shallow weathered basement lithologies around the orebodies. The second layer represents the deeper basement rocks including the orebody and footwall and hanging wall sequences. The model was set up in

the AMG grid coordinate system with a non-uniform grid size ranging between 1000 m at the model boundaries and 50 m in the vicinity of the ore body. The grid has been aligned along the main strike of the ore body and basement rocks. The model grid is made up of 121 columns and 134 rows and the active region of the model covers an area of almost 1000 km² (Figure 7).

The model is bounded to the west and northwest by a constant head outflow boundary (coast line) and to the east and southeast by a specified (in) flow boundary (refer Figure 7). That is, water flows into the model from inland areas and discharges to the sea. No recharge (from rainfall or infiltration of river flow) has been specified in the model. In this regard, the modelling approach is conservative, especially with respect to the Fortescue River Alluvium, where infiltration from the river is the main recharge mechanism. As such, model predictions will tend to over predict drawdowns in the longer term (in both the basement and the alluvium). The base of Layer 1 is consistent with structural contours for the base of the alluvium gravel developed by previous studies of the Fortescue River alluvium (Commander, 1993). The base of Layer 2 was set at a constant elevation of -350 mAHD.

3.1.4 Model Calibration

The changes outlined above were not anticipated to result in significant changes to the model performance. Comparison with available data (groundwater levels measured by GSWA and Aquaterra) suggest that the model still provides a good match to available monitoring data. As such the model is considered to be calibrated to steady state or long term average conditions. Measured and predicted groundwater levels are presented in Figure 8. Calibrated aquifer parameters remain unchanged from the previous model calibration, apart from the changes made to the Balmoral South Orebody and are summarised in Table 3. Anisotropy has been retained in layer 2 to account for preferred flow paths in the basement along declining planes and other strike related preferential flow paths.

Table 3
Calibrated Aquifer Parameters

	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Anisotropy Ratio (x:y)	Unconfined Storage*	Confined Storage*
Layer 1					
Alluvium	50-150	5-15	1:1	0.1	NA
Clays	1	0.1	1:1	0.01	NA
Orebody	0.01-0.6	0.01-0.6	1:1	0.001	NA
Brockman/Basement	0.001	0.001	1:1	0.001	NA
Layer 2					
Orebody	0.01-0.6	0.01-0.6	1:10	0.001	1x10 ⁻⁴
Brockman/Basement	0.001	0.001	1:10	0.001	1x10 ⁻⁴

*Values not calibrated in steady state model but assigned in prediction runs consistent with similar hydrogeological environments

The model predicted water balance is shown in Table 4. The model predicted values are consistent with groundwater throughflow calculations made by Commander (Hydrogeology of the Fortescue River Alluvium, 1993) which estimated that annual alluvium throughflow is between 6,300 and 25,000 kL/d.

Table 4
Model Predicted Water Balance (Steady State Calibration)

Unit	Inflow (kL/d)	Outflow (kL/d)
Layer 1		
Alluvium	9170	9150
Clays	0	10
Basement	1	1
Layer 2		
Basement	30	40
TOTAL	9201	9201

At this time there are insufficient data available to attempt transient calibration or history matching. As a result storage parameters (as summarised in Table 3) adopted for the model predictions are set consistent with similar hydrogeological environments.

3.1.5 Model Predictions

The calibrated groundwater model was used to predict the inflows associated with the simultaneous development of the Balmoral South Orebody (Stages 1 and 2) and the Central Block (67mtpa case). For both mine developments, inflows to the base are mining are simulated using the Drain package in Modflow with the drain levels set consistent with the projected mining schedule. Information available for development of the Central Block suggests that development will take place over a period of 20 years. The development of Balmoral South is projected over a 24 year period. For the final four years of the Balmoral South project it was assumed that the Central Block remains dewatered to maximum depth (-150 mRL).

3.1.6 Results

Predicted groundwater inflows for the Balmoral South are presented in Figure 9. Groundwater inflows are predicted to peak at around 2,300 kL/d (27 L/s) as Stage One of mining reaches its maximum depth (Figure 9).

The lateral and vertical extent of the a “cone of depression” in groundwater levels will be dependent on the nature of local and regional aquifers, the depth of the pit and the “interference” effects of dewatering at the nearby Central Block. The results of groundwater modelling indicate that the cumulative impacts of both dewatering operations will result in one large elongate cone of depression.

Predicted drawdown contours after 24 years of mining are presented in Figure 10. Groundwater level drawdowns in close proximity to the mine will be at, or close to the deepest section of the pit (approximately 300 mbgl). At the end of the 24 year mining period the predicted 0.5 m contour extends 21 km northwards to the coast, 12 km southwards to the intersection with the Fortescue River and the upper reaches of the Fortescue River alluvial aquifer, 3.5 km to the west to the margin of the Fortescue River alluvial aquifers and 7 km to the east within the basement rock aquifers. Predicted drawdowns within the adjacent Fortescue River alluvial aquifers are minimal.

It should be noted that the model predicts drawdowns within the basement rock aquifers around the mine sites and within the main Fortescue River alluvial aquifers. There are also minor (and largely seasonally intermittent) aquifers associated with shallow alluvium within several creeks that drain westwards through the mine areas towards the Fortescue River. While the drawdowns in the basement rock aquifers will induce some leakage from these shallow alluvial aquifers (depending on local aquifer properties), these aquifers will be recharged seasonally and will maintain some perched groundwater levels.

3.2 PIT DEWATERING

3.2.1 Inflow Results and Dewatering Options

The results of modelling indicate that inflows into the open pit are likely to peak at around 2,300 kL/d (27 L/s) in year 16 of mining, average predicted inflows over the life of the mine are around 1,700 kL/day (20 L/s). This equates to a total volume of approximately 15 GL over the 24 year mining period (Figure 9).

Modelling has assumed that pit dewatering will be achieved via sump pumping with the water level maintained just below the level of mining as the pit progresses. This may also be the most appropriate method of dewatering in the real world with inflows to be directed towards pit sumps that can then be pumped to the surface. However, during the permeability investigations, airlift yields as high as 10L/s were recorded from mineral exploration holes. If purpose built dewatering bores were able to intercept similar structures as these high yielding mineral holes, then significant dewatering may be able to be achieved in advance of mining with residual groundwater inflows collected and removed via sump pumping. If advance dewatering is achievable it has the advantage of being able to lower water levels significantly below the pit floor thus reducing the likelihood of wet blasting.

The viability of advance dewatering via dewatering bores would require additional drilling and testing investigations to be undertaken.

Should geotechnical (pit wall stability) conditions require more dewatering or depressurisation than will be achieved via seepage through the pit walls, this would most probably be best achieved by lateral drain holes drilled from the pit floor as it deepens. These would then drain into the pit and the water collected and removed via the in-pit sump pumping system.

3.2.2 Potential Inflow from Du Boulay Creek Alluvium

At mineral exploration hole SB024 located within the northern extent of the pit alluvial deposits were intersected to a depth of 12 m below ground. The standing water level at this location is approximately 6m bgl, which indicates that the pit may intersect up to 6m of saturated sediments. Modelled pre-development 100 year ARI flood stage heights (refer Surface Water Management Plan, Aquaterra, 2007-b) may be well above the natural pit crest especially adjacent to Du Boulay Creek where flood stage heights may be some 3 to 4 m above the natural pit crest; however a flood protection bund is planned around the northern and western extent of the pit.

As outlined in Section 3.1.6, the groundwater flow model does not take into account the Du Boulay Alluvial deposits between the Central and Southern Block deposits. Potential inflow to the open pit from the

saturated alluvium has been assessed using a simple analytical flow model (Darcy model), and the following assumptions:

- 8 m of alluvial deposits are present along a 500 m intersection of the pit wall adjacent to Du Boulay Creek.
- 4 m of this alluvium is saturated under average conditions.
- The alluvium has an average permeability of 5 m/day.

Based on the above assumptions, groundwater inflow to the pit from the Du Boulay alluvium is likely to be of the order of 5 to 10 L/s during the early stages of mining. Longer term inflows will depend on the hydraulic connection between the alluvium and the underlying basement rocks. If the shallow water table is perched and through flow in the alluvium is not caught by the dewatering cone of depression then inflows may continue throughout the mine life. If, however, the water table is not perched then groundwater through flow in the alluvium will be captured by the cone of depression and inflows from the alluvium will tail off.

In times of high flow or flooding in Du Boulay Creek the entire thickness of alluvium is likely to become saturated up to the flood protection bund, thus increasing potential inflow to the pit. Under these conditions inflows may be as high as 30 to 60 L/s.

Potential inflows can be prevented by the installation of a cut-off wall beneath the flood protection bund, keyed into low permeability residual clays or basement rocks. If thicknesses of alluvium are too great for the installation of a cut-off wall, a low permeability grout curtain could be installed to reduce groundwater inflows.

It is planned to conduct more detailed investigations of ground conditions in this area, prior to mining, to develop the optimum inflow control measures.

3.2.3 Impact on Local and Regional Groundwater Levels

Overall, the results suggest that inflows in the order of 1.3 to 2.3 ML/d could be expected throughout the development of the mine with a combined annual discharge with Central Block dewatering of around 1 GL/annum. In practice, inflows (and groundwater level drawdowns) will commence once the pit progresses below the water table and gradually increase as the pit deepens. This will cause a convergence of groundwater flow lines about the pit and could result in the interception of most of the groundwater throughflow in the Basement Rocks aquifer in the pit area. Some of the groundwater throughflow in the Fortescue River alluvium will also be captured by the dewatering cone of depression and diverted towards the pit. Assuming (conservatively) that around a quarter of the water pumped from both Balmoral South and the Central Block operations derives from the alluvium; this would represent only 3% of current estimated groundwater throughflow (9 GL/annum) in the alluvium.

Figure 10 shows predicted drawdown contours at the end of mining (24 years) resulting from abstraction from both Balmoral South and the Central Block. Significant drawdown impacts do not extend into the alluvial aquifer. At the end of the 24 year mining period, the predicted drawdown cone extends approximately 3.5 km to the west and 5.5 km to the east from the centre of the pit and approximately 14 km

to the north and south of the pit. As shown on Figure 10, there are some ten pastoral wells within the predicted drawdown cone, and several others just outside of the predicted area of influence.

3.3 FINAL VOIDS

For the purposes of this assessment, it has been assumed that the open pit will be left largely as is at the completion of mining. That is, the pit will neither have been backfilled or infilled with waste rock from the George Palmer Orebody mining operations, nor will it be infilled with waste rock from any future mining expansion.

3.3.1 Pit Lake Level

At the completion of mining and the cessation of sump pumping, the pit will gradually fill with water to a level defined by the long-term balance between inflows and outflows. The inflows will be groundwater flow and incident rainfall recharge. The principal outflow mechanism will be evaporation losses from the free water surface in the pit and from seepage faces on the pit walls. Outflow to groundwater can also occur if the pit water level recovers sufficiently to be higher than the water table on the down-gradient side of the pit.

Based on published figures for Onslow and Port Hedland, average pan evaporation for the area is around 3150 mm/yr, while average rainfall is around 260 mm/yr. Allowing for a pan factor of 0.6, this results in a potential deficit (or net loss) of around 1630 mm/yr. If this is applied to the pit area (i.e. assuming the base of the pit is covered with water) average net losses would be around 1,100 kL/d. At the end of mining average inflows are predicted to be around 1,500 kL/d. This results in a net inflow to the pit at the end of mining of around 5 L/s and the pit will slowly start to fill with water. At the -230 mRL level the greater area of the pit means that evaporation exceeds inflows and the pit lake reaches equilibrium. The estimated time for the pit lake to reach this level is approximately 330 years. After this time, losses from the pit will exceed inflows and the pit will become a groundwater sink with the final pit lake level some 240 m below the original standing water level.

3.3.2 Impact on Groundwater Flows

The post mining impact on local and regional groundwater levels will be marginally less than for active pit dewatering. The impact on groundwater flows, then, will also be similar. That is, the expected impacts would be interception of most of the groundwater throughflow in the Basement Rocks aquifer in the pit area together with interception of up to around 3% of the estimated throughflow in the Fortescue River alluvium indefinitely.

3.3.3 Impact on Groundwater Quality

As a result of high predicted evaporative losses from the pit surface in relation to groundwater inflow the long-term pit lake will be fairly shallow. Evaporation from the pit lake will result in progressively increasing pit lake and/or shallow groundwater salinity.

However, as the pit will become a long-term groundwater sink, groundwater will flow into the pit, but not out of the pit and so regardless of the salinity of the pit water, there will be little to no impact on groundwater quality outside the pit.

There is, however, the potential for saline water to flow out of the bottom of the pit in the very long term if pit water salinity becomes sufficiently high that density differences (between sub-pit groundwater and regional groundwater) are sufficient to overcome normal hydraulic gradients. That is, saline water could “sink” out of the pit and into the Basement Rock aquifer. The saline plume could then migrate away from the pit under the influences of gravity and hydraulic gradients. However, as the pit is a groundwater sink, the hydraulic gradients over a large area will be towards the pit. As such, it is expected that the plume will tend to remain beneath the pit and not have any impact on groundwater quality, other than in the immediate vicinity of the pit.

3.4 IMPACTS ON OTHER GROUNDWATER USERS

3.4.1 Existing Groundwater Users

Of the 13 existing pastoral bores and wells in the Project area, 9 are sufficiently within the dewatering induced cone of depression that continued operation could be impacted by drawdowns in groundwater levels below existing pump inlets and/or the base of the bores/wells.

The interference drawdown impacts of the Balmoral South dewatering operations will also result in some minor reduction in dewatering requirements at the Central Block.

3.4.2 Future Groundwater Users

The main future potential groundwater user will be the Balmoral South operated borefield in the Fortescue River alluvial aquifers. However, the resulting cone of depression from both the Balmoral South and Central Block dewatering operations is predicted to intercept some 3% of the current groundwater flow through the alluvial aquifers.

However, any losses of water from the Fortescue River alluvial aquifers back towards the pits would most likely be made up from increased recharge from the Fortescue River, and little to no long term impact on sustainable aquifer/borefield yield is expected.

3.5 IMPACTS ON GROUNDWATER DEPENDENT ECOSYSTEMS

The potential impacts of lowering groundwater levels are detailed in another (Maunsell, 2007), and summarised below. Please note that the references in the summaries below can be found in the original Maunsell document referred to above.

3.5.1 Phreatophytic Vegetation

Not all phreatophytic vegetation has the same degree of dependency on groundwater and therefore the same response to drawdown. This variability in dependence has a significant effect on the risk of impact from groundwater drawdown.

A number of possible responses of phreatophytic vegetation due to long term changes in water regimes and progressive long term drying have been identified by Froend, Bowen & Associates (2005) and they are as follows:

- Change in species distribution ie Phreatophytic vegetation will only continue to be represented in a community if their water requirements are met;
- Change in vegetation compositions; and
- Measurable changes in the vigour of phreatophytic vegetation, associated with reduced water availability.

The loss of phreatophytic vegetation inadvertently contributes to the loss of vegetation connectivity and corridor linkages. These linkages assist in connecting isolated habitats and allow plants to disperse from one habitat to another which helps facilitate gene flows and colonisation of suitable sites (Main Roads, 2000). Habitats that are physically interconnected to a larger pool of organisms will maintain and support greater species richness than habitats that are not physically connected.

As outlined in Section 2.7.1, *Melaleuca argentea* suffers stress with only minimal changes in groundwater levels. Accordingly, impacts have the potential to occur at drawdown levels greater than 1 m, while the phreatophytic eucalypts discussed earlier are likely to survive drawdowns of up to 5 m, with evidence indicating that with careful management of the rate of drawdown, this depth can be greater. Water stress levels of all phreatophytic vegetation will increase the closer to the centre of the cone of depression that they are located. .

However, it is important to note that the above assessment is based on the predicted drawdowns in the basement rock aquifers and the Fortescue River alluvium. As outlined in Section 3.1, the model does not take into account shallow alluvial aquifers associated with the local creeks. These are also minor (and largely seasonally intermittent) aquifers. While the drawdowns in the basement rock aquifers will induce some leakage from these shallow alluvial aquifers (depending on local aquifer properties), these aquifers will be recharged seasonally and will maintain some perched groundwater levels. The vegetation risk assessments take no account of seasonal creek flows and perched water tables within the main creeks, which will be available to the vegetation. Due to the action of perched aquifers based on the creek or river alluvium within which the vegetation exists, it is difficult to predict with any accuracy the extent of this impact.

3.5.2 Stygofauna

There is the potential for localised impact on stygofauna through the loss of habitat due to groundwater level drawdowns in both the basement rock aquifers and in the local creek alluvium. However, as outlined above (phreatophytic vegetation), the actual groundwater level drawdowns in some areas are expected to be less than predicted. As a result, the loss of stygofauna habitat during mining is also expected to be less than predicted.

SECTION 4 - TAILINGS STORAGE FACILITY

Ore processing will include a concentrator process (basically a wash plant), which will produce large volumes of tailings. The tailings slurry will essentially contain fine sand to silt sized particles of the host rock and water. The tailings storage facility (TSF) will be located immediately east of the plant site (Figure 11). The total area of the TSF at the end of mining occupies a nominal area of approximately 800 ha set against the eastern lease boundary.

Much of the water discharge to the TSF will be recovered (by decant pumping and under-drainage and seepage collection systems) and recycled back to the plant. However, there will be some water that remains entrained in the tailings and there will be some water that may bypass the under-drainage and seepage collection systems. Any water that does bypass these systems will enter the local aquifers (alluvium-eluvium and underlying Basement Rocks) and move down hydraulic gradient. Seepage losses would result in a water table mound beneath the TSF and initial flow would be away from the TSF in an almost radial pattern. However, the overall hydraulic gradient in the area will be initially towards the west following the regional groundwater flow. As mining progresses and the dewatering cone develops groundwater flow paths from the TSF will be westward directly toward the cone of depression resulting from the pit dewatering operations. Any seepage will ultimately be captured by the dewatering cone and transported towards the pit void.

Initially, the seepage water will be fresh (note that process water will be fresh groundwater) and would result in a fresh water plume within the marginal to brackish Basement Rock and local superficial aquifers.

There will likely be some minor evaporative concentration of salts in open water areas on the TSF and where the phreatic surface within the tailings is close to the surface. However, it is expected that the areas of open water and the phreatic surface will be controlled to minimise water losses (and thus reduce make-up water requirements). Incident rainfall over the TSF will also act to partially dilute any salinity build-up within the TSF.

It is not expected that seepage from the TSF will result in any reduction in the beneficial use of local groundwater. In fact, seepage may well result in an improvement in groundwater quality in the Basement Rock and overlying alluvial-eluvial aquifers in the vicinity of the TSF.

SECTION 5 - IMPACT MANAGEMENT STRATEGIES

The following management strategies are proposed to address the identified potential impacts of mine operations on the local and regional groundwater systems, other groundwater users and GDEs.

5.1 GROUNDWATER MANAGEMENT

5.1.1 Dewatering Discharge

Pit dewatering is anticipated to yield approximately 0.5 to 0.8 GL/annum over the life of the mine, dewatering discharge will be used preferentially to other sources and will reduce overall demand on the Fortescue River alluvial aquifer by up to 15 GL over the life of the mine.

5.1.2 Pit Dewatering

As outlined in Section 3.2, sump pumping to maintain dry mining conditions will intercept most groundwater throughflow in the Basement Rocks in the vicinity of the pit and will result in a “cone of depression” in groundwater levels around the pit. The predicted cone of depression will be elongated along strike, with the predicted impacts extending up to 20 km to the north and 12 km to the south of the pit, up to 7 km to the east and up to 3 km to the west of the pit. The drawdown predictions are considered to be conservative and in practice it is likely that there will be a much steeper hydraulic gradient towards the pit with a much smaller (overall extent) cone of depression. However, for the purpose of developing the Groundwater Management Strategy, the “worst case” scenario has been adopted.

The locations of wells in relation to the predicted drawdown are presented on Figure 11, and summarised on Table 5.

Table 5
Summary of Pastoral Wells Affected by Dewatering

Well	Easting	Northing	Predicted Water Level Decline after 24 Years (m)
Balmoral Well	408646	7659590	>200
Woolie Paddock Well	406977	7658168	>100
Tarquin Well	412353	7663112	40
Fortescue Bore	408033	7666784	35
Du Boulay Well	409499	7656034	25
Neera Well	415363	7677498	20
Marda Well	415653	7673781	15
Diorite Well	412611	7658469	8
Violet Well	407168	7655697	7.5
Currangi Well	408712	7651946	0.5
Jilan Jilan Well	403834	7659382	nil
Carrawar Well	415995	7656575	nil
Waralee Well	404302	7655314	nil

Significant drawdowns are predicted to occur at a the majority of pastoral wells in the immediate vicinity of the pit. Should actual drawdowns result in the loss of practical use of any of these wells, the Project proposes to provide alternative water supplies to the pastoralists, most probably via small diameter off-take lines from the main plant water supply, or by provision of alternative wells outside the area of influence of mining.

In terms of the Fortescue River alluvium, there are no existing station wells down-hydraulic gradient of the pit that might be impacted. In fact, it is considered unlikely that the impact of the diversion (towards the pit) of such a small proportion of the total groundwater throughflow could be measured. The range of natural variations in groundwater throughflow, as a result in variations in river flow (and recharge) will greatly exceed the small proportion of average flow that could be captured by the pit dewatering.

Monitoring to confirm and quantify any impacts, and to provide data for refinement of predicted future impacts, is recommended in Section 5.1.5.

Monitoring bores located near the coast will also be used to monitor for potential saline intrusion, however, due to the very low permeability of the orebody and surrounding Proterozoic basement lithologies, saline intrusion to groundwater is not expected to be an issue. In the event that saline intrusion is identified the appropriate regulatory authority will be consulted to decide on the best course of action to be taken.

All dewatering discharge will be used around the mine site either for dust suppression or to supplement water produced through desalination in the plant process water circuit.

5.1.3 Pit Void

As outlined in Section 3.3, the final pit void will act as a groundwater sink in the long term with a pit lake level at or near the base of the pit. The potential impacts on groundwater levels will therefore be similar to active dewatering. Also, as outlined in Section 3.3, there will be some salinity build-up within the pit lake and shallow groundwater but this saline water will largely remain confined to the immediate pit area with the possibility of some very long-term density flow of hypersaline water at very low rates downwards out of the bottom of the pit.

Groundwater quality monitoring to confirm and quantify any impacts, and to provide data for refinement of predicted future impacts, is recommended in Section 5.1.5.

5.1.4 Tailings Storage Facility

As outlined in Section 4, it is not expected that the TSF will have any adverse impact on local or regional groundwater. In fact seepage from the TSF will likely result in:

- the development of a local groundwater mound which would have the effect of reducing the potential drawdown impacts of pit dewatering on the two nearby station wells;
- possible improvement in groundwater quality around the TSF.

However, if free water is allowed to remain on the TSF for extended periods, the salinity of the water within the tailings could increase due to evaporative concentration. Seepage quality may then be poorer than the surrounding groundwater and a more brackish plume might develop. To reduce the risk of this, it is proposed that the use of tailings return water be prioritised over the use of raw desalinated water. This will also help in achieving maximum possible settled tailings density and TSF disposal life.

Groundwater quality monitoring will be undertaken on the TSF monitoring bores. In the event that adverse conditions are noted in local groundwater, a risk assessment will be undertaken of the likely impacts

associated with those conditions and in consultation with the relevant regulatory authority, appropriate remediation and or management will be undertaken.

Monitoring to confirm and quantify any impacts, and to provide data for refinement of predicted future impacts, is recommended in Section 5.1.5 below.

5.1.5 Groundwater Monitoring

A groundwater monitoring network comprising both existing and purposely constructed bores will be implemented. Three main areas of monitoring will be carried out, these being:

- Monitoring in the Fortescue River alluvium
- Monitoring in the orebody and basement lithologies
- Monitoring in the vicinity of the TSF

The proposed monitoring schedule is provided in Table 6 below, notional monitoring bore locations are shown on Figure 11. These bores would be monitored to assess regional drawdown and groundwater quality impacts of dewatering and to provide data for refinement of predicted future impacts. An adaptive approach to monitoring will be adopted with groundwater abstraction and water level data used to recalibrate the groundwater model and to refine predictions of future dewatering requirements and associated impacts.

Monitoring bores should be installed to a depth of at least 20 m below the water table or 20 m below the maximum predicted groundwater decline.

Groundwater abstraction from the in pit sumps will also need to be monitored.

Fortescue River Alluvium

It is proposed that monitoring of the water level response to dewatering in the alluvial aquifer is undertaken utilising seven existing DoW (Old GSWA) monitoring bores as indicated on Figure 11. It is recommended that these bores are monitored on a regular basis as detailed in Table 6.

Orebody and Basement Lithologies

Monitoring of water level decline in the orebodies and surrounding basement lithologies will be undertaken with the use of purposely constructed monitoring bores. It is recommended that 8 monitoring bores are constructed. Four of these monitoring bores are to be placed along strike of the orebodies with the other two to be constructed in flanking basement rocks either side of the orebody. The recommended monitoring program for these bores is detailed on Table 6.

Tailings Storage Facility

Purposely constructed monitoring bores will also be required for the monitoring of groundwater in the vicinity of the TSF. Initially it is proposed to install four monitoring bores around the perimeter of the main TSF cell. Basement monitoring bores along the northern margin of the TSF will also have the dual purpose of monitoring impact due to the TSF and it may be useful at these locations to install split level piezometers for the monitoring of both deep and shallow groundwater responses. The recommended monitoring program for these bores is detailed on Table 6.

Pastoral Wells

In addition to the monitoring of the purpose built and existing bores, all of the pastoral wells in the area should also be routinely monitored. A fixed reference point will need to be installed at the wells to allow for consistent measurements to be made.

**Table 6
Proposed Groundwater Monitoring Programme**

Parameter	Monitoring / Sampling Site	Frequency
Water Quantity		
Dewatering	Flow meter on each sump pump	monthly
Water Levels		
Water Levels	Alluvial monitoring bores	monthly
	Basement monitoring bores	monthly
	TSF monitoring bores	monthly
	Pastoral Wells	monthly
Water Quality		
Salinity (EC) and pH	Alluvial and Basement Monitoring bores	annually
	TSF monitoring bores	quarterly
	Pastoral Wells	quarterly
	Dewatering Sumps	monthly
Hydrochemistry	TSF monitoring bores	annually
	Dewatering Bores and Sumps	annually

5.1.6 Trigger Levels

In order to be able to react to unforeseen detrimental impacts on groundwater users and groundwater dependant ecosystems, the following trigger levels for excessive drawdown and degradation of groundwater quality are proposed.

Groundwater Levels

Due to the highly variable nature of responses to dewatering in an environment such as the Southern Block orebody, appropriate trigger levels should be set that reflect this variability. It is proposed that an exceedance of 20% or greater of the predicted water level decline for any observation point for a given depth of mining should trigger a more detailed analysis and review of dewatering and monitoring data to be undertaken.

In the case of pastoral wells, trend analysis of dewatering impacts should be undertaken during annual aquifer reviews so that alternative water supplies can be emplaced in advance of water level decline causing wells to go dry.

Groundwater Quality

Groundwater quality data collected from monitoring bores should be reviewed annually as part of the annual aquifer review. Any persistent increasing (or decreasing) trend in salinity, pH or other monitored parameter

should be a trigger for a detailed analysis and review of dewatering and monitoring data to be undertaken. Levels which are significantly elevated above background levels should be flagged as the start of a potential increasing or decreasing trend and checked against future monitoring data to discern if a trend is developing.

5.1.7 Maintenance of Existing Supplies

It is possible that pastoral wells in the vicinity of the project area will be impacted by drawdowns due to mine dewatering. In the event that actual drawdowns result in the loss of practical use of any of the existing wells, the Project proposes to provide alternative water supplies to the affected groundwater users, most probably via small diameter off-take lines from the main plant water supply, or by provision of alternative wells outside the area of influence of mining.

5.2 PHREATOPHYTIC VEGETATION MANAGEMENT

Management strategies for phreatophytic vegetation are detailed in another report (Maunsell, 2007), and are summarised below.

5.2.1 Impact Management

The key objective for managing groundwater drawdown impacts with regard to phreatophytic vegetation is to limit the extent of vegetation loss due to water stress as much as is practicable, commensurate with the requirements of mining. As outlined in the previous section, there will be some unavoidable loss of vegetation due to drawdown effects

Management of these effects will be accomplished by:

- Minimising, wherever possible, the rate and extent of groundwater drawdown by developing the mining plan to ensure that the dewatering effects on the groundwater levels are reduced;
- Monitoring of rates of drawdown to confirm the extent of conditions likely to result in vegetation losses, and comparison with predictions to confirm the reliability of future projected drawdowns.
- Monitoring the effects of groundwater drawdown on phreatophytic vegetation to assess actual against predicted impacts;
- Establishing trigger levels, in consultation with DEC, these will be used to identify impacts that are in excess of those modelled.

In addition to the above, the Project will determine, in consultation with the regulatory authorities, appropriate offset strategies to compensate for any loss in phreatophytic vegetation.

5.2.2 Monitoring and Trigger Levels

Bi-annual monitoring of vegetation health is proposed. Should this monitoring indicate that there have been vegetation losses within an area exceeding 70% of the predicted vegetation impact zone (ie within the 1 m drawdown contour for *Melaleuca argentea*, and within the 5 m drawdown contour for all other vegetation), it is proposed to:

- Assess possible options for reducing rates of drawdown by modifying mining plans (where possible within the constraints of practical mining);

- Engage in stakeholder discussions to develop agreed actions plans should vegetation loss reach or exceed the predicted vegetation impact zone.

5.3 STYGOFAUNA MANAGEMENT

Management strategies for stygofauna are detailed in another report (Maunsell, 2007), and are summarised below.

5.3.1 Impact Management

The overall target for stygofauna management is no long term impact on species distribution or diversity. It is proposed to develop a Project specific Stygofauna Monitoring and Assessment Programme in conjunction with the DEC, which will include such things as:

- Continued monitoring of existing sampling bores (and others as agreed) to increase the current knowledge base on the distribution and diversity of stygofauna communities and habitat conditions (water quality etc).
- Research into the biology of the species involved to increase the knowledge base.
- Ongoing reporting to DEC and other stakeholders of results.
- Implementation of remedial actions to reduce impacts, should monitoring indicate a risk to stygofauna.

5.3.2 Monitoring and Trigger Levels

Monitoring will be undertaken on a bi-annual basis. The number and distribution of monitoring sites will be confirmed in the Stygofauna Monitoring and Assessment Programme, but will include all bores which have been sampled to date as part of the baseline studies.

Trigger levels for remedial action will also be confirmed in the Stygofauna Monitoring and Assessment Programme.

5.4 GROUNDWATER OPERATING STRATEGY

A detailed Operating Strategy will be prepared to support the application for a 5C Groundwater Licence which will be required prior to any dewatering. The Operating Strategy will be developed from this Groundwater Management Plan and will be updated with all newly available data and include details of the groundwater, vegetation and stygofauna monitoring assessment and management plans. This Operating Strategy will require approved by Department of Water (DoW) with input from the Department of Environment & Conservation (DEC).

SECTION 6 - REFERENCES

Aquaterra, 2001. *Austeel Iron Ore Project Prediction of Groundwater Level Drawdown*, August 2001. Unpublished report prepared for Halpern Glick Maunsell

Aquaterra, 2007-a. *Fortescue Iron Ore Project – Groundwater Management Plan*, March 2007. Unpublished report prepared for Mineralogy Pty Ltd.

Aquaterra, 2007-b. *Balmoral South Iron Ore Project – Surface Water Management Plan*, April 2007. Unpublished report prepared for International Minerals Ltd.

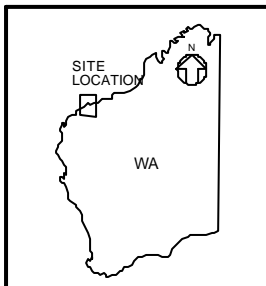
Bradberry Associates, 1965. *Water Resources of the Lower Fortescue River Area*. Unpublished report to Raymond International and Cliffs International.

Commander, D.P, 1993. *Hydrogeology of the Fortescue River Alluvium*. Unpublished GSWA Hydrogeology Report No. 1993/14.



Maunsell, 2007. *Balmoral South Iron Ore Project – Environmental Impact Assessment and Monitoring Programme*, April 2007. Unpublished report prepared for International Minerals Ltd.

Ypma, P.J, 1992. *Mineable Ore Reserves of the Central Block of the Balmoral Mining Lease*. Unpublished report to Mineralogy Pty Ltd by YRS Offshore Research Services B.V.

FIGURES



LEGEND

-  Proposed Pit Outline
-  Project Area

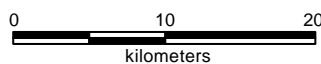
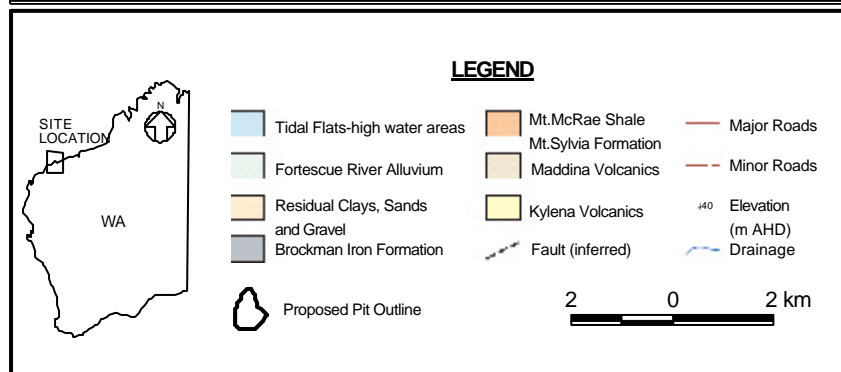
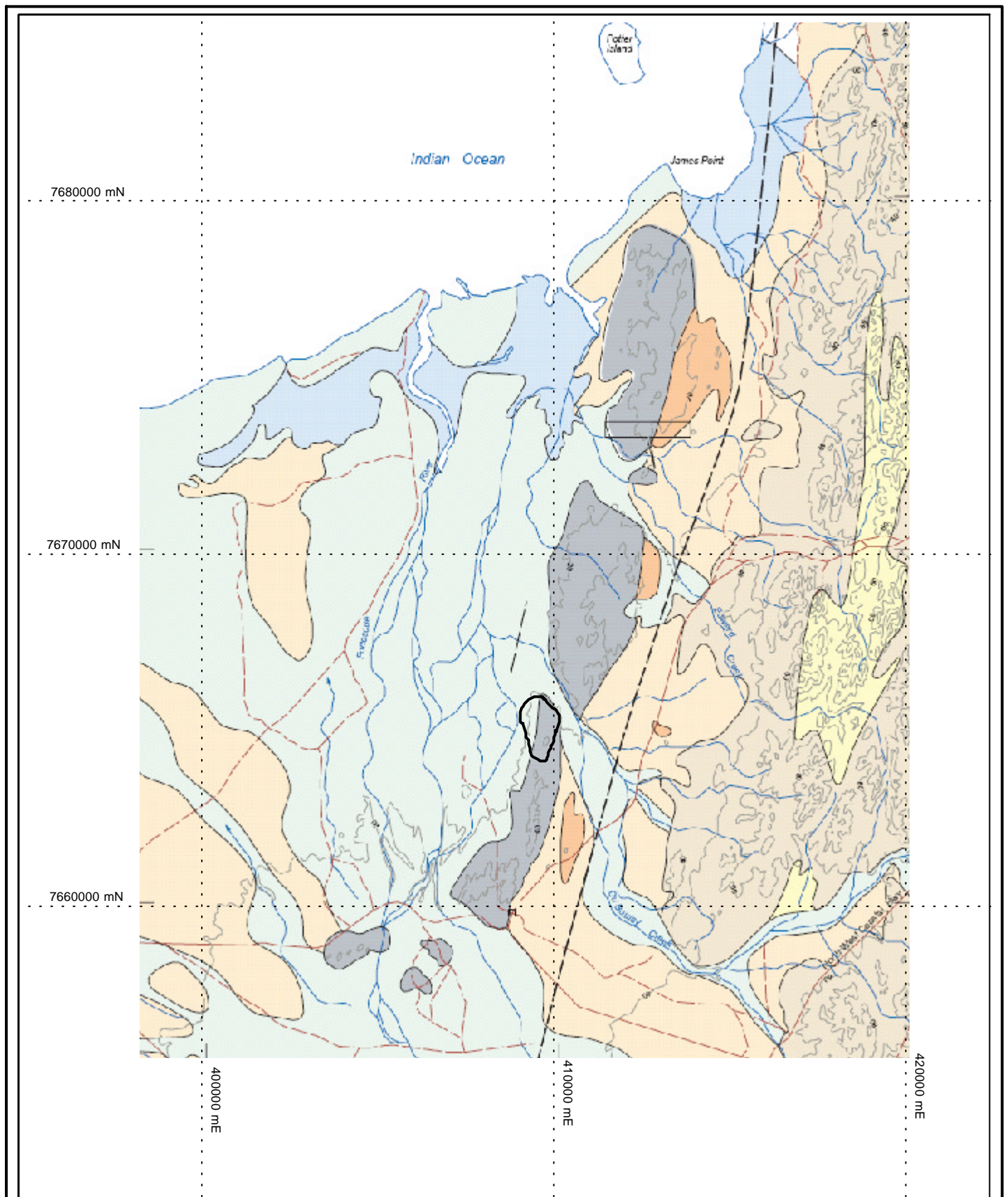


Figure 1
Project Location
Balmoral South Iron Ore Project

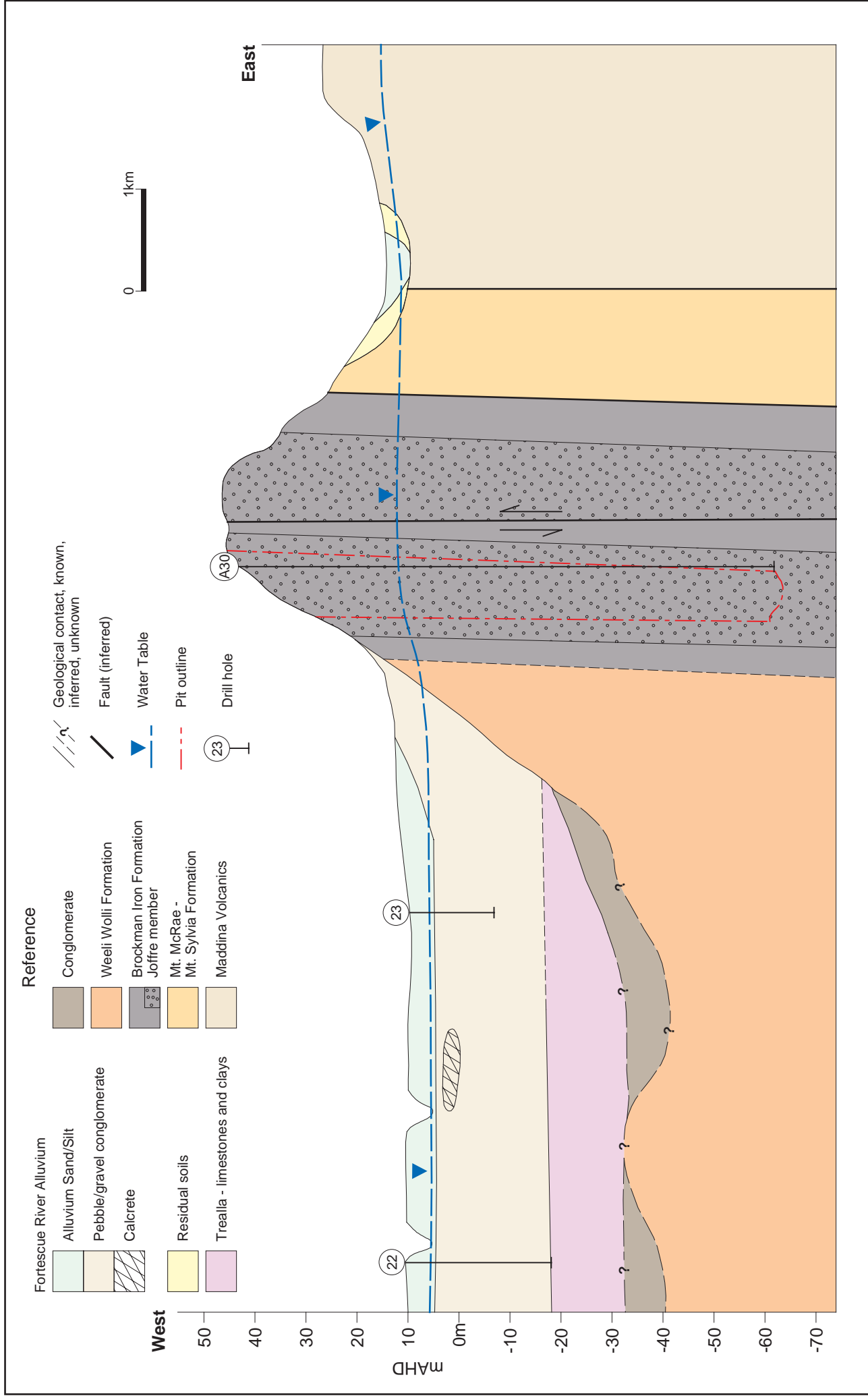
Author: GMS	Date: 19 April 2007
Drawn By: GMS	Revised:
Job No.: 773	Report No.: 010a
GDA94 Zone50	Scale: 1:500,000



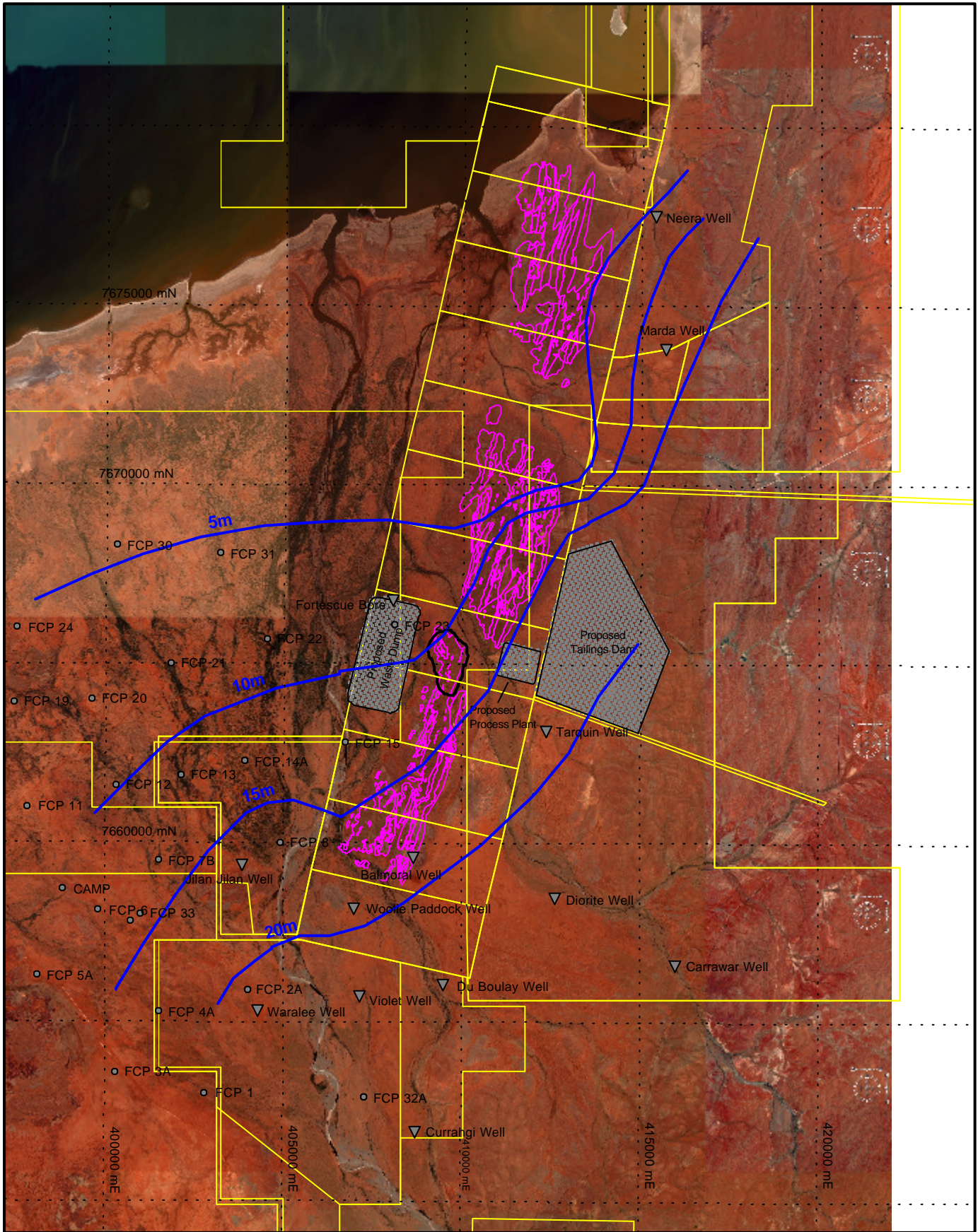
aquaterra

**Figure 2
Regional Geology
Balmoral South Iron Ore Project**

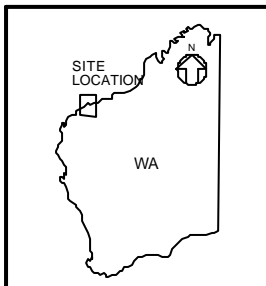
Author: GMS	Date: 19 April 2007
Drawn By: GMS	Revised:
Job No.: 773	Report No.: 010a
GDA94 Zone50	Scale: 1:150,000



Schematic Geological Cross Section
Figure 3



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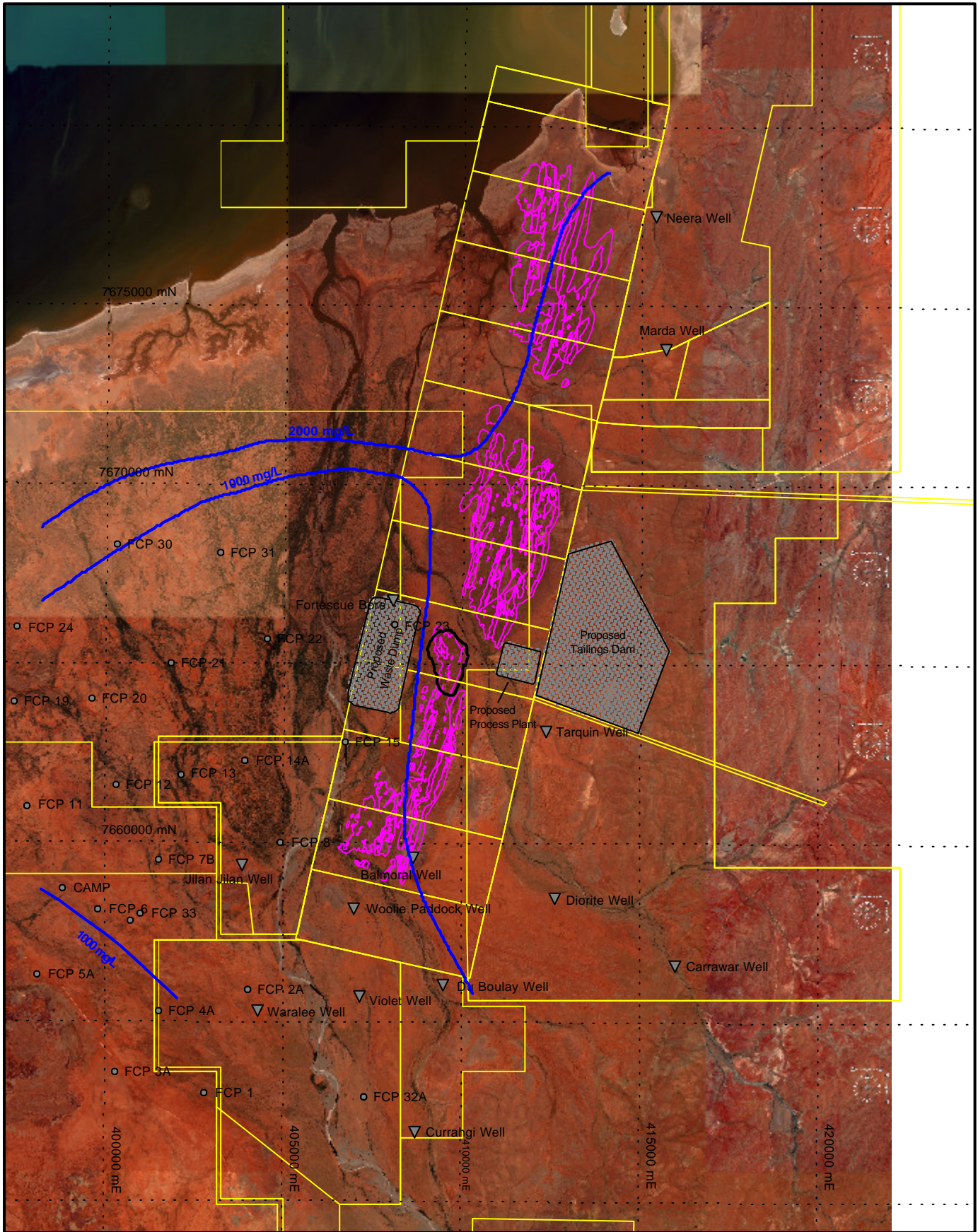
- ▽ Pastoral Wells
- Old GSWA Bores
- ▭ Proposed Pit Outline
- ▭ Tenements
- ▭ Orebodies
- ~ 10m Water Level Contours (mAHD)

2 0 2 km

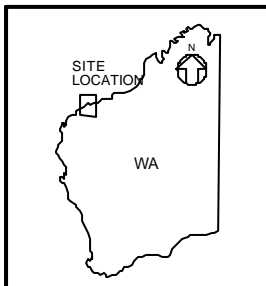


Figure 4
Groundwater Level Contours
Balmoral South Iron Ore Project

Author: GMS	Date: 19 April 2007
Drawn By: GMS	Revised:
Job No.: 773	Report No.: 010a
GDA94 Zone50	Scale: 1:150,000



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LEGEND

- ▼ Pastoral Wells
- Old GSWA Bores
- ▭ Proposed Pit Outline
- ▭ Tenements
- ▭ Orebodies
- Salinity Contours (mg/L TDS)

2 0 2 km



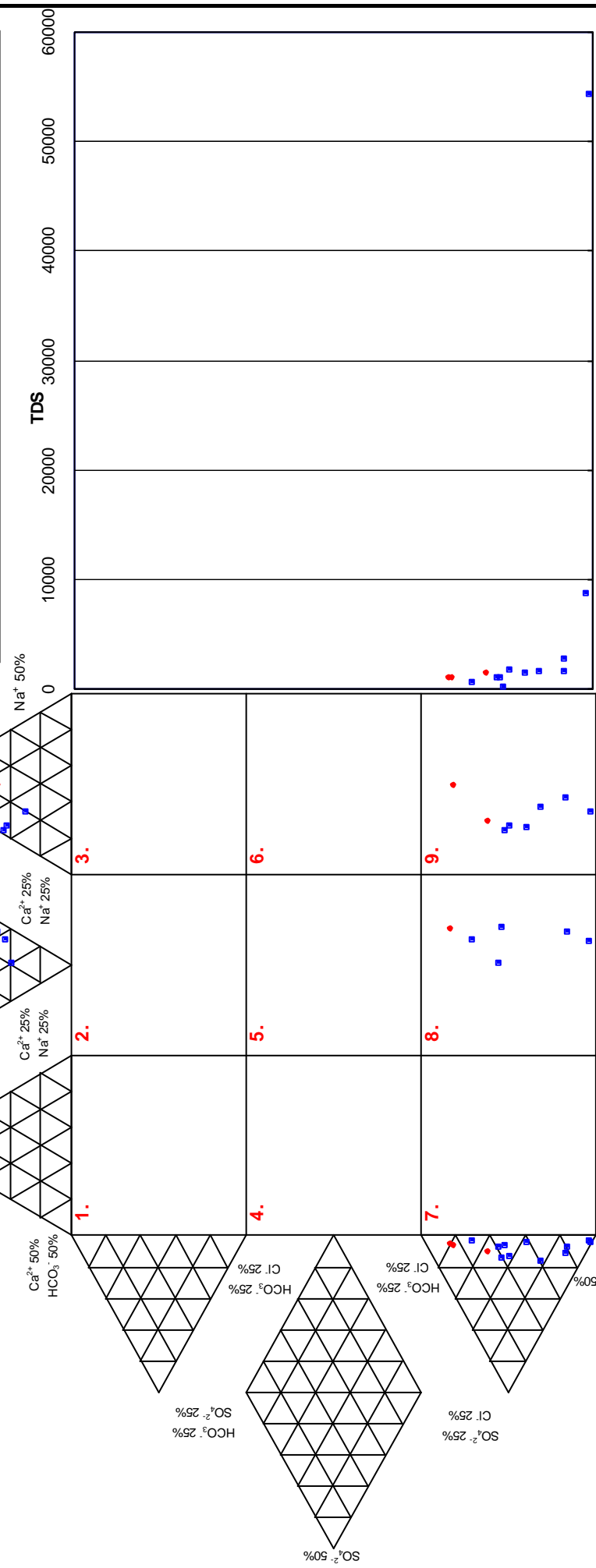
Figure 5
Groundwater Salinity Contours
Balmoral South Iron Ore Project

Author: GMS	Date: 19 April 2007
Drawn By: GMS	Revised:
Job No.: 773	Report No.: 010a
GDA94 Zone50	Scale: 1:150,000

• Pastoral Wells
■ Orebody Exploration Holes

WATER TYPE SUB-FIELDS

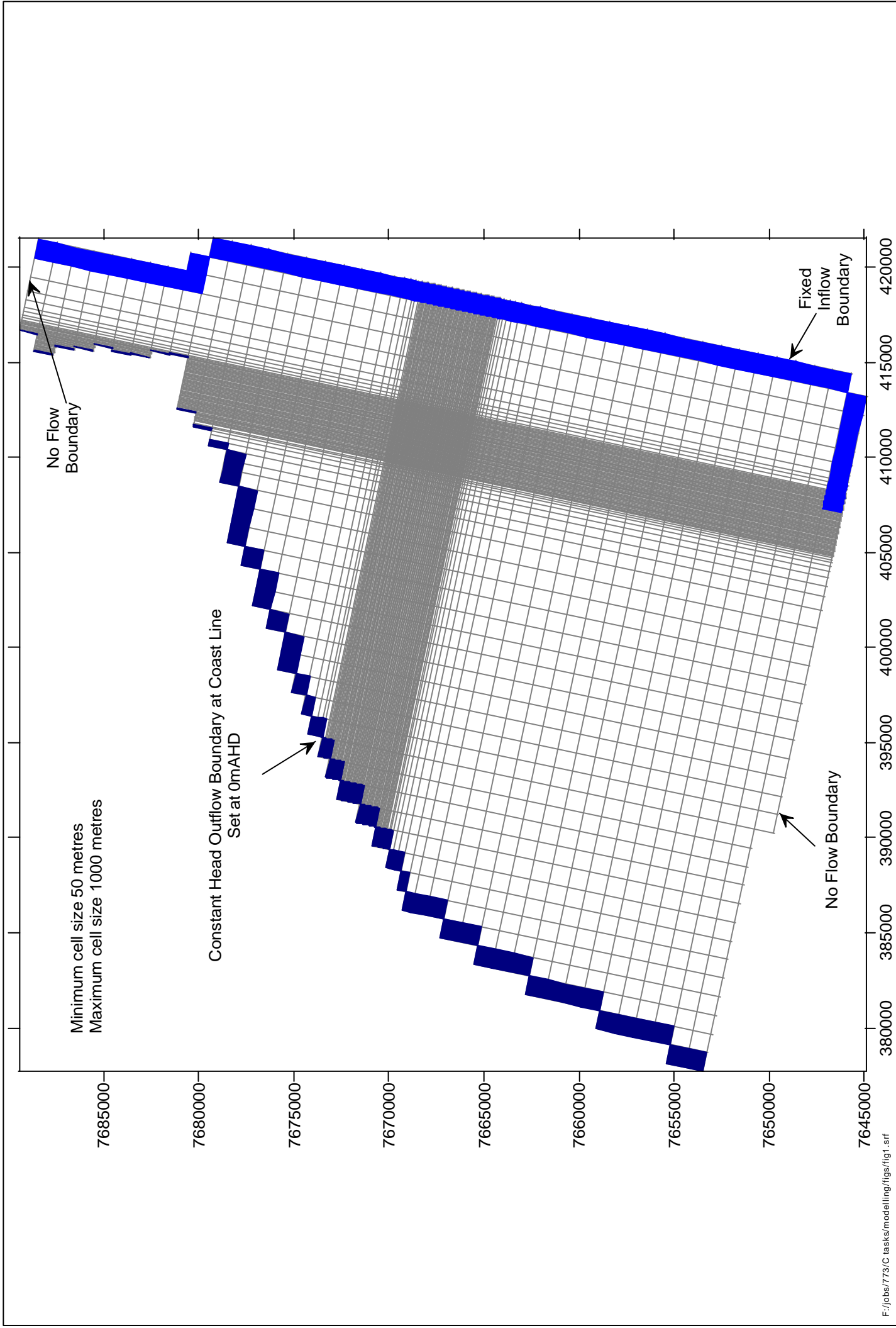
1. HCO₃⁻ and Ca²⁺ dominant (frequently indicates recharging waters)
2. HCO₃⁻ dominant and Mg²⁺ dominant or cations indiscriminant
3. HCO₃⁻ and Na⁺ dominant (ion exchanged waters)
4. SO₄²⁻ dominant or anions indiscriminant and Ca²⁺ dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO₄²⁻ dominant or anions indiscriminant and Na⁺ dominant (mixing influences)
7. Cl⁻ and Ca²⁺ dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl⁻ dominant and no dominant cation (reverse ion exchange of NaCl waters)



Expanded Durov Diagram

Figure 6

Date: 19/04/07	Project: Balmoral South	Description: Groundwater Chemistry	HydroCHEM 2.0
F:\Users\779\GW_C_Tasks\HydroCHEM2.D.xlsx\Project Information	Project No: 773	Client: International Minerals	



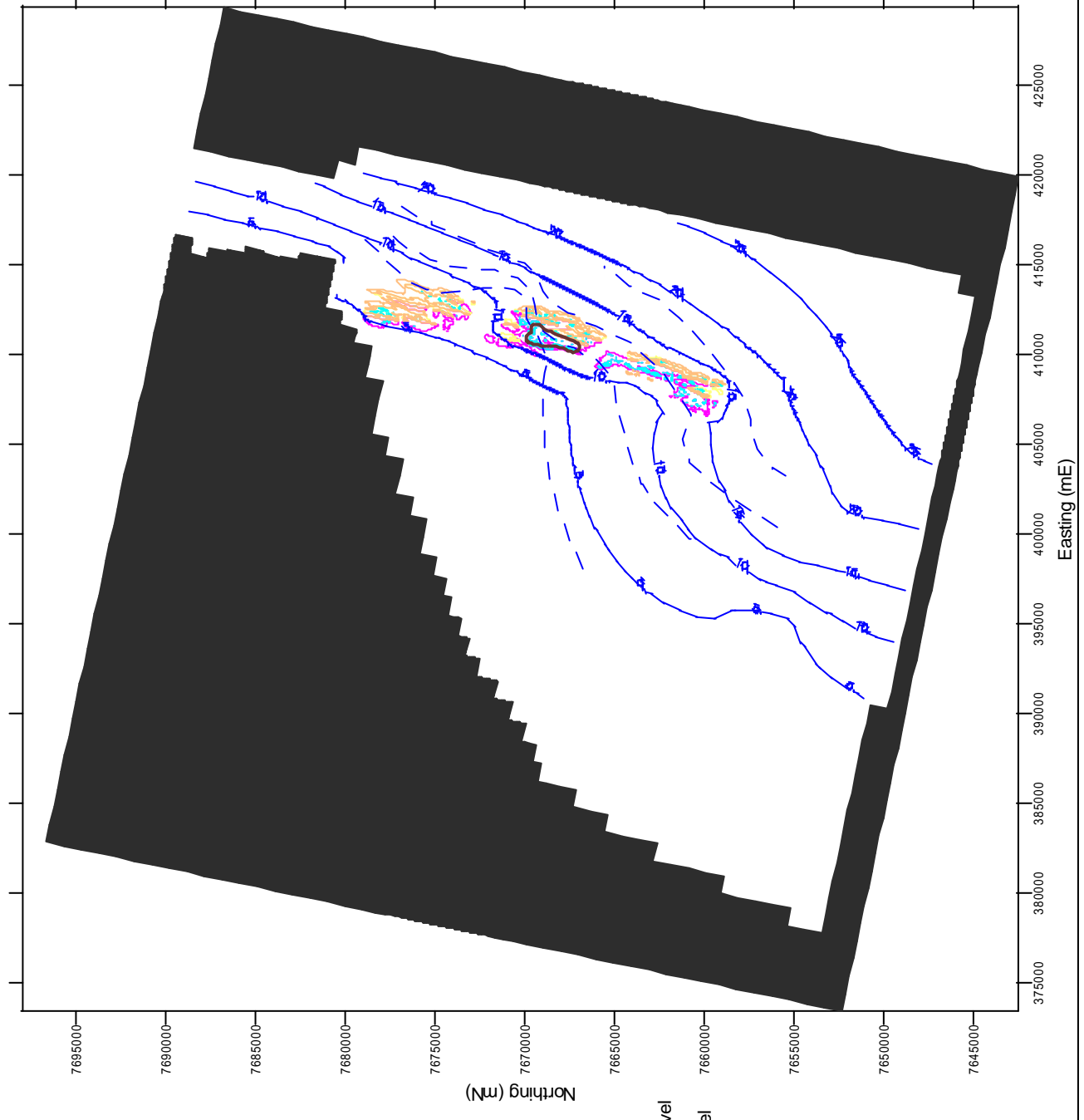
Minimum cell size 50 metres
Maximum cell size 1000 metres

No Flow Boundary

Constant Head Outflow Boundary at Coast Line
Set at 0m AHD

No Flow Boundary

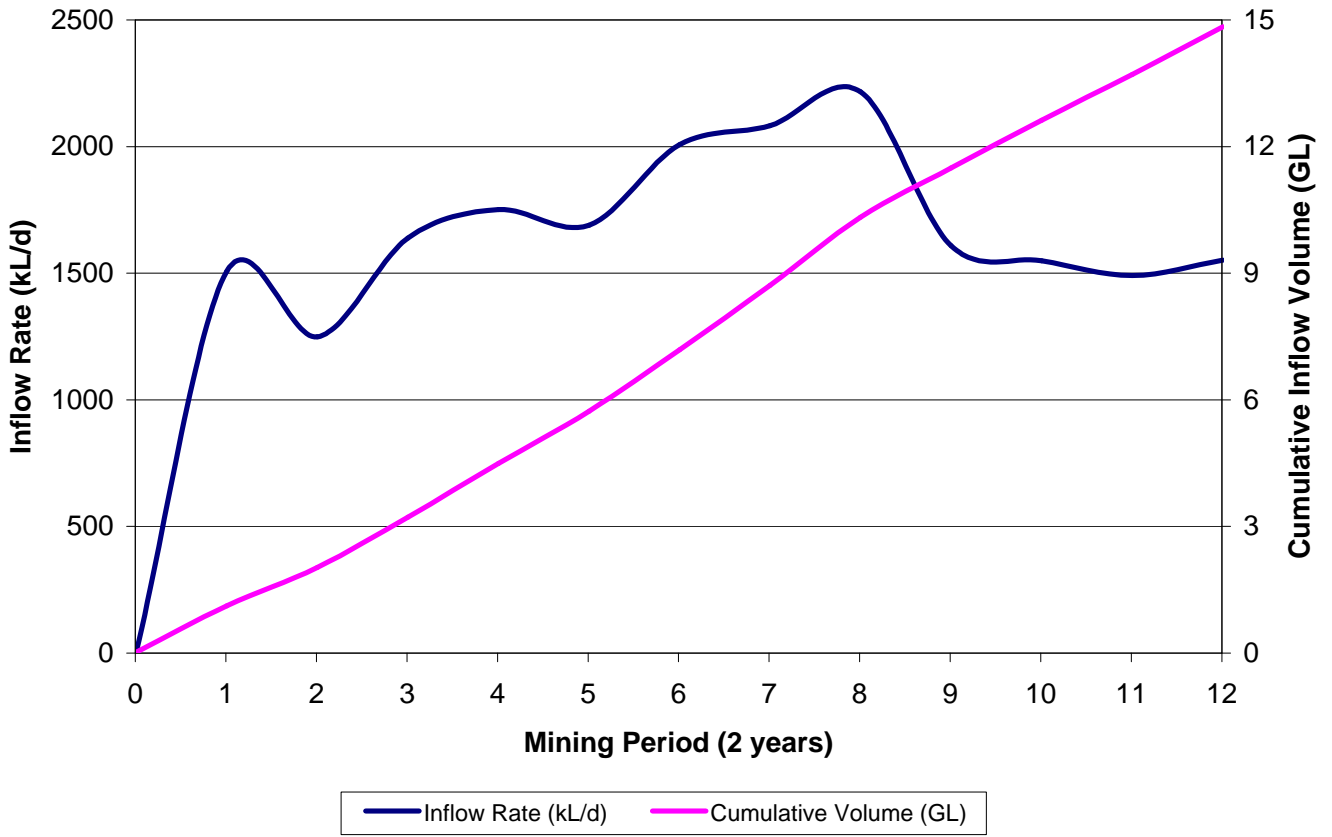
Fixed Inflow Boundary



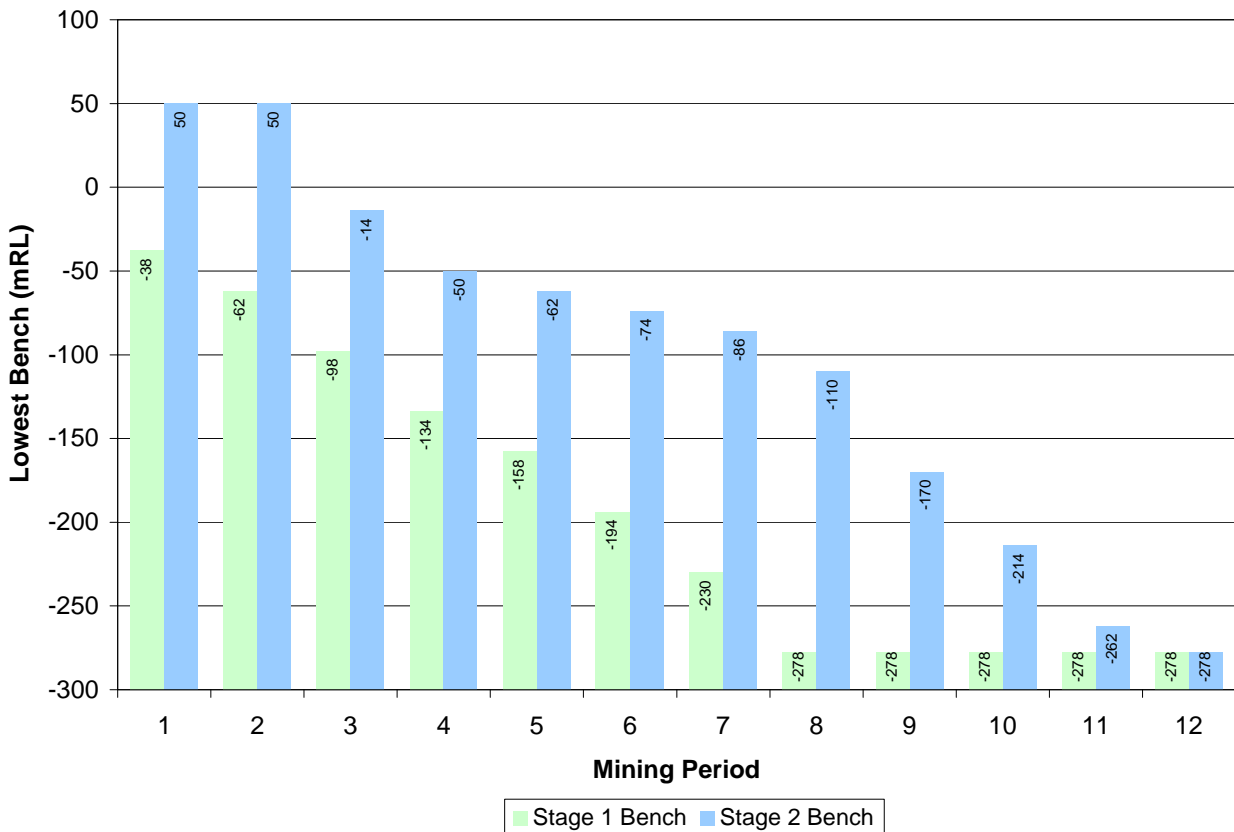
LEGEND
 - - - Measured Groundwater Level Contour (Aquaterra, 2000)
 ——— Modelled Groundwater Level Contour

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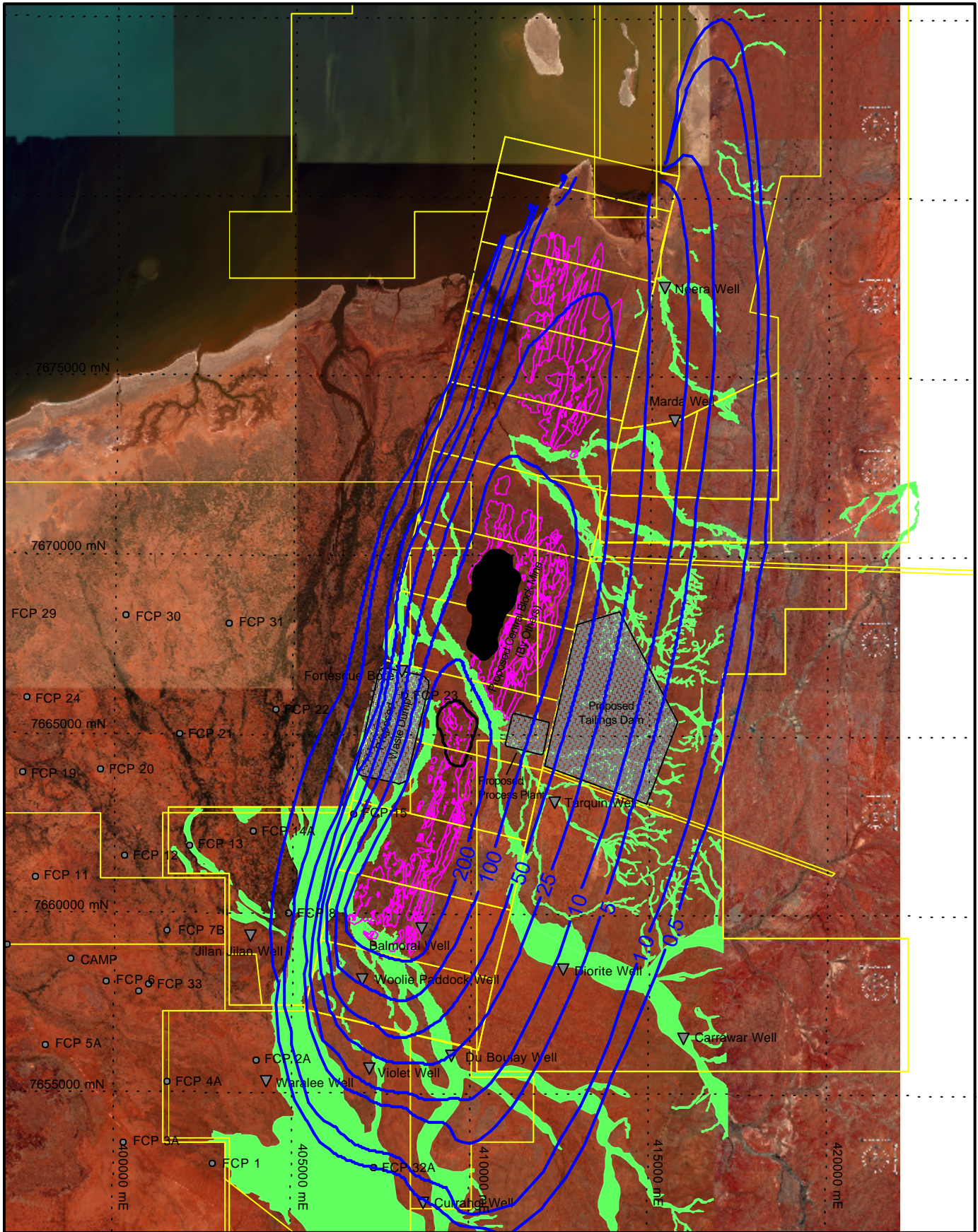
Inflow Rate and Volume



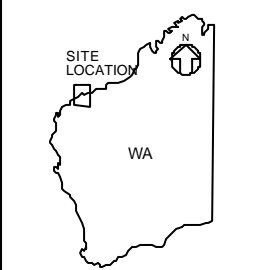
Lowest Bench Height



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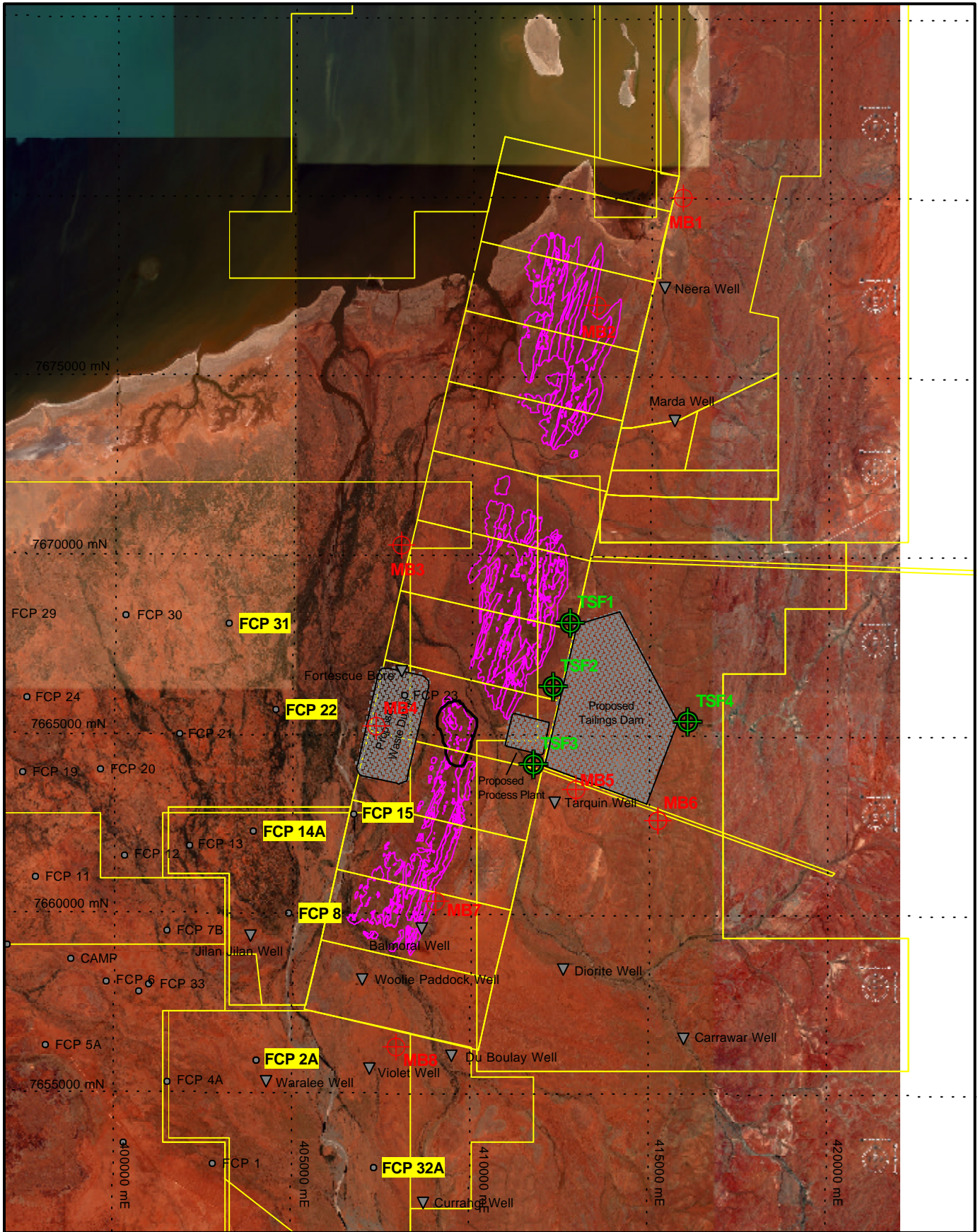
Pastoral Wells	Old GSWA Bores
Proposed Pit Outline	Tenements
Orebodies	Phreatophytic Vegetation
Predicted Drawdown Contours after 24 years (m)	

2 0 2 km

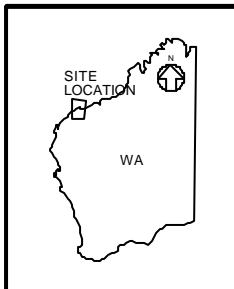
aquaterra

Figure 10
End of Mining
Cummulative Water Level Drawdowns
Balmoral South Iron Ore Project

Author: GMS	Date: 19 April 2007
Drawn By: GMS	Revised:
Job No.: 773	Report No.: 010a
GDA94 Zone50	Scale: 1:150,000



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LEGEND

Pastoral Wells	FCP 31	GSWA Bores for Monitoring
Proposed Pit Outline	Monitoring Bores	TSF Monitoring Bores
Orebodies		
Tenements		

2 0 2 km



Figure 11
Proposed Monitoring Bore locations
Balmoral South Iron Ore Project

Author: GMS	Date: 19 April 2007
Drawn By: GMS	Revised:
Job No.: 773	Report No.: 010a
GDA94 Zone50	Scale: 1:150,000

APPENDIX A
PERMEABILITY TESTING

Balmoral South Permeability Testing Summary

Hole ID	Bulk K (m/day)			
AR029	3.1E-07	Average	0.59	m/day
SB003A	3.5E-01	Max	5.8	m/day
SB005A	2.1E-02	Min	1.07E-08	m/day
SB006	2.8E-02	Count	13	
SB008A	6.9E-03			
SB009	8.1E-08			
SB012	1.1E-08			
SB022	4.0E-01			
SB025	5.8E+00			
SB027	1.4E-02			
SB030	4.5E-03			
SB034	4.1E-01			
SB035	1.1E-01			

SB007	high	losing air to formation - small water return through ground
SB036	high	no airlift - air/water lost to formation

SB002	insufficient submergence
SB039	insufficient submergence

Airlift Recovery Test Record

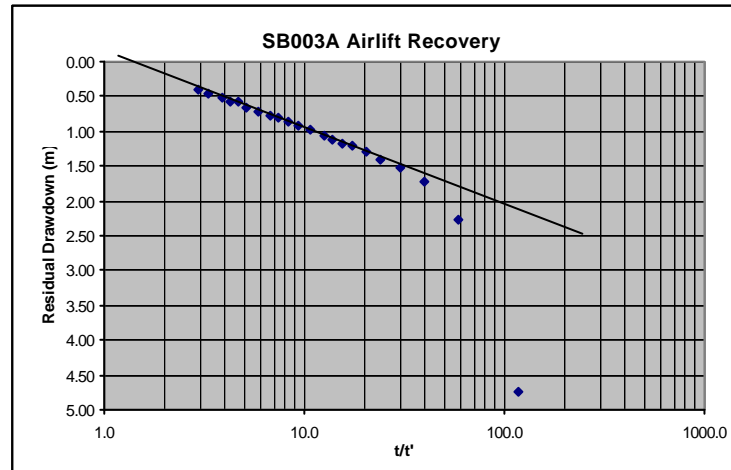
Hole ID: SB003A

Easting	409499 m	Dia.	146 mm
Northing	7665224 m	Depth	289 m
RL	22.741 mAHD	Corrected depth	250 m
Dip	60 degrees		
Azimuth	110 degrees		

		Discharge Data			
Average Q	5.7 L/s	Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
Duration:	58 minutes	3	20	3	6.7
		13	20	3.5	5.7
		28	20	3.2	6.3
SWL:	15.29 mbrp	38	20	3.5	5.7
Corrected SWL	13.24 mbrp	58	20	3.8	5.3
Sat. thickness	237 m				

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.5	117.0	20.75	17.97	4.73
1.0	59.0	17.92	15.52	2.28
1.5	39.7	17.29	14.97	1.73
2.0	30.0	17.04	14.76	1.52
2.5	24.2	16.91	14.64	1.40
3.0	20.3	16.78	14.53	1.29
3.5	17.6	16.7	14.46	1.22
4.0	15.5	16.65	14.42	1.18
4.5	13.9	16.59	14.37	1.13
5.0	12.6	16.52	14.31	1.07
6.0	10.7	16.43	14.23	0.99
7.0	9.3	16.35	14.16	0.92
8.0	8.3	16.28	14.10	0.86
9.0	7.4	16.23	14.06	0.81
10.0	6.8	16.19	14.02	0.78
12.0	5.8	16.11	13.95	0.71
14.0	5.1	16.05	13.90	0.66
16.0	4.6	15.97	13.83	0.59
18.0	4.2	15.94	13.80	0.56
20.0	3.9	15.9	13.77	0.53
25.0	3.3	15.82	13.70	0.46
30.0	2.9	15.76	13.65	0.41



CALCULATIONS				
SLOPE ONE		SLOPE TWO		
Ds Estimate	1.1 m	Ds Estimate	n/a	m
T	83 m ² /day	T	n/a	m ² /day
Bulk K	3.5E-01 m/day	Bulk K	n/a	m/day

Airlift Recovery Test Record

Hole ID: SB005A

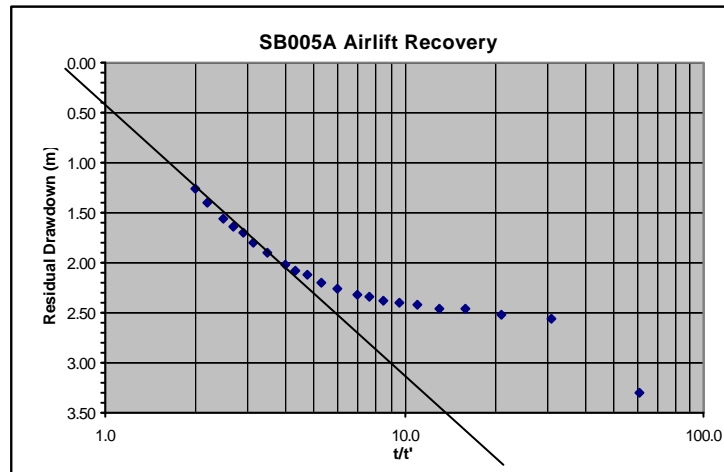
Easting	409860 m	Dia.	146 mm
Northing	7665022 m	Depth	289 m
RL	30.333 mAHD	Corrected Depth	250 m
Dip	60 degrees		
Azimuth	110 degrees		

		Discharge Data			
Average Q	0.9 L/s	Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
Duration:	30 minutes	2	20	24.5	0.8
		12	20	22.75	0.9
		30	20	23.75	0.8

SWL:	22.64 mbrp
Corrected SWL	19.61 mbrp
Sat. thickness	231 m

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.5	61.0	26.44	22.90	3.29
1.0	31.0	25.59	22.16	2.55
1.5	21.0	25.54	22.12	2.51
2.0	16.0	25.47	22.06	2.45
2.5	13.0	25.47	22.06	2.45
3.0	11.0	25.43	22.02	2.42
3.5	9.6	25.42	22.01	2.41
4.0	8.5	25.38	21.98	2.37
4.5	7.7	25.35	21.95	2.35
5.0	7.0	25.31	21.92	2.31
6.0	6.0	25.25	21.87	2.26
7.0	5.3	25.19	21.82	2.21
8.0	4.8	25.09	21.73	2.12
9.0	4.3	25.04	21.69	2.08
10.0	4.0	24.97	21.62	2.02
12.0	3.5	24.84	21.51	1.91
14.0	3.1	24.72	21.41	1.80
16.0	2.9	24.61	21.31	1.71
18.0	2.7	24.53	21.24	1.64
20.0	2.5	24.43	21.16	1.55
25.0	2.2	24.25	21.00	1.39
30.0	2.0	24.09	20.86	1.26



CALCULATIONS			
SLOPE ONE		SLOPE TWO	
Ds Estimate	2.75 m	Ds Estimate	n/a m
T	5 m ² /day	T	n/a m ² /day
Bulk K	2.1E-02 m/day	Bulk K	n/a m/day

Airlift Recovery Test Record

Hole ID: SB006

Easting	409586 m	Dia.	146 mm
Northing	7665634 m	Depth	290 m
RL	21.911 mAHD	Corrected depth	251 m
Dip	60 degrees		
Azimuth	100 degrees		

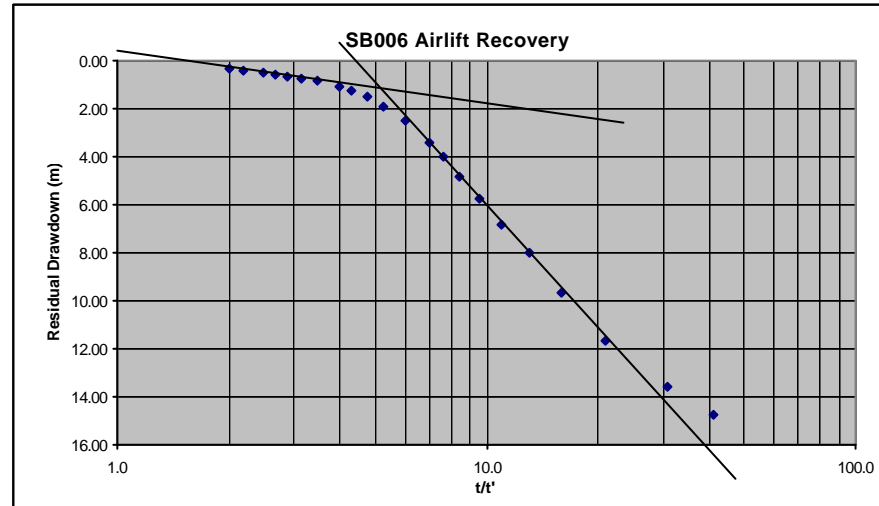
Average Q 0.9 L/s
Duration: 30 minutes

Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
8	20	22	0.9
20	20	20	1.0
30	20	22	0.9

SWL: 14.57 mbrp
Corrected SWL 12.62 mbrp
Sat. thickness 239 m

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.8	41.0	31.62	27.38	14.77
1.0	31.0	30.3	26.24	13.62
1.5	21.0	28.04	24.28	11.67
2.0	16.0	25.77	22.32	9.70
2.5	13.0	23.82	20.63	8.01
3.0	11.0	22.45	19.44	6.82
3.5	9.6	21.2	18.36	5.74
4.0	8.5	20.15	17.45	4.83
4.5	7.7	19.2	16.63	4.01
5.0	7.0	18.51	16.03	3.41
6.0	6.0	17.45	15.11	2.49
7.0	5.3	16.76	14.51	1.90
8.0	4.8	16.32	14.13	1.52
9.0	4.3	16.04	13.89	1.27
10.0	4.0	15.83	13.71	1.09
12.0	3.5	15.58	13.49	0.87
14.0	3.1	15.42	13.35	0.74
16.0	2.9	15.31	13.26	0.64
18.0	2.7	15.22	13.18	0.56
20.0	2.5	15.15	13.12	0.50
25.0	2.2	15.03	13.02	0.40
30.0	2.0	14.96	12.96	0.34



SLOPE ONE		SLOPE TWO	
Ds Estimate	2.2 m	Ds Estimate	17 m
T	7 m ² /day	T	1 m ² /day
Bulk K	2.8E-02 m/day	Bulk K	3.7E-03 m/day

Airlift Recovery Test Record

Hole ID: SB008A

Easting 409940 m **Dia.** 146 mm
Northing 7665446 m **Depth** 290 m
RL 19.825 mAHD **Corrected Depth** 251 m
Dip 60 degrees
Azimuth 100 degrees

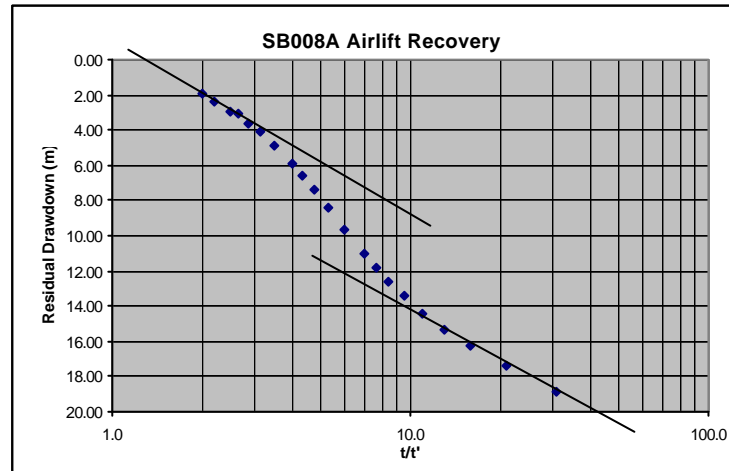
Average Q 1.0 L/s
Duration: 30 minutes

Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
11	20	20	1.0
20	9	10	0.9
30	20	17.3	1.2

SWL: 10.99 mbrp
Corrected SWL 9.52 mbrp
Sat. thickness 242 m

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.5	-	-	-	-
1.0	31.0	32.75	28.36	18.84
1.5	21.0	31.13	26.96	17.44
2.0	16.0	29.81	25.82	16.30
2.5	13.0	28.7	24.85	15.34
3.0	11.0	27.6	23.90	14.38
3.5	9.6	26.49	22.94	13.42
4.0	8.5	25.57	22.14	12.63
4.5	7.7	24.64	21.34	11.82
5.0	7.0	23.7	20.52	11.01
6.0	6.0	22.14	19.17	9.66
7.0	5.3	20.7	17.93	8.41
8.0	4.8	19.56	16.94	7.42
9.0	4.3	18.56	16.07	6.56
10.0	4.0	17.83	15.44	5.92
12.0	3.5	16.58	14.36	4.84
14.0	3.1	15.72	13.61	4.10
16.0	2.9	15.17	13.14	3.62
18.0	2.7	14.56	12.61	3.09
20.0	2.5	14.34	12.42	2.90
25.0	2.2	13.68	11.85	2.33
30.0	2.0	13.25	11.47	1.96



CALCULATIONS			
SLOPE ONE		SLOPE TWO	
Ds Estimate	9.7 m	Ds Estimate	9.5 m
T	2 m ² /day	T	2 m ² /day
Bulk K	6.9E-03 m/day	Bulk K	7.0E-03 m/day

Airlift Recovery Test Record

Hole ID: SB025

Easting	409537 m	Dia.	146 mm
Northing	7665912 m	Depth	241 m
RL	22.203 mAHD	Corrected Depth	209 m
Dip	60 degrees		
Azimuth	80 degrees		

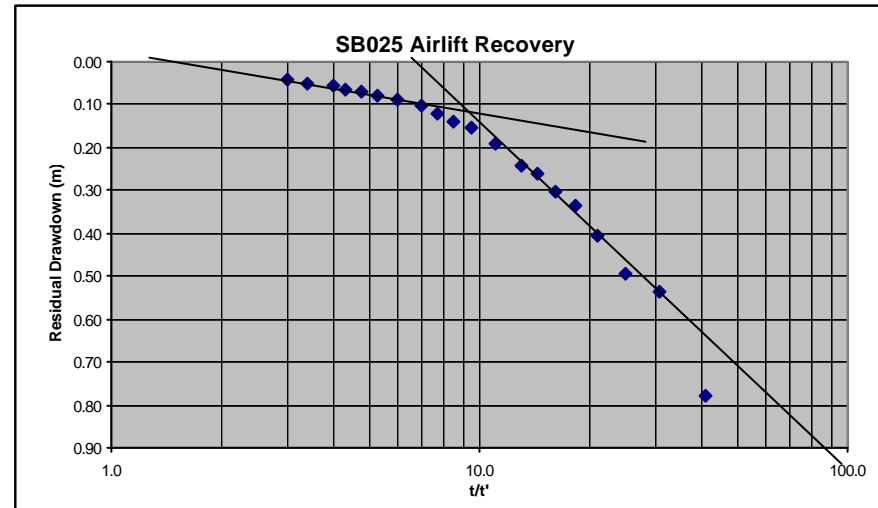
Average Q 8.5 L/s
Duration: 60 minutes

SWL: 15.18 mbrp
Corrected SWL 13.15 mbrp
Sat. thickness 196 m

Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
1	20	2.2	9.1
12	20	2.2	9.1
27	20	2.2	9.1
37	20	2.4	8.3
47	20	2.5	8.0
60	20	2.5	8.0

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.5	121.0	15.45	13.38	0.23
1.5	41.0	16.08	13.93	0.78
2.0	31.0	15.8	13.68	0.54
2.5	25.0	15.75	13.64	0.49
3.0	21.0	15.65	13.55	0.41
3.5	18.1	15.57	13.48	0.34
4.0	16.0	15.53	13.45	0.30
4.5	14.3	15.48	13.41	0.26
5.0	13.0	15.46	13.39	0.24
6.0	11.0	15.4	13.34	0.19
7.0	9.6	15.36	13.30	0.16
8.0	8.5	15.34	13.28	0.14
9.0	7.7	15.32	13.27	0.12
10.0	7.0	15.3	13.25	0.10
12.0	6.0	15.28	13.23	0.09
14.0	5.3	15.27	13.22	0.08
16.0	4.8	15.26	13.22	0.07
18.0	4.3	15.255	13.21	0.06
20.0	4.0	15.245	13.20	0.06
25.0	3.4	15.24	13.20	0.05
30.0	3.0	15.23	13.19	0.04



SLOPE ONE		SLOPE TWO	
Ds Estimate	0.12 m	Ds Estimate	0.8 m
T	1126 m ² /day	T	169 m ² /day
Bulk K	5.8E+00 m/day	Bulk K	8.6E-01 m/day

Airlift Recovery Test Record

Hole ID: SB027

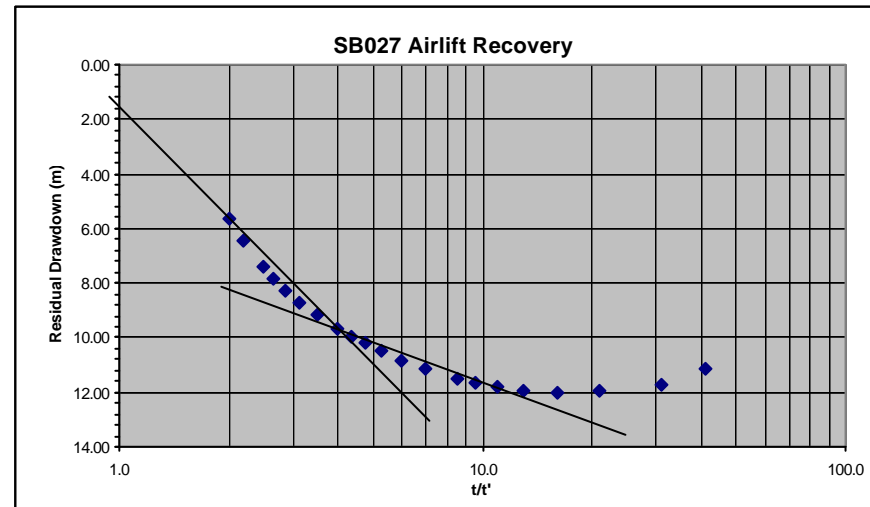
Easting	409382 m	Dia.	146 mm
Northing	7665048 m	Depth	289 m
RL	19.975 mAHD	Corrected Depth	250 m
Dip	60 degrees		
Azimuth	90 degrees		

Average Q	2.9 L/s	Discharge Data			
Duration:	30 minutes	Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
		5	20	4.7	4.3
		15	20	5.5	3.6
		30	20	9.8	2.0

SWL:	11.53 mbrp
Corrected SWL	9.99 mbrp
Sat. thickness	240 m

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.8	41.0	24.4	21.13	11.15
1.0	31.0	25.04	21.69	11.70
1.5	21.0	25.3	21.91	11.93
2.0	16.0	25.42	22.01	12.03
2.5	13.0	25.32	21.93	11.94
3.0	11.0	25.16	21.79	11.80
3.5	9.6	24.98	21.63	11.65
4.0	8.5	24.78	21.46	11.47
4.5	7.7	24.59	21.30	
5.0	7.0	24.4	21.13	11.15
6.0	6.0	24.02	20.80	10.82
7.0	5.3	23.67	20.50	10.51
8.0	4.8	23.33	20.20	10.22
9.0	4.3	23.04	19.95	9.97
10.0	4.0	22.74	19.69	9.71
12.0	3.5	22.11	19.15	9.16
14.0	3.1	21.6	18.71	8.72
16.0	2.9	21.08	18.26	8.27
18.0	2.7	20.55	17.80	7.81
20.0	2.5	20.11	17.42	7.43
25.0	2.2	18.96	16.42	6.43
30.0	2.0	18.02	15.61	5.62



CALCULATIONS			
SLOPE ONE		SLOPE TWO	
Ds Estimate	13.6 m	Ds Estimate	4.8 m
T	3 m ² /day	T	10 m ² /day
Bulk K	1.4E-02 m/day	Bulk K	4.0E-02 m/day

Airlift Recovery Test Record

Hole ID: SB030

Easting	409618 m	Dia.	146 mm
Northing	7666262 m	Depth	289 m
RL	15.811 mAHD	Corrected Depth	250 m
Dip	60 degrees		
Azimuth	90 degrees		

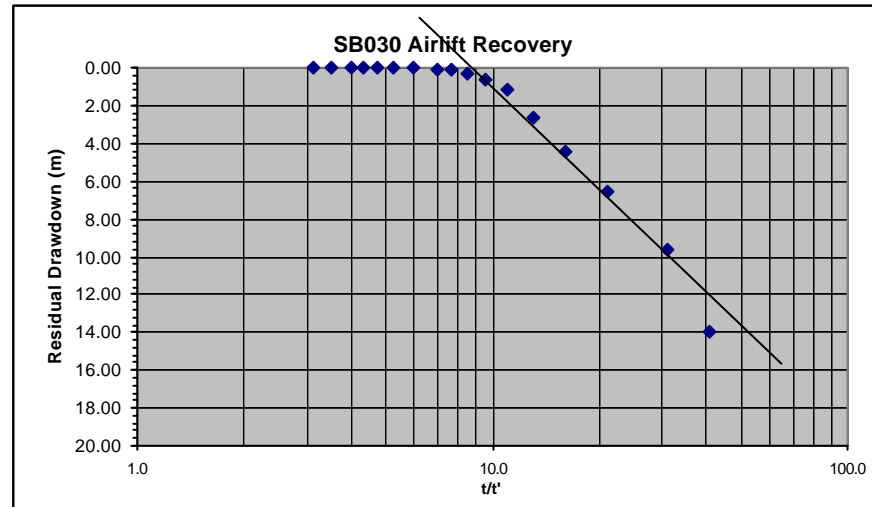
Discharge Data

Average Q	1.3 L/s	Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
Duration:	30 minutes	7	9	4.6	2.0
		17	9	8.2	1.1
		30	9	8.5	1.1

SWL:	7.79 mbrp
Corrected SWL	6.75 mbrp
Sat. thickness	244 m

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.8	41.0	23.88	20.68	13.93
1.0	31.0	18.89	16.36	9.61
1.5	21.0	15.33	13.28	6.53
2.0	16.0	12.88	11.15	4.41
2.5	13.0	10.83	9.38	2.63
3.0	11.0	9.14	7.92	1.17
3.5	9.6	8.49	7.35	0.61
4.0	8.5	8.13	7.04	0.29
4.5	7.7	7.95	6.88	0.14
5.0	7.0	7.88	6.82	0.08
6.0	6.0	7.84	6.79	0.04
7.0	5.3	7.83	6.78	0.03
8.0	4.8	7.81	6.76	0.02
9.0	4.3	7.805	6.76	0.01
10.0	4.0	7.8	6.75	0.01
12.0	3.5	7.795	6.75	0.00
14.0	3.1	7.79	6.75	0.00



CALCULATIONS			
SLOPE ONE		SLOPE TWO	
Ds Estimate	0.24 m	Ds Estimate	18.6 m
T	84 m ² /day	T	1 m ² /day
Bulk K	3.5E-01 m/day	Bulk K	4.5E-03 m/day

Airlift Recovery Test Record

Hole ID: SB034

Easting	409228 m	Dia.	146 mm
Northing	7664241 m	Depth	289 m
RL	24.509 mAHD	Corrected Depth	250 m
Dip	60 degrees		
Azimuth	100 degrees		

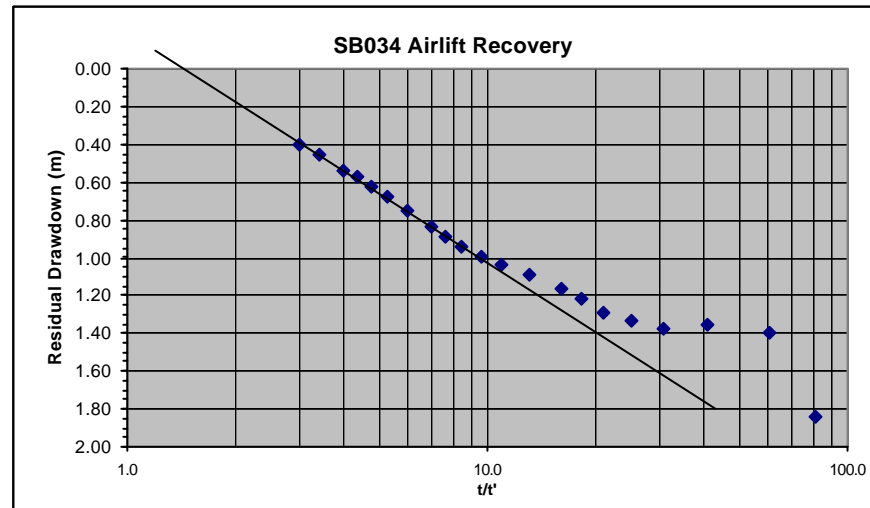
Average Q 7.6 L/s
 Duration: 60 minutes

SWL: 16.09 mbrp
 Corrected SWL 13.93 mbrp
 Sat. thickness 236 m

Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
2	20	2	10.0
17	20	2.5	8.0
27	20	2.6	7.7
37	20	2.75	7.3
60	20	2.74	7.3

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.8	81.0	18.22	15.78	1.84
1.0	61.0	17.7	15.33	1.39
1.5	41.0	17.65	15.29	1.35
2.0	31.0	17.68	15.31	1.38
2.5	25.0	17.63	15.27	1.33
3.0	21.0	17.58	15.22	1.29
3.5	18.1	17.5	15.16	1.22
4.0	16.0	17.44	15.10	1.17
4.5	14.3			
5.0	13.0	17.35	15.03	1.09
6.0	11.0	17.29	14.97	1.04
7.0	9.6	17.24	14.93	1.00
8.0	8.5	17.18	14.88	0.94
9.0	7.7	17.12	14.83	0.89
10.0	7.0	17.05	14.77	0.83
12.0	6.0	16.96	14.69	0.75
14.0	5.3	16.87	14.61	0.68
16.0	4.8	16.81	14.56	0.62
18.0	4.3	16.75	14.51	0.57
20.0	4.0	16.71	14.47	0.54
25.0	3.4	16.61	14.38	0.45
30.0	3.0	16.55	14.33	0.40



SLOPE ONE		SLOPE TWO	
Ds Estimate	1.25 m	Ds Estimate	n/a m
T	96 m ² /day	T	n/a m ² /day
Bulk K	4.1E-01 m/day	Bulk K	n/a m/day

Airlift Recovery Test Record

Hole ID: SB035

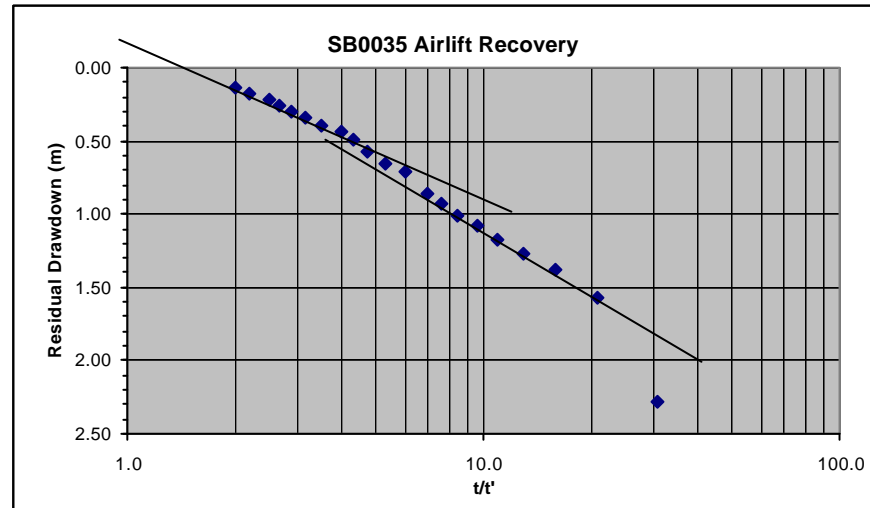
Easting	409381 m	Dia.	146 mm
Northing	7664393 m	Depth	289 m
RL	30.026 mAHD	Corrected Depth	250 m
Dip	60 degrees		
Azimuth	90 degrees		

		Discharge Data			
Average Q	1.7 L/s	Time (min)	Vol (L)	Time to fill (s)	Q (L/s)
Duration:	30 minutes	6	9	4.5	2.0
		16	9	5	1.8
		30	9	6	1.5

SWL:	21.89 mbrp
Corrected SWL	18.96 mbrp
Sat. thickness	231 m

Recovery Data

Time (min)	t/t'	Water Level (mbrp)	Corrected WL (mbrp)	Residual Drawdown (m)
0.5				
1.0	31.0	24.52	21.23	2.28
1.5	21.0	23.7	20.52	1.57
2.0	16.0	23.49	20.34	1.39
2.5	13.0	23.35	20.22	1.26
3.0	11.0	23.25	20.14	1.18
3.5	9.6	23.14	20.04	1.08
4.0	8.5	23.06	19.97	1.01
4.5	7.7	22.96	19.88	0.93
5.0	7.0	22.88	19.81	0.86
6.0	6.0	22.71	19.67	0.71
7.0	5.3	22.64	19.61	0.65
8.0	4.8	22.55	19.53	0.57
9.0	4.3	22.46	19.45	0.49
10.0	4.0	22.4	19.40	0.44
12.0	3.5	22.34	19.35	0.39
14.0	3.1	22.29	19.30	0.35
16.0	2.9	22.24	19.26	0.30
18.0	2.7	22.19	19.22	0.26
20.0	2.5	22.15	19.18	0.23
25.0	2.2	22.09	19.13	0.17
30.0	2.0	22.04	19.09	0.13

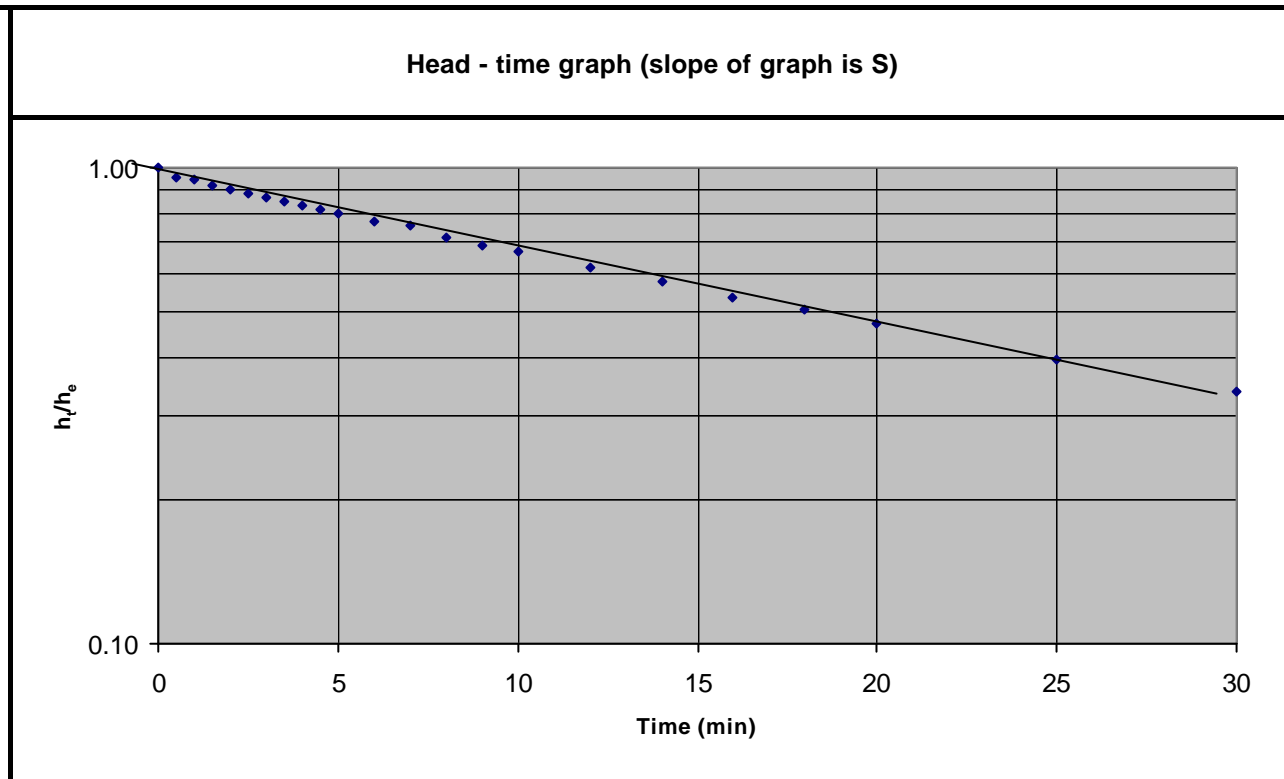


CALCULATIONS			
SLOPE ONE		SLOPE TWO	
Ds Estimate	1.1 m	Ds Estimate	1.4 m
T	24 m ² /day	T	19 m ² /day
Bulk K	1.1E-01 m/day	Bulk K	8.3E-02 m/day

RISING HEAD TEST

Bore No: SB009	Test No: #1	Job No: 773/C4	Date: 4-Apr-07	Logged by: GMS
Borehole co-ordinates: Easting: 410122		Northing: 8E+06		Collar elevation (m): 19.96
Depth to top of test section (m): 7.38		Length of test section, L (m): 122.62		
Depth of static water level, H_w (m): 7.38		Radius of borehole, r (m): 0.0685		
Excess head, h_e (m): -33.62		Radius of standpipe or casing, r_c (m): 0.0685		

Time (min)	Depth to water, h _w (m)	Excess head, h _i =H _w -h _w (m)	h _i /h _e
0.0	41.00	-33.62	1.00
0.5	39.50	-32.12	0.96
1.0	38.98	-31.6	0.94
1.5	38.28	-30.9	0.92
2.0	37.62	-30.24	0.90
2.5	37.01	-29.63	0.88
3.0	36.33	-28.95	0.86
3.5	35.84	-28.46	0.85
4.0	35.29	-27.91	0.83
4.5	34.73	-27.35	0.81
5.0	34.20	-26.82	0.80
6.0	33.25	-25.87	0.77
7.0	32.75	-25.37	0.75
8.0	31.36	-23.98	0.71
9.0	30.52	-23.14	0.69
10.0	29.7	-22.32	0.66
12	28.15	-20.77	0.62
14.0	26.79	-19.41	0.58
16	25.25	-17.87	0.53
18.0	24.3	-16.92	0.50
20	23.23	-15.85	0.47
25	20.71	-13.33	0.40
30	18.8	-11.42	0.34



Calculations:	h₁	0.96		
	t₁	0.5		
	h₂	0.47		
	t₂	20.0		
	S	1.6E-02		
	k	8.10E-08		

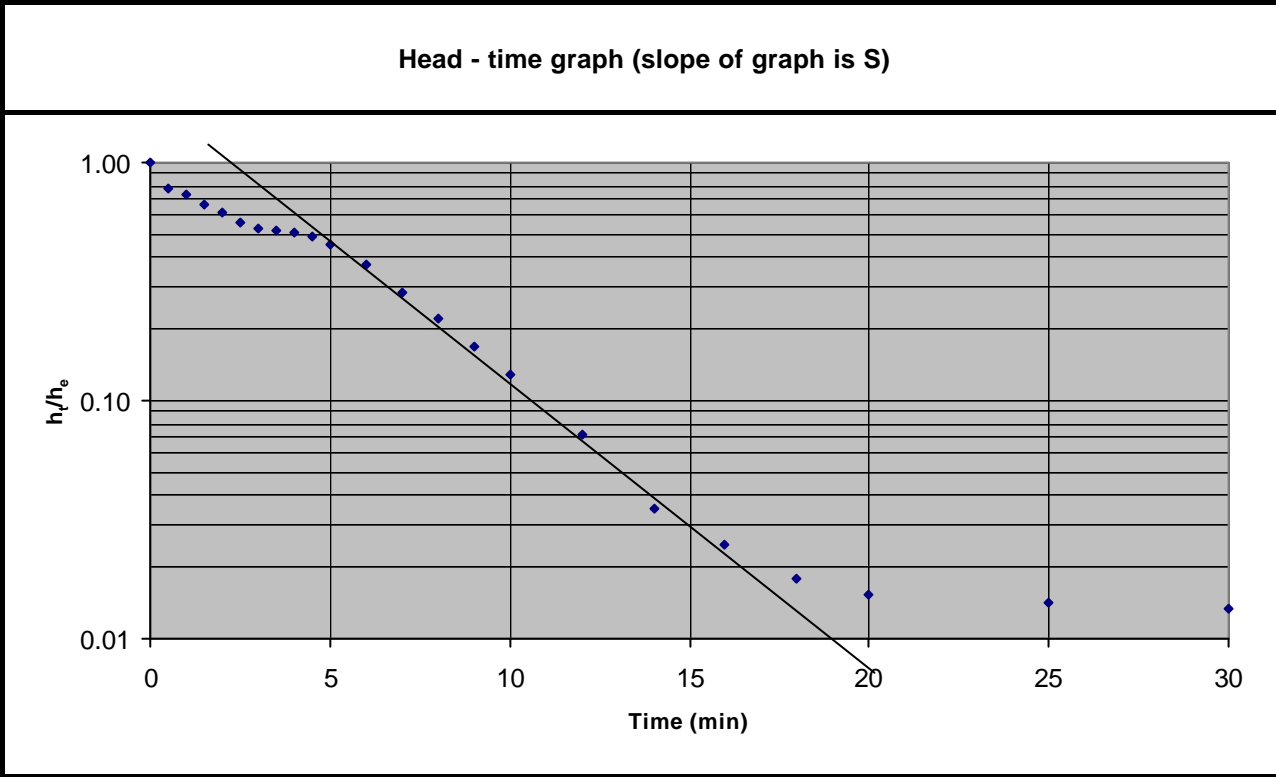
Notes:

Permeability, $k = 0.133 \times S \times (rc^2/L)$ (m/sec)
 where $S = (\log(h_1/h_2))/(t_2 - t_1)$, (ie slope of plot, t in mins)

RISING HEAD TEST

Bore No: AR029	Test No: #1	Job No: 773/C4	Date: 3-Apr-07	Logged by: GMS
Borehole co-ordinates: Easting: 409875	Northing: 8E+06	Collar elevation (m): 20.853		
Depth to top of test section (m): 10.38	Length of test section, L (m): 279		Radius of borehole, r (m): 0.073	
Depth of static water level, H_w (m): 10.38	Radius of standpipe or casing, r_c (m): 0.073		Excess head, h_e (m): -24.62	

Time (min)	Depth to water, h _w (m)	Excess head, h _i =H _w -h _w (m)	h _i /h _e
0.0	35.00	-24.62	1.00
0.5	29.57	-19.19	0.78
1.0	28.28	-17.9	0.73
1.5	26.87	-16.49	0.67
2.0	25.59	-15.21	0.62
2.5	24.22	-13.84	0.56
3.0	23.50	-13.12	0.53
3.5	23.24	-12.86	0.52
4.0	22.77	-12.39	0.50
4.5	22.35	-11.97	0.49
5.0	21.50	-11.12	0.45
6.0	19.55	-9.17	0.37
7.0	17.41	-7.03	0.29
8.0	15.81	-5.43	0.22
9.0	14.55	-4.17	0.17
10.0	13.55	-3.17	0.13
12	12.15	-1.77	0.07
14.0	11.25	-0.87	0.04
16	10.99	-0.61	0.02
18.0	10.82	-0.44	0.02
20	10.76	-0.38	0.02
25	10.73	-0.35	0.01
30	10.71	-0.33	0.01



Calculations:	h₁	0.50		
	t₁	5.0		
	h₂	0.03		
	t₂	15.0		
	S	1.2E-01		
	k	3.07E-07		

Notes:

Permeability, $k = 0.133 \times S \times (rc^2/L)$ (m/sec)
 where $S = (\log(h_1/h_2))/(t_2 - t_1)$, (ie slope of plot, t in mins)

APPENDIX B
LABORATORY REPORTS



LABORATORY REPORT COVERSHEET

DATE: 3 May 2000

TO: Aquaterra
22 Bowman Street
SOUTH PERTH WA 6151

ATTENTION: Mr Paul Hamer

YOUR REFERENCE: 132


OUR REFERENCE: 51410

SAMPLES RECEIVED: 4/14/00

SAMPLES/QUANTITY: 8 Waters

The above samples were received intact and analysed according to your written instructions. Unless otherwise stated, solid samples are reported on a dry weight basis and liquid samples as received.


JANICE VENNING
Manager Operations


PETER BAMFORD
Manager Laboratory Services

*This report supersedes our preliminary results that were reported by facsimile.
This report must not be reproduced except in full.*

CLIENT: Aquaterra
PROJECT: 132

OUR REFERENCE: 51410

LABORATORY REPORT

Your Reference Our Reference Date Sampled Type of sample	Units	A28 51410-1 11/04/00 Water	A17 51410-2 11/04/00 Water	M25 51410-3 11/04/00 Water	A15 51410-4 11/04/00 Water	MW100400 51410-5 11/04/00 Water
pH	pH Units	7.6	8.1	7.6	7.4	7.9
Electrical Conductivity @ 25°C	µS/cm	1100	2800	2500	1900	2500
Total Dissolved Solids (calc)	mg/L	700	1800	1600	1200	1600
Iron, Fe (soluble)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Sodium, Na	mg/L	110	350	280	190	320
Potassium, K	mg/L	3.5	6.6	18	3.9	1.0
Calcium, Ca	mg/L	68	150	120	160	120
Magnesium, Mg	mg/L	27	73	73	47	84
Chloride, Cl	mg/L	220	670	650	450	580
Carbonate, CO ₃	mg/L	<1	<1	<1	<1	<1
Bicarbonate, HCO ₃	mg/L	200	330	260	280	420
Sulphate, SO ₄	mg/L	<10	80	20	30	55
Nitrate, NO ₃	mg/L	11	30	0.3	29	26
Cation/Anion balance	%	4.11	4.39	3.40	4.77	3.94
Sum of Ions (calc.)	mg/L	639	1690	1421	1190	1606

Your Reference Our Reference Date Sampled Type of sample	Units	TW120400 51410-6 11/04/00 Water	A11 51410-7 11/04/00 Water	BHS120400 51410-8 11/04/00 Water
pH	pH Units	8.2	6.6	7.9
Electrical Conductivity @ 25°C	µS/cm	1800	460	1900
Total Dissolved Solids (calc)	mg/L	1200	300	1200
Iron, Fe (soluble)	mg/L	<0.05	<0.05	<0.05
Sodium, Na	mg/L	190	52	290
Potassium, K	mg/L	1.4	1.9	1.4
Calcium, Ca	mg/L	92	24	53
Magnesium, Mg	mg/L	64	12	58
Chloride, Cl	mg/L	340	90	390
Carbonate, CO ₃	mg/L	<1	<1	<1
Bicarbonate, HCO ₃	mg/L	410	50	450
Sulphate, SO ₄	mg/L	20	<10	25
Nitrate, NO ₃	mg/L	22	47	7.0
Cation/Anion balance	%	3.06	4.41	2.71
Sum of Ions (calc.)	mg/L	1139	277	1274

CLIENT: Aquaterra
PROJECT: 132

OUR REFERENCE: 51410

LABORATORY REPORT

TEST PARAMETERS	UNITS	LOR	METHOD
Standard 1			
pH	pH Units	0.1	PEI-001
Electrical Conductivity @ 25°C	µS/cm	1	PEI-032
Total Dissolved Solids (calc)	mg/L	5	PEI-032
Iron, Fe (soluble)	mg/L	0.05	PEM-001
Sodium, Na	mg/L	0.5	PEM-001
Potassium, K	mg/L	0.5	PEM-001
Calcium, Ca	mg/L	0.5	PEM-002
Magnesium, Mg	mg/L	0.5	PEM-002
Chloride, Cl	mg/L	5	PEI-008
Carbonate, CO ₃	mg/L	1	PEI-006
Bicarbonate, HCO ₃	mg/L	5	PEI-006
Sulphate, SO ₄	mg/L	10	PEI-034
Nitrate, NO ₃	mg/L	0.2	PEI-061
Cation/Anion balance	%		Calc.
Sum of Ions (calc.)	mg/L		Calc.

NOTES:

LOR= Limit of Reporting.

aquaterra
Job # 132
File # 322
Doc # 35
Date: 10/4/00

AUSTEEL PTY LTD
A.C.N. 058 430 032

To Aquaterra
Jon Hall
93684055
From Ian McCordle

FACSIMILE TRANSMITTAL SHEET

TO: IAN MCCARDLE FROM: MASSIMO RAVEGGI

COMPANY: HGM DATE: 10/4/2000

FAX NUMBER: (08) 92816297 TOTAL NO. OF PAGES INCLUDING COVER: 9

PHONE NUMBER: (08) 92816191 SENDER: Bronwyn Hall

RE: WATER SAMPLES COPIES TO:

- URGENT FOR REVIEW PLEASE COMMENT PLEASE REPLY PLEASE RECYCLE

NOTES/COMMENTS:

DEAR IAN,

PLEASE FIND ATTACHED CHEMICAL
ANALYSES OF EIGHT WATER SAMPLES
COLLECTED DURING 1993 DRILLING
PROGRAM.

REGARDS,

MASSIMO

GPO BOX 1538
BRISBANE QLD 4001
PHONE: (07) 3832 2044
FAX: (07) 3832 2021
E-MAIL: mineralogy@mineralogy.com.au

Received Time 10 Apr 12:37

No. 377

HALPER GLICK MAUNSELL

10 APR 2000 13:37

Mineralogy Pty. Ltd.
8th Floor, 445 Upper Edward Street
Brisbane
QLD 4000

CB
GLS 8.11.93
09 December 1993

CERTIFICATE OF ANALYSIS

Samples M-9, 180m 25.9.93

Ref: 01479.001

Analyte	Result	Units	Method
As	<0.02	mg/L	APHA 3112.B;3114.B
Rb	0.13	mg/L	
Cd	0.015	mg/L	APHA 3113.B Electrothermal AA
Cr	<0.05	mg/L	APHA 3110;3111.A,B,D
Co	0.01	mg/L	
Mo	0.005	mg/L	
Cu	<0.01	mg/L	APHA 3110;3111.A,B,D
Pb	0.02	mg/L	APHA 3113.B Electrothermal AA
Mn	0.99	mg/L	APHA 3110;3111.A,B,D
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Ni	<0.05	mg/L	APHA 3110;3111.A,B,D
Zn	<0.01	mg/L	APHA 3110;3111.A,B,D
Ba	3.	mg/L	APHA 3110;3111.A,B,D
B	1.2	mg/L	ASTM D4190, APHA 3111B.
Sr	19.5	mg/L	APHA 3110;3111.A,B,D



Lien Tang Chemist

The results pertain to the sample as received.

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Brisbane
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09 December 1993

CERTIFICATE OF ANALYSIS

Ref: 01479.002

Sample: M-11, 145m 16.9.93

Analyte	Result	Units	Method
pH	7.5		APHA 4500-H.B
Cl	1445.	mg/L	APHA 4500-Cl.B
EC	4.62	ms/cm	APHA 2510.B
Rb	0.37	mg/L	
Alkalinity_T	140.	mg/L	APHA 2320.B
TSS	12.	mg/L	
Cd	<0.001	mg/L	
Pb	0.002	mg/L	
TDS	2830.	mg/L	APHA 2540.C
Co	0.001	mg/L	
Mo	0.002	mg/L	
CO3	<1.	mg/L	APHA 2320.B
HCO3	170.	mg/L	APHA 2320.B
SO4	75.	mg/L	SO4_Turbidity
Ni	0.16	mg/L	APHA 3110;3111.A,B,D
NO3	22.	mg/L	Skalar Auto-Analyser
Ca	285.	mg/L	APHA 3110;3111.A,B,D
Mg	145.	mg/L	APHA 3110;3111.A,B,D
Ba	0.38	mg/L	APHA 3110;3111.A,B,D
Fe	0.1	mg/L	APHA 3110;3111.A,B,D
Si	29.	mg/L	APHA 3110;3111.A,B,D
B	1.1	mg/L	ASTM D4190, APHA 3111B.
Na	520.	mg/L	APHA 3110;3111.A,B,D
K	44.8	mg/L	APHA 3110;3111.A,B,D
Sr	4.4	mg/L	APHA 3110;3111.A,B,D
C/A_Balance	1.09		Calculation
As	<0.002	mg/L	APHA 3112.B;3114.B
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Mn	0.07	mg/L	APHA 3110;3111.A,B,D
Cu	<0.01	mg/L	APHA 3110;3111.A,B,D
Zn	<0.01	mg/L	APHA 3110;3111.A,B,D
Cr	<0.05	mg/L	APHA 3110;3111.A,B,D
F	0.2	mg/L	4500-F MINUS C


Lien Tang Chemist

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NO. 3777



Mineralogy Pty. Ltd.
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Brisbane
QLD 4000

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09 December 1993

CERTIFICATE OF ANALYSIS

Ref: 01479.003

Sample: M-15, 125m 13.9.93

Analyte	Result	Units	Method
PH	7.6		APHA 4500-H.B
EC	2.05	mS/cm	APHA 2510.B
Cl	485.	mg/L	APHA 4500-Cl.B
Cd	<0.001	mg/L	
TSS	480.	mg/L	
Alkalinity_T	225.	mg/L	APHA 2320.B
Rb	0.04	mg/L	
Pb	<0.002	mg/L	
TDS	1200.	mg/L	APHA 2540.C
Co	0.001	mg/L	
Mo	0.009	mg/L	
CO3	<1.	mg/L	APHA 2320.B
HCO3	275.	mg/L	APHA 2320.B
SO4	63.	mg/L	SO4_Turbidity
Ni	<0.05	mg/L	APHA 3110;3111.A,B,D
NO3	13.6	mg/L	Skalar Auto-Analyser
Ca	105.	mg/L	APHA 3110;3111.A,B,D
Mg	65.	mg/L	APHA 3110;3111.A,B,D
Fe	<0.1	mg/L	APHA 3110;3111.A,B,D
Ba	0.17	mg/L	APHA 3110;3111.A,B,D
Si	17.6	mg/L	APHA 3110;3111.A,B,D
B	0.9	mg/L	ASTM D4190, APHA 3111B.
Na	215.	mg/L	APHA 3110;3111.A,B,D
K	6.4	mg/L	APHA 3110;3111.A,B,D
Sr	1.24	mg/L	APHA 3110;3111.A,B,D
C/A_Balance	1.01		Calculation
As	<0.002	mg/L	APHA 3112.B;3114.B
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Mn	0.77	mg/L	APHA 3110;3111.A,B,D
Cu	0.06	mg/L	APHA 3110;3111.A,B,D
Zn	0.09	mg/L	APHA 3110;3111.A,B,D
Cr	<0.05	mg/L	APHA 3110;3111.A,B,D
F	0.2	mg/L	4500-F MINUS C

Lien Tang Chemist

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CERTIFICATE OF ANALYSIS

Sample: M-16, 89m 6.10.93

Ref: 01479.004

Analyte	Result	Units	Method
Cd	0.001	mg/L	
As	0.005	mg/L	APHA 3112.B;3114.B
Rb	0.11	mg/L	
Co	0.016	mg/L	
Cr	<0.05	mg/L	APHA 3110;3111.A,B,D
Mo	0.001	mg/L	
Cu	0.08	mg/L	APHA 3110;3111.A,B,D
Pb	0.005	mg/L	APHA 3113.B Electrothermal AA
Mn	0.34	mg/L	APHA 3110;3111.A,B,D
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Ni	<0.05	mg/L	APHA 3110;3111.A,B,D
Zn	0.04	mg/L	APHA 3110;3111.A,B,D
Ba	0.23	mg/L	APHA 3110;3111.A,B,D
B	0.9	mg/L	ASTM D4190, APHA 3111B.
Sr	1.5	mg/L	APHA 3110;3111.A,B,D


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10 APR 1993 13 33

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8th Floor, 445 Upper Edward Street
Brisbane
QLD 4000

CB
GLS 8.11.93
09 December 1993

CERTIFICATE OF ANALYSIS

Ref: 01479.005

Sample: M-23, 180m 22.10.93

Analyte	Result	Units	Method
Cd	0.001	mg/L	APHA 2510.B
EC	13.9	mS/cm	
TSS	15.	mg/L	
pH	7.5		APHA 4500-H.B
Alkalinity_T	80.	mg/L	APHA 2320.B
Cl	5135.	mg/L	APHA 4500-Cl.B
Rb	0.1	mg/L	
TDS	8830.	mg/L	APHA 2540.C
Co	0.008	mg/L	
Mo	0.001	mg/L	
CO3	<1.	mg/L	APHA 2320.B
HCO3	98.	mg/L	APHA 2320.B
SO4	92.	mg/L	SO4_Turbidity
Ni	<0.05	mg/L	APHA 3110;3111.A,B,D
NO3	0.2	mg/L	Skalar Auto-Analyser
Ca	750.	mg/L	APHA 3110;3111.A,B,D
Mg	550.	mg/L	APHA 3110;3111.A,B,D
Ba	0.54	mg/L	APHA 3110;3111.A,B,D
Fe	<0.1	mg/L	APHA 3110;3111.A,B,D
Si	7.2	mg/L	APHA 3110;3111.A,B,D
B	0.8	mg/L	ASTM D4190, APHA 3111B.
Na	1280.	mg/L	APHA 3110;3111.A,B,D
K	28.	mg/L	APHA 3110;3111.A,B,D
Sr	11.	mg/L	APHA 3110;3111.A,B,D
C/A_Balance	0.93		Calculation
Pb	<0.005	mg/L	APHA 3113.B Electrothermal AA
As	<0.005	mg/L	APHA 3112.B;3114.B
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Mn	0.4	mg/L	APHA 3110;3111.A,B,D
Cu	<0.01	mg/L	APHA 3110;3111.A,B,D
Zn	<0.01	mg/L	APHA 3110;3111.A,B,D
Cr	<0.05	mg/L	APHA 3110;3111.A,B,D
F	0.2	mg/L	4500-F MINUS C

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CERTIFICATE OF ANALYSIS

Sample: M-26, 180m 27.10.93

Ref: 01479.006

Analyte	Result	Units	Method
EC	3.16	mS/cm	APHA 2510.B
TSS	<5.	mg/L	
Alkalinity_T	78.	mg/L	APHA 2320.B
pH	7.9		APHA 4500-H.B
Cl	925.	mg/L	APHA 4500-Cl.B
Cd	<0.001	mg/L	
Rb	0.05	mg/L	
Pb	<0.002	mg/L	
TDS	1770.	mg/L	APHA 2540.C
Co	<0.001	mg/L	
Mo	0.001	mg/L	
CO3	<1.	mg/L	APHA 2320.B
HCO3	95.	mg/L	APHA 2320.B
SO4	75.	mg/L	SO4_Turbidity
Ni	<0.05	mg/L	APHA 3110;3111.A,B,D
NO3	0.4	mg/L	Skalar Auto-Analyser
Ca	77.	mg/L	APHA 3110;3111.A,B,D
Mg	115.	mg/L	APHA 3110;3111.A,B,D
Fe	<0.1	mg/L	APHA 3110;3111.A,B,D
Ba	0.03	mg/L	APHA 3110;3111.A,B,D
B	0.7	mg/L	ASTM D4190, APHA 3111B.
Si	<0.1	mg/L	APHA 3110;3111.A,B,D
Na	375.	mg/L	APHA 3110;3111.A,B,D
Sr	0.98	mg/L	APHA 3110;3111.A,B,D
K	12.2	mg/L	APHA 3110;3111.A,B,D
C/A_Balance	1.01		Calculation
As	<0.002	mg/L	APHA 3112.B;3114.B
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Mn	<0.01	mg/L	APHA 3110;3111.A,B,D
Cu	<0.01	mg/L	APHA 3110;3111.A,B,D
Zn	<0.01	mg/L	APHA 3110;3111.A,B,D
Cr	<0.05	mg/L	APHA 3110;3111.A,B,D
F	0.3	mg/L	4500-F MINUS C



Lien Tang Chemist

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Brisbane
QLD 4000

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GLS 8.11.93
09 December 1993

CERTIFICATE OF ANALYSIS

Sample: M-27, 155m 2.11.93

Ref: 01479.007

Analyte	Result	Units	Method
TSS	18.	mg/L	
Rb	<0.05	mg/L	
EC	3.11	mS/cm	APHA 2510.B
Cl	840.	mg/L	APHA 4500-Cl.B
Alkalinity_T	165.	mg/L	APHA 2320.B
Cd	<0.001	mg/L	
pH	7.8		APHA 4500-H.B
Pb	<0.002	mg/L	
TDS	1780.	mg/L	APHA 2540.C
Co	0.001	mg/L	
Mo	0.003	mg/L	
CO3	<1.	mg/L	APHA 2320.B
HCO3	200.	mg/L	APHA 2320.B
SO4	110.	mg/L	SO4_Turbidity
NO3	2.2	mg/L	Skalar Auto-Analyser
Ni	<0.05	mg/L	APHA 3110;3111.A,B,D
Ca	95.	mg/L	APHA 3110;3111.A,B,D
Mg	110.	mg/L	APHA 3110;3111.A,B,D
Fe	<0.1	mg/L	APHA 3110;3111.A,B,D
Ba	0.02	mg/L	APHA 3110;3111.A,B,D
B	0.9	mg/L	ASTM D4190, APHA 3111B.
Si	11.9	mg/L	APHA 3110;3111.A,B,D
Na	360.	mg/L	APHA 3110;3111.A,B,D
Sr	1.1	mg/L	APHA 3110;3111.A,B,D
K	11.1	mg/L	APHA 3110;3111.A,B,D
C/A_Balance	1.01		Calculation
As	0.002	mg/L	APHA 3112.B;3114.B
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Mn	0.15	mg/L	APHA 3110;3111.A,B,D
Cu	<0.01	mg/L	APHA 3110;3111.A,B,D
Zn	<0.01	mg/L	APHA 3110;3111.A,B,D
Cr	<0.05	mg/L	APHA 3110;3111.A,B,D
F	0.3	mg/L	4500-F MINUS C


Lien Tang Chemist

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10:40:10 AM 10 Apr 2000 12:37

HALPER GLICK MAUNSELL

10:40:10 AM 10 Apr 2000 13:38

Mineralogy Pty. Ltd.
8th Floor, 445 Upper Edward Street
Brisbane
QLD 4000

CB
QLS 8.11.93
09 December 1993

CERTIFICATE OF ANALYSIS

Sample: M-7, 180m 24.9.93

Ref: 01479.008

Analyte	Result	Units	Method
Rb	2.75	mg/L	APHA 4500-H.B
pH	6.2		APHA 4500-cl.B
Cl	33080.	mg/L	
TSS	19.	mg/L	
Alkalinity_T	35.	mg/L	APHA 2320.B
EC	93.1	mS/cm	APHA 2510.B
Cd	0.03	mg/L	
TDS	54420.	mg/L	APHA 2540.C
Co	0.04	mg/L	
Mo	<0.01	mg/L	
CO3	<1.	mg/L	APHA 2320.B
HCO3	43.	mg/L	APHA 2320.B
SO4	855.	mg/L	SO4_Turbidity
Ni	<0.05	mg/L	APHA 3110;3111.A,B,D
NO3	0.2	mg/L	Skalar Auto-Analyser
Ca	4720.	mg/L	APHA 3110;3111.A,B,D
Mg	1720.	mg/L	APHA 3110;3111.A,B,D
Ba	0.46	mg/L	APHA 3110;3111.A,B,D
Fe	<0.1	mg/L	APHA 3110;3111.A,B,D
Si	3.1	mg/L	APHA 3110;3111.A,B,D
B	0.6	mg/L	ASTM D4190, APHA 3111B.
Na	12800.	mg/L	APHA 3110;3111.A,B,D
K	535.	mg/L	APHA 3110;3111.A,B,D
Sr	64.	mg/L	APHA 3110;3111.A,B,D
C/A_Balancia	0.99		Calculation
Pb	0.05	mg/L	APHA 3113.B Electrothermal AA
As	<0.05	mg/L	APHA 3112.B;3114.B
Hg	<0.001	mg/L	APHA 3112.B;3114.B
Mn	4.7	mg/L	APHA 3110;3111.A,B,D
Cu	0.14	mg/L	APHA 3110;3111.A,B,D
Zn	<0.01	mg/L	APHA 3110;3111.A,B,D
Cr	0.16	mg/L	APHA 3110;3111.A,B,D
F	<0.1	mg/L	4500-F MINUS C



Lien Tang Chemist

The results pertain to the sample as received.

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Amberley Pty Ltd
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as trustee for the
AALQ Unit Trust

10 Apr. 2000 13:33 HALPER GLICK MAUNSELL
Time 10 Apr. 12:37
No. 3777