RPS Aquaterra

ROBERTSON RANGE AREA - CONSOLIDATED HYDROGEOLOGY AND SURFACE WATER MANAGEMENT REPORT





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EXECUTIVE SUMMARY

FerrAus Pty Ltd is currently assessing the possibility of mining iron ore at the Robertson Range site. RPS Aquaterra has conducted a number of groundwater and surface water investigations within the Robertson Range Area on behalf of FerrAus Pty Ltd since 2007. This report provides a consolidation of various reports and memorandum using the current mine plan and excavation schedules.

Robertson Range is located approximately 100km east of the township of Newman in Western Australia. The deposit is at the very top end of the catchment of Bobbymia Creek, which flows southeast to Savory Creek and then east to Lake Disappointment, some 200km away.

The most important aspect of the hydrogeology of the site is the aquifer associated with the Marra Mamba Iron Formation. This aquifer has a higher hydraulic conductivity than the surrounding Jeerinah and Wittenoom Formations and is capable of delivering significant bore yields. Since a significant proportion of the Robertson Range orebody lies beneath the watertable, dewatering will be required to provide dry mining conditions.

A mine scale groundwater model was developed for the Robertson Range orebody based on current hydrogeological understanding. The model was calibrated to available data from the existing Robertson Range bores and the model was then used to predict the dewatering requirements for the 12 years of the projected mine life.

Model predictions completed show that four production bores can adequately dewater the planned mine pit area. Resulting dewatering rates for the Base Case Scenario are predicted to be 7.8ML/day (90L/s) initially and reaching a maximum of 9.5ML/day (110L/s) in Year 4 of mining. Based on the sensitivity analysis, the worst case scenario (the case of high specific yield alluvium), the maximum pumping rate required to drop water levels below the pit floor, is 12.1ML/day (140L/s).

Mine dewatering is predicted to result in a zone of groundwater depression, controlled by the permeability of varying hydrogeological units around the mine site. The zone of groundwater depression is likely to extend marginally further to the south in higher permeability units but will be curtailed by low permeability granite, greenstone and other units that surround the model domain. Model predictions show that after 12 years of mining drawdown of 1m extends to between 4 and 6km away from the open pits.

Potential surface water impacts associated with the planned mining activities include:

- Interruption to existing surface water flow patterns.
- Runoff loss to downstream environment.
- Increased risk of erosion and sedimentation.
- Contamination of surface water by chemicals or hydrocarbons.

Minor drainage paths from the upstream catchment extend through the proposed mine area. To prevent flooding of the mine pits and associated infrastructure, bunding and diversion drains will be required to manage these flows. Diversions will be designed to re-route flows back into their original drainage paths downstream of the development, or via minor channels and overland flow.

The diversion of this flow into diversion drains will potentially impact vegetation downstream of the drains.

The mine developments have the potential to reduce the effective catchment area of Lake Disappointment by 1.7km^2 or less than 0.01%. These changes are not significant to the overall hydrological system, particularly in comparison to the natural seasonal variations in catchment runoff.

Runoff from the planned waste dump and other disturbance areas and the concentration of flow into diversion drains has the potential to significantly increase erosion and sediment loads in the natural drainage systems, if appropriate management measures are not implemented.

The post closure topography of the pit area will be formed by backfill placement into the mine voids as far as practicable. Most areas will be backfilled below the existing surface level and the south west mini-pit will be left as a void. This change in topography will impact on the surface water flow regime of the area.

To minimise the impact of mining operations on surface water draining from the site and consequently on the Lake Disappointment catchment, a number of measures will be adopted during construction and operation of the mine. These measures will include the use of buffer zones between mine developments and creek systems, minimisation of clearing, dry season construction where possible, bunding of hydrocarbon storage areas and separation of runoff from disturbed areas.

Sediment basins will be constructed to treat the runoff from each waste dump and stockpile area in the development area. Each of these areas will be locally bunded to contain the internal runoff and direct runoff to a sediment basin prior to disposal to the main drainage system.

Direct rainfall on the pit floor would be removed by pumping. After treatment to remove the sediments, the in-pit water would typically be used for dust suppression, with any excess discharged to the environment under relevant licence conditions. In-pit stormwater will be discharged to an adjacent creek following a significant rainfall event when the creeks would already be saturated or possibly still flowing and sediment would be removed prior to discharge.

Around the stockpile areas and the process plant, bunding will be installed to protect the infrastructure from flooding as required. The flood bunding will be installed prior to the construction of the waste dumps to ensure that flood protection is achieved for the commencement of mining.

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1. INTRODUCTION

1.1 Introduction

FerrAus Pty Ltd is currently assessing the possibility of mining iron ore at the Robertson Range site. RPS Aquaterra has conducted a number of groundwater and surface water investigations within the Robertson Range Area on behalf of FerrAus Pty Ltd since 2007. During this time several dewatering estimates have been made, in response to changes in the mine plan. Earlier estimates using analytical methods were superseded by a groundwater model built in 2010. Additional model runs in response to further alterations of the mine plan and items not addressed in the 2010 reports have been reported in various memorandum. The purpose of this report is to provide a consolidation of various reports and memorandum using the current mine plan and excavation schedules, suitable for a Definitive Feasibility Study (DFS).

1.2 Location

Robertson Range is located approximately 100km east of the township of Newman in Western Australia. It is located on the Jigalong Aboriginal Reserve. Access is via either Jimblebar access road or alternatively the Coobina Road. Site position is shown on the location map (Figure 1).

1.3 Topography

In the mine area, the land slopes gently to the south east of the proposed pit and rises abruptly to the north and west of the most northern part of the proposed pit. A predominant hill, upon which a telephone tower is located, lies approximately 1 – 2km to the west of the pit. Approximately 3 – 4km west of the pit, there is a catchment divide between the inland (easterly) flowing Savory Creek Catchment and the westerly flowing Fortescue River Catchment. The deposit is at the very top end of the catchment of Bobbymia Creek, which flows southeast to Savory Creek and then east to Lake Disappointment, some 200km away.

1.4 Climate and Hydrology

Western Australia has three broad climate divisions. The northern part which includes the Pilbara has a dry tropical climate. The south-west corner has a Mediterranean climate, with long, hot summers and mild wet winters. The remainder is mostly arid land or desert climates.

The Pilbara region is characterised by an arid-tropical climate resulting from the influence of tropical maritime and tropical continental air masses, receiving summer rainfall. Cyclones can occur during this period, bringing heavy rain, causing potential destruction to coastal and inland towns.

1.4.1 Temperature

The Pilbara region has an extreme temperature range, rising up to 50 degrees Celsius (°C) during the summer, and dropping to around 0°C in winter (Bureau of Meteorology [BOM], 2010). The nearest BOM climatic station (temperature) to the project area is at Newman (Site Numbers 007151 and 007176 – approximately 70km to the west). Mean monthly maximum temperatures at Newman range from 39°C in January to 23°C in July, while mean monthly minimum temperatures range from 25°C in January to 7°C in July (BOM, 2011). The average monthly temperatures at Newman are given in Table 2.1. High summer temperatures and humidity seldom occur together, giving the Pilbara its very dry climate. Light frosts occasionally occur during the winter season.

Table 1.1: Newman - Average Monthly Temperatures

Average Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Maximum [°C]	39.2	37.1	35.6	31.7	26.4	22.6	22.5	25.1	29.5	34.0	36.8	38.6
Minimum [°C]	25.2	24.3	22.1	18.1	12.6	8.7	7.4	9.3	13.1	17.7	21.2	23.8

1.4.2 Rainfall

The Pilbara region has a highly variable rainfall, which is dominated by the occurrence of tropical cyclones mainly from January to March. The moist tropical cyclones from the north bring sporadic and drenching rainfall events. With the exception of these large events, rainfall can be erratic, and localised, due to thunderstorm activity. Therefore, rainfall from a single site may not be representative of the spatial variability of rainfall over a wider area.

During winter, cold fronts move in an easterly direction across Western Australia and sometimes reach the Pilbara region producing light winter rains.

The nearest rainfall gauging stations to the project area are at Sylvania (Site Number 007079 – approximately 49km to the south-west) and at Ethel Creek (Site Number 005003, – approximately 68km to the north-west). The annual average rainfall recorded at Sylvania and Ethel Creek is 261mm and 268mm respectively (BOM, 2011).

This is slightly lower than at Newman Aerodrome, which has an annual average rainfall of 319mm (BOM, 2011). Average monthly rainfall totals for Newman Aerodrome are shown in Table 2.2. On average the driest period is August to November, with September and October historically being the driest months. Typically, January and February are the wettest months. However, variability is high with recorded annual rainfall at Newman varying between 153mm (1976) and 619mm (1999). The highest recorded annual rainfall at Sylvania and Ethel Creek was 713mm (1998) and 814mm (1942) respectively.

Table 1.2: Newman - Average Monthly Rainfall

Average Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall [mm]	57.3	78.8	40.3	19.6	18.1	14.2	14.9	8.0	4.6	4.9	10.3	37.6

1.4.3 Rainfall Intensity

Design rainfall intensity data for the project area for selected rainfall durations and Average Recurrence Interval (ARI) events are given in Table 2.3 (Institution of Engineers Australia 1987 and BoM, 2011). This data can be used for waterway designs.

Table 1.3: Davidson Creek Area - Design Rainfall Intensities [mm/hr]

Rainfall Duration	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
1 hour	31.2	36.5	43.3	52.6	59.8
3 hours	15.1	18.2	22.2	27.7	32.1
6 hours	9.3	11.5	14.3	18.3	21.6
12 hours	5.8	7.4	9.2	12.0	14.3
24 hours	3.6	4.6	5.9	7.7	9.2
48 hours	2.2	3.0	3.6	4.7	5.7
72 hours	1.6	2.1	2.6	3.5	4.2

1.4.4 Evaporation

The mean annual pan evaporation rate as measured by a Class A pan at Jigalong (around 34km to the east) is 4,066mm and at Newman is 3,733mm (Department of Agriculture, 1987). These average evaporation rates at Jigalong vary between 176mm in June and 497mm in January/December. The average monthly pan evaporation rates for Jigalong are shown in Table 2.4. Evaporation rates at the project site would be expected to be similar to the evaporation averages at Jigalong.

Table 1.4: Jigalong - Average Monthly Evaporation

Average Evaporation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Evaporation [mm]	497	406	397	326	211	176	180	229	301	396	450	497

Comparing the average rainfall rates at Newman to the average evaporation rates at Jigalong, average evaporation exceed average rainfall for every month of the year and annual average evaporation exceeds annual average rainfall by about 3,700mm. However, as discussed above, annual rainfall variability is high.

1.4.5 Streamflow

Streamflow in the Pilbara region is typically correlated to rainfall, with the majority of streamflow occurring during the summer months of December through to March. Streamflow in the smaller flow channels is typically short in duration, and ceases soon after the rainfall passes. In the larger river channels which drain the larger catchments, runoff can persist for several weeks and possibly months following major rainfall events such as those resulting from tropical cyclones.

Streamflow gauging stations are widely spaced in the Pilbara region, with none located in the immediate vicinity of the project area. The nearest Department of Water (DoW) gauging station is at Newman, on the Fortescue River (Site Number 708011), located approximately 70km west of the planned mine site. This gauging station records streamflow from the Fortescue River Upper catchment which has an area of 2,822km^2 area above the gauging station.

Available gauging data for Fortescue River covering the period from 1980 to 2010 indicates an average annual runoff volume of about 4.8% of the annual rainfall recorded in that area (at DoW rainfall gauging station 507005 at Newman). However the variability of annual runoff volume is high with annual runoff varying between 0 to 23% of the annual rainfall. A similar analysis of Marillana Creek at Flat Rocks gauging station (DoW Site Number 708001) indicates an average annual runoff volume of about 2.2% of the annual rainfall recorded in that area. Due to relative catchment sizes, streamflow data recorded at these stations do not necessarily represent runoff within the Davidson Creek project area.

Peak streamflow discharges from ungauged catchments in the Pilbara region can be estimated using empirical techniques, such as those recommended in "Australian Rainfall and Runoff" (Institution of Engineers, 1987).

1.5 Geology

1.5.1 Regional Geology

The Robertson Range area is located on the eastern margin of the Hamersley Province, Western Australia. The area is dominated by the Archean granitoid-greenstone sequence of the Sylvania Inlier and the Fortescue Group and Hamersley Group successions and to the east the Bangemall Group.

The Capricorn and Ashburton Orogenies are the two main deformational episodes in the southern part of the Hamersley Province, although up to five deformation events have been recognized. The Capricorn (or Opthalmian) Orogeny is characterised by south-over-north directed thrusting and folds with tight inter-limb angles and southerly dipping fold axes. The later Ashburton Orogeny is characterised by large scale, upright E-W trending folds that define the regional outcrop pattern.

The ore body at Robertson Range is contained within the Marra Mamba Formation, which is of Archaean age. This formation is part of The Hamersley Group and is commonly characterised by banded iron formation (BIF). Folding and faulting within the Hamersley Group is a common feature. Alluvial deposits of Cainozoic age often overlie the sequence.

1.5.2 Local Geology

At Robertson Range, the structurally complex geology of the area is concealed by an alluvial/colluvial cover of variable thickness of up to 80m, which generally thickens to the east.

Within the proposed mine area, the Fortescue Group Jeerinah Formation is overlain by the Hamersley Group's Marra Mamba Formation, which in turn is overlain by the Wittenoom Formation. The stratigraphy dips at 25-35 degrees to the east and southeast.

West of the proposed pits, Granite, Greenstone and Fortescue Group rocks have been identified in mineral exploration drilling, while to the south, Fortescue Group and Hamersley Group have been identified. Drilling to the north and north east has encountered Granite, Fortescue Group and Bangemall Group bedrock. Bangemall Group rocks also outcrop to the east of the project area.

1.6 Hydrogeology

The most important aspect of the hydrogeology of the site, is the aquifer associated with the Marra Mamba Iron Formation. This aquifer has a higher hydraulic conductivity than the surrounding Jeerinah and Wittenoom Formations and is expected to deliver significant inflows to any open pit developed. The ore body is generally restricted to the Mount Newman Member of the Marra Mamba and is characterised by vughs and brecciation, comprising the most permeable zone of the aquifer system. The prevailing aquifer system is similar to that defined by Johnson and Wright (2001) and shown in Figure 2.

During mineral exploration drilling at Robertson Range, groundwater has been encountered in variable quantities, depending on the permeability of the formation being drilled. Very low in-flow rates have been common in all bores away from the ore-body, while inflows in those holes drilled into the ore body have been high enough to impede the progress of drilling. Airlift yields of exploration holes drilled away from the ore body ranged from 0.07L/s to 3.9L/s while bore airlift yields within the ore body ranged from 17L/s to 25L/s.

The static water level (SWL) is approximately 30 to 35 m below ground level and groundwater flow is to the south, with a very low gradient, following the low relief topography.

Overall, groundwater from the main aquifer system has a total dissolved solids (TDS) ranging from 690 - 1300mg/L TDS.

Recharge in the low rainfall, high evaporation area will be low, but it is likely higher rates of recharge will result from periodic, high intensity, cyclonic rainfall events.

2. BACKGROUND

2.1 Fieldwork

Six test production bores have been drilled, constructed and pump tested during two filed programmes in 2007/2008 and 2010. Airlift testing of eleven existing RC mineral exploration holes was also conducted in 2010. This work is detailed in a consolidated fieldwork report Appendix A.

2.2 Mine plan

The current mine plan for Robertson Range consists of a main pit progressively mined from the north to south in 3 stages and a second, smaller pit to the southwest of the main pit designated stage 4 (Figure 3). The mine schedule indicates that mining is planned to start in 2014 and will continue to the end of 2023. Mining will reach the existing groundwater level of 546mAhd in 2015 and continue until the end of 2023. The final pit base at 462mAhd is some 84m below the current groundwater level.

Table 2.1 summarises the development of mining below the watertable for each Stage.

Table 2.1: Open Pit Development Milestones

Stage	Year	Base level (m AHD)	Comment
1	2015	546	Mining to Watertable
1	2016	534	Mining below Watertable
1	2017	474	Stage complete
2	2017	570	Mining above Watertable
2	2018	510	Mining below Watertable
2	2020	474	Stage complete
3	2019	534	Mining below Watertable
3	2021	462	Stage complete
4	2021	534	Mining below Watertable
4	2023	462	Stage complete

3. HYDROGEOLOGICAL CONCEPTUAL MODEL

General descriptions of the hydrogeology of the Robertson Range project area are briefly presented in Section 1.5. The conceptual hydrogeological model presented in this section provides more detail on the overall hydrogeology and specifically, on the key hydrogeological features that will determine mine dewatering requirements.

The conceptual hydrogeological model is based on the integration of all available information, including background information from previous investigations and information generated by the specific investigations described in Section 2. The conceptual hydrogeological model represents a simplified understanding of the natural behaviour and dynamics of the aquifer systems and provides the technical foundation for the detailed numerical modelling process described in Section 4.

3.1 Regional hydrogeology

Figures 4 - 8 show the interpreted hydrogeological model layers for the project area. These maps show the main regional hydrogeological units including:

- Regional aquitards to the west of the Robertson Range mine associated with the Jeerinah Formation (Fortescue Group) and granitic basement rocks of the Sylvania Inlier. These are mostly low permeability units, but there may be limited local aquifer potential associated with secondary fracture permeability and porosity.
- Regional aquitards to the east of the Robertson Range mine associated with the Bangemall Group and greenstone basement rocks. These are mostly low permeability units, but there may be minor local aquifer potential associated with secondary fracture permeability and porosity.
- The Marra Mamba BIF, including the locally significant Robertson Range orebody aquifer (Mt Newman Member) – this is the main aquifer unit.
- The Wittenoom Formation, including the West Angela Member which forms the hanging wall to the Robertson Range orebody. It is noted that unlike many other sites across the Pilbara region, the Paraburdoo Member of the Wittenoom Formation does not form a regionally significant aquifer associated with weathered dolomite (as shown in Figure 2). Mineral exploration drilling has intersected shale and BIF overlying the West Angela Member that is interpreted as a stratigraphical equivalent of the Paraburdoo Member.
- Alluvium overlying the area forms a regionally significant aquifer up to 80m thick.

Regional groundwater flow is from north to south, with local groundwater flow paths being influenced by local geology, structure and recharge.

3.2 Local Hydrogeology

Key elements of the local conceptual hydrogeological model are outlined below.

3.2.1 Main Aquifers

Robertson Range Orebody

The mineralised Marra Mamba Iron Formation (comprising mainly the Mt Newman Member) forms a linear aquifer system. The key aquifer parameters in terms of dewatering are permeability and specific yield, which define the volume of water in the orebody and the hydraulic connection along the orebody. These are interpreted to be in the ranges:

- Permeability of 1 to 10m/d.
- Specific yield of $1.3x10^{-3}$ to $6.6x10^{-2}$.

West Angela Member

The overlying West Angela shale unit forms a barrier to groundwater flow from the overlying alluvial aquifer, to the Marra Mamba aquifer. However, where they exist, faults and fractures in the West

Angela can provide a limited conduit for groundwater flow. The key aquifer parameter in terms of dewatering is permeability, which defines the degree of hydraulic connection provided between the Alluvium and Marra Mamba. As no permeability pathways have been identified, the West Angela Shale has been assigned a low permeability of 0.01m/d during the modelling.

Alluvial Sediments

The saturated alluvium potentially provides a large source of recharge (via downward leakage) to the Marra Mamba aquifer, particularly through faulting and fractures in the Wittenoom. The key aquifer parameters controlling leakage are still permeability and specific yield, however it should be noted that in such sedimentary deposit aquifers, the vertical permeability will be much less than the horizontal permeability, due to local clay and silt layers. These key aquifer parameters are interpreted to be in the following ranges:

- Permeability – 0.5 to 1m/d (with vertical permeability one order of magnitude lower).
- Specific Yield – 2.5 to 10%.

3.2.2 Other Aquifers/Aquitards

The rest of the basement rock units in the project area away from the mine site, form local and regional aquitards. There has been no specific investigation of these units as part of this study, and parameter values adopted in groundwater modelling (refer Section 4) have been based on values adopted in previous investigations in the region. Interpreted permeability for the bedrock ranges from:

- 0.004m/d for the Granite, Greenstone and Bangemall Group.
- 2.0m/d for areas interpreted as Marra Mamba formation.

3.3 Recharge and Discharge

Recharge in the project area is by way of infiltration of rainfall. Groundwater flows from areas of topographic high to topographic low, to the discharge zone associated with surface water drainage systems – generally to the south away from the mine site. This regional recharge and groundwater flow system can be readily simulated (in groundwater modelling) by assigning recharge to the model surface and the adoption of an outflow boundary (refer Section 4).

In the mine area, recharge to the main aquifer units will occur as follows:

- Infiltration of rainfall to the bedrock aquifers, in areas with a thin veneer of unsaturated sediments, or where basement outcrops, at recharge rates of up to 1%.
- Infiltration of rainfall and runoff to alluvial aquifers, in areas with a thicker covering of saturated sediments in the central parts of the catchment, adjacent to the ore body, at recharge rates of up to 2% of rainfall.

3.4 Groundwater Quality

Water quality (electrical conductivity [EC] and pH) was monitored in the field during the airlift development of each bore constructed and during the pumping of the test bores, while samples were also collected from each of the bores aquifer tested, for laboratory analysis. Detailed data on the water chemistry is provided in Appendix A.

Analyses show that groundwater sourced at the Robertson Range site from the Marra Mamba Formation (or equivalent) appears to be relatively good quality with total dissolved solids (TDS) values ranging from 690mg/L to 1300mg/L (laboratory analyses) with a neutral pH ranging from 6.9 to 7.7 (field determinations). Further characterization of the groundwater also shows some variation in terms of chemical signature on the basis of the cation / anion content. Piper diagram analysis shows the water to have a sodium / chloride dominant signature, normally an indicator of "old" groundwater. However bicarbonate concentrations which are similar to chloride concentrations, do suggest some "recent" water in the aquifer system. This is especially the case in shallower bores (upper alluvium), where TDS concentrations are generally below 500mg/L.

4. MINE DEWATERING PREDICTIONS

4.1 Background

A significant proportion of the Robertson Range orebody lies beneath the watertable. To provide dry mining conditions, dewatering is required. It is anticipated that this will be achieved by bores located outside the final pit limits (ex-pit bores) that draw from the orebody aquifer.

A calibrated groundwater flow model was developed and used to predict dewatering requirements to draw water levels to below the projected base of mining for the proposed 10 year mine life. Details of the model set up and calibration are presented in Appendix B. The projected 10 year mine plan, as provided by FerrAus (2011) for stages 1 to 4, is summarised in Table 4.1. Note that Table 4.1 displays 12 years of dewatering, since dewatering needs to begin in 2012, two years before mining starts. Optimisation of dewatering was completed as part of predictive modelling and focused on minimising dewatering requirements (and hence number of bores) while still achieving the required water level drawdown necessary to allow dry mining.

4.2 Model Limitations

The groundwater flow model has been developed with data limitations in mind (i.e. no time series data) and is of a complexity that is consistent with the available data. The model is calibrated to the available data and fit for the purpose of predicting the dewatering infrastructure required and the extent of drawdown. The potential impacts of the development on the hydrological system are readily identified from the model output.

As with all models, there are limitations associated with the data availability, conceptualisation, and representation of dynamic flow processes. Although the model includes the known essential features of the hydrogeological system, and is calibrated to available data, the predictions are simulations based on the best available knowledge and techniques, and should not be regarded as matters of fact. The model should be refined as additional data becomes available (specifically time series water level and rainfall events) and dewatering predictions up-dated in the fullness of time.

4.3 Dewatering Prediction

4.3.1 Prediction Setup

A number of model predictions were completed, to assess the dewatering necessary to achieve a drop in water levels across the deposit, to below the projected base of mining, consistent with the mine schedule in Table 4.1. Dewatering predictions were optimised to use the minimum number of bores and minimum pumping rate necessary to achieve dewatering.

Table 4.1: Robertson Range Mine Schedule – Pit Floor Base mAHD

Pit Stage	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Stage 1	606	606	570	546	534	474	474	474	474	474	474	474
Stage 2	594	594	594	594	594	570	510	474	474	474	474	474
Stage 3	582	582	582	582	582	582	558	534	486	462	462	462
Stage 4	582	582	582	582	582	582	582	582	582	534	498	462

Details of the model predictions completed are summarised below:

- Aquifer parameters used for model predictions, are summarised in Table 4.2. Since no time varying data exists for the site, the model has not been calibrated to transient or time varying conditions – as a result, the model has not been calibrated to both confined and unconfined aquifer storage values. These values have been assigned consistent with similar hydrogeological environments that RPS Aquaterra have encountered on other Marra Mamba projects in the Pilbara Region.
- Modelled dewatering bores and in pit observation bores are simulated using the Well package (WEL) in Modflow.
- Pumping of dewatering bores commences in 2012 and continues for the projected life of mine (2023) to achieve dewatering to the pit base of each stage. Bores are assigned pumping rates up to 35L/s (2592KL/d) which is consistent with rates achieved in the test pumping bores. It was assumed that the bores would be installed to sufficient depths and that they would operate at maximum specified rates until the end of mine life.
- The prediction assumed average rainfall, consistent with the steady state calibration and no allowance was made for seasonal high rainfall or episodic events such as cyclone associated rainfall and flooding.

Table 4.2: Adopted Aquifer Parameters for Prediction Scenarios

Aquifer/Aquitard Unit	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Yield	Confined Storage
Alluvium	1.7	0.17	0.05	0.0001
Bangemall Group	0.004	0.0004	0.001	0.0001
Marra Mamba Banded Iron Formation	2.0	2.0	0.04	0.0001
Marra Mamba Ore	3.0	3.0	0.04	0.0001
Jeerinah Formation	0.04	0.004	0.005	0.0001
Granite	0.004	0.0004	0.001	0.0001
Greenstone	0.004	0.0004	0.001	0.0001
Wittenoom	0.1	0.01	0.005	0.0001

4.3.2 Dewatering Prediction Results

A number of prediction runs were completed to optimise dewatering pumping rates. The optimised bore operating schedule required to achieve dewatering, is summarised in Table 4.3 with the location of modelled ex-pit pumping bores and modelled in pit observation locations shown in Figure 9. Total predicted dewatering rates associated with the optimised dewatering strategy are shown in Figure 10 referred to as the Base Case Scenario.

Dewatering commences in 2012 at bores located to the east of pit stages 1, 2 and 3, resulting in total predicted dewatering of 7776KL/day (90L/s) and is maintained until the end of 2015. In 2016 the Stage 4 bore begins pumping and the Stage 2 bore pumping rate is reduced, resulting in the peak total rate of 9504KL/day (110L/s). The peak rate is only required in 2016 and progressively reduces to 4320KL/day (50L/s) in 2022.

Predicted water levels and projected mining levels for observation locations across the mine area over the life of the mine are shown in Figure 11. At all locations, the operation of dewatering bores at the rates displayed in Table 4.3, are sufficient to keep predicted water levels below the base of mining.

Table 4.3: Bore Pumping Schedule - Base Case Scenario (KL/day)

Year	Stage 1	Stage 2	Stage 3	Stage 4	Total
2012	2592	2592	2592	0	7776
2013	2592	2592	2592	0	7776
2014	2592	2592	2592	0	7776
2015	2592	2592	2592	0	7776
2016	2592	1728	2592	2592	9504
2017	1728	1728	2592	2592	8640
2018	0	2160	2592	2592	7344
2019	0	0	2592	2592	5184
2020	0	0	2592	2592	5184
2021	0	0	2592	2592	5184
2022	0	0	1728	2592	4320
2023	0	0	1728	2592	4320

4.3.3 Sensitivity Runs

While a reasonable calibration of the groundwater flow model has been achieved (Appendix B), there remains inherent uncertainty in the parameters adopted to describe the hydrogeological system and associated risks in the estimates of dewatering requirements due to the absence of historical monitoring data. Sensitivity analysis has been undertaken to assess the uncertainty and risk, by adjusting aquifer hydraulic conductivity and specific yield values to higher values than used in the optimised prediction. This provides a level of conservatism and an upper limit to predicted dewatering requirements.

The three hydrogeological units considered to have the most influence upon predicted dewatering requirements are the Marra Mamba, Wittenoom and Alluvium. The potential impacts on dewatering requirements resulting from higher aquifer parameters for the specified hydrogeologic units are summarised in Table 4.4.

Table 4.4: Summary of Sensitivity Runs

Run	Parameter Assessed	Anticipated Impact
1	K of Marra Mamba increased from 2m/d t 4 m/d and K of Marra Mamba Ore increased from 3m/d to 6m/d	Potential for a higher dewatering rates over the life of the mine
2	Sy of Marra Mamba increased from 0.04 to 0.08 and Sy of Marra Mamba Ore increased from 0.04 to 0.08	Potential for a higher volume of dewatering over the life of the mine
3	K of Alluvium increased from 1.7m/d to 3.4 m/d	Potential for larger volumes from the alluvial aquifer to drain toward the mine area
4	Sy of Alluvium increased from 0.05 to 0.1	Potential for greater volumes to be removed as drawdown from the mine area spreads to the alluvial
5	K of Wittenoom increased from 0.1 m/d to 0.2 m/d	Potential for greater volume from the Wittenoom aquifer to drain toward the mine area
6	Sy of Wittenoom increased from 0.005 to 0.01	Potential fro greater volumes to be removed as drawdown from the mine area spreads to the Wittenoom

The potential for increased dewatering requirements was systematically tested by doubling the hydraulic conductivity or specific yield for each unit in turn and observing the effect upon dewatering efficacy, compared to the Base Case pumping regime (as shown in Table 4.3).

Predicted water levels for the Base Case and for the sensitivity runs are presented in Figure 12, presuming that the Base Case bores are pumped at the same rates. In each run, the predicted water level was higher than the water level predicted in the optimised Base Case. However Runs 1, 3 and 6 (double the hydraulic conductivity for the Marra Mamba and Alluvium and double Specific Yield for the Wittenoom) still achieved water levels sufficient for dewatering to below the pit floor. Runs 2, 4 and 5 (double Specific Yield of Marra Mamba and Alluvium and double the hydraulic conductivity of Wittenoom) do not sufficiently lower predicted water levels to achieve dewatering to below the pit floor.

Run 4 has the greatest predicted impact upon dewatering and further optimisation of bore abstraction rates was completed to see what abstraction was necessary to achieve dry mining. The bore operating schedule necessary is summarised in Table 4.5 with the total predicted dewatering rate presented in Figure 13. For the first four years beginning in 2012, Stages 1, 2 & 3 are required to begin dewatering the main pit with a total pumping rate of 9072KL/day (105L/s). In 2016 stage 4 dewatering begins, lifting the required total pumping rate to 12,096KL/day (140L/s). In 2018 the Stage 1 Bore is turned off, returning the total rate to 9072KL/day (105L/s) and in 2020 the Stage 2 bore is turned off and the total pumping rate is reduced to 6048KL/day (70L/s).

Table 4.5: Bore Pumping Schedule – High Specific Yield Alluvium Scenario (KL/day)

Year	Stage 1	Stage 2	Stage 3	Stage 4	Total
2012	3024	3024	3024	0	9072
2013	3024	3024	3024	0	9072
2014	3024	3024	3024	0	9072
2015	3024	3024	3024	0	9072
2016	3024	3024	3024	3024	12,096
2017	3024	3024	3024	3024	12,096
2018	0	3024	3024	3024	9072
2019	0	3024	3024	3024	9072
2020	0	0	3024	3024	6048
2021	0	0	3024	3024	6048
2022	0	0	3024	3024	6048
2023	0	0	3024	3024	6048

4.4 Drawdown Predictions

Predicted water levels (mAHD) at the end of mine Life (end 2023) are displayed in Figure 14 while the predicted drawdown in water level at the end of mine Life (end 2023) is displayed in Figure 15. Maximum drawdown of approximately 110 metres is predicted in the immediate vicinity of the Stage 3 and 4 pumping bores, with drawdown reducing with distance away from the four pumping bores. At the end of mining, the 1m drawdown contour is predicted to extend between 4.5 and 6km from the mine area. Immediately south east of the mine site, the predicted extent of drawdown is limited by the very low hydraulic conductivity of the greenstones. This demonstrates the confining effect that the greenstone and granite surrounding the site are likely to have upon drawdown away from the mine site and beyond the model boundaries.

The predicted model water balance at the end of mining suggests that the majority of dewatering is sourced from groundwater storage. Consistent with the hydrogeological conceptual model, there is not a significant amount of groundwater throughflow in the Robertson Range aquifer system. As such, large drawdowns are predicted across the model domain, as dewatering of the mine area drains both the mine area and surrounding areas and is not replenished by groundwater inflow from adjacent catchments. As a result, the current model setup provides conservatism, or a potential over estimate, of predicted drawdown. It is likely that the mine area groundwater levels will be recharged by significant rainfall or flood events (cyclones) – this has not been included in current model predictions and could result in some increased aquifer recharge after major rainfall events.

Table 4.6: Model Prediction Water Balance

Flow Component	Inflow (KL/day)	Outflow (KL/day)
Recharge	174	
Groundwater Outflow		122
Dewatering Pumping		4320
Storage	4269	1
TOTAL	4443	4443

4.5 Dewatering Impacts on Other Users

The Robertson Range proposed mine site is quite remote. Within the predicted extent of drawdown, no groundwater users have been identified and queries of the Department of Water databases have not identified the presence of any existing bores. Thus dewatering associated with mining at Robertson Range is not anticipated to impact upon any other groundwater users.

4.6 Effect of Seasonal Variations on Dewatering

The region has a highly variable rainfall, which is dominated by the occurrence of tropical cyclones mainly, during the period January to March. The driest months are September to November. The moist tropical storms from the north bring sporadic and drenching thunderstorms. With the exception of these large events, rainfall is mainly from thunderstorm activity and can be erratic and localised. Rainfall from a single site may not therefore be representative of the spatial variability of rainfall over the entire catchment during an event.

The annual average rainfall for Newman (the closest rainfall station) is 300mm pa. Variability is high with annual rainfall varying between about 150mm and 500mm. The mean annual pan evaporation rate is about 3200-3600mm, which exceeds annual rainfall by around 3000mm. Average monthly pan evaporation rates vary between a minimum 144mm in June and a maximum 384mm in December.

The modelling undertaken has indicated that the water abstracted during dewatering is derived predominantly from aquifer storage. As a result, any changes to recharge (due to seasonal fluctuations in rainfall and associated recharge) will have a limited impact on the dewatering rates required, or the drawdown impact on the surrounding aquifer. The modelling has assumed average long term recharge conditions – even under abnormal “cyclonic” rainfall events, the amount of enhanced recharge is still small in comparison to the volume of water removed from storage. Cyclonic recharge events may slow the rate of mine dewatering (or speed up the rate of water level recovery post-mining), but the slow rates of seepage through the predominantly low permeability surface alluvium, mean that enhanced recharge to the aquifer being dewatered, will be slow. No dramatic influx of groundwater to the open pit is to be expected after cyclonic events, although surface water inflow and direct rainfall into the pits will necessitate substantial extra dewatering to return the mine to a dry state.

4.7 Effect of Climate Change on Dewatering

Climate change has the potential to impact groundwater resources and mine dewatering endeavours through changes in groundwater recharge rates. Changes to rainfall and evapotranspiration (increase or decrease) may alter the rate of recharge to aquifer systems.

The Climate Change in Australia web site (CSIRO, Bureau of Meteorology and the Australian Greenhouse Office) provides projections of climate change for the years 2030, 2050 and 2070 for various climate variables (e.g. rainfall, temperature) for low, medium and high rates of Carbon emissions. The results are the consensus of a number of climate models. The results labelled 50th percentile, represent the midpoint of the spread of model results and was reviewed. For the 50th percentile case, temperature is projected to rise by 1 to 1.5oC for low, medium and high emission scenarios while evapotranspiration potential is projected to change by -2% to +4% with a rise more likely than a fall. Annual rainfall is projected to change by -5% to -2% however the 10th and 90th percentile projections provide a range of change in annual rainfall between -20% and +10%.

From these projections it appears likely that recharge to aquifers will decrease. However, as stated above, the dewatering modelling for Robertson Range indicates that water held in aquifer storage is the major source of inflow into the pits during open pit dewatering. The low rainfall rate and high evapotranspiration rate result in very low recharge to the aquifer. As a result, any changes to recharge (due to climate change) will have a limited impact on inflow volumes or to the impact that the dewatering will have on regional water levels. However, a decreased recharge rate may decrease the rate of water level recovery post mining. This decrease in recharge rate could be countered by the increased recharge during cyclonic events when direct rainfall will enter into any open pits.

4.8 Effect of Mining on Groundwater Chemistry

The high yielding bores linked to the Marra Mamba aquifer system have a water quality ranging from 690 - 1300mg/L TDS. There does appear to be a worsening of salinity with depth from under 500mg/L TDS in the top ~80m, to above 1300mg/L TDS below that depth. During open pit dewatering the water pumped is expected to average 1000mg/L. As the cone of depression extends outwards during dewatering, inflow from the upper aquifers and from the less permeable aquifer systems away from the Marra Mamba system will be captured. However these inflow volumes will be low compared to that abstracted from the permeable Marra Mamba systems, so major changes to water chemistry are not expected. After closure, some deterioration in the water in the pit lake would be expected as evaporation concentrates the salts.

5. SURFACE WATER MANAGEMENT

5.1 Regional Surface Water Hydrology

The proposed Robertson Range project lies within the Lake Disappointment catchment, an inwardly draining salt lake catchment with an area of approximately 145,100km^2. The project area lies very closely to the boundary of the Upper Fortescue catchment area (Figure 16). The main feature of Lake Disappointment catchment is Lake Disappointment, some 200km away, of which the main tributary is Savory Creek. The project area drains to Bobbymia Creek, a tributary of Savory Creek, which lies approximately 40km to the south-east.

5.2 Local Surface Water Hydrology

The surface water catchments that impact on the project are presented in Figure 17.

The Robertson Range project area is flat to gently sloping with a prominent hill rising some 40 to 50m above the surrounding plains immediately northwest of the proposed pit. The catchment area is approximately 12km^2, and has no defined creek beds.

There is no published water quality data for the project area. However, consistent with surface water quality in nearby catchments following rainfall events, it is expected that surface water run-off would generally be of potable quality, though turbid.

5.3 Potential Impacts from Mining Activities

Potential surface water impacts associated with the planned Robertson Range mining activities include:

- Interruption to existing surface water flow patterns.
- Runoff loss to downstream environment.
- Increased risk of erosion and sedimentation.
- Contamination of surface water by chemicals or hydrocarbons.

5.3.1 Interruption to Existing Surface Water Flow Patterns

The interruption of surface water flow patterns has the potential to reduce and in some cases, increase the surface water runoff volumes.

The catchment boundaries and flowpaths through the planned Robertson Range area are shown on Figure 17.

Surface water flows at the Robertson Range project area are generally in a south-easterly direction from the area of higher ground located to the north-west of the development area. There are no defined flow paths of significance.

The proposed pits, waste dumps and stockpiles will intercept / block natural drainage paths within the catchment. The proposed Robertson Range development will potentially reduce discharges flowing towards Lake Disappointment.

To prevent flooding of the mine pits and associated infrastructure, bunding and minor diversion drains will be required to manage these flows. Indicative locations of the required bunding and diversion drains are shown on Figure 17. The operational life of diversion drains and bunds will vary from a few years to permanent structures. The drains and bunds will be designed based on an Average Recurrence Interval (ARI) flood event selected with consideration to the expected life and consequences of failure. Diversions will be designed to re-route flows back into their original drainage paths downstream of the development, or via minor channels and overland flow.

5.3.2 Runoff Loss to Downstream Environment

The loss of catchment area contributing runoff to the downstream drainage systems, due to the planned mining development works, may have an impact on the downstream environment. Runoff volume is likely to decrease from areas containing pits, waste dumps and upstream catchments blocked by these works.

Locally, within pit areas, internal stormwater runoff would collect at the pit base and typically be removed by sump pumping, with discharge of excess water to the environment after sediment treatment. Within the waste dump, stockpile and ROM areas, internal runoff will collect at the perimeter bunding and be discharged via a sediment basin to the downstream environment. Overall loss of runoff volume from pit and waste dump development areas is estimated at a maximum 50% of the pre-development runoff volume and accounts for the losses to the downstream environment from non-recovered runoff from the pit and waste dumps.

Runoff volumes to the downstream environment from some infrastructure areas (e.g. roofs, hardstands, access route) may be increased, whereas from other infrastructure development areas (e.g. ponds, stockpiles) runoff volumes may be reduced. Overall runoff volumes from infrastructure and stockpile areas are considered to be effectively unchanged by the planned works. The planned pit development area and estimated maximum catchment area intercepted is shown below in Table 5.1.

Table 5.1: Robertson Range Catchment Area Losses

Location	Development Area (km^2)	Adopted Runoff Loss	Effective Catchment Area Loss Estimate (km^2)
Pits	1.4	0.5	0.7
Waste Dumps	2.0	0.5	1.0
Total	3.4		1.7

The potential decrease in runoff volume to Lake Disappointment would be extremely low (less than 0.01%) based on a catchment area of approximately 145,100km^2.

5.3.3 Increased Risk of Erosion and Sedimentation

Runoff from the planned waste dump and other disturbance areas has the potential to significantly increase erosion and sediment loads in the natural drainage systems, if appropriate management measures are not implemented.

The concentration of flows from overland flow into diversion drains/bunds has the potential to increase peak flow rates and consequently increase the potential for erosion and sedimentation at locations with increased or decreased velocities.

5.3.4 Contamination of Surface Water by Chemicals or Hydrocarbons

Spillage of chemicals or hydrocarbons from storage and/or transfer areas is possible, if appropriate control measures and operating procedures are not used.

5.4 Surface Water Management Objectives

The overall surface water management objectives are as follows:

- To prevent or minimise impacts on the quality of surface water resulting from mining operations and contain any contaminated water on site.
- To ensure that the quality of water returned to local and regional surface water resources will not result in significant deterioration of those resources.

The following sub-sections describe management strategies that will be used by FerrAus to meet the above management objectives, and to minimise the potential impacts identified.

5.5 General Water Management Strategies

The planned development of Robertson Range would have a localised effect on the surface water runoff through the redirection of flow and the development of bunded off areas which may intercept minor drainage lines and collect some surface water. The implementation of the general surface water management strategies outlined below is expected to effectively manage mining related impacts on the existing hydrology so that the project will have negligible impact on local surface water resources.

- Vehicle Movements: Vehicle movements will be kept to the minimum necessary and existing tracks will be used where possible.
- Buffer Zones: Where possible, adequate buffer zones will be provided between the areas of disturbance and the natural drainage lines to protect the drainage lines from impacts resulting from construction activities.
- Limiting Clearing: Vegetation is the most effective method of minimising erosion and sedimentation. Initial clearing will be limited to areas of workable size actively being used for construction.
- Topsoil Storage: Topsoil storages will be located away from drainage lines and upstream of sediment basins. Topsoil will be stored such that it is protected from internal rainfall and runoff using temporary vegetation or mulching, and protected from external runoff using diversion banks/drains.
- Dry Season Construction: Construction on or near natural flowpaths will be planned for the dry season where practicable. Temporary stabilisation measures will be used in areas where there is a high risk of erosion.
- Internal Stormwater Provisions: Internal stormwater runoff in the development areas may cause localised flow velocities to increase around the mine infrastructure, as water is concentrated in diversion channels, or alongside flood bunds or raised pads. This flow is to be handled by the internal stormwater provisions for the developed areas. Formalised drainage networks are to be installed in plant site areas.
- Flow Dispersion: If it is necessary for concentrated flow diversions to discharge to sheet flow zones, the diverted surface water will be discharged over spreader mechanisms to encourage the flows to slow and disperse.
- Separate Flowpaths: Flows from undisturbed areas will be kept separate from disturbed areas.
- Bunding: All waste dumps and stockpiles have the potential to generate sediment laden runoff water which may require treatment in sediment basins prior to discharge to the environment. Bunding will be provided as appropriate to contain internal surface water runoff for treatment, plus to divert external surface water runoff.
- Temporary Works: Surface runoff from disturbed areas will typically contain some sediment, and may also include pollutant loads such as oil and grease. Temporary erosion and sediment control structures will be provided such as diversion banks, drains and sediment traps.
- Hydrocarbon Management: Hydrocarbon storage areas are to be bunded to prevent uncontrolled release. Potentially hydrocarbon polluted runoff such as from workshop areas will be directed to basins fitted with baffle mechanisms to trap possible pollutants before discharge to the downstream environment.

5.5.1 Surface Water Diversions

The following criteria should be adopted with regards to surface water diversions:

- Reduce the volume of run-off lost from the natural drainage systems.
- Reduce the likelihood of flooding of the mine areas due to surface water inflow.
- Reduce the volume of surface water entering the active mine areas.
- Reduce the volume of surface water which could potentially be contaminated as a result of contact with mining activities.
- Reduce the potential for erosion and sedimentation in the natural drainage systems.
- Where possible a diverted water course will be directed into the original water course at a point downstream or to the downstream water course.

Diversions require a combination of bunding and excavated channels to carry floodwaters via a flowpath different from the natural water course. The diverted water is directed into a defined water course, preferably the original water course at a point downstream. Energy may need to be removed from the flow at the entry point (e.g. riprap lining) to match the receiving channel characteristics.

The design capacity selected for the constructed diversion depends on the impacts of failure of the diversion. If there are potential adverse impacts of flow in areas that are normally flood free, or negatively impact on mine infrastructure or the environment, then diverted water needs to remain confined within its diversion flowpath (e.g. 100 year ARI capacity). If flow in areas that are normally flood free is acceptable or otherwise only represents nuisance flow, then a lesser ARI capacity and less costly diversion (e.g. 2 year ARI capacity) may be suitable.

Where diversion structures are required, bunding should typically consist of a level top section (minimum) 3m wide with side batters of 1:2.5, and be built to an engineering specification using competent materials. Bunding dimensions and the diversion channel should be capable of containing or diverting runoff flows up to the design flood event, plus a freeboard allowance. Excavated channels should typically have side batters of 1:2 and be of sufficient bottom width and depth to contain the design flood event. Larger flows would overtop the channel and potentially become overbank flow.

5.5.2 Bunding

It is a general requirement to bund the perimeters of the waste dumps, waste dumps, stockpiles and other disturbed areas as appropriate to prevent natural runoff from outside the disturbed areas from mixing with internal site runoff. Internal runoff would be collected and treated in a sediment basin to remove sediments prior to release to the natural environment. Where possible, diversion bunding would also act as perimeter (diversion) bunding to minimise the quantities of earthworks required.

Although the diversion works discussed above would serve to protect the pits from flooding, local perimeter bunding would also be installed at the pits as appropriate to prevent unnecessary nuisance water entering the pit. Where nuisance water cannot be drained, it can be trapped against flood bunding and either be pumped away or allowed to dissipate by a combination of seepage and evaporation as appropriate.

The flood bunding height will vary across the site dependent on local topography, and the flood protection requirements. The bund would require construction and compaction to an engineering specification. Whilst the slopes will be dependent on the material used and the achievable compaction, indicative slopes are 1:2.5.

Upon completion of the waste dump, the flood protection bund can be incorporated into the toe of the waste dump at an angle appropriate to provide long term stability and then rehabilitated.

5.5.3 Sediment Basins

The planned mining operations for Robertson Range would potentially mobilise additional sediments to the natural drainage systems with the main potential sediment sources being the waste dumps and stockpiles. The most effective method of sediment management is to control sediment at their sources. Sediment basins are one such method, and should be constructed down slope of all waste dumps and stockpiles (as appropriate) to help manage surface water sediment. Sediment basins should be used in conjunction with erosion minimisation strategies such as vegetated batters, coarse sheeting and engineered drainage systems.

Sediment basins collect internal runoff and remove sediments to acceptable levels prior to release to the natural environment. Bunds and drainage diversion works will be constructed around the perimeter of all waste dumps and stockpile areas, to divert and separate the natural runoff outside the development sites from the internal site runoff. Basins are typically located at a low point on the infrastructure perimeter and constructed by a combination of excavation and earth bunds. Sediment basin designs are based on the removal of a target sediment size. Removal of medium sized silt particles > 0.02mm (20 micrometres [μm]) for the design storm event is commonly used. The sediment trap is then expected to be effective in removing sand and medium to coarse silt. The removal of fine silt and clay is generally not as effective.

Sediment basins should be constructed to treat the runoff from each waste dump and stockpile area in the development area. Each of these areas should be locally bunded to contain the internal runoff and direct runoff to a sediment basin prior to disposal to the main drainage system. The final locations and layouts for these bunds and sediment basins will need to be determined in association with the detailed mine plans.

5.6 Specific Surface Water Management Works

At the project area, a proposed diversion bund to the west of the plant area would intercept undisturbed surface water flows and reduce the quantities of water flowing across the plant area. Disturbed surface water within the plant area and from the waste dumps would be intercepted by diversion bunding and brought around to a low point at the south-eastern extremity of the project area where it would be passed through a sediment trap(s) before discharging to the environment.

5.6.1 In-Pit Stormwater

Although the diversion works discussed above will serve to protect the pits from flooding, local perimeter bunding will also be installed at the pits as appropriate to prevent unnecessary nuisance water entering the pit. Direct rainfall on the pit floor would be removed by pumping. After treatment to remove the sediments, the in-pit water would typically be used for dust suppression, with any excess discharged to the environment under relevant licence conditions.

FerrAus would only pump in-pit stormwater to an adjacent creek following a significant rainfall event when the creeks would already be saturated or possibly still flowing. These discharges would be a short term activity and all water would be treated via detention storage to remove sediments prior to discharge. A rock fill pad would be installed at the pipe discharge point, to dissipation energy and reduce the potential for erosion.

5.7 Surface Water Management for Mine Closure

The post closure topography of the pit area will be formed by in-pit overburden placement into the mine voids. It is likely that some sections will be below the pre-mining level. The majority of the backfill will comprise of waste material.

The change in topography post mine closure may potentially impact on surface water flow through the proposed disturbance area. Such potential impacts include:

- Drainage stability and erosion of mine closure landforms.
- Permanent changes to the pattern of overland and sheet flow.

To mitigate the risk of these potential impacts, it is recommended the following closure surface water management objectives are implemented:

- To restore baseline flow regimes in areas affected by mining and closure works.
- To maintain baseline surface water quality.
- To ensure stability of permanent diversions, creek reconstructions and other constructed water management works left after mine closure.
- To ensure stability of drainage from landforms created by mining.

Permanent changes to the pattern of flows due to post closure landforms are likely to result in geomorphic changes to drainage lines around and downstream of the mine site. The degree of change would depend on how post closure flows would be distributed compared to the natural distribution of flows with the aim to ensure post closure flows are as close as possible to natural conditions.

Some of the runoff through the project area would be unable to flow along the entire length of their original drainage lines due to post closure landforms. Where appropriate, it is proposed to construct a series of diversion drains to redirect water around or through the mine site. Once downstream of the mine site, flow would be diverted back to the original drainage course wherever possible.

Diversion channels would be designed with sufficient capacity for a nominated rainfall event, while minimising earthworks and the channel footprint. The channel would be an appropriate width and depth, and have a bed gradient and side batters to minimise channel velocities and ensure a stable channel profile.

6. CONCLUSIONS

6.1 Mine Impacts on Groundwater

The hydrogeology of the mine site at Robertson Range is controlled by the Mara Mamba orebody which forms a significant aquifer, which will result in high inflows into the pit if dewatering does not take place.

The groundwater level at the Robertson Range mine site lies approximately 30 to 33 metres below ground level (mbgl). The groundwater flow at the site is to the south with limited recharge from rainfall in the immediate area. Greater recharge to groundwater is expected after cyclonic rainfall events. Pump testing of test production bores drilled into the ore body indicate the high yield capacity of this aquifer, suggesting large production bores could deliver 30 – 60L/s.

A mine scale groundwater model has been developed for the Robertson Range orebody based on current hydrogeological understanding. The model is calibrated to available data from the existing Robertson Range bores. The model has been used to predict the dewatering requirements for the 12 years of the projected mine life.

Model predictions completed show that four production bores can adequately dewater the planned mine pit area. Resulting dewatering rates for the Base Case Scenario are predicted to be 7.8ML/day (90L/s) initially and reaching a maximum of 9.5ML/day (110L/s) in Year 4 of mining. Based on the sensitivity analysis, the worst case scenario (the case of high specific yield alluvium), the maximum pumping rate required to drop water levels below the pit floor, is 12.1ML/day (140L/s).

Mine dewatering is predicted to result in a zone of groundwater depression, controlled by the permeability of varying hydrogeological units around the mine site. The zone of groundwater depression is likely to extend marginally further to the south in higher permeability units but will be curtailed by low permeability granite, greenstone and other units that surround the model domain. Model predictions show that after 12 years of mining drawdown of 1m extends to between 4 and 6km away from the open pits.

6.2 Mine Impacts on Surface Water

6.2.1 Potential Impacts

Potential surface water impacts associated with the planned mining activities include:

- Interruption to existing surface water flow patterns.
- Runoff loss to downstream environment.
- Increased risk of erosion and sedimentation.
- Contamination of surface water by chemicals or hydrocarbons.

Minor drainage paths from the upstream catchment extend through the proposed mine area. To prevent flooding of the mine pits and associated infrastructure, bunding and diversion drains will be required to manage these flows. Diversions will be designed to re-route flows back into their original drainage paths downstream of the development, or via minor channels and overland flow.

The diversion of this flow into diversion drains will potentially impact vegetation downstream of the drains.

The mine developments have the potential to reduce the effective catchment area of Lake Disappointment by 1.7km^2 or less than 0.01%. These changes are not significant to the overall hydrological system, particularly in comparison to the natural seasonal variations in catchment runoff.

Runoff from the planned waste dump and other disturbance areas and the concentration of flow into diversion drains has the potential to significantly increase erosion and sediment loads in the natural drainage systems, if appropriate management measures are not implemented.

The post closure topography of the pit area will be formed by backfill placement into the mine voids. Most areas will be backfilled below the existing surface level. This change in topography will impact on the surface water flow regime of the area.

6.2.2 Management Measures

To minimise the impact of mining operations on surface water draining from the site and consequently on the Lake Disappointment catchment, a number of measures will be adopted during construction and operation of the mine. These measures will include the use of buffer zones between mine developments and creek systems, minimisation of clearing, dry season construction where possible, bunding of hydrocarbon storage areas and separation of runoff from disturbed areas.

Sediment basins will be constructed to treat the runoff from each waste dump and stockpile area in the development area. Each of these areas will be locally bunded to contain the internal runoff and direct runoff to a sediment basin prior to disposal to the main drainage system.

Direct rainfall on the pit floor would be removed by pumping. After treatment to remove the sediments, the in-pit water would typically be used for dust suppression, with any excess discharged to the environment under relevant licence conditions. In-pit stormwater will be discharged to an adjacent creek following a significant rainfall event when the creeks would already be saturated or possibly still flowing and sediment would be removed prior to discharge.

Around the stockpile areas and the process plant, bunding will be installed to protect the infrastructure from flooding as required. The flood bunding will be installed prior to the construction of the waste dumps to ensure that flood protection is achieved for the commencement of mining.

Post-closure, where appropriate, it is proposed to construct a series of diversion drains to redirect water around or through the mine site. Once downstream of the mine site, flow would be diverted back to the original drainage course wherever possible.

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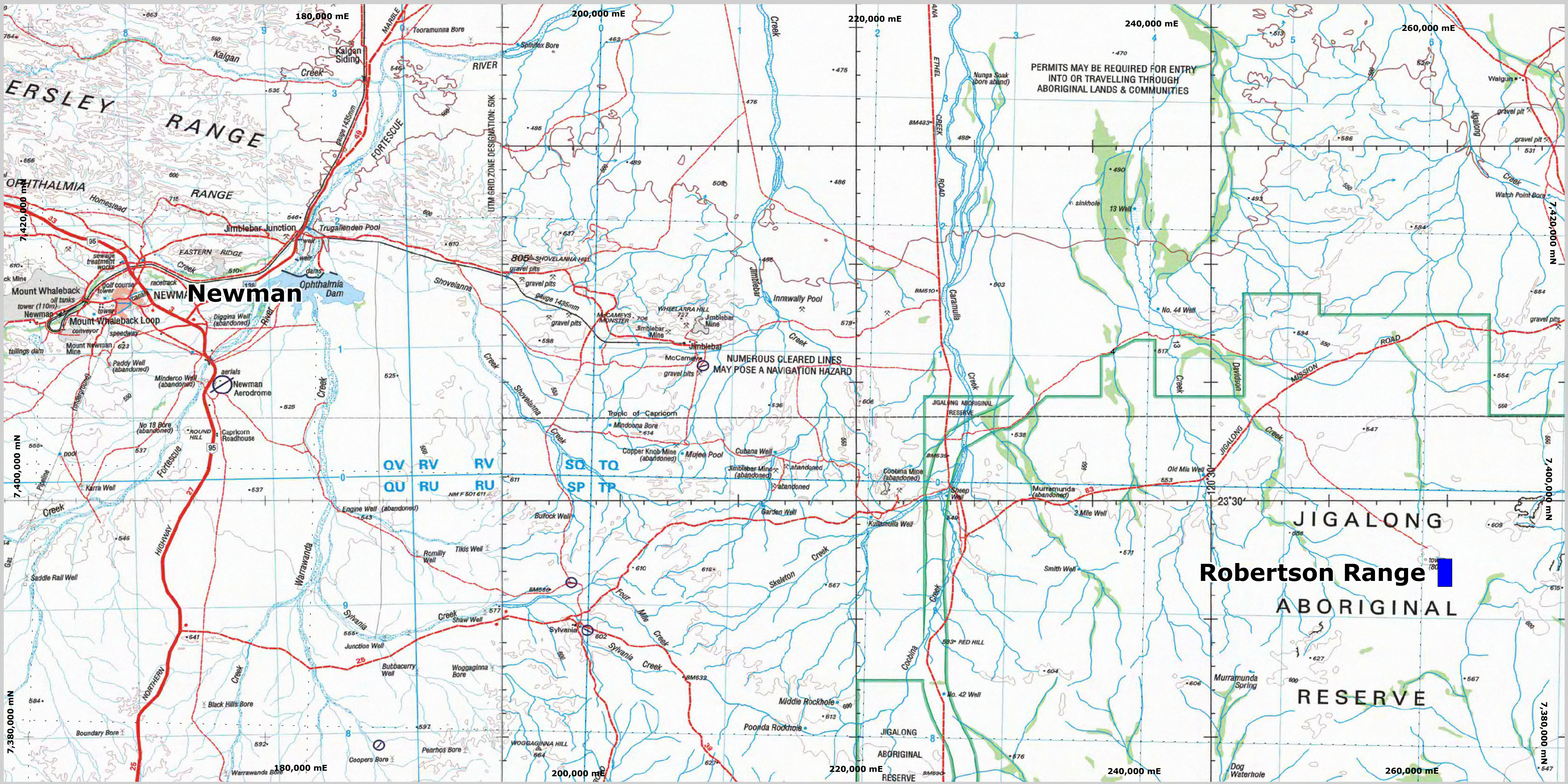
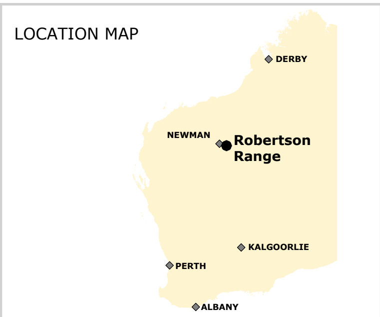
FIGURES





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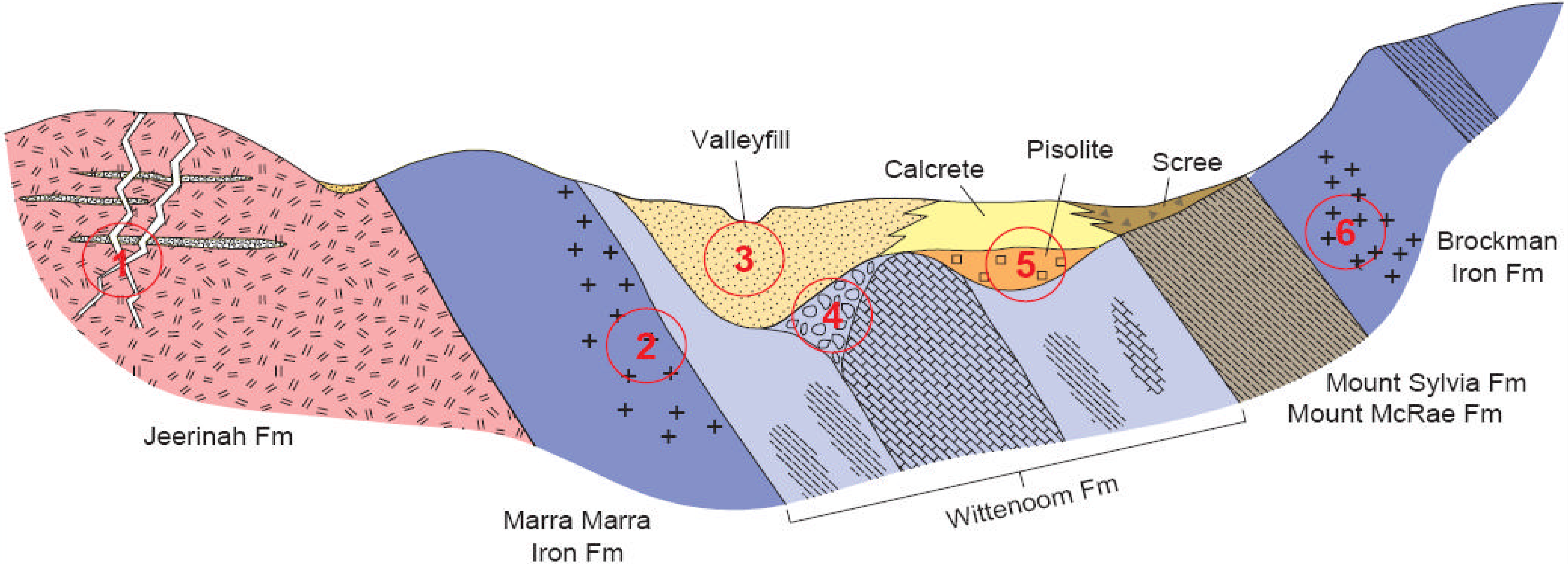
AUTHOR:	GB	REPORT NO:	015a
DRAWN:	GB	REVISION:	a
DATE:	7/7/2011	JOB NO:	1294B / B9

DATA SOURCES:
1:250,000 Scale State Topographic Map

RPS Aquaterra

FIGURE 1
LOCATION OF ROBERTSON RANGE

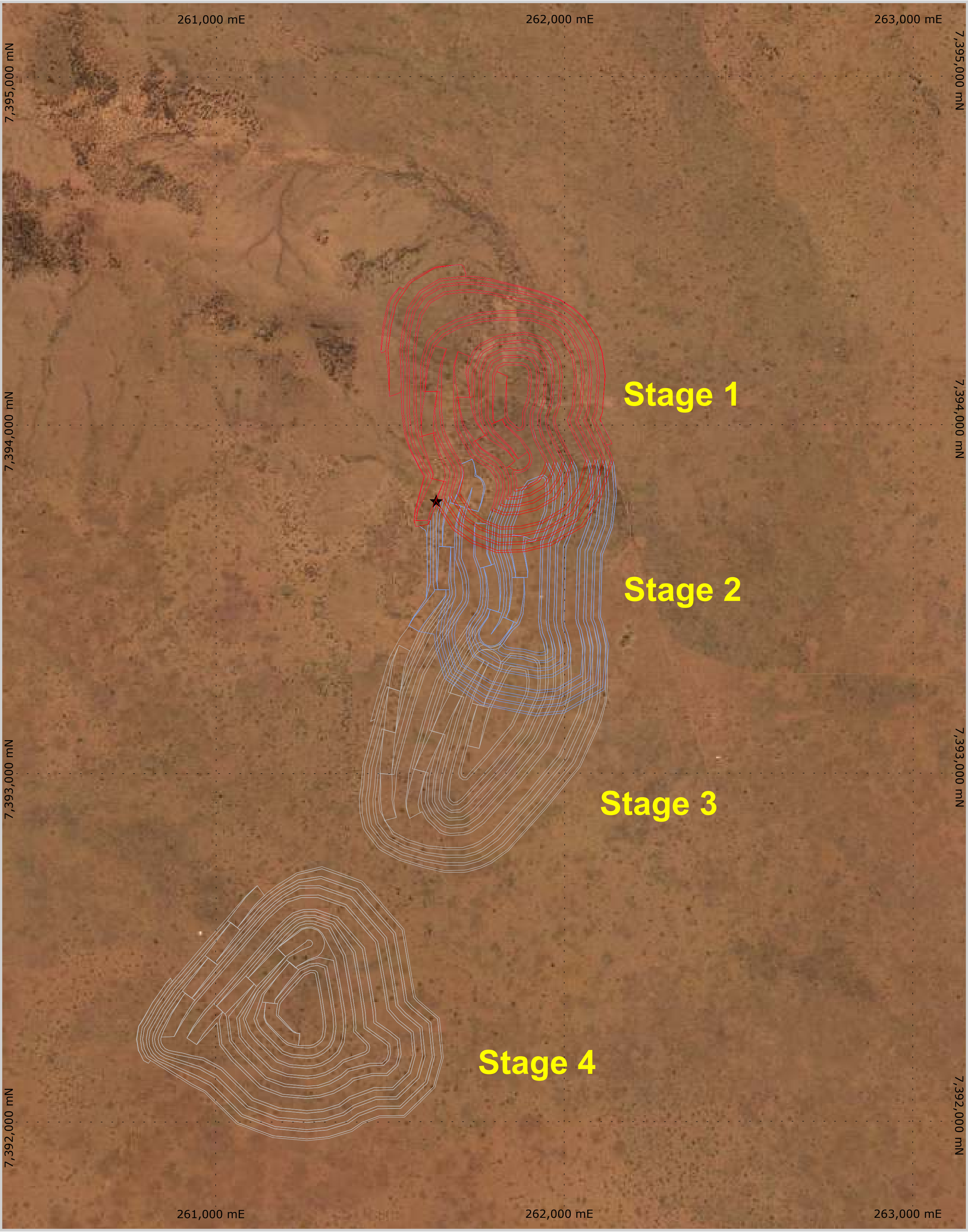
Location: F:\Jobs\1294B\MapInfo\RR Con rep\015a Fig1_Location.wor



1 Fractured rock
2 Mineralized Marra Mamba (BIF)
3 Valleyfill
4 Karstic dolomite
5 Pisolite and calcrete
6 Mineralized Brockman (BIF)
Karstic
+ + Mineralized

HG8-Fig2-1

Most Significant Aquifers in the Pilbara (Johnson & Wright, 2001) FIGURE 2



N

200 0 200

Meters

Scale: 1:15,000 @A4

GDA 1994 Zone 51

AUTHOR: GB	REPORT NO: 015a
DRAWN: GB	REVISION: a
DATE: 7/7/2011	JOB NO: 1294B / B9

LEGEND

Proposed Pit Outline

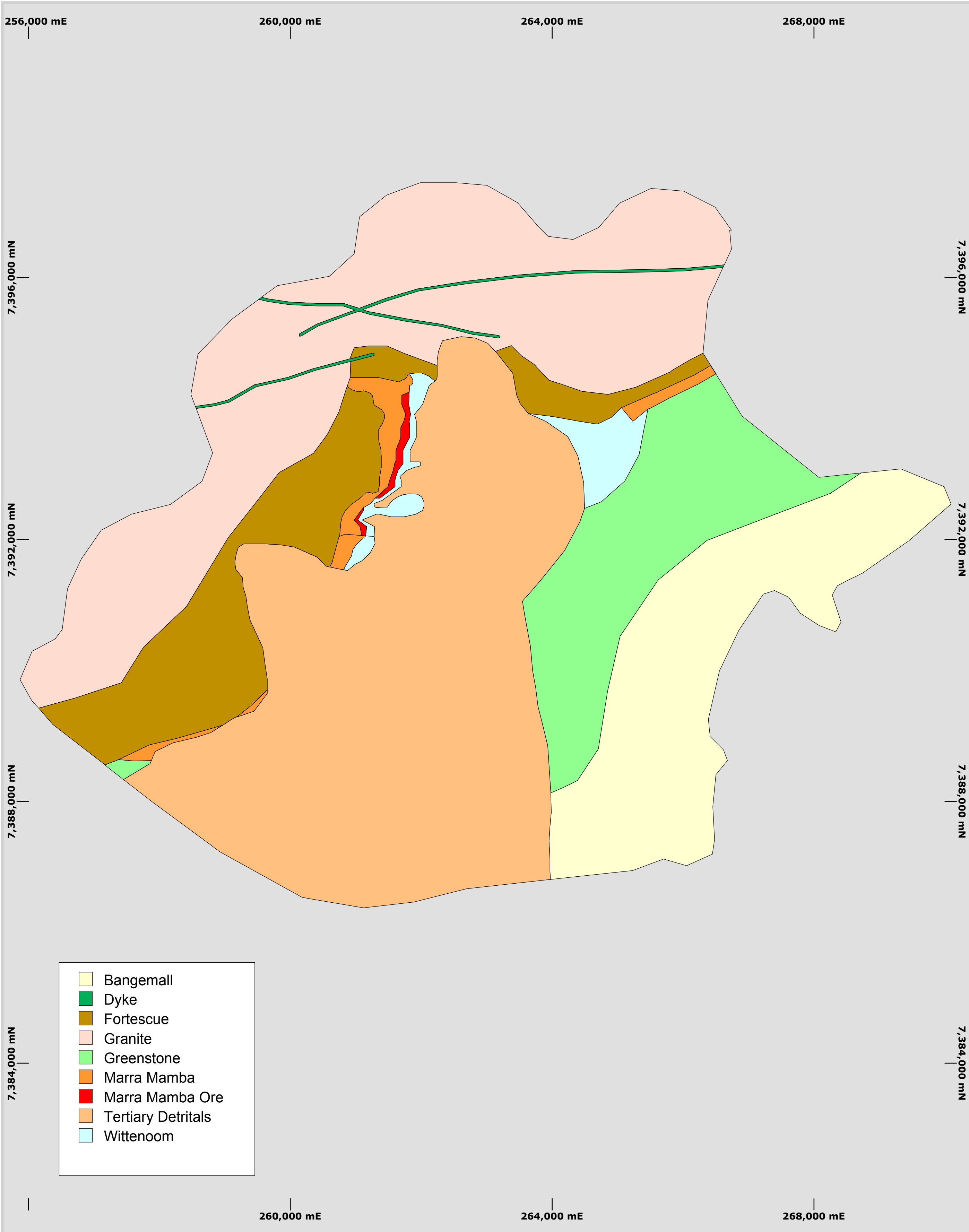
DATA SOURCES:
Ferraus Ltd

RPS Aquaterra

FIGURE 3

ROBERTSON RANGE PROPOSED MINE PITS STAGES 1 TO 4

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig2.1.wor



N

1 0 1 2

Kilometers

Scale: 1:80,000 @A4

GDA 1994 Zone 51

AUTHOR: GB
DRAWN: GB
DATE: 7/7/2011

REPORT NO: 015a
REVISION: a
JOB NO: 1294B / B9

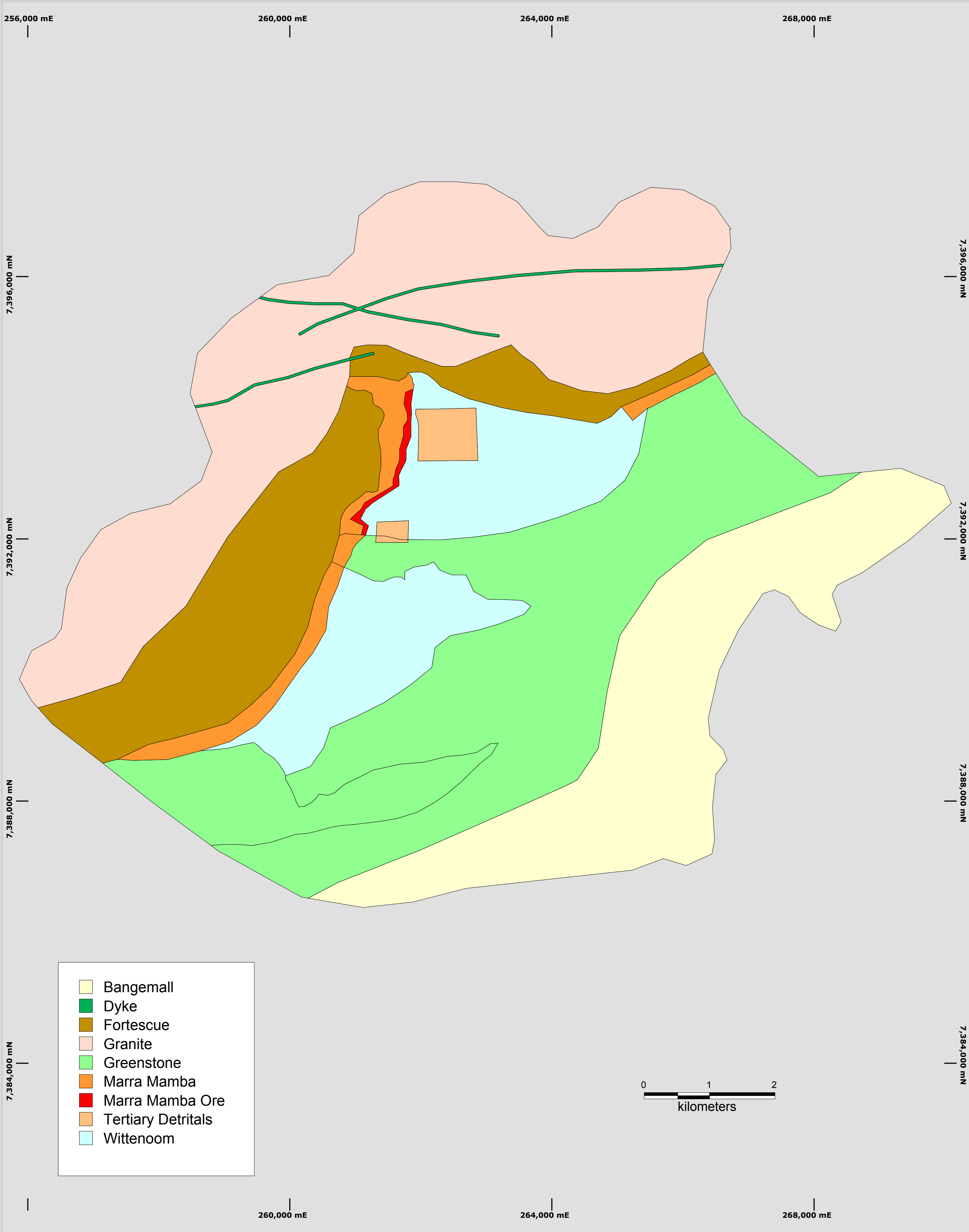
DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

RPS Aquaterra

FIGURE 4

ROBERTSON RANGE INTERPRETED GEOLOGY LAYER 1

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig4.6.wor



N

1 0 1 2

Kilometers

Scale: 1:80,000 @A4

GDA 1994 Zone 51

AUTHOR: GB	REPORT NO: 015a
DRAWN: GB	REVISION: a
DATE: 7/7/2011	JOB NO: 1294B / B9

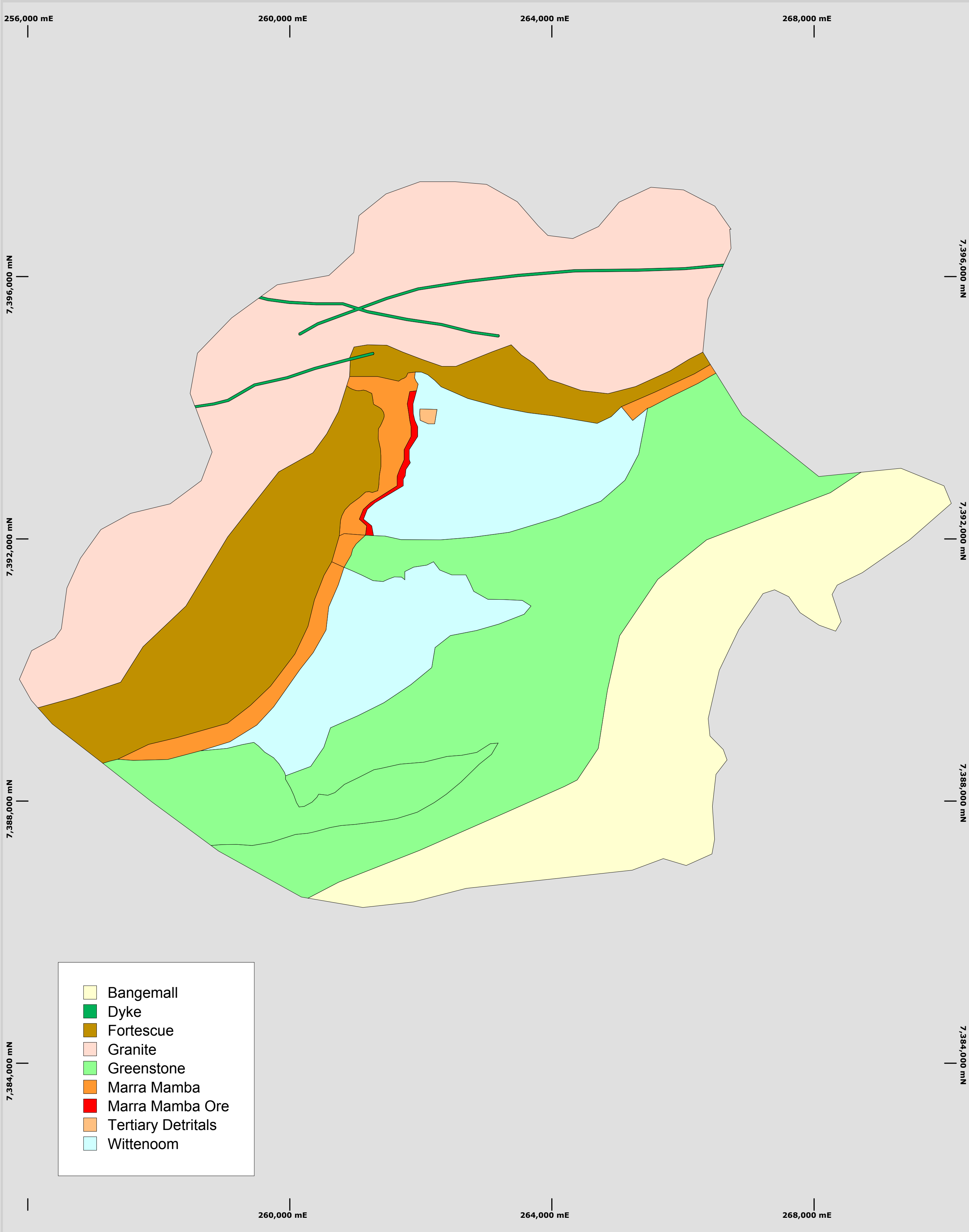
RPS Aquaterra

FIGURE 5

ROBERTSON RANGE INTERPETED GEOLOGY LAYER 2

DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig3.2.wor



N

1 0 1 2

Kilometers

Scale: 1:80,000 @A4

GDA 1994 Zone 51

AUTHOR: GB	REPORT NO: 015a
DRAWN: GB	REVISION: a
DATE: 7/7/2011	JOB NO: 1294B / B9

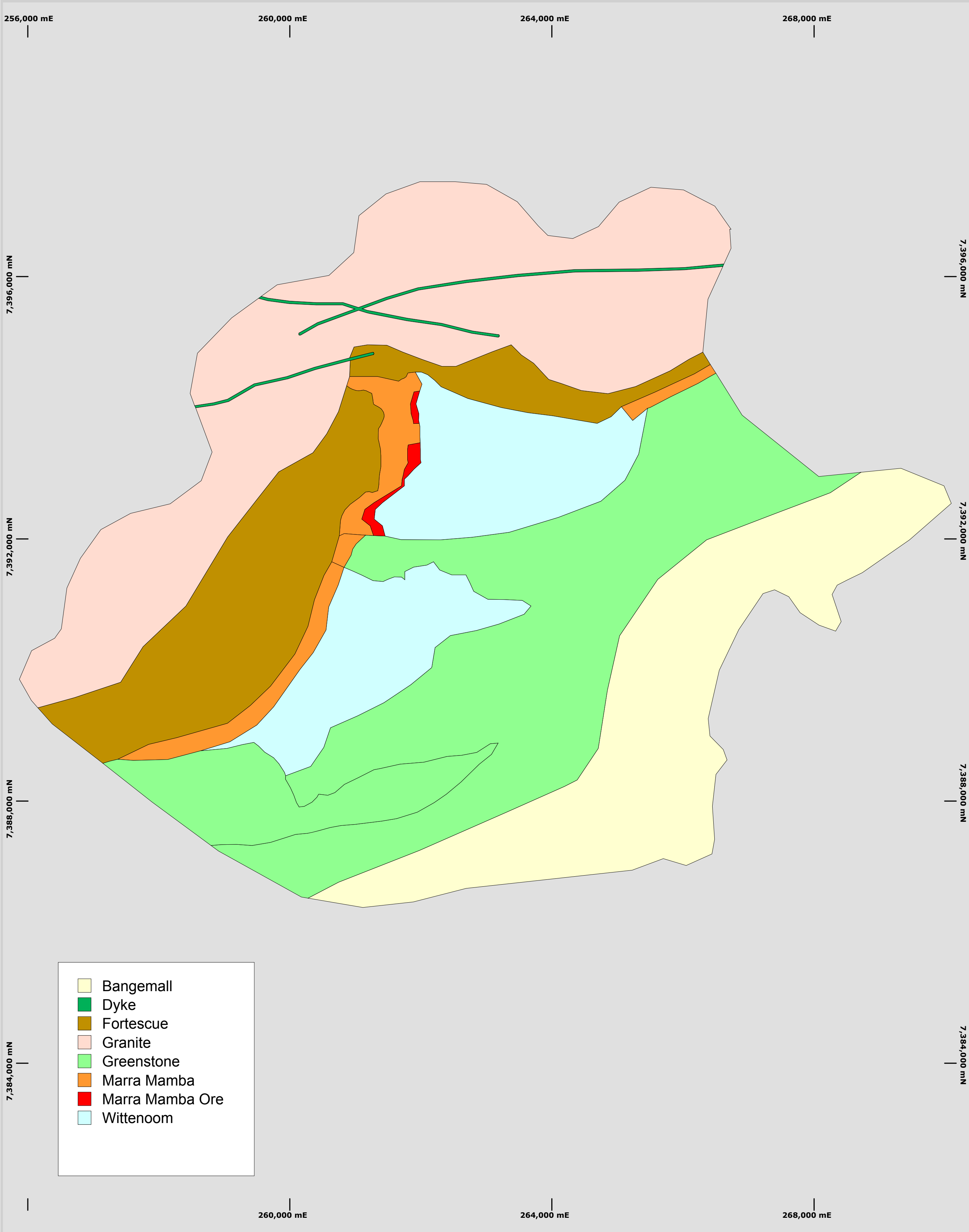
RPS Aquaterra

FIGURE 6

ROBERTSON RANGE INTERPRETED GEOLOGY LAYER 3

DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig3.3.wor



LOCATION MAP

N

1 0 1 2

Kilometers

Scale: 1:80,000 @A4

GDA 1994 Zone 51

AUTHOR: GB
DRAWN: GB
DATE: 7/7/2011

REPORT NO: 015a
REVISION: a
JOB NO: 1294B / B9

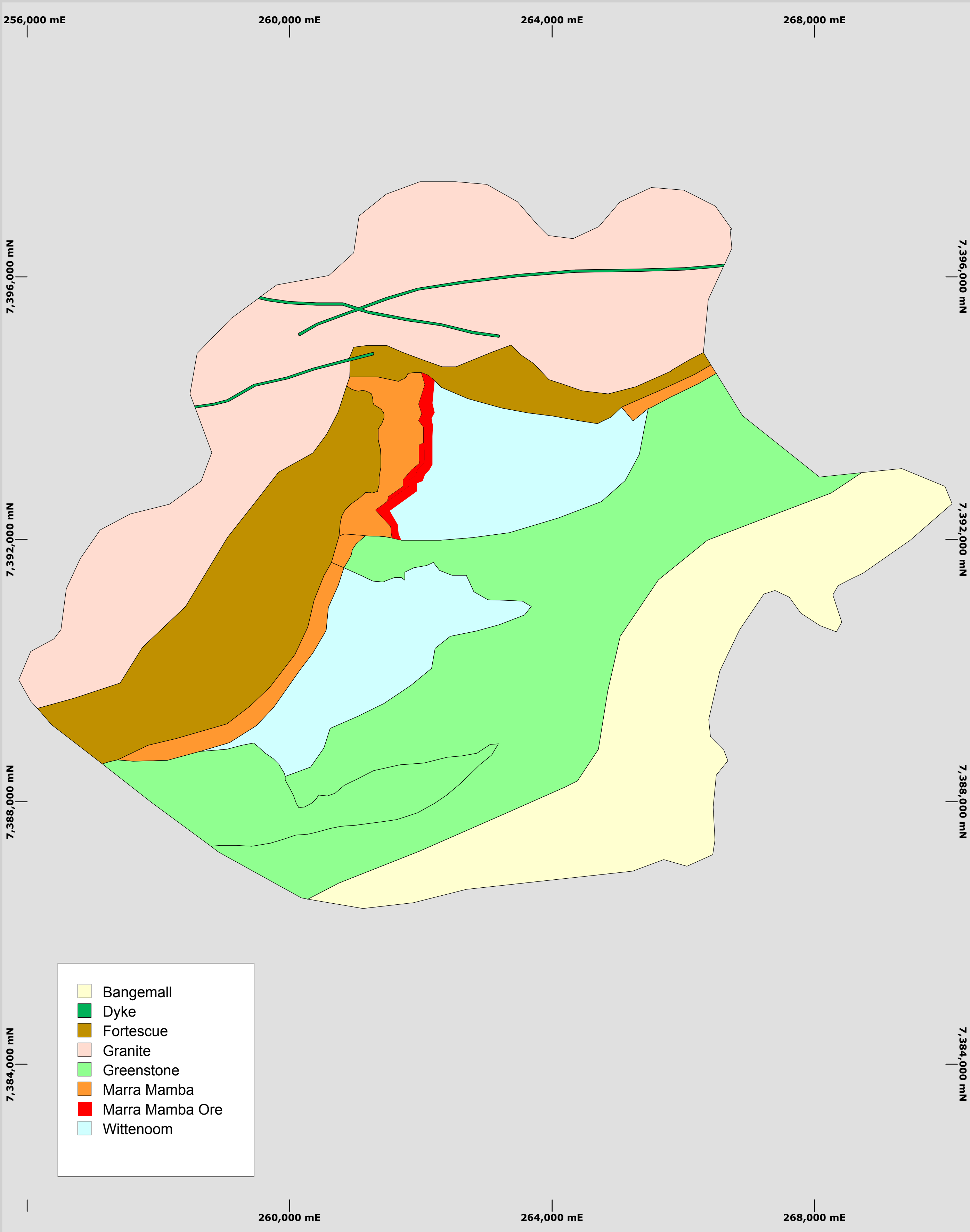
RPS Aquaterra

FIGURE 7

ROBERTSON RANGE INTERPRETED GEOLOGY LAYER 4

DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig3.4.wor



N

1 0 1 2

Kilometers

Scale: 1:80,000 @A4

GDA 1994 Zone 51

AUTHOR: GB
DRAWN: GB
DATE: 7/7/2011

REPORT NO: 015a
REVISION: a
JOB NO: 1294B / B9

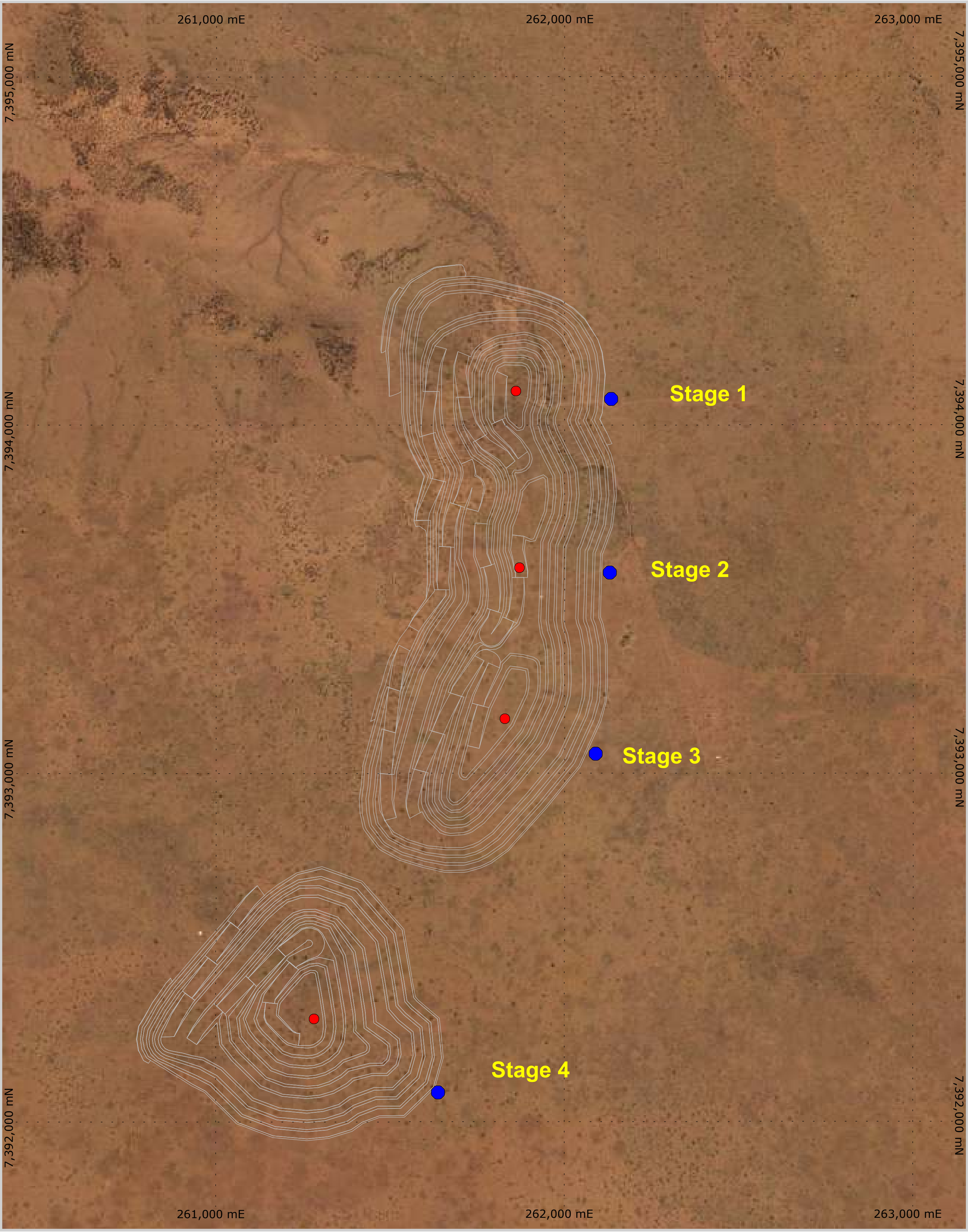
DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

RPS Aquaterra

FIGURE 8

ROBERTSON RANGE INTERPETED GEOLOGY LAYER 5

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig3.5.wor



N

200 0 200

Meters

Scale: 1:15,000 @A4

GDA 1994 Zone 51

AUTHOR: GB	REPORT NO: 015a
DRAWN: GB	REVISION: a
DATE: 7/7/2011	JOB NO: 1294B / B9

LEGEND

- Proposed Pit Outline
- Dewatering Bore
- Observation Point

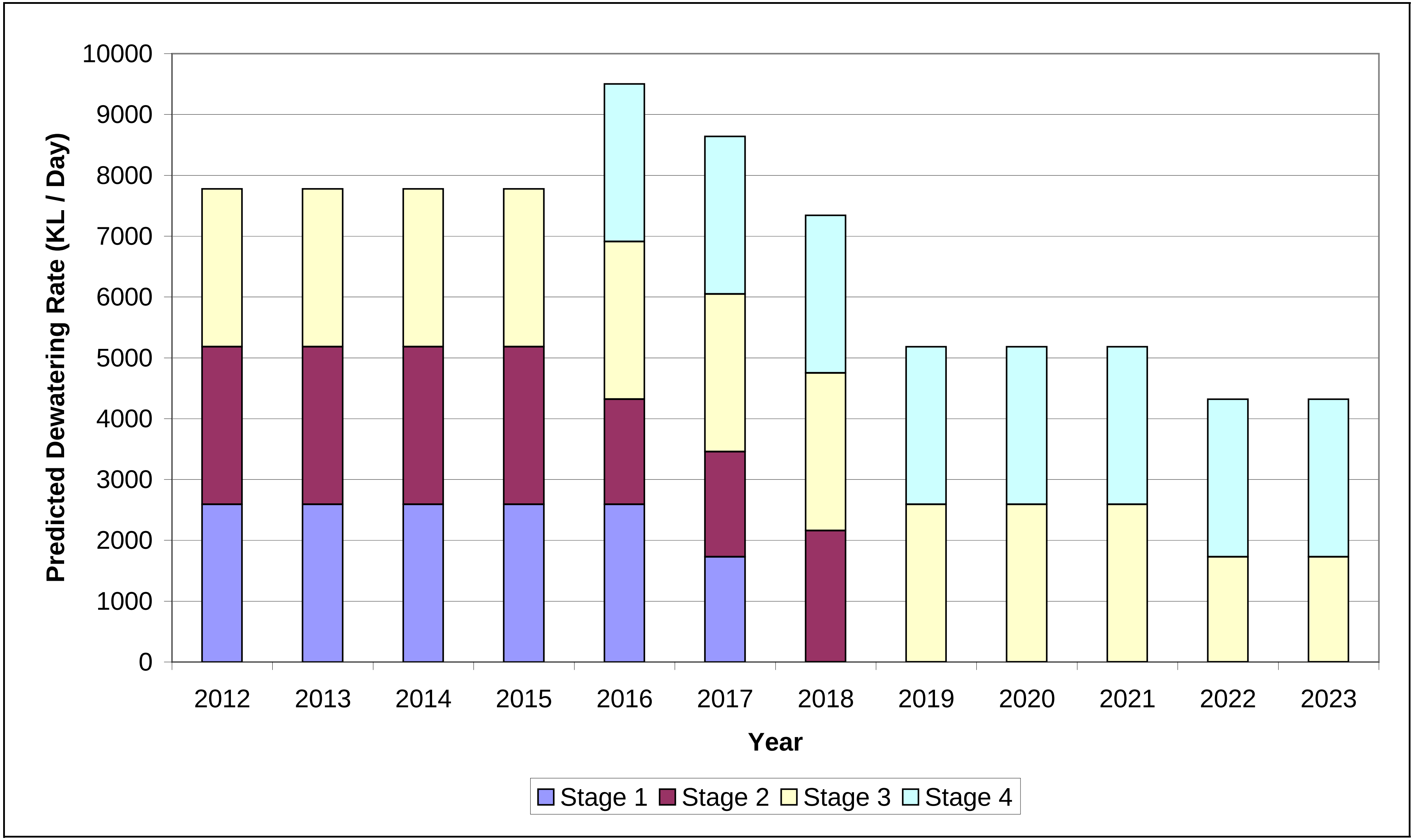
DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

RPS Aquaterra

FIGURE 9

ROBERTSON RANGE PROPOSED DEWATERING BORES & PIT OBSERVATION POINTS

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig4.2.wor

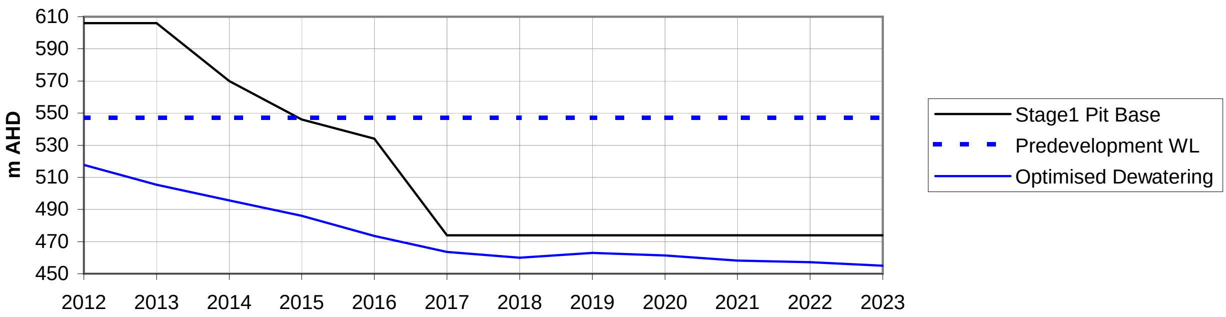


RPS Aquaterra

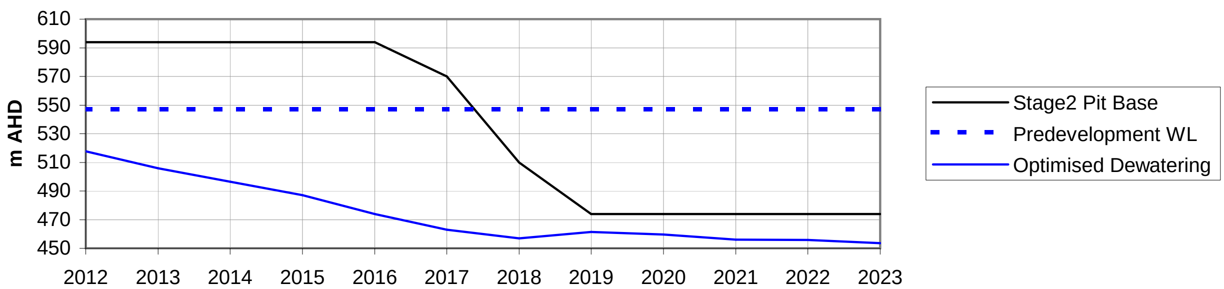
DEWATERING PUMPING RATES FIGURE 10

F:\Jobs\1294B\B9 RRA Consolidated Report\Figures\[Report Figures 2 10 11 12 13.xls]Fig 10

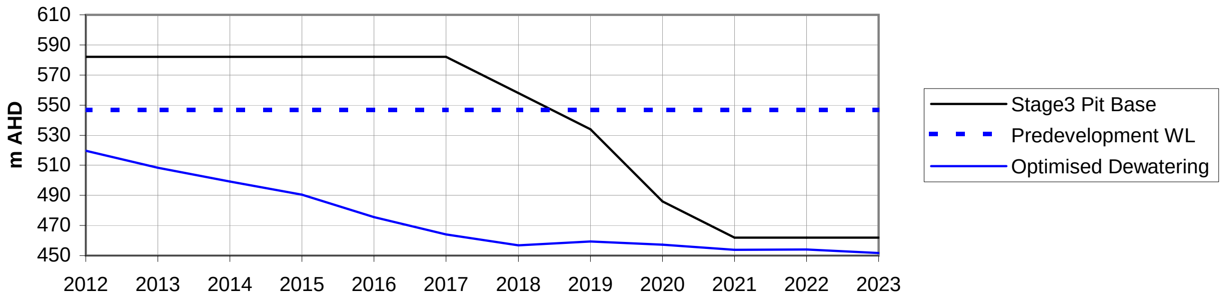
Stage 1



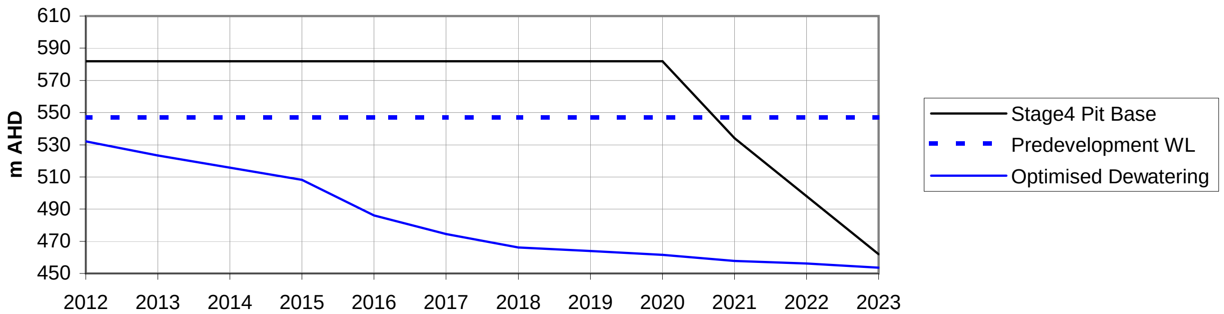
Stage 2



Stage 3



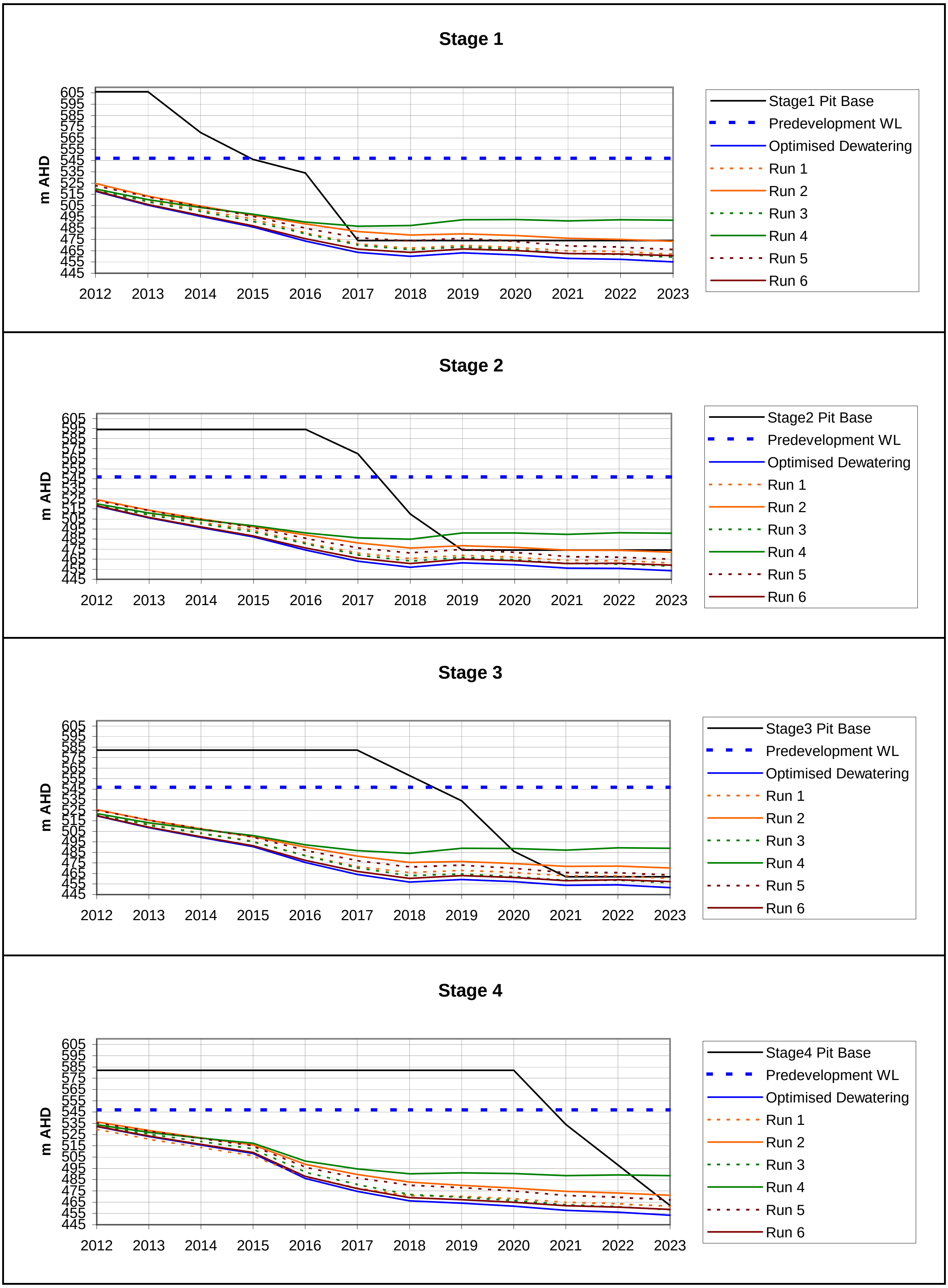
Stage 4



RPS Aquaterra

PREDICTED WATER LEVELS vs TIME FIGURE 11

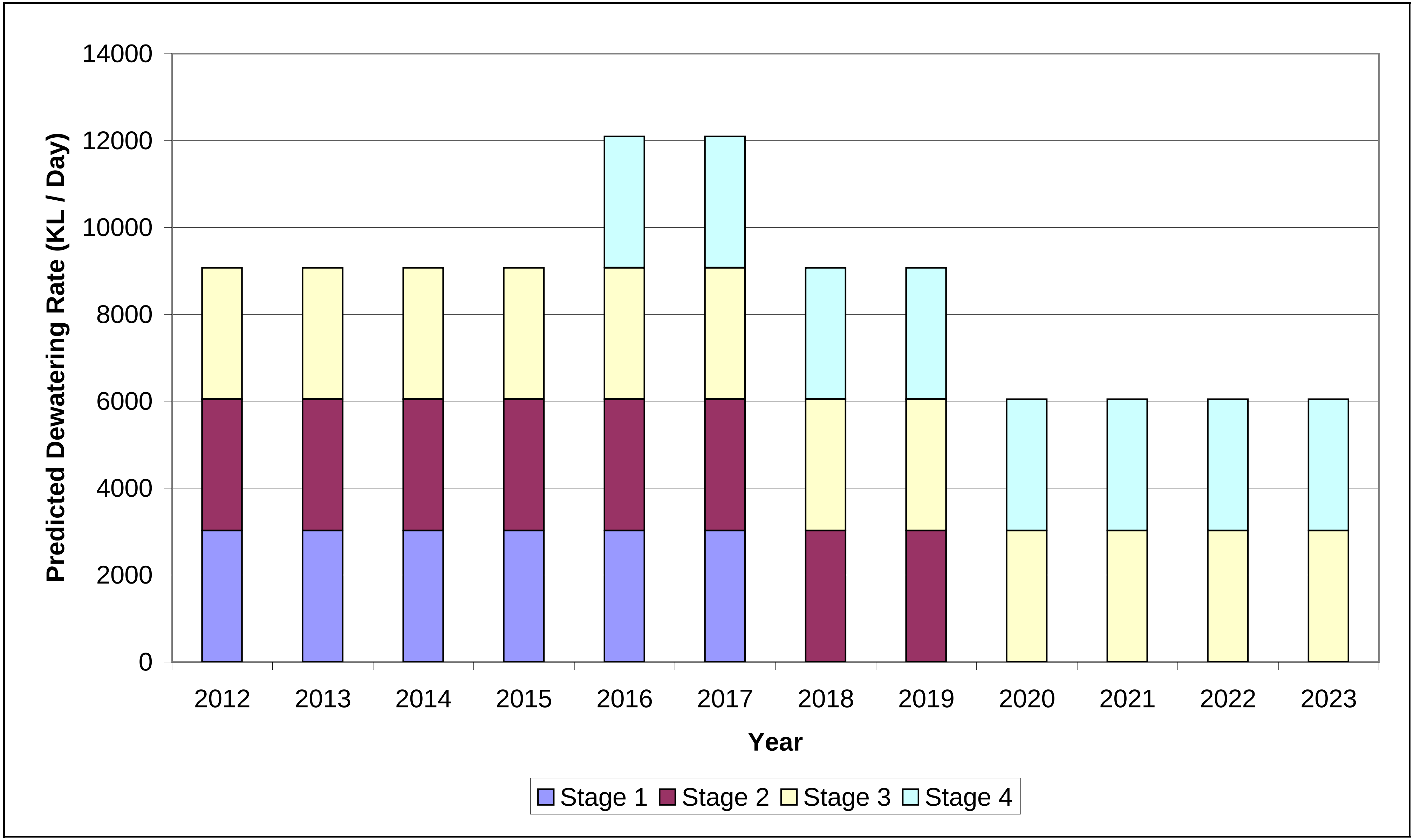
F:\Jobs\1294B\B9 RRA Consolidated Report\Figures\[Report Figures 2 10 11 12 13.xls]Fig 11



RPS Aquaterra

SENSITIVITY RUNS PREDICTED WATER LEVELS vs TIME FIGURE 12

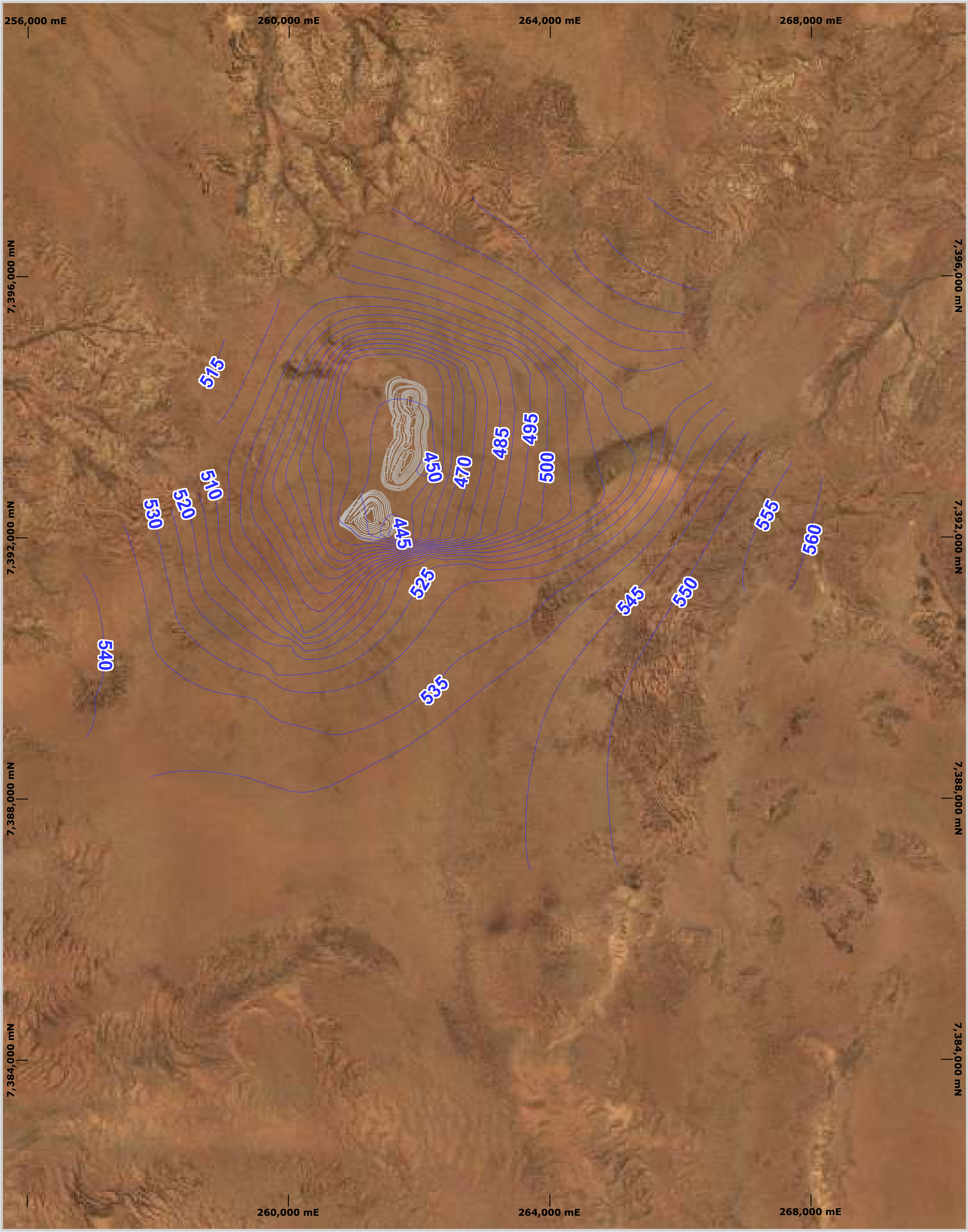
F:\Jobs\1294B\B9 RRA Consolidated Report\Figures\[Report Figures 2 10 11 12 13.xls]Fig 12



RPS Aquaterra

SENSITIVITY RUN #4 - DEWATERING PUMPING RATES FIGURE 13

F:\Jobs\1294B\B9 RRA Consolidated Report\Figures\[Report Figures 2 10 11 12 13.xls]Fig 13



N

1 0 1 2
Kilometers

Scale: 1:80,000 @A4

GDA 1994 Zone 51

AUTHOR: GB	REPORT NO: 015a
DRAWN: GB	REVISION: a
DATE: 7/7/2011	JOB NO: 1294B / B9

LEGEND

Proposed Pit Outline

Water Level Contour (mAHD)

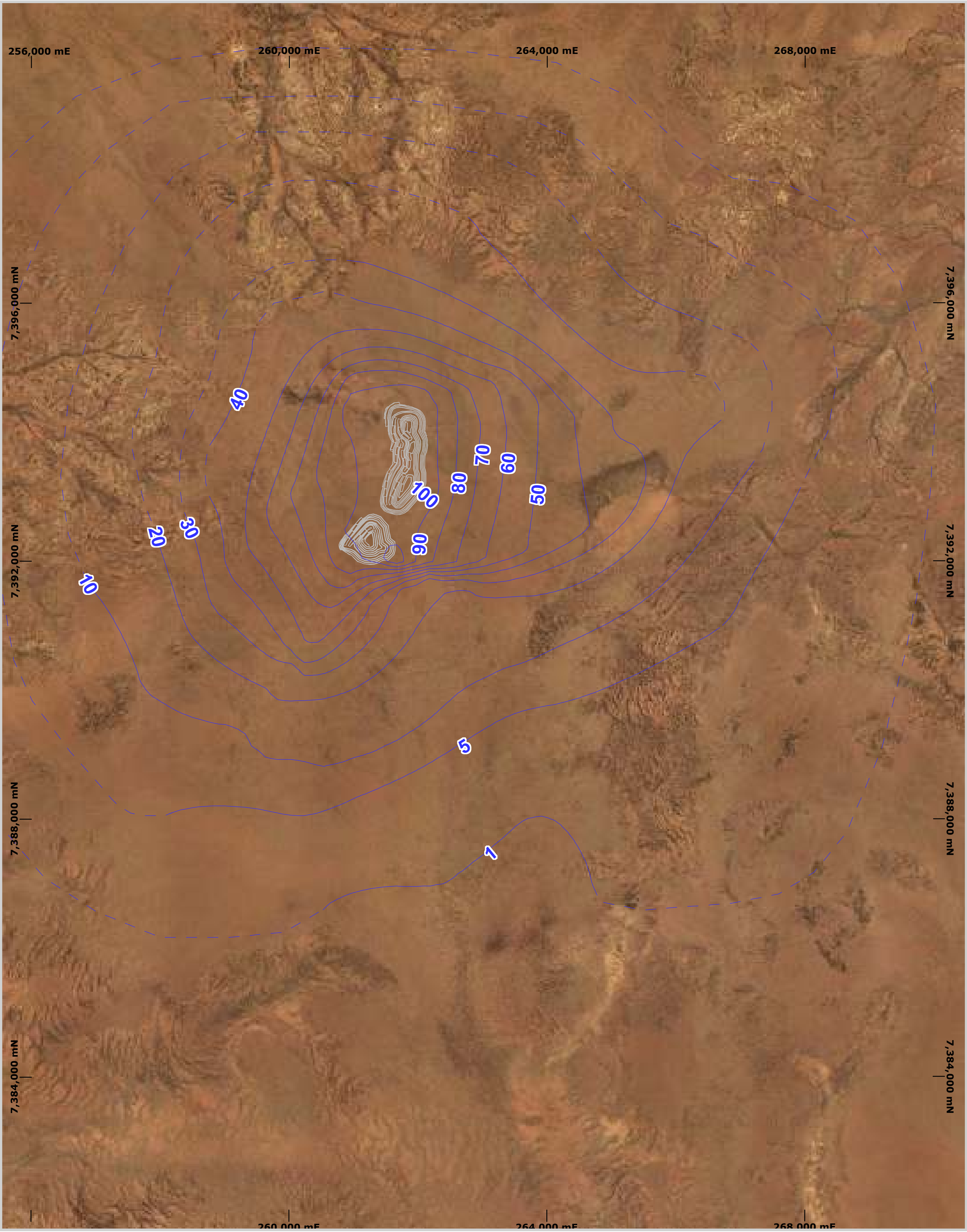
DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

RPS Aquaterra

FIGURE 14

ROBERTSON RANGE PREDICTED WATER LEVELS END OF MINE (2023)

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig4.8.wor



N

1 0 1 2
Kilometers

Scale: 1:80,000 @A4

GDA 1994 Zone 51

AUTHOR: GB
DRAWN: GB
DATE: 7/7/2011

REPORT NO: 015a
REVISION: a
JOB NO: 1294B / B9

LEGEND

Proposed Pit Outline

Modelled Drawdown Contour (m)

Interpreted Drawdown Contour (m)

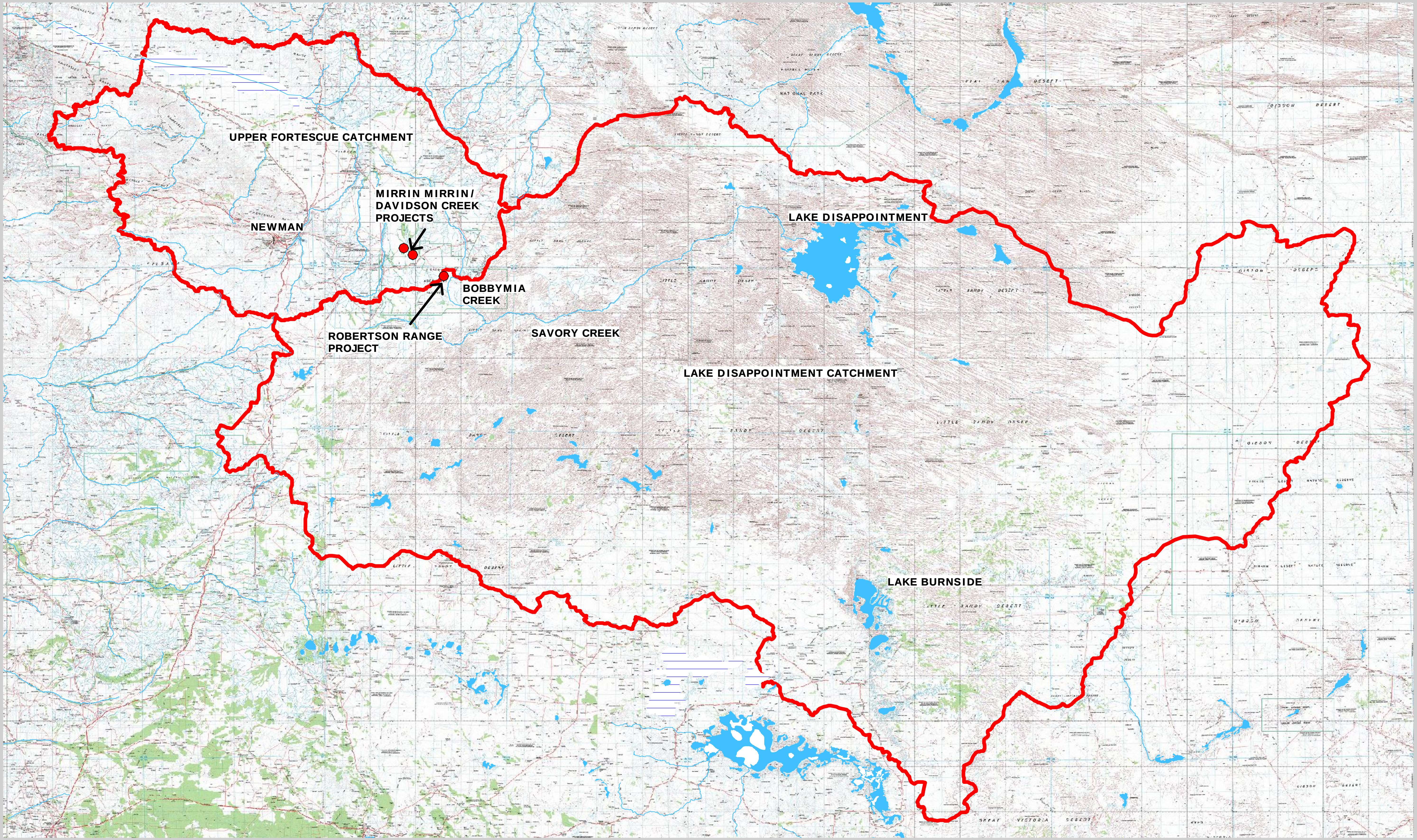
DATA SOURCES:
Ferraus Ltd, RPS Aquaterra

RPS Aquaterra

FIGURE 15

ROBERTSON RANGE PREDICTED DRAWDOWN END OF MINE (2023)

Location: F:\Jobs\791\MapInfo\E Task\E6\Modelling_Report\077a Fig4.8.wor



LOCATION MAP

Location: JOBS/1294B/RRA CONSOLIDATED REPORT/

%

0 40 80
Kilometres

Scale: 1:200,000 @ A3

GDA 1994 Zone 51

AUTHOR:	DM	REPORT NO:	015
DRAWN:	DM	REVISION:	a
DATE:	8/07/2011	JOB NO:	1294B

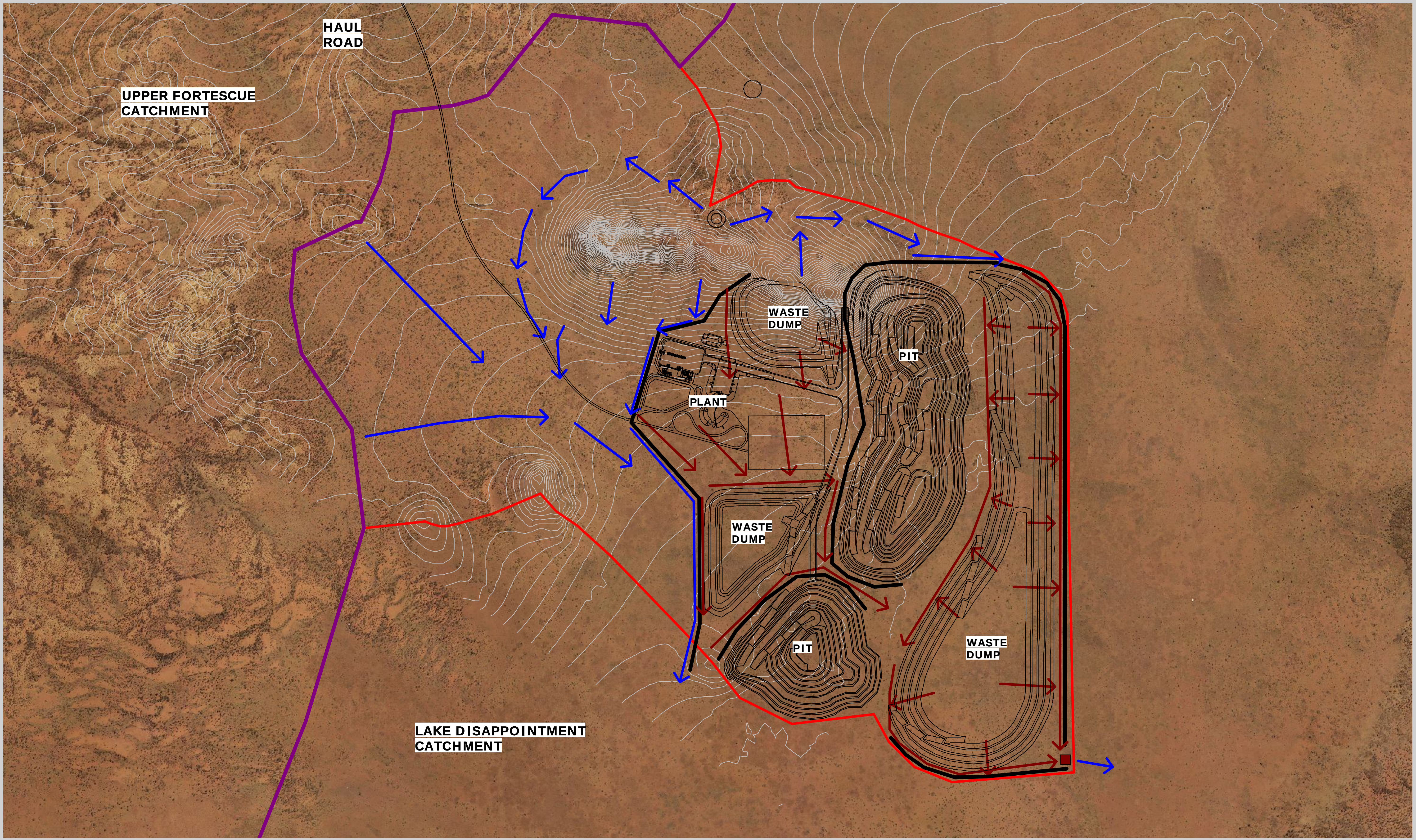
LEGEND

Regional Catchment Boundary

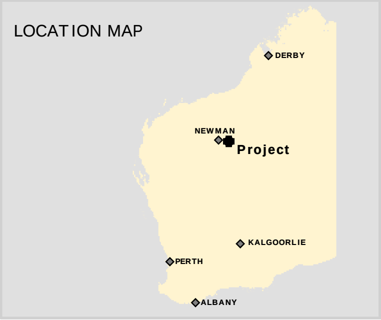
DATA SOURCES:
1:250,000 MAPPING

RPS Aquaterra

FIGURE 16
REGIONAL CATCHMENTS



LOCATION MAP



Location: JOBS/1294B/RRA CONSOLIDATED REPORT

%

0 400 800
Kilometres

Scale: 1:20,000 @A3

GDA 1994 Zone 51

AUTHOR:	DM	REPORT NO:	015
DRAWN:	DM	REVISION:	a
DATE:	8/07/2011	JOB NO:	1294B

LEGEND

- Regional Catchment Boundary
- Project Catchment Boundary
- Dirty Water Flow
- Clean Water Flow
- Diversion / Flood Protection Bunding
- Sediment Trap

DATA SOURCES:
Client supplied aerial photography and 1m contours

RPS Aquaterra

FIGURE 17

ROBERTSON RANGE: SURFACE WATER MANAGEMENT

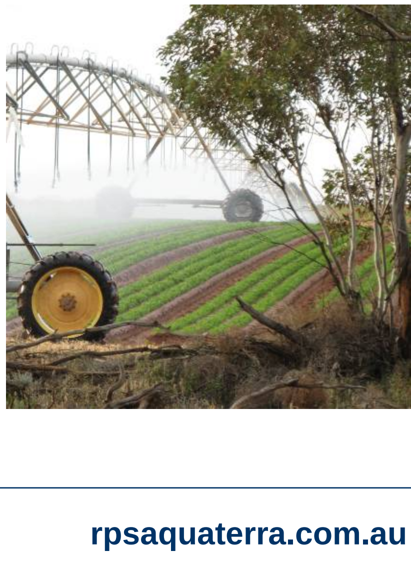
APPENDIX A:
ROBERTSON RANGE - FIELD PROGRAMMES CONSOLIDATED REPORT

RPS Aquaterra

ROBERTSON RANGE - CONSOLIDATED REPORT ON FIELD PROGRAMMES







ROBERTSON RANGE - CONSOLIDATED REPORT ON FIELD PROGRAMMES

Prepared by:

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Suite 10, 100 Mill Point Road
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Our ref: 1294B\020a

Date: 11 July 2011

Document Status

	Issue Date	Purpose of Document
Revision A	11/07/2011	Consolidate of Fieldwork – Appendices to dewatering estimate report

	Name	Position	Signature	Date
Author	Jeremy Bowyer	Hydrogeologist		11/07/2011
Author	Gary Bownds	Project Hydrogeologist		11/07/2011
Reviewer	Jeff Jolly	Principal Hydrogeologist		11/07/2011

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TABLES

FIGURES (compiled at end of report)

APPENDICES

1. INTRODUCTION

1.1 Background

FerrAus Limited is planning to mine iron ore at the Robertson Range Project site. The orebody and proposed mine extend below the watertable. Since 2007, RPS Aquaterra has conducted several field investigations to collect data that will allow a better understanding of the hydrogeologic environment and to progress dewatering estimates from prefeasibililty analytical calculations to definitive feasibility modelled dewatering estimates. Six test bores have been drilled, constructed and pump tested in the proposed pit area, four in 2007/2008 with another two in 2010. In addition, ten existing RC exploration bores in and around the pit area were airlift tested in 2010.

A number of reports have been compiled, that contain details of the field programmes and included dewatering estimates which are now redundant, since the mine plans have changed. This report is intended to consolidate the field programmes, separate from any dewatering estimate, so that it can be referenced as an appendix to the most current dewatering estimate.

1.2 Location

The Robertson Range Project Area (Figure 1) is located approximately 95km east of the township of Newman on the western fringe of the Little Sandy Desert. It is situated on the Jigalong Aboriginal Reserve. Access is via either Jimblebar access road or alternatively the Coobina Mine Road.

1.3 Topography

The Robertson Range project area is flat to gently sloping with a prominent hill rising some 20m above the surrounding plains immediately northwest of the proposed mine. The area is situated near the catchment divide between the northwest catchments flowing to the coast and inland catchments draining to Lake Disappointment some 200km east, via Savory Creek. The project area drains south to Bobbymia Creek which flows southeast to Savory Creek.

1.4 Climate

The Pilbara Region is characterised by an arid climate, receiving summer rainfall. Cyclones occur during this period, bringing heavy rain and causing potential destruction to inland and coastal towns.

The region has an extreme temperature range, potentially rising to 50°C during the summer, and dropping to around 0°C in winter. At Newman, mean monthly maximum temperatures range from 39°C in January to 22°C in July (with corresponding monthly minimum temperatures range 25°C and 7°C). High summer temperatures and humidity seldom occur together, giving the Pilbara its very dry climate.

The region has a highly variable rainfall, which is dominated by the occurrence of tropical cyclones, mainly during the period from January to March. The moist tropical storms from the north bring sporadic and drenching thunderstorms. With the exception of these large events, rainfall can be erratic and localised, due to thunderstorm activity. Therefore, rainfall from a single site may not be representative of the spatial variability of rainfall over the entire catchment during an event. The driest months are September to November.

1.5 Geology

1.5.1 Regional Geology

The Robertson Range project area is located on the eastern margin of the Hamersley Province, Western Australia. The area is dominated by the Archean granitoid-greenstone sequence of the Sylvania Inlier and the Fortescue Group and Hamersley Group successions.

The Capricorn and Ashburton Orogenies are the two main deformational episodes in the southern part of the Hamersley Province, although up to five deformation events have been recognized. The Capricorn (or Opthalmian) Orogeny is characterised by south-over-north directed thrusting and folds with tight inter-limb angles and southerly dipping fold axes. The later Ashburton Orogeny is characterised by large scale, upright E-W trending folds that define the regional outcrop pattern.

1.5.2 Local Geology

The ore body is hosted in the Hamersley Group Marra Mamba Iron Formation and, more specifically, in the uppermost Mount Newman Member.

The structurally complex geology of the area is concealed by an alluvial/colluvial cover of variable thickness of up to 80m that generally thickens to the east.

Within the proposed mine pit area, the Hamersley Group; Marra Mamba Formation is overlain by the Wittenoom Formation and dips at 25-35 degrees to the east and southeast.

West of the proposed pits, Granite, Greenstone and Fortescue Group rocks have been identified in mineral exploration drilling, while to the south, Fortescue Group and Hamersley Group have been identified. Drilling to the north and north east has encountered Granite, Fortescue Group and Bangemall Group. Bangemall Group rocks also outcrop to the east of the project area.

2. TEST BORE DRILLING & CONSTRUCTION

2.1 Test Production Boreholes, 2007

In September 2007 Connector Drilling Ltd (Connector) were contracted by Australasian Manganese to drill four test production bores (RRRC 345 B to RRRC 349 B) to a depth of approximately 120mbgl. The purpose of these holes was primarily to assess aquifer conditions. Additionally, the bores were completed as test production bores to serve as water supply during continuing exploration and also to allow de-watering operation should mining commence. Connector mobilised to site on 23rd September 2007 and commenced drilling the first pilot hole on 24th September 2007, using air hammer techniques with a 155mm (6") bit. (Note: At hole RRRC 348 B drilling method changed to mud rotary, due to unstable hole conditions). Drill cuttings were collected at 1m intervals and logged onsite.

On reaching total depth, each hole was airlifted for a period and the drill string was removed from the hole. All pilot holes were then reamed to be completed as production bores, using a 265mm (10½") bit. These were reamed slightly deeper than the proposed casing base to allow for possible fallback of drilled material (from up-hole that was not cleared from the hole during drilling). All reamed hole were again airlifted for a period following reaming.

Each bore was then equipped with 155 ID mm steel plain casing, and 155mm ID slotted steel casing. The bores were completed with 6.4-3.2mm graded gravel pack from total depth back to ground level, and a concrete pad was installed at the surface. Airlift yields were recorded (where practicable) using a v-notch weir during up to 8 hours of airlift development of the bores. (Borehole 347 B was airlifted for a longer period.).

The Connector drill rig demobilised from site on 18th October 2007.

All holes were subsequently geophysically logged at a later date with a gamma tool. This tool was run within the casing.

2.2 Test Production Boreholes, 2010

Due to an expanded and deeper mine plan it became necessary to obtain additional aquifer parameters for the Mount Newman Member (ore body) aquifer within the proposed mine pit and at greater depths than earlier bores. Two test bores, RRWB05 and RRWB06, were drilled by mud rotary method to supplement the previous test bore drilling form 2007. Drilling utilised existing mineral exploration holes as pilot holes. Due to the drilling method and pre-existing pilot holes, water strike depth and yields were not obtained and bore design was based upon geological logging of the mineral exploration hole.

RRWB05 was drilled by reaming an existing RC mineral exploration hole (RRRC0576). The hole was initially reamed to 6mbgl with a 14" bit and 6m of 320mm (12 3/4") ID steel surface casing was installed and concreted in place. The hole was then reamed from 6 to 138mbgl with a 12 ¼" bit. Geological samples were taken every 2m for logging by the attending hydrogeologist. Detrital alluvial and colluvial sand, silt gravel and clay was encountered to 54mbgl. From 54 to 60mbgl hematite was encountered and goethite from 60 to 72mbgl. From 72 to 92mbgl clay was encountered. Goethite and hematite was encountered from 92 to 132mbgl. This was followed by hematite and clay to 138mbgl (EOH). The bore was completed with blank (206.4mm ID) steel casing from ground level to 83.5mbgl and slotted steel casing (206.4mm ID) from 83.5 to 131mbgl with the bottom of the casing closed and welded into a "spear". The bore was gravel packed to near surface and the annulus between the surface casing and bore casing sealed with a 0.5m cement plug.

The bore was developed by airlifting through the drilling rods, from 96 to 130mbgl, until the water was clear. The final airlift yield during development was 20L/s, measured using a 90˚ V-notch weir.

RRWB06 was drilled by reaming an existing RC mineral exploration hole (RRDD0023) by mud rotary drilling method. The hole was initially reamed to 6mbgl with a 14" bit and 6m of 320mm (12 3/4") ID steel surface casing was installed and concreted in place. The hole was then reamed from 6 to 190mbgl with a 12 ¼" bit. Geological samples were taken every 2m for logging by the attending hydrogeologist. Detrital alluvial and colluvial sand, silt gravel and clay was encountered to 102mbgl. From 102 to 110mbgl shale was encountered and from 110 to 130mbgl shale and goethite was encountered. From 130 to 153mbgl magnetite and shale was encountered and Magnetite and hematite was encountered from 153 to 166mbgl. This was followed by shale and goethite to 190mbgl (EOH). The bore was completed with blank (206.4mm ID) steel casing from ground level to 108mbgl and slotted steel casing (206.4mm ID) from 108 to 180mbgl with the bottom of the casing closed and welded into a “spear”. The bore was gravel packed to near surface and the annulus between the surface casing and bore casing sealed with a 0.5m cement plug. The bore was developed by airlifting through the drilling rods, from 106 to 178mbgl, until the water was clear. The final airlift yield during development was 25L/s, measured using a 90˚ V-notch weir.

Table 2.1: Robertson Range Bore Completion Details

Bore ID	Date Drilled	MGA94, Z51		Ground Level Elevation (marl)	Construction Details					SWL (mbgl) and Date Taken	Airlift Yield L/s
		Easting	Northing		Total Completed Depth (mbgl)	Slotted Interval (mbgl)	Casing ID (mm)	Material	Case Stick-up (m)		
RRRC 345 B	25-29/09/07	261942	7393414	577.5	126	30 – 120	155	steel	0.28	30.71 18/10/07	22
RRRC 347 B2	01-06/10/07	261799	7392810	577	138	30 – 120	155	steel	0.21	33.16 13/10/07	9
RRRC 348 B	06-13/10/07	261926	7393939	581	126	72 – 120	155	steel	0.3	35.03 28/10/07	4
RRRC 349 B	14-18/10/07	261867	7393712	579	126	30 – 120	155	steel	0.2	32.76 23/10/07	17
RRWB05	14-22/05/10	261247	7392450	578.84	132.5	83.5 – 131.5	206.4	steel	0.46	31.61 22/05/10	20
RRWB06	21-30/05/10	261737	7392909	577.29	180	90 - 179	206.4	steel	0.59	30.42 30/05/10	25

[2] Slots filled with silicon from 30 to 72 in RRRC 347B to exclude clay horizons

3. TEST PUMPING

3.1 Test Pumping, 2007

Test pumping of the four production bores RRRC345 B to RRRC 349 B was undertaken by Test Pumping Australia (TPA) who were contracted to FerrAus Limited. The four bores were tested between 13 October and 01 November 2007, after the completion of the drilling programme. Flow rates were monitored with a digital flow meter that yields instantaneous and cumulative flow measurements. The pump intake depth was generally set about 70m below the top of the casing. The turbine pump used for the testing was capable of lifting greater than 25L/s depending on the depth to static

Boreholes RRWB05 and RRWB06 were subjected to both multi rate "step" pumping tests and 48 hour constant rate pumping tests, with recovery monitoring for up to 3 hours or until the water level had recovered 90% of the drawdown experienced in the test. Testing was undertaken by WellDrill between the 20th May and 10th June 2010. In conjunction with the step and constant rate tests existing RC and DD holes in the Robertson Range project area were airlift tested from the 11th to 17th June 2010. The purpose of the assessment was to provide an understanding of the spatial variability of aquifer characteristics within and outside of the ore body aquifer. The data will be used in conjunction with pump testing data during numerical modelling of mine dewatering.

Results for all pump testing are given in the Appendices B to D.

3.1.1 Step Discharge Test

In each case a brief preliminary test was undertaken to assess the appropriate range of pumping rates for the step discharge test. The step discharge tests were subsequently conducted with 4 consecutive steps, each of 100 minutes duration. (At boreholes RRRC 347 B and RRRC 348 B, only 3 step flow rates were undertaken because of the low flow potential of those bores.)

3.1.2 Constant Rate Test And Recovery

Constant rate tests were conducted for 72 hours, followed by a 2 hour recovery period (Table 3.1). Drawdown data from the pumping tests was plotted against log time. These plots were visually interpreted to identify the most appropriate phase of the test on which to undertake an assessment of hydraulic parameters using the Cooper-Jacob Straight Line method. Where possible, observation bores (old mineral exploration bores) were monitored to enable an assessment of storativity. The hydraulic parameters have been calculated using Waterloo Hydrogeologic Aquifer Test Pro software.

For the recovery phase, data was interpreted using the Theis Recovery method where residual drawdown is plotted against t/t' (time since start of test / time since pumping ceased). The hydraulic parameters for Theis Recovery test have again been calculated using Aquifer Test Pro software. Observation bore data is given in Table 3.2 and a summary of the pump test data is given in Table 3.3.

Table 3.1: Constant Rate Test Parameters

Bore ID	CRT pumping rate L/s	Drawdown (after 72 hours)
RRRC 345 B	18	7.13
RRRC 347 B	4	26.87
RRRC 348 B	2.5	22.85
RRRC 349 B	18	5.15

Table 3.2: Observation Bore Data

Bore ID		**RRRC 337M**	**RRRC 258M**	**RRRC 255M**	**RRRC 176M**	**RRRC 269M**	**RRRC 245M**	**RRD 008M**	**RRD 009M**	**RRRC 355M**
Description		Monitoring Bore	Monitoring Bore	Monitoring Bore	Monitoring Bore	Monitoring Bore	Monitoring Bore	Monitoring Bore	Monitoring Bore	Monitoring Bore
GDA94 Zone50	Easting	262105	261890	261941	261641	261640	261536	261790	261830	261689
	Northing	7393399	7393558	7393663	7392661	7392813	7392664	7394158	7393958	7393614
Date Drilled		21 - 21/08/07	01 - 02/07/07	26 - 26/06/07	20 - 20/10/06	13 - 13/07/07	27 - 27/02/07	08 - 08/06/07	03 - 03/09-06	16 - 16/08/07
Elevation (AHD)		577	578	578.5	577.5	577.8	577.8	585	581.5	580
SWL (mbgl)		29.73	31.03	31.49	30.60	30.72	31.16	42.74	34.65	32.77
Casing Stick-up (m)		0.00	0.07	0.10	0.12	0.00	0.11	0.17	0.20	0.09
SWL (mbtoc)		29.73	31.10	31.58	30.72	30.72	31.27	42.90	34.85	32.86
Date of SWL Reading		5/10/2007	5/10/2007	5/10/2007	5/10/2007	5/10/2007	5/10/2007	17/10/2007	16/10/2007	17/10/2007
Drilled Depth (m)		187	144	162.0	90	114	106	84.04	98.7	219
Depth open to (mbgl)		74.88	38.2	47.7	40.32	36.2	39.92	42.9	98.7	>40
Slotted Interval (mbgl)		not cased	not cased	not cased	not cased	not cased	not cased	not cased	not cased	not cased
Comments		Open Hole	Open Hole	Open Hole	Open Hole	Open Hole	Open Hole	Open Hole	Open Hole	Open Hole

Table 3.3: Test Pumping Summary 2007

Bore ID (Pumping Bore in Bold)	**Distance of Observation Bore From Pumping Bore (m)**	**Type of Test**	**Rate(s) (L/s)**	**Analysis**	**Transmissivity m^2/d**	**Hydraulic Conductivity m/d**	**Storativity**
RRRC 345B		Step	10, 15, 20, 24				
		Constant Rate	18	Cooper - Jacob	238	2.64	
		Recovery	-	Theis Recovery	589	6.56	
RRRC 255	249	Constant Rate	18	Cooper - Jacob	519	5.77	.0175
RRRC 258	154	Constant Rate	18	Cooper - Jacob	355	3.94	.0225
RRRC 337	164	Constant Rate	18	Cooper - Jacob	719	7.99	.0658
Geometric Mean					484	5.4	.0355
RRRC 347B		Step	3, 5, 7				
		Constant Rate	4	Cooper - Jacob	7.52	0.313	
		Recovery	-	Theis Recovery	11.66	0.486	
RRRC 176	217	Constant Rate	4	Cooper - Jacob	Insufficient data	Insufficient data	
RRRC 245	301	Constant Rate	4	Cooper - Jacob	Insufficient data	Insufficient data	
RRRC 269	159	Constant Rate	4	Cooper - Jacob	Insufficient data	Insufficient data	
Geometric Mean					9.59	0.40	

Table 3.4: Test Pumping Summary 2007 (Continued)

Bore ID (Pumping Bore in Bold)	Distance of Observation Bore From Pumping Bore (m)	Type of Test	Rate(s) (L/s)	Analysis	Transmissivity m^2/d	Hydraulic Conductivity m/d	Storativity
RRRC 348 B		Step	1, 2, 3				
		Constant Rate	2.5	Cooper - Jacob	33.6	1.12	
		Recovery		Theis Recovery	37.0	1.23	
RRRC 008	258	Constant Rate	2.5	Cooper – Jacob	Insufficient data	Insufficient data	
RRRC 009	98	Constant Rate	2.5	Cooper – Jacob	Insufficient data	Insufficient data	
Geometric Mean					35.3	1.18	
RRRC 349 B		Step	10, 15, 19, 24				
		Constant Rate	18	Cooper - Jacob	208	2.81	
		Recovery		Theis Recovery	350	4.6	
RRRC 355	206	Constant Rate	18	Cooper - Jacob	476	6.26	.019
RRRC 258	157	Constant Rate	18	Cooper - Jacob	630	8.3	.054
RRRC 255	87	Constant Rate	18	Cooper - Jacob	375	4.9	.016
Geometric Mean					408	5.37	.030

3.1.3 Observations from Pumping Tests

This section briefly summarises any observations for the individual bores based on the pump test data in Appendices B through D. Constant rate (CRT), and recovery analysis plots for each production bore are also included. The details are summarised in Tables 3.3 and 3.4. These tables includes the geometric mean of derived aquifer parameters, which provides a useful estimate of transmissivity, hydraulic conductivity and storativity over the area assessed.

RRRC 345 B

- A low permeability boundary was observed at the pumping bore during the 72 hour constant rate test (CRT) after approximately 2 days of pumping. The total drawdown at the end of the 18.0L/s test was 7.21m, with 5.09m of this occurring within the first 2.0 minutes, and 0.24m drawdown over the last 24 hours.
- Drawdowns at the observation wells (RRRC 337 - 164m away, RRRC 258 - 154m away, and RRRC 255 - 249m) were less than 0.2m, 0.3m, and 0.6m respectively over the duration of the CRT.
- Within 2 hours of pump turn-off, at the end of the CRT, water levels in the pumping well had recovered to within 0.61m of the original static water level.
- A clear low permeability boundary was observed in both the pumping bore and all observation bores supporting the concept that higher permeabilities are a function of groundwater flow through fractured ore zones.
- Aquifer parameters were estimated using the portion of the curves that reflected the low permeability boundary as there is at this time no modelling planned.

RRRC 347 B

- It was difficult to maintain a constant flow rate during this test because of the relatively low flow rate at which the test was run.
- A low permeability boundary was observed at the pumping well very early during the 72 hour CRT. The impact of this boundary was observed during the remainder of the test. The total drawdown at the end of the 4.0L/s test was 26.87m, with only 5.5m of this occurring within the first 10 minutes of the test. Sudden drawdown observed after the 2.5 day mark is believed to be a result of pumping rate upward drift and not an additional boundary condition.
- This pumping test is believed to represent the relatively low permeability conditions existing outside of the proposed pit boundary.
- Observed drawdowns at the three observation wells provided insufficiently valid data for analyses due to the low pumping rates at which the test was run.
- Within 2 hours of pump turn-off, at the end of the CRT, water levels in the pumping well had recovered to within 8.00m of the original static water level.

RRRC 348 B

- It was very difficult to maintain a constant flow rate during this test because of the relatively low flow rate at which the test was run. As a result, the drawdown curve proved difficult to analyse.
- It is likely that a low permeability boundary was observed at the pumping well very early during the 72 hour CRT. The drawdown curve appears erratic as repeated attempts were made to control the low flow rate of 2.5L/s. This made analyses difficult, however a fairly stable section of the curve between approximately 900 minutes and 2000 minutes was analysed for aquifer parameters and is believed to be representative of the entire test. It is thought likely that (as in the test at 347 B) the impact of the early observed boundary was maintained during the remainder of the test. The total drawdown at the end of the 2.5L/s test was 23.84m, with only approximately 11m of this occurring within the first 10 minutes of the test. Sudden repeated changes in the drawdown pattern are largely due to adjustments made with the pumping rate.

- This pumping test is believed to represent the relatively low permeability conditions when extensive ore body is not present.
- Observed drawdowns at the three observation wells provided insufficiently valid data for analyses due to the low pumping rates at which the test was run.
- Within 2 hours of the termination of pumping at the end of the CRT, water levels in the pumping well had recovered to within approximately 1m of the original static water level.
- The location of this bore is within the proposed pit boundary. The bore did not intersect extensive ore material and the hydraulic conductivity in the area immediately near the bore has been estimated to be low. This area of lower hydraulic conductivity would however be in close proximity to an area of higher permeability (i.e. fractured ore body) which could therefore account for the good 2-hour recovery observed. This is on contrast to the recovery observed at RRRC 347 B where similar drawdowns were observed during similar constant rate tests however recovery patterns observed were markedly different. Being situated at some distance from the proposed pit boundary, the location of RRRC 347 B would not be in relative close proximity to the relatively permeable ore resulting in poorer water level recovery.

RRRC 349 B

- A low permeability boundary was observed at the pumping bore during the 72 hour constant rate test (CRT) after approximately 2 days of pumping. The total drawdown at the end of the 18.0L/s test was 5.15m, with approximately 3.00m of this occurring within the first 2.0 minutes, and 0.12m drawdown over the last 24 hours.
- Drawdowns at the observation wells (RRRC 355 - 206m away, RRRC 258 - 157m away, and RRRC 255 - 87 m) were approximately 0.2m, 0.4m, and 1.0m respectively over the duration of the CRT.
- Within 2 hours of pump turn-off, at the end of the CRT, water levels in the pumping well had recovered to approximately 0.80m of the original static water level.
- A clear low permeability boundary was observed in both the pumping bore and all observation bores supporting the concept that higher permeabilities are a function of groundwater flow through fractured ore zones.
- Aquifer parameters were estimated using the portion of the curves that reflected the low permeability boundary.

The aquifer tests suggest that the nature of groundwater occurrence does not appear to be uniform across the area and seems to be dependent upon location and geology. Specifically:

- The more highly transmissive water bearing strata seem to occur in the ore body itself and the test analyses suggest a range of hydraulic conductivities in the ore body from 3 – 9m/d.
- In the bores where ore has not been intercepted, analyses have suggested noticeably lower hydraulic conductivities ranging from 0.3 to approximately 1m/s. Outside of the proposed pit boundary the hydraulic conductivities are believed to lie toward the lower end of this range.

3.2 Test Pumping, 2010

3.2.1 Step Discharge Test

The multi-rate testing data was analysed using Rorabaugh's equation to determine the coefficients of aquifer loss (B), well loss (C) and to determine the proportion of drawdown due to laminar flow in the bore (apparent efficiency) at each pumping rate. The step tests data was also used to determine the pumping rate to be used in the constant rate test. Details of the step test analysis are included in Appendix B and are summarised below in Table 3.5 below.

Table 3.5: Summary of Step Test Analysis

Bore	Step Number	Discharge Rate (L/s)	Corrected Drawdown (m)	Apparent Well Efficiency (%).
RRWB05	1	7	5.48	99.7
	2	14	11.22	99.5
	3	20	15.87	99.2
	4	25	19.76	99.1
RRWB06	1	7	8.85	116
	2	14	16.89	139
	3	20	15.87	168
	4	24	19.76	194

3.2.2 Constant Rate Test

Drawdown and recovery data from the constant rate pumping tests was analysed to estimate hydraulic characteristics (transmissivity and storativity) of the aquifer using Cooper-Jacob and Theis methods and is presented in Appendix C.

Results from test pumping at Robertson Range are presented in Table 3.6 and 3.7, with detailed analysis in Appendix C.

The pump test data for both RRWB05 and RRWB06 show a decrease in the rate of drawdown after approximately 100 minutes of pumping. The reasons for this decrease is unclear, however are likely to be due to either by vertical leakage from the less permeable overlying Wittenoom formation, or recharge from fractures with increased storage. Where such a response was observed, early data was used to give an estimate of aquifer parameters.

Table 3.6: Test Pumping Results RRWB05

Pumped Bore	Data Observed at Bore	T (m2/d)	K (m/d)	S	Method of Analysis
RRWB05	Pumping				
	RRWB05_Obs_1	159	33	1.29E-3	Cooper Jacob
	RRWB05_Obs_3	310	7	-	Cooper Jacob
	RRWB05	121	3	-	Cooper Jacob
	RRWB05	152	3	7.01E-7	Theis
	Recovery				
	RRWB05	127	3	-	Theis Recovery
	RRWB05_Obs_1	2540	53	-	Theis Recovery
	RRWB05_Obs_3	388	8	-	Theis Recovery
RRWB05 Recommended Value		133		1.29E-3	T: Average between Cooper Jacob, Theis and Theis Recovery interpolations for RRWB05. S: Taken as Observation 1.

Table 3.7 Test Pumping Results RRWB06

Pumped Bore	Data Observed at Bore	T (m2/d)	K (m/d)	S	Method of Analysis
RRWB06	Pumping				
	RRWB06	42.4	0.5	-	Cooper Jacob
	RRWB06_Obs_1	537	8	7.83E-4	Cooper Jacob
	RRWB06_Obs_3	902	13	6.16E-2	Cooper Jacob
	RRWB06	40.2	0.5	2.17E-3	Theis
	RRWB06_Obs_1	538	8	1.02E-3	Theis
	RRWB06_Obs_3	530	7.	7.37E-2	Theis
	Recovery				
	RRWB06	44.3	0.5	-	Theis Recovery
	RRWB06_Obs_1	387	5	-	Theis Recovery
RRWB06 Recommended Value		42.3		3.12E-2	T: Average between Cooper Jacob, Theis and Theis Recovery interpolations for RRWB06. S: Average between Cooper Jacob interpolations for Observations 1 and 3.

3.3 Airlift Testing

Kalgoorlie based drilling contractors Top Drill were engaged to carry out airlift testing under supervision by Aquaterra, during 2010. The airlift programme utilised existing mineral exploration bores that were cleared of blockages using an RC drilling rig, prior to lowering airlifting apparatus down the hole. The apparatus consisted of 6.6m lengths of 50mm steel pipe with camlock joints. The basal pipe housed a pressure transducer for measuring water levels during drawdown and recovery. The pressure transducer was set to take readings every 30 seconds. Compressed air pumped into the pipe escaped through holes drilled several metres above the pressure transducer, to lift water from the drill hole, without turbulence around the pressure transducer. Bores were airlifted for approximately 1 hour, with groundwater flows from the hole measured by v-notch weir. Water levels were also monitored in nearby drill holes during airlifting and for 1 hour after completion of airlifting.

Thirteen locations were selected for testing, targeting varying lithologies in and around the proposed mine pit. Many of these holes had previously been rehabilitated, including cutting-off of the collar pipe below ground level, capping and covering with soil. These sites were located and uncovered by FerrAus staff prior to airlifting.

Four of the thirteen airlift tests did not produce sufficient data for analysis, due to blockages, collapse at shallow depths within the over lying transported material and very low to no flow. In general, the airlift tests were carried out at low airlift yields (< 1L/s) and produced drawdown data that was not suitable for analysis. However, the data gained during the recovery period was suitable for analysis. Submergence of the airlift apparatus was generally less than optimum due to:

- The depth to water .
- The maximum depth limitations of the equipment.
- Hole blockages.
- Maximum hole depth.
- Rapid drawdown to the airlift level.

Details of the observation and airlift bores are presented in Tables 3.8 and 3.9, including the airlift yields obtained. The data was analysed to obtain estimates of aquifer parameters for use in the numerical modelling process. Table 3.10 presents a summary of the derived aquifer parameters and the analyses are in Appendix D. Aquifer thickness (h) was estimated from the geological logs of the exploration holes and used to estimate the hydraulic conductivity (k) of the aquifer. As the holes were logged for mineral exploration purposes, information relating to groundwater occurrence is scant and the aquifer thickness was not always clear. In most cases, within the Marra Mamba Iron Formation, the ore body thickness was assumed to be the aquifer thickness.

Table 3.8: Details of Observation Bores during Airlift Testing

Airlift Test #	FerrAus Drill Hole #	Easting	Northing	Elevation (mahd)	Radial Distance Pump Hole (m)	SWL (mbgl)
		MGA94, Z51				
2	RRRC0720	262088	7394159	582	50	35.06
3	RRRC0728	261866	7393712	578	100	30.44
6	RRRC0700	260849	7392352	581	75	33.62

Table 3.9: Details of Airlifted Holes

Airlift Test #	Hole ID	Bore Depth (mbgl)	Easting	Northing	SWL (mbgl)	Elevation (mahd)	SWL (mahd)	Airlift Yield (L/s)	Target Formation	Saturated Thickness (m)
			MGA94, Z51							
1	RRRC0503	70	261991	7394400	37.99	585.07	547.08	0.13	Wittenoom – West Angela Member	32.01
2	RRRC0613	198	262080	7394106	35.00	581.895	546.895	3.39	Wittenoom – West Angela	46
3	RRRC0723	288	262188	7393606	29.88	577.492	547.612	3.89	Transported	38.47
4	RRRC0718	56	261991	7393155	28.75	576.581	547.831	1.0	Transported	27.25
5	RRRC0308	90	261300	7393400	34.06	581.83	547.77	0.18	Jerrinah	55.94
6	RRRC0545	80	260800	7392300	34.09	581.42	547.33	0.95	Marra Mamba - Macleod	45.91
7	RRRC0525	82	261240	7392142	29.30	577.55	548.25	No Flow	Wittenoom – West Angela	52.7
8	RRRC0669	36	261800	7392193	29.04	576.418	547.378	0.45	Marra Mamba – Mount Newman	6.96
9	RRRC0292	72	261293	7392950	37.92	579.55	541.63	0.05	Nammuldi or Jerrinah	34.08
10	RRRC0199	54	261687	7394361	47.40	594.39	546.99	0.4	Marra Mamba – Mt Newman	6.6
11	RRRC0213	48	261641	7394108	41.40	588.83	547.43	0.07	Marra Mamba – Mt Newman	6.6
No Test*	RRRC0708	36	261740	7392668	29.97	577.305	547.635	n/a	n/a	n/a
No Test*	RRRC0315	36	261465	7393799	39.27	585.35	546.08	n/a	n/a	n/a

Table.3.10: Summary of Aquifer Parameters

Airlift Test #	Hole ID	Target Formation	Analysis Method	Transmissivity (T in m2 /day)	Storativity (S)	Saturated Aquifer Thickness (m)	Hydraulic Conductivity (K in m/d)
1	RRRC0503	West Angela	Theis Recovery	0.147	-	32.01	4.61 E-3
2	RRRC0613	West Angela	Theis Recovery	37.6	-	46	0.82
2	RRRC0613	Mount Newman	Cooper and Jacob (1946)	114	1.28 E-4	46	2.47
3	RRRC0723	Transported	Theis (1935)	9.39	1.88 E-4	38.47	2.44 E-1
3	RRRC0723	Transported	Theis Recovery	7.38	-	38.47	1.92 E-1
4	RRRC0718	Transported	Theis Recovery	1.30	-	27.25	4.76 E-2
5	RRRC0308	Jerrinah	Theis Recovery	0.057	-	55.94	1.02 E-3
6	RRRC0545	Macleod	Theis Recovery	0.229	-	33.62	6.81 E-3
6	RRRC0545	Macleod	Cooper and Jacob (1946)	92.2	9.2 E-4	33.62	2.74
9	RRRC0292	Jerrinah	Theis Recovery	3.14 E-1	-	34.08	9.2 E-3
11	RRRC0213	Mount Newman	Theis Recovery	0.493	-	6.6	7.47 E-2
11	RRRC0213	Mount Newman	Theis (1935)	0.579	-	6.6	8.77E-2

4. GROUNDWATER CHEMISTRY

Water quality (electrical conductivity [EC] and pH) was monitored in the field during the airlift development for each bore RRRC 345 B to RRRC 349 B. The airlift was continued until the field parameters stabilised and the visual appearance of the discharge water was clear. This ensured that all finer grained material had been removed from the formation in the vicinity of the bore (and in the case of RRRC 348 B all drilling fluid used during drilling was removed). Measurements of EC and PH for bores RRWB05 and RRWB06 were taken from water samples at the near end of each constant rate test where chemical analysis at all sites was carried out. Table 4.1 is a summary of laboratory water quality analysis. Appendix E contains the laboratory results.

Analyses show that groundwater sourced at the Robertson Range site from the Marra Mamba Formation (or equivalent) appears to be relatively good quality with total dissolved solids (TDS) values ranging from 690mg/L to 1300mg/L (laboratory analyses) with a neutral pH ranging from 6.9 to 7.7 (field determinations). Further characterization of the groundwater also shows some variation in terms of chemical signature on the basis of the cation / anion content. Piper diagram analysis shows the water to have a sodium / chloride dominant signature, normally an indicator of “old” groundwater. However bicarbonate concentrations which are similar to chloride concentrations, do suggest some “recent” water in the aquifer system. This is especially the case in shallower bores (upper alluvium and shallow Marra Mamba), where TDS concentrations are generally below 500mg/L.

Table 4.1: Water Quality Analysis Results for Pumping Test Bores 2007 and 2010

Analyte Description	Units	RRRC 345 B	RRRC 347 B	RRRC 348 B	RRRC 349 B	RRWB05	RRWB06
pH	pH Units	7.6	7.6	7.7	7.6	7.1	6.9
Conductivity @25^{o}C	µS/cm	1300	800	1800	1500	2200	1500
Total Dissolved Solids @ 180^{o}C	mg/L	690	420	900	770	1300	910
Soluble Iron, Fe	mg/L	0.04	0.13	0.1	0.02	0.03	0.04
Sodium, Na	mg/L	130	80	180	170	220	160
Potassium, K	mg/L	26	26	48	33	29	26
Calcium, Ca	mg/L	44	37	73	54	92	61
Magnesium, Mg	mg/L	65	29	72	67	88	53
Chloride, Cl	mg/L	200	88	310	240	410	270
Carbonate, CO_3	mg/L	<1	<1	<1	<1	9	4
Bicarbonate, HCO_3	mg/L	230	230	270	260	300	240
Sulphate, SO_4	mg/L	160	49	180	180	250	160
Nitrate, NO_3	mg/L	3.4	42	20	6.2	3.4	22
Fluoride, F	mg/L	0.7	0.8	0.8	0.8	0.4	0.7
Soluble Manganese, Mn	mg/L	0.006	0.007	0.082	<0.005	<0.005	0.006
Soluble Silica, SiO2	mg/L	24	24	50	46	32	47
Cation/Anion balance	%	3.8	2.3	3.9	3.9	1	-1
Sum of Ions (calc.)	mg/L	860	582	1153	1010	1340	953

5. SUMMARY

Drilling at Robertson Range has suggested that:

- The geology is variable over relatively short distances which affects the hydrogeology.
- The groundwater potentiometric surface is approximately 30 – 35m below ground surface over much of the area.
- The ore body, when intersected tends to have a comparatively high hydraulic conductivity and strong groundwater interceptions.
- Sections without significant ore body tend to have a hydraulic conductivity approximately an order of magnitude lower than that in the ore body.
- Changes in hydraulic conductivity can change significantly over relatively short distances.
- The groundwater is likely to be semi-confined.
- Groundwater is generally of good quality.

Four of the bores constructed, intersected thick sections of ore body which acts as an aquifer with a relatively high hydraulic conductivity. These 155mm ID bores were capable of yielding up to 25L/s in the short term. Transmissivity would appear to be governed by fractures in the ore body itself. In boreholes where little or no ore body was intersected hydraulic conductivity (and resultant yields) was much lower. The potentiometric head of water lies above the top of the ore body in those holes drilled. From the data gathered, it would appear that hydraulic conductivities are likely to be comparatively high in the proposed pit area, but are likely to be surrounded by an area of much lower hydraulic conductivity – sands and silts that are have a variable clay content.

6. REFERENCES

Aquaterra. 2008. Robertson Range Dewatering Study, Document 791/C3/032b, 1 September 2008, Perth, WA.

Aquaterra. 2010. Davidson Creek Preliminary Mine Dewatering Analysis, Document 791E\E5\072a, 9 September 2010, Perth, WA.

FIGURES

APPENDIX A:
DRILL LOGS
(INCLUDING GAMMA LOGS WHERE APPROPRIATE)

APPENDIX B:
STEP TESTS

APPENDIX C:
CONSTANT RATE TESTS

APPENDIX D:
AIRLIFTING TESTS

APPENDIX E:
WATER CHEMISTRY

APPENDIX B: ROBERTSON RANGE GROUNDWATER MODEL SETUP AND CALIBRATION

RPS Aquaterra

ROBERTSON RANGE GROUNDWATER MODEL SETUP AND CALIBRATION

Prepared for	FerrAus
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ROBERTSON RANGE GROUNDWATER MODEL SETUP AND CALIBRATION

	Date	Revision Description
Revision A	09/12/2010	Draft

	Name	Position	Signature	Date
Originator	Gary Bownds	Project Hydrogeologist		09/12/2010
Reviewer	Kathryn Rozlapa	Principal Groundwater Modeller		09/12/2010

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1.1 MODELLING OBJECTIVES

The aim of the groundwater flow modelling was to assess dewatering requirements and associated groundwater drawdown of the proposed Robertson Range Iron Ore project. The model is based on current conceptual hydrogeological understanding. The key features of the groundwater model are discussed in detail in the following sections, but can be summarised as follows:

- Multiple unconfined and semi-confined aquifer and aquitard units simulated by five model layers.
- Groundwater recharge from incident rainfall.
- Groundwater outflow to downstream catchments.
- Groundwater pumping from proposed dewatering bores to be located outside of the final pit perimeters.

1.2 GROUNDWATER FLOW MODEL SETUP

1.2.1 GROUNDWATER MODEL CODE AND INTERFACE

The numerical modelling package Modflow 1996 (Harbaugh & McDonald, 1996), was used to develop the groundwater model operating under the Groundwater Vistas graphical user interface (Version 5, Rumbaugh and Rumbaugh, 1996 to 2009).

1.2.2 GRID AND EXTENT

The model extent was defined by the hydrologic catchment in which the Robertson Range Project Area is located. The southern boundary is set approximately 5km downstream of the project area. The locations of the model boundaries are shown in Figure 1.1 and are described further in Section 1.3.1. All model data has been plotted using the GDA94 Zone 51 co-ordinate system. The corner coordinates of the model are listed in Table 1.1.

Table 1.1: Model Extents

Corner	Easting*(m)	Northing*(m)
North West	255740	7397560
North East	270460	7397560
South West	255740	7386240
South East	270460	7386240

*MGA94 zone 51

Model cell size ranges from 20 metres east-west and north-south in the mine area, to a maximum of 200 metres at model boundaries away from the mine area. A reduced grid size was adopted in the mine area to provide better resolution of the Robertson Range orebody aquifers. The model consists of 5 layers, 180 rows and 143 columns resulting in 103,715 active model cells.

1.2.3 MODEL GEOMETRY

The Robertson range ore body aquifer and surrounding areas are represented by 5 layers of varying thickness to represent the hydrogeology of the mine area. Model layer details are summarised in Table 1.2

Table 1.2: Model Layer Details

Layer	Description	Layer Geometry
Layer 1 (L1)	Alluvium Marra Mamba Marra Mamba Ore Wittenoom Formation Jeerinah Formation Bangemall Group Granite Greenstone	Top of layer set at 560 mAHD Base of Layer ranges from 511 to 540 mAHD largely to simulate the base of the Alluvium and part of the Marra Mamba Ore
Layer 2 (L2)	Alluvium Marra Mamba Marra Mamba Ore Wittenoom Formation Jeerinah Formation Bangemall Group Granite Greenstone	Base of Layer ranges from 475 to 525 mAHD to simulate Marra Mamba Ore
Layer 3 – Layer 5 (L3-L5)	Marra Mamba Marra Mamba Ore Wittenoom Formation Jeerinah Formation Bangemall Group Granite Greenstone	Base of layer 3 ranges from 441 to 506 mAHD Base of layer 4 ranges from 413 to 477 mAHD Base of Layer 5 set at 330 mAHD

The hydrogeological units represented in each layer are illustrated in Figures 1.2 to 1.6. A representative cross section view of the hydrogeological units is shown in Figure 1.7.

1.3 GROUNDWATER THROUGHFLOW

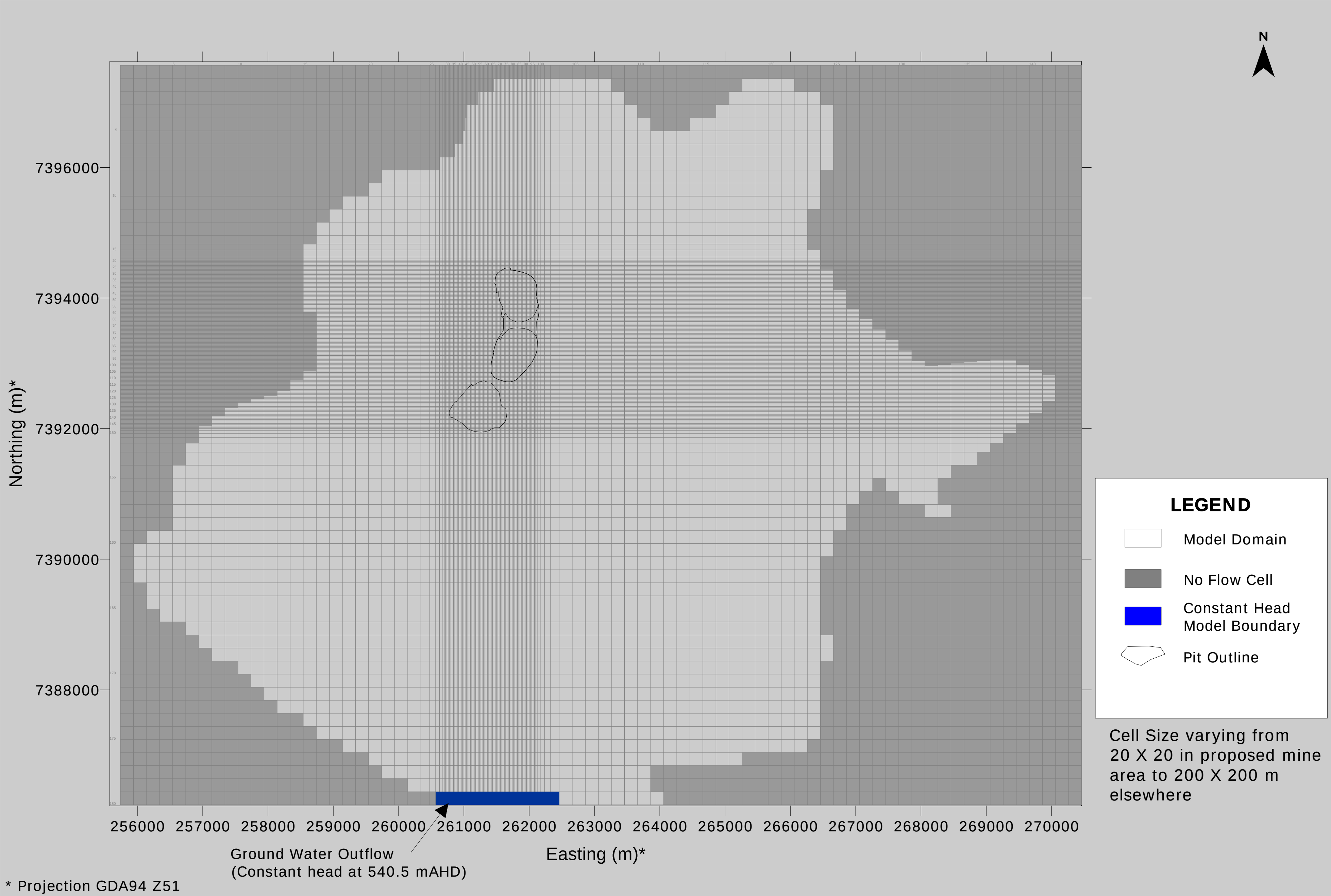
1.3.1 GROUNDWATER THROUGHFLOW

The Robertson Range Iron Ore Project is located close to upstream boundary of the catchment. Groundwater gradients are relatively flat with the direction of groundwater flow inferred to be consistent with topography toward the catchment boundary to the south. This is simulated in the model with a no flow boundary to the east, west and north and a constant head outflow boundary to the south. The fixed head outflow boundary is set at an elevation of 540.5mAHD. This elevation of this boundary was adjusted during model calibration but is assigned consistent with regional groundwater trends. The location of model boundaries is shown in Figure 1.1

1.3.2 RAINFALL RECHARGE

Inflow to the groundwater system is provided via rainfall recharge. The average annual rainfall recorded for the region is around 300 mm per year. Rainfall recharge is applied in the model as a percentage of measured annual average rainfall and was adjusted within realistic limits for similar catchments during model calibration. The recharge rates adopted for model calibration are as follows:

- Alluvium, at 0.3% of average annual rainfall or 2.5e-06m/d.
- Other hydrogeological units (Bangemall, Marra Mamba, Wittenoom, Fortescue, Granite and Greenstone) at 0.18% of average annual rainfall or 1.5e-06m/d.
- The rainfall recharge distribution is shown schematically in Figure 1.8.



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MODEL DOMAIN AND BOUNDARY CONDITIONS FIGURE 1.1

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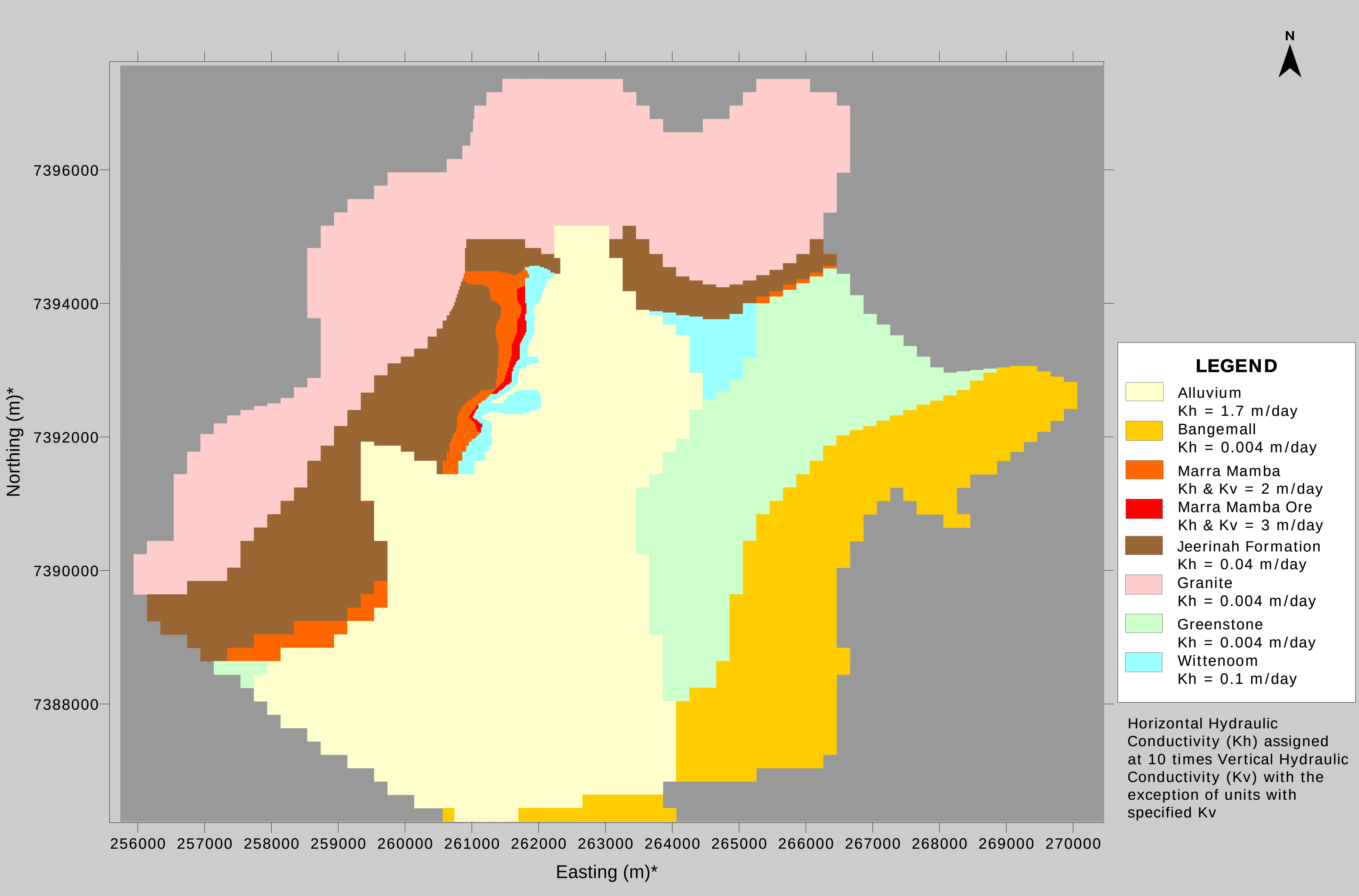

* Projection GDA94 Z51

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MODELLED HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 1 FIGURE 1.2

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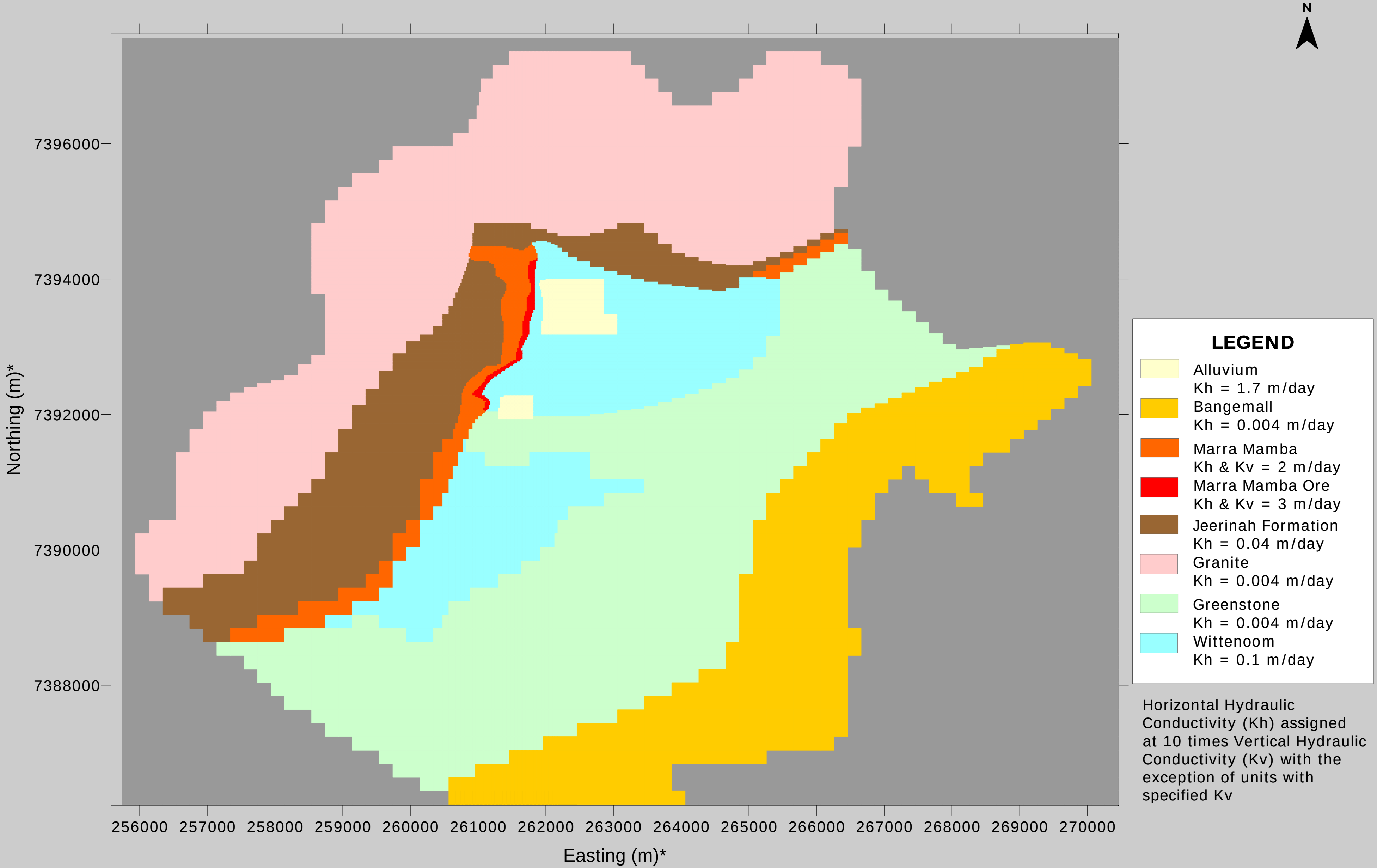

Horizontal Hydraulic Conductivity (Kh) assigned at 10 times Vertical Hydraulic Conductivity (Kv) with the exception of units with specified Kv

* Projection GDA94 Z51

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MODELLED HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 2 FIGURE 1.3

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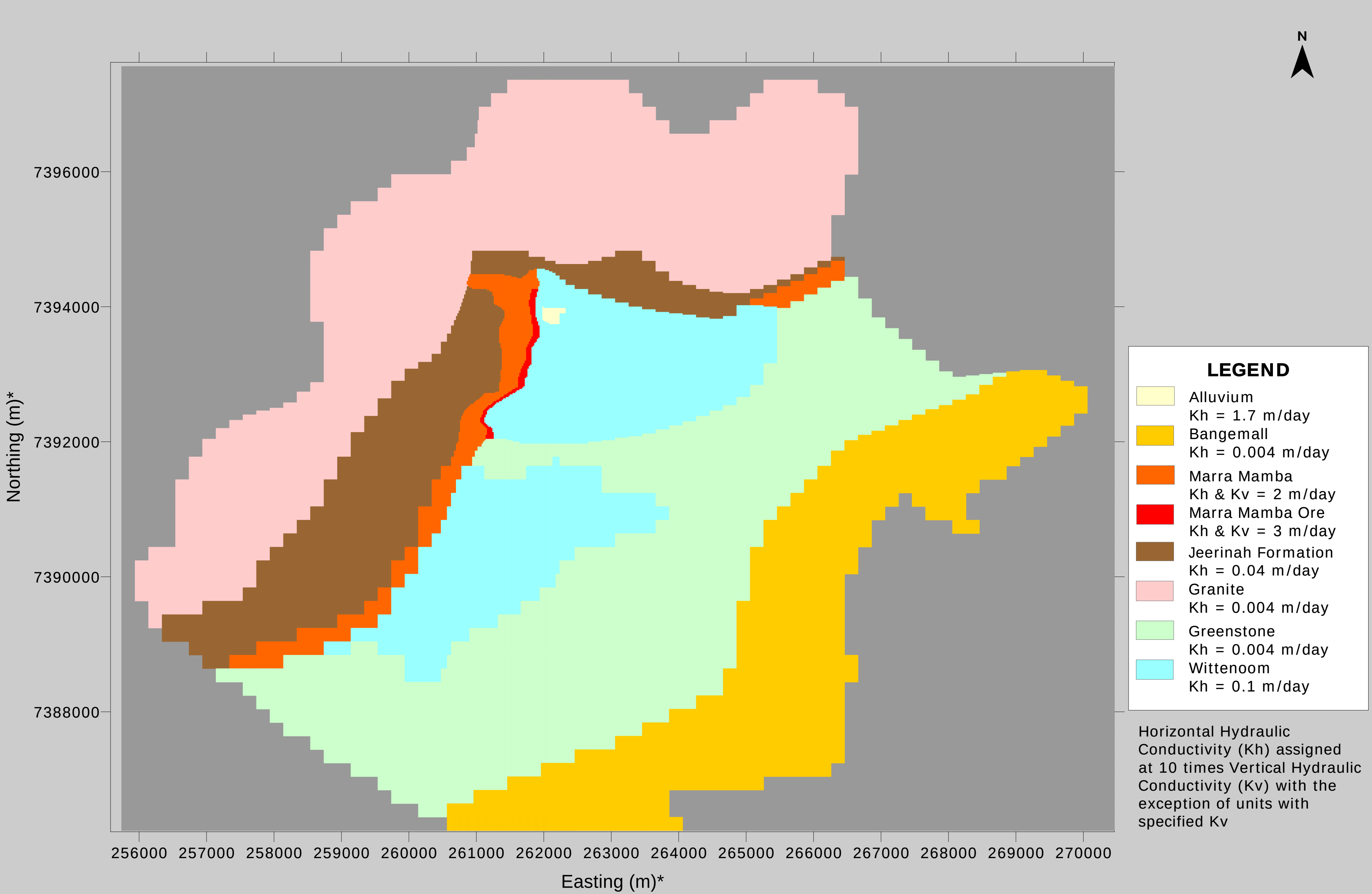

* Projection GDA94 Z51

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MODELLED HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 3 FIGURE 1.4

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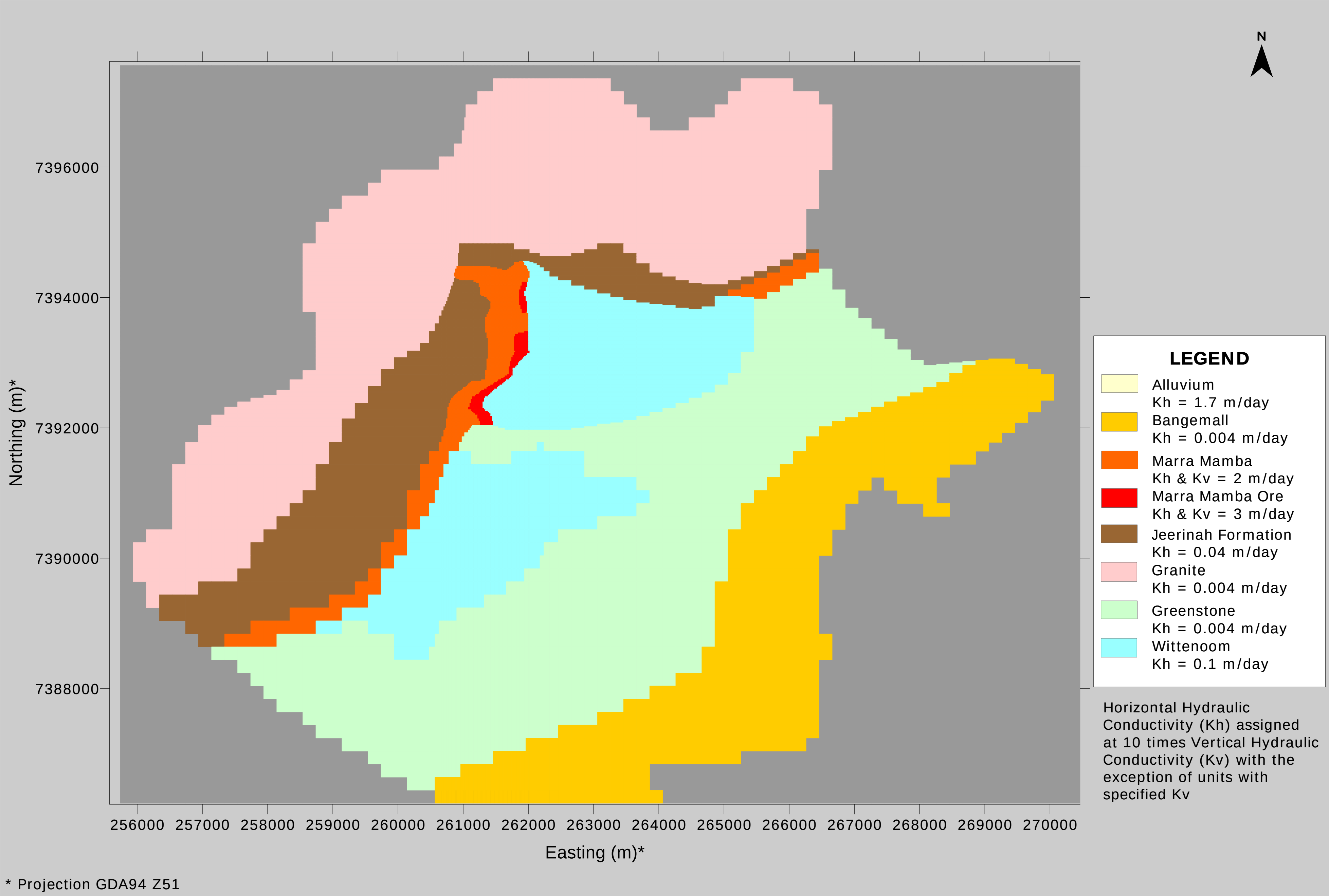

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MODELLED HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 4 FIGURE 1.5

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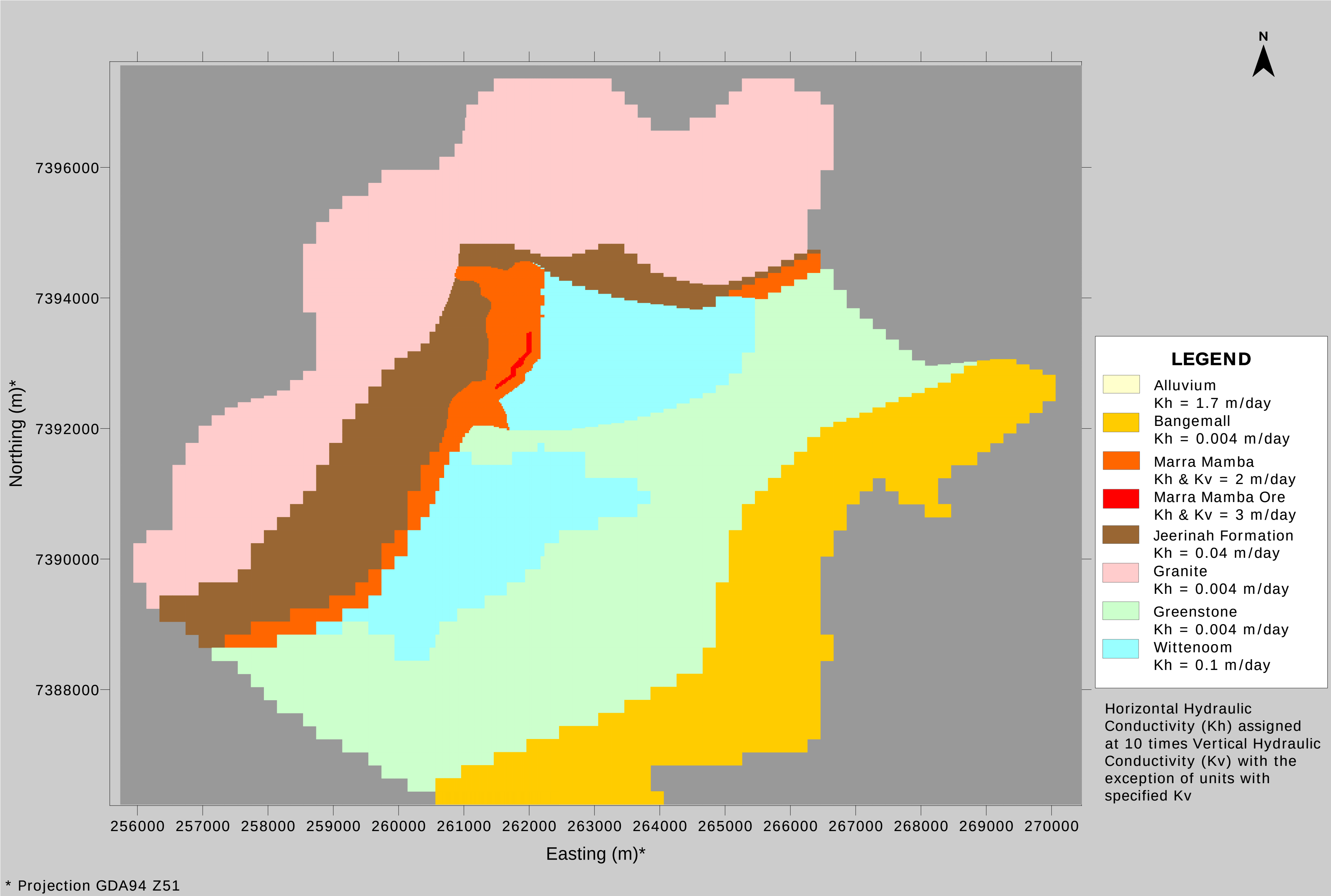

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MODELLED HYDRAULIC CONDUCTIVITY DISTRIBUTION LAYER 5 FIGURE 1.6

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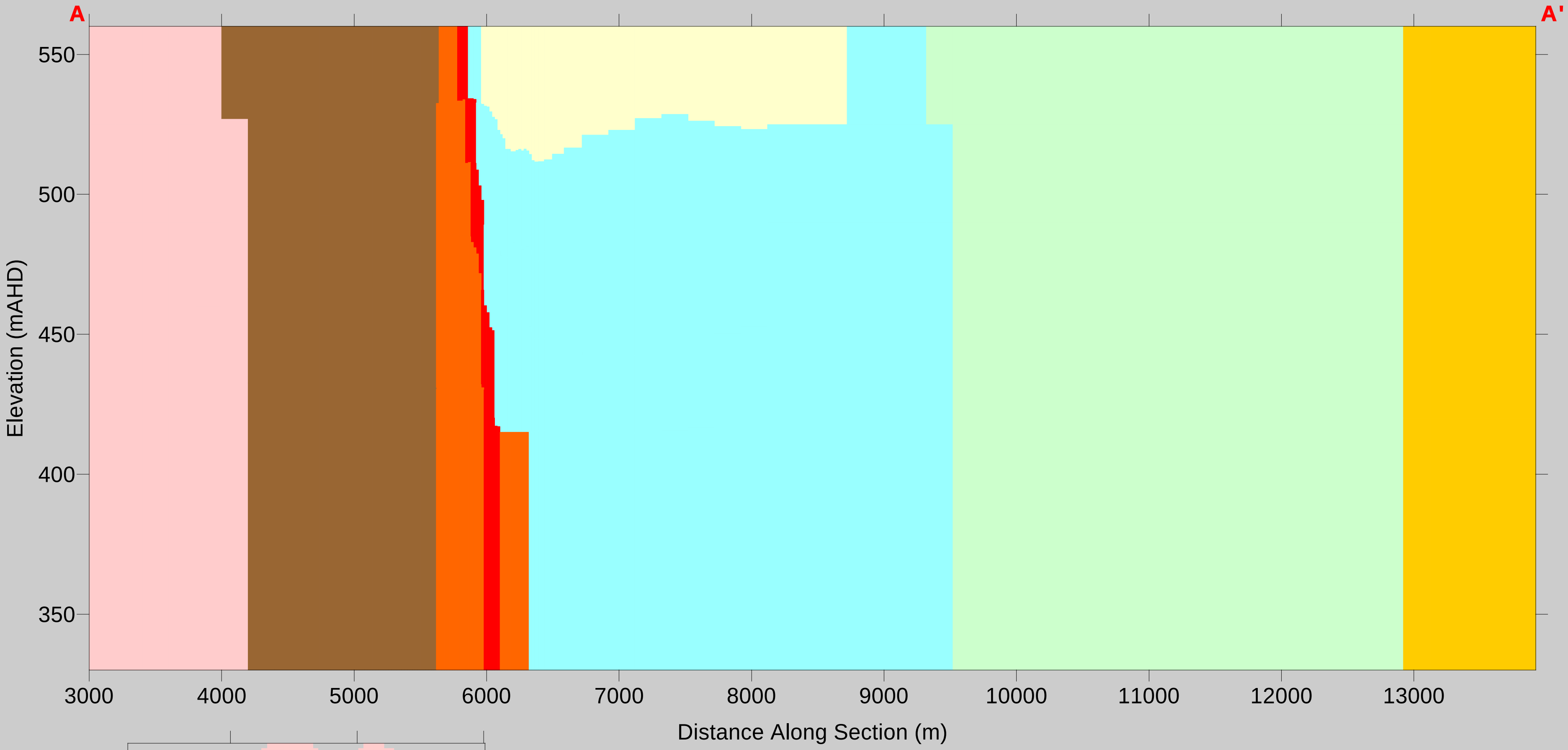

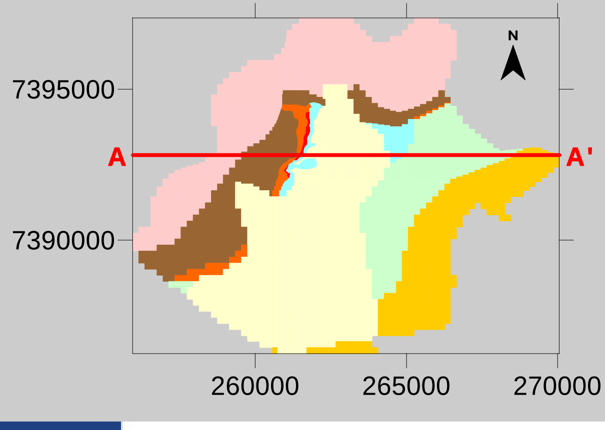

LEGEND

- Alluvium
- Bangemall
- Marra Mamba
- Marra Mamba Ore
- Jeerinah Formation
- Granite
- Greenstone
- Wittenoom

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SCHEMATIC CROSS-SECTION FIGURE 1.7

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1.4 MODEL CALIBRATION

Model calibration is a process of demonstrating that a groundwater model can replicate observed data. During model calibration, aquifer parameters, the proportion of rainfall assigned as recharge and the values assigned to fixed head boundaries were adjusted, within realistic limits, until a reasonable match between measured, expected and predicted groundwater levels was produced. The model is only calibrated to steady state or long term average water levels, as no historical monitoring data was available to allow a time varying or transient model calibration.

1.4.1 STEADY STATE CALIBRATION

The steady state or long term average calibration provides:

- A distribution of water levels that reflects the groundwater system prior to any development.
- Initial conditions for the model predictions.
- Quantification of the groundwater flow through the model domain, under average recharge conditions prior to any development.

Measured water levels are restricted to the immediate mine area and show significant variability and little discernable pattern. Water levels recorded during mineral exploration drilling have not been adequately recorded and are not considered in calibration of the model. Water levels obtained during water bore construction and testing have been used along with water levels recorded during airlift testing of open RC exploration drill holes conducted in 2010. Of the 6 constructed bores, 4 were constructed and tested in 2007 and 2 in 2010 with water levels recorded at the time of testing.

Due to the restricted spatial distribution of water level measurements, topography, drainage, geology and geophysics were used to guide interpretation of the available water level data to provide groundwater flow levels across the entire model area. This pattern along with the measured water levels was used to assess the model calibration performance.

Observed water levels, interpreted water level contours and modelled water level contours for the steady state calibration are shown in Figure 1.9. Modelled water level contours are consistent with those interpreted from available data and catchment characteristics.

Measured and predicted water levels are plotted in Figure 1.10 along with a red line representing a perfect correlation. The Scaled Root Mean Squared Error (SRMS) as a percentage of the measured water levels is greater than 20%. Whilst this value is too high to represent a satisfactory calibration, examination of the data reveals that the four locations where there is the greatest mismatch between measured and modelled groundwater levels are over predicted by up to 6 metres/ Of these measurements, one is from an airlift test in which a very low airlift yield was experienced suggesting a low hydraulic conductivity testing interval. It may be likely that water level had not fully recovered from preparing the hole for air lift testing at the time of measurement resulting in lower than expected water level. The remaining three measurements are from 2007 and maybe subject to seasonal variations in water levels in the area that have not as yet been measured or quantified. .

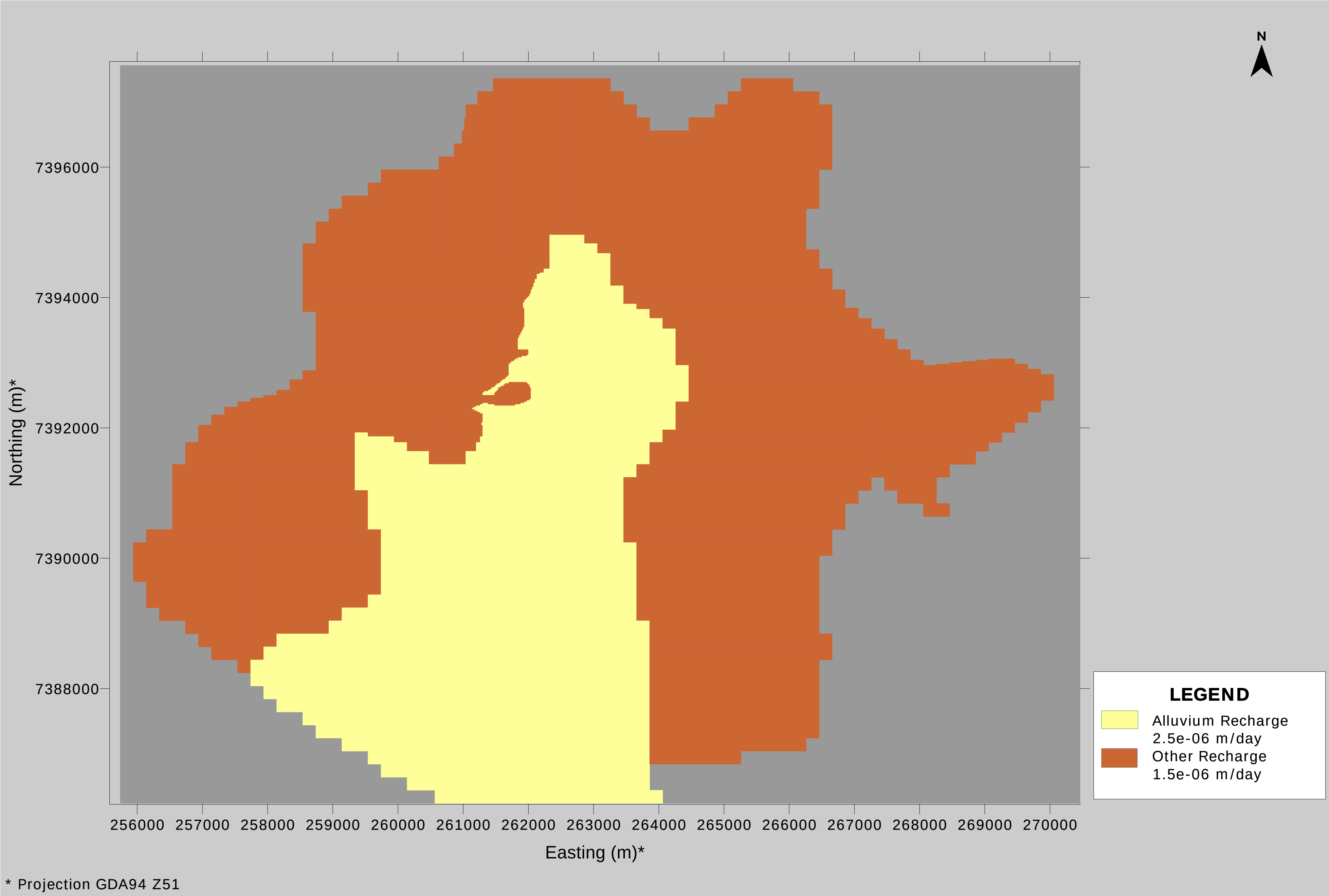
When these four measurements are removed from the calibration data set, resulting in a SRMS value of 8.39%which is a measure of acceptable calibration performance for an undeveloped site where long term data is not available (MDBC, 2001).

The predicted water balance for the steady state calibration is shown in Table 1.3.

Table 1.3: Steady State Calibration Water Balance

Flow Component	Inflow (KL/day)	Outflow (KL/day)
Recharge	170	
Groundwater Outflow		170
TOTAL	170	170

The aquifer parameters adopted for the steady state model calibration are presented in Table 1.4 with aquifer extents shown in Figures 1.2 to 1.6. Assigned aquifer parameters are consistent with available hydraulic testing data and similar hydrogeological environments. As outlined above the model is calibrated to steady state conditions only.



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MODELLED RECHARGE DISTRIBUTION FIGURE 1.8

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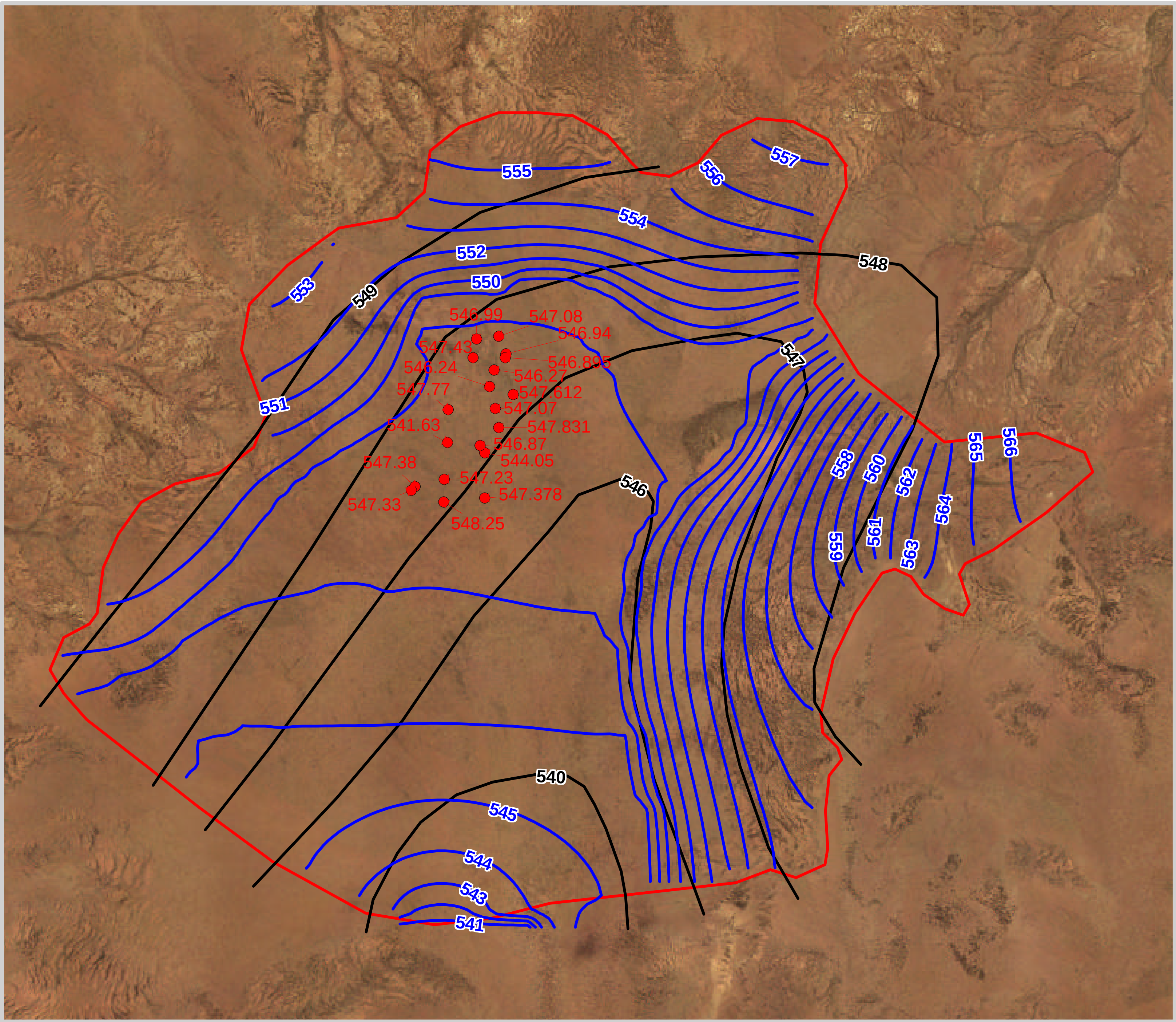

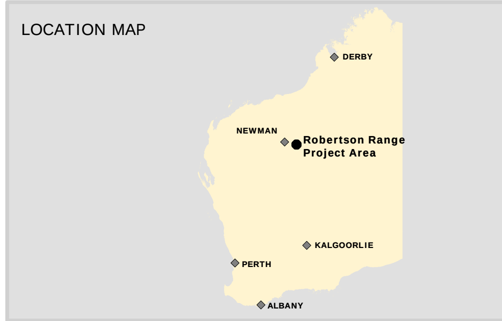

LEGEND

547	Observed Water Levels
547	Interpreted Water Levels
552	Modelled Water Levels

N

1 0 1 2

Kilometers

Scale: 1:75000 @A4

MGA 1994 Zone 51

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FIGURE 1.9

OBSERVED, INTERPRETED & PREDICTED STEADY STATE WATER LEVELS

AUTHOR:	G Bownds	REPORT NO:	076
DRAWN:	G Bownds	REVISION:	a
DATE:	25/11/2010	JOB NO:	791E / E6

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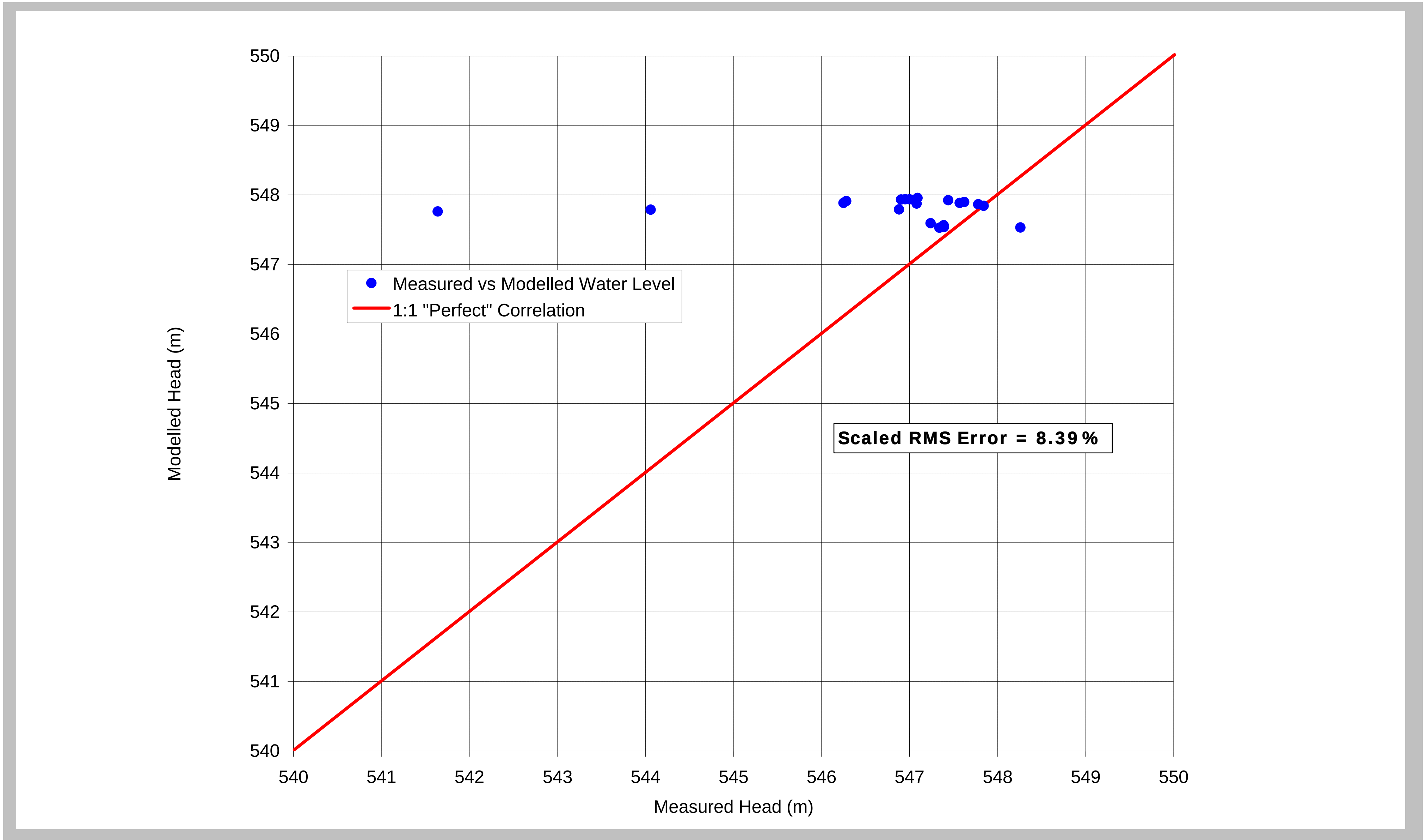

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MEASURED VERSUS MODELLED WATER LEVEL FIGURE 1.10

F:\Jobs\791\E\E6\Model\Model Archive\791E_Model_036\[RMS.xls]Figure 1.10

Table 1.4: Calibrated Model Aquifer Parameters

Formation	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Specific Yield*	Confined Storage*
Alluvium	1.7	0.17	0.05	0.0001
Bangemall Group	0.004	0.0004	0.001	0.0001
Marra Mamba Banded Iron Formation	2.0	2.0	0.08	0.0001
Marra Mamba Ore	3.0	3.0	0.08	0.0001
Jeerinah Formation	0.04	0.004	0.005	0.0001
Granite	0.004	0.0004	0.001	0.0001
Greenstone	0.004	0.0004	0.001	0.0001
Wittenoom	0.1	0.01	0.005	0.0001

* Model not calibrated to these values. Values assigned consistent with similar hydrogeological environments and testing data available for the Robertson Range area.

1.4.2 SUMMARY OF CALIBRATED MODEL

Key features of the calibrated model and the distribution of aquifer/model parameters include:

- The model is satisfactorily calibrated to the available steady state data. The calibration is sensitive to a number of parameters; however the model parameters adopted are consistent with those derived in historical investigations elsewhere in the Pilbara and with values derived during project specific investigations.
- The set of calibrated model parameters is not unique and there remains the possibility that actual aquifer conditions could be, in places, different to that simulated. As such there remains some uncertainty in model predictions.

The groundwater model was calibrated to steady state condition i.e., long term average conditions only. No calibration to transient or time varying conditions was completed as no data are available to complete the calibration. As a result the groundwater model is not calibrated to unconfined or confined aquifer storage values.

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