Appendix C

Groundwater Assessment

REPORT

MRM Expansion EIS - Groundwater Investigations to Determine the Potential Impacts of Dewatering

Prepared for

Xstrata Plc

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Executive Summary

Xstrata Plc (Xstrata) owns and operates the McArthur River Mine (MRM) near Borroloola, Northern Territory, which uses underground mining methods to extract lead-zinc ore. Xstrata is currently studying the feasibility of changing the existing underground mining operation to an open cut. The proposed open cut will be 215 m deep, cover an area of 1 km^2 and have a mining life of up to 25 years. The McArthur River currently flows through the area of the proposed open cut and will require diversion while open cut mining is occurring, to prevent flooding of the mine.

Based on historical groundwater data in the mining area and groundwater studies (completed as part of the feasibility study), dewatering of the open cut will be required to lower the groundwater levels to achieve relatively dry and efficient mining conditions. The required groundwater pumping quantities to achieve dewatering have not yet been accurately determined, but <u>estimated</u> quantities are included in this report and previous work.

There are **<u>two main aquifer types</u>** at MRM:

- **Bedrock** -secondary structures in the fresh bedrock (such as faults, shears and joints) and in the upper oxidised portion of the bedrock, where permeability has been enhanced by rock weathering and dissolution to form karst and other local aquifer zones.
- **Alluvial** – sand and sand and gravel deposits in the major river channels and associated palaeochannels. These aquifers are in hydraulic connection with surface water in these areas.

These two aquifer types are in hydraulic connection where large-scale permeable structures in the bedrock, such as faults, underlie major river channels.

During mining, dewatering will lower groundwater levels significantly in faults in the fresh bedrock, causing large drawdown in close proximity to the open-pit. Conceptually, the lateral and vertical extent of this drawdown should be limited by downward groundwater leakage and recharge in areas where these faults intersect and underlie major alluvium-filled river valleys.

A groundwater flow model has been constructed and used to estimate pit dewatering requirements and determine any **<u>potential</u>** environmental impacts of this dewatering, including:

- A lowered water table;
- A reduction in surface water flows in drainages at certain times of the year;
- Impacts on other groundwater users, e.g. reduction of yield to stock wells;
- The water quality of dewatering discharge; and
- The potential for increase of leakage from the tailings storage facility.

Based on the results of the groundwater flow modelling, most of these potential impacts are expected to be minor at MRM. It has been shown that surface flows will not be affected. Stock wells in the area are distant enough from the open cut to not be affected and no other major groundwater users are known in the area. MRM will reuse of the dewatering discharge for mineral processing and dust suppression.

Model results indicate that the cone of depression caused by the dewatering will not reach the TSF and therefore there is no potential to draw TSF seepage towards the pit or increase this seepage.

Estimated groundwater abstraction for open-pit dewatering ranges up to about 6,220 kL/day in mining year 17.

One potential environmental impact from the dewatering is related to the Billabong pool ("Djirrinmini"), located in the current McArthur River channel about 2 km upstream of the proposed open cut. This pool is permanent and its water level is primarily supported by groundwater in the dry season. Riparian vegetation and aquatic fauna in and around these pools could be affected in the dry season if the water level of the pool is reduced because of lowered groundwater levels in the bedrock aquifers being pumped for open cut dewatering. The modelling results confirm that the extent of drawdown in both the bedrock and alluvium is limited by vertical leakage and indicate that pit dewatering could lower groundwater levels near the Billabong by less than 0.5 m during the dry season, potentially causing it to be smaller earlier in the dry season. The Billabong pool probably mainly receives lateral groundwater recharge from the alluvium, as it is located on low permeability bedrock that transmits very little upward recharge to the pool.

A reduction in groundwater level of 0.5 m in both the weathered bedrock and alluvial aquifers can be expected to result in a reduced lateral flow into the waterhole. This may result in a decrease in the depth and extent of the waterhole at the end of the dry season prior to it being replenished in the following wet season.

It should be noted that the predicted drawdown of 0.5 m is a maximum which will not occur until after 25 years of mining. Prior to that, the drawdown will be less. During the initial years of mining, a program for monitoring groundwater levels in both the weathered bedrock and the alluvial aquifers at the waterhole will be implemented to confirm the accuracy of the predicted effects.

Additional groundwater and environmental monitoring will be required during mine dewatering. The current groundwater monitoring network will need to be expanded to include: (i) monitoring around the open cut and environmental features; and (ii) selected stock wells.

1.1 Background

A feasibility study is currently being undertaken at McArthur River Mining Pty Ltd (MRM) by Xstrata Plc (Xstrata) to change from underground to open cut mining.

Xstrata, as part of project's Environmental Impact Study (EIS), requires an assessment of the environmental impacts of groundwater level lowering (drawdown) caused by pit dewatering and borefield operation (for process water supply) – on both stream flow and summer pool levels in rivers near the proposed mine.

URS Australia Pty Ltd (URS) was engaged by Xstrata to assess the impacts of mine dewatering through the use of groundwater flow modelling, as detailed in URS proposal 04-262(b), dated 27 August 2004.

1.2 Project Location

The McArthur River Mine is located 45 km south west of the township of Borroloola in the Gulf Region of the Northern Territory, approximately midway between Darwin and Mount Isa. The McArthur River Mine is accessible by sealed road from Daly Waters to the west and from the Barkly Highway 350 km to the south. The mine site is located adjacent to the McArthur River (Figure 1), in the middle reaches of the river catchment between the confluences of the Kilgour and Glyde Rivers.

1.3 Open Pit Features and Development

The proposed open cut development comprises a conventional staged open pit development of the "Here's Your Chance" (HYC) deposit (Figure 2). The ultimate open cut is likely to be approximately 215 m deep, 1400 m long by 700 m wide, with an area of around 100 ha. The open-pit mining rate would be around 1.8 Mtpa of ore, which is expected to improve the economics of mining compared to the current operation. Currently, the McArthur River flows through the area of the proposed open cut and the project would therefore commence with the construction of a diversion of the McArthur River and construction of a levee bank to protect the future open pit workings from inundation during wet season flooding.

Mining would be by a fleet of conventional rope shovels, hydraulic excavators and large haul trucks. The mining rate would peak at around 20 Mtpa and the project life would be around 25 years.

2.1 Scope of Work

The scope of work for this project was outlined in URS proposal 04-262(b) and is summarised below.

- Data Review, Model Conceptualisation and Liaison;
- Groundwater Drilling and Testing Programs;
- Groundwater Model Construction and Features;
- Groundwater Model Calibration;
- Predictive Simulations – Dewatering and Environmental Impacts, and
- EIS Groundwater Model Reporting.

2.1.1 Variations Since Commencement of Scope

- Predictive Simulations of Flooding Events; and
- Predictive Simulations of Alluvium Cut-off Trench.

2.2 Proposed Approach

The proposed approach (as described in our proposal) to complete the scope of work is outlined below.

2.2.1 Data Review, Model Conceptualisation and Liaison

In order to form a conceptual model of the mining area and surrounding region, it is necessary to review geological and geophysical data, past borefield pumping data and data from current groundwater-related programs.

The conceptual model discussed with NT Regulatory Authorities to ensure that it is acceptable to them and to ensure that it has features that are required to fulfil the EIS scope.

2.2.2 Groundwater Drilling and Testing Programs

Based on the conceptual model and known geology, a program of groundwater drilling and testing completed to allow: (i) estimation of the dewatering requirements for the open-pit; and (ii) assessment of environmental impacts.

2.2.3 Groundwater Model Construction and Features

The model has incorporated groundwater drilling and testing information as it has become available from the program described above and this has led to gradual model refinement during the work. In this manner, the model can be used to refine, predict and quantify the required dewatering system for mining and potential environmental impacts associated with dewatering. As such, the model should satisfy both the requirements for the EIS and future dewatering design and environmental impact assessments.

The modelled area is divided into different material types and layers in order to simulate the interpreted geology and hydrogeology as closely as possible. The model includes such features as:

- The geometry and properties of known aquifer systems, both fractured rock and alluvium;
- The geology and structural geology of the site and the impact of these structures on groundwater flow;
- The interrelationship between the bedrock and the superficial deposits, such as river alluvium;
- The layout of the mining area and the proposed open-pit and existing underground mine;
- The relationship between groundwater and surface water – both flows and levels; simulation of river pool locations;
- Potential seepage from the tailings area;
- Groundwater and surface water recharge-discharge mechanisms;
- Existing production and monitoring bores and the historical performance of borefields in the area;
- Regional groundwater flow; and
- Quantification of stream flows, flooding levels and the width of drainage floodplains for flooding events.

2.2.4 Groundwater Model Calibration

The calibration of the model occurs in two steps:

- **Steady State** – during this calibration stage, groundwater levels generated by the model are matched to known groundwater levels and flow directions across the mining region. This is achieved by small variations in model parameters, especially hydraulic parameters such as permeability and storativity. A successful steady-state calibration is a necessary precursor to the next stage of model development.
- **Transient** – this is the most difficult and time-consuming stage of model calibration. During this work, known aquifer response to pumping by bores, borefields or mine dewatering is matched by

simulating this pumping in the model. This can be difficult to achieve, especially in a fractured rock environment. Model parameters are varied until a satisfactory drawdown response to actual pumping is achieved. The model can then be used for predictive simulations to forecast dewatering.

- **Occasional Re-calibration** – as results from future groundwater drilling and testing programs and other field investigations become available, the model calibration can be refined. During such refinement, model parameters and perhaps model layers and material types may be varied. As this occurs, the model provides improved estimates of dewatering requirements and environmental impacts.

2.2.5 Predictive Simulations – Dewatering and Environmental Impacts

Using the calibrated model, various simulated pumping scenarios around and in the pit can be used to give preliminary indications of environmental impacts and the amount of groundwater that has to be pumped to achieve dewatering. This, combined with groundwater chemistry studies, will greatly assist in the final design of the dewatering system and allow planning for dewatering discharge disposal options.

2.2.6 Environmental Impact Assessment

The main potential environmental impacts resulting from the pit dewatering are associated with regional groundwater level lowering around the mine and borefields, in the tailings area and under the main drainages and rivers of the area. Such groundwater lowering may result in vegetation stress, induce leakage of contaminated water from tailings areas and have impacts on the ecological water requirements needed to sustain flora and fauna associated with summer pools in drainages of the area. In addition, groundwater level lowering may cause reduced dry season stream flows earlier than normal and influence ecosystems dependent on this stream flow.

The model will simulate the interaction of groundwater and surface water in the major drainages of the area. Specialised model cells, which represent potential points of leakage from surface water to groundwater are included in the model. These cells will occur in main drainages, floodplains of these drainages and perhaps under the tailings area. This will allow modelled leakage to occur during: (i) normal wet season streamflow; (ii) large wet season streamflow during high average recurrence interval (ARI) events, and (iii) dry season periods with no flow, but isolated river pools present. Previous flood studies can be used to define the extent of flooding and hence the probable groundwater recharge areas around the mine and will be used to predict stream flows in the McArthur River and relevant tributaries. These stream flows can be input to the groundwater model and flow depths and durations can be used to define the presence of water in streamlines/floodplains and hence seepage to groundwater.

Mapping of pool locations and characteristics (area, volume, typical wetting/drying cycles) supplied by Xstrata are used in conjunction with drawdown predictions from the groundwater modelling to evaluate impacts of dewatering on the pool hydroperiods. Any increased seepage of stream flow/ponded water can be subtracted from the predicted stream flows and used to determine cumulative impacts on the stream flow volumes. Thus, the groundwater/surface water modelling can assist in quantifying environmental impacts and planning the mitigation of such impacts. This will be an important aspect of regulatory approval of the proposed expansion.

3.1 Groundwater Drilling

Two test production bores and five groundwater monitoring bores were installed at the McArthur River mine (MAC series bores, Figure 3) during October and November 2004. Drilling was completed by H2O Drilling and Rehabilitation contractors with a truck-mounted drilling rig using air-hammer and mud rotary methods.

A 165 mm or 203 mm diameter pilot hole was drilled at each bedrock site location. All holes were lithologically logged and sampled. Groundwater discharge in air-hammer holes was measured at regular intervals during drilling using a V-notch weir. The pilot holes were converted either to groundwater monitoring bores or to test production bores (suffixed with a ‘P’), depending on airlift discharge and location. An alluvial test production bore (MAC3P) was constructed to replace a previously unsuccessful production bore in a separate geotechnical testing program by other consultants.

Bore construction details are summarised in Table 1 and discussed below.

Table 1
New Groundwater Bores - Construction Details

Bore Number	Collar Co-ordinates			Total Depth (mbgl)	Screened Interval (mbgl)	Screened Interval Lithology	Groundwater Depth (mbtoc)
	Easting	Northing	m AHD				
MAC1P	618,470.68	8,182,092.13	36.10	120.0	11.23 – 43.89	Dolomite	14.88
MAC2	618,499.61	8,182,176.56	37.13	120.0	11.62 – 119.62	Dolomite	16.08
MAC3P	617,105.21	8,181,502.23	32.93	31.5	20.23 – 26.50	Sand/Gravel	11.37
MAC4	616,332.95	8,180,808.62	32.74	18.0	3.00 – 15.00	Sandstone	10.50
MAC5	615,809.99	8,180,946.29	34.59	18.0	6.00 – 18.00	Dolomite	11.32
MAC6	618,352.20	8,182,559.93	32.39	102.0	11.50 – 101.50	Dolomite	12.71
MAC7	618,362.49	8,182,962.61	29.68	121.0	12.97 – 120.92	Dolomite	11.19

Notes: mbgl = metres below ground level
mbtoc = metres below top of collar

Bore logs, showing descriptions of strata and graphical well construction details, are presented in Appendix A.

3.1.1 Test Production Bores

Two test production bores (MAC1P and MAC3P) were constructed and cased with 203 and 152 mm internal diameter casing. Slotted steel casing was used for the screened section in MAC1P and wire-wound stainless steel used for MAC3P. The annulus in each bore was filled with washed filter gravel (3 to 6 mm graded gravel). The slotted steel casing design for MAC1P comprised four vertical rows of slots, each consisting of 300 mm long slots (3 mm aperture) separated by 300 mm unslotted sections. The stainless steel screen installed in MAC3P had 0.8 mm aperture slots.

Bore development was by air-lifting and surging, using compressed air to cause groundwater to flow into and out of the screened section, and out of the top of the bore. Each bore was developed by this method until silt-free groundwater returns were obtained.

MAC1P

Twenty-seven metres of 254 mm diameter steel casing were used to stabilise the unconsolidated surface material during drilling. Transported Tertiary sediments cover the bedrock sequence to a depth of 14 m at this location. Weathered bedrock was encountered at 27 m. The bedrock lithology comprises dolomite to 120 m. Slightly fractured dolomite was intersected between 27 and 30 m, with caverns intersected between 33 and 34 m and highly fractured dolomite intersected between 43 and 46 m. Slightly fractured dolomite was intersected from 66 to 69 m, 91 to 92 m, and 95 to 99 m.

Groundwater discharge increased from 86 kL/d at 30 m to approximately 864 kL/d at 46 m. Surges up to 1,730 kL/day occurred while airlifting from 46 m depth. Plates 1 and 2 show photos of the drilling of the production bore.

MAC3P

Because it was located in alluvial sediments, Bore MAC3P was drilled using mud-rotary techniques to stabilise the unconsolidated silt, clay, sand and gravel encountered during drilling. Alluvial material was intersected to 26 m with basal gravel and sand intersected between 20 and 26 m. The airlifting yield during development was 170 kL/day.

3.1.2 Groundwater Monitoring Bores

Five groundwater monitoring bores (MAC2 and MAC4 to 7) were drilled and constructed (without reaming the 152 or 203 mm pilot holes) using 50 mm nominal diameter uPVC casing. Machine-slotted uPVC was used for the screened section (1 mm aperture slots), which was gravel packed with washed filter gravel. Bentonite seals were placed above the gravel pack and the bore annulus cement grouted to ground surface.

In addition, two geotechnical boreholes, GWM103 and GWPB01c (drilled during a separate investigation) were constructed as groundwater monitoring bores and used as observation bores during aquifer tests.

MAC2

Steel surface casing was installed to 15.1 m to case off unconsolidated sand and clay. The hole intersected fractured dolomite between 21 and 24 m and minor fracturing between 24 and 27 m.

Airlifting yield from the bore commenced at 86 kL/day at 32 m and remained constant for the remainder of the drilling of the hole.

The bore was constructed with 50 mm uPVC casing, with the slotted interval located between 11.6 and 119.6 metres.

MAC4

MAC 4 was drilled to 18 m and intersected clay, sandstone and shale/dolomite. A minor amount of groundwater flow (10 kL/day) was airlifted from the bore during drilling.

The bore was cased with uPVC and the slotted interval set between 3 and 15 m below ground surface.

MAC5

MAC 5 was drilled to 18 m and intersected clay to 3 m and weathered dolomite and sandstone to 18 m. Slightly fractured dolomite was intersected between 15 and 18 m. Airlift yield from the bore was 86 kL/day.

The bore was cased with uPVC and the slotted section set between 6 and 18 m below ground surface.

MAC6

A short section (9.3 m) of steel casing was used to stabilise unconsolidated sand intersected in the upper section of this bore. Weathered/fractured dolomite was intersected between 9 and 18 m with minor fractures intersected between 27 and 36 m, 51 and 63 m and 75 and 78 m. A groundwater flow of 40 kL/day was intersected at 75 m and this increased to 86 kL/day at 90 m.

The bore was lined with 50 mm uPVC casing and the slotted interval set between 11.5 and 101.5 m.

MAC7

Steel surface casing was installed to 13.4 m to stabilise unconsolidated sand and clay. Weathered dolomite was intersected between 12 and 18 m, and fractured dolomite to 42 m. Non-fractured to slightly fractured dolomite was intersected to 121 m. Airlift yield from the bore progressively increased from 86 kL/day at 22 m to 432 kL/day at 90 m.

Geotechnical Investigation Boreholes

Two bores (GWM103 and GWPB01c, a failed test production bore), drilled during a separate geotechnical investigation, were completed as groundwater monitoring bores and used for groundwater level observations during the MAC3P aquifer test. These bores were drilled to depths of 23 and 28 m, respectively and intersected the complete suite of alluvial deposits (including the basal sand and gravel aquifer) associated with the present day channel and palaeochannel of the McArthur River. An airlift yield of 86 kL/day was recorded from GWPB01c.

Slotted and blank uPVC 50mm casing was used to construct the bores, with the slotted casing installed against the basal sand and gravel aquifer for GWM103. Due to collapsing hole conditions, the 50mm casing in GWPB01c could not be installed to total depth.

3.2 Bore and Aquifer Testing

A program of bore and aquifer testing was completed in each of the test production bores to determine bore and aquifer properties.

Three types of tests were undertaken:

- Step-drawdown tests;
- Constant-discharge tests; and
- Recovery tests.

3.2.1 Step-Drawdown Tests

The step-drawdown tests were used to determine bore pumping characteristics and estimate a pumping rate suitable for the constant-discharge test. These tests comprised pumping the bore at rates that were increased incrementally ("steps"). The steps were generally of 30 minutes duration. Analyses of these results were used to determine well and formation loss factors and to select a suitable rate for the constant -discharge test.

Groundwater level drawdown in a pumping bore has two components, formation loss and well loss. Formation loss is dependent on the hydraulic characteristics of the aquifer in the vicinity of the bore and is directly proportional to the pumping rate. Well loss is caused by turbulent flow and friction head loss through casing slots and around the pump, and thus depends on bore construction and development. It is generally considered proportional to the square of the pumping rate.

Therefore, drawdown in a pumping bore can be expressed by the formula:

$$Sw = BQ + CQ^2$$

where: $Sw =$ Groundwater level drawdown (m)

$Q =$ Pumping rate (kL/day)

$B =$ Formation loss factor (day/m^2)

$C =$ Well loss factor (day^2/m^5)

$$WellEfficiency = \left(\frac{BQ}{BQ + CQ^2} \right) \times 100$$

The step-drawdown test results have been analysed by the Bierschenk and Wilson method, whereby Sw/Q is plotted against Q, giving a line with a y-intercept of B and slope C (Table 2, Figure 4).

Table 2
Step-Drawdown Test Results

Step	Pumping Rate (kL/day)	Drawdown (m)	Formation Loss BQ (m)	Well Loss, CQ^2 (m)	Well Efficiency (%)
MAC1P					
1	1,443	9.23	6.06	1.09	85
2	1,607	15.03	6.74	1.35	83
3	1,901	19.41	7.98	1.89	80
Constant Rate (@ 30 mins.)	433	2.54	1.81	0.09	94

Well efficiency generally decreases as pumping rate increases, due to the higher proportion of well loss (CQ^2) contributing to total drawdown ($BQ + CQ^2$) in the well. At higher pumping rates, the higher velocity of groundwater entering the well causes a higher proportion of well loss resulting in lower bore efficiency. The calculated values of efficiency are relatively high in comparison to wells completed with slotted casing in fractured rocks.

The MAC3P step-rate test was not completed due to a limited project timeframe available before the onset of the wet season.

3.2.2 Constant-Discharge and Recovery Tests

The constant-discharge test in each production bore was commenced following the step-drawdown test and after groundwater levels had recovered to initial static levels. Upon completion of each constant-discharge test, recovering groundwater levels were also measured and analysed.

The test pumping was undertaken by the drilling contractors using electric submersible pumps. Pumping rates were measured through an orifice weir. Electric contact meters (dip meters) were used to measure groundwater levels in both the pumped bore and suitable observation bores.

The constant-discharge test results enable the hydraulic characteristics of the aquifers intersected by each test production bore to be determined. These parameters quantify the storage and transmission of groundwater in the aquifer.

The results of the constant-discharge tests and the calculated hydraulic parameters are shown on Table 3.

Table 3
Constant-Discharge Test Results

Pumping Bore	Date of Test	Pumping Rate (kL/day)	Final Drawdown (m)	Observation Bores		Transmissivity (m^2/day)			Storativity /
				Bore No.	Distance (m)	Theis Method	Cooper – Jacob[1] / Papadopulos-Cooper[2]	Gringarten-Witherspoon Kx (Kx/Ky=0.5)	Specific Storativity*
MAC1P	18/11/2004	1,114	21.66	-	-	-	-	9.3	-
		1,114	0.57	MAC2	90	-	-	96	0.0001[+]
		Recovery	-	-	-	-	-	14.6	-
	19/11/2004	433	5.75	-	-	-	-	5.4	-
MAC3P	21/11/2004	Recovery	-	-	-	785	-	-	-
		393	0.77	GWM103	10.9	631	-	-	-
		Recovery	0.77	GWM103	10.9	-	753[1]	-	-
		393	0.28	GWPB01c	17.2	530	-	-	0.002
						-	574[2]	-	0.001

MAC1P

Bore MAC1P was pumped during the step-drawdown test at rates of 1,443, 1,607 and 1,901 kL/day, followed by a constant-discharge test at 1,114 kL/day (Figures 5, 6, and 7). After 10 minutes the drawdown followed a sloping trend that continued to the end of the test when, due to the available drawdown, the test was converted to a constant drawdown, variable discharge test. After 1,070 minutes the test was aborted prematurely due to equipment failure.

The bore was re-tested at 432 kL/day, showing a near linear trend after 10 minutes. The test ceased prematurely due to equipment failure at 540 minutes. Analysis of the data using the Gringarten-Witherspoon method (vertical fracture model) indicated a transmissivity of 9.3 m^2/day for the first test, and 5.4 m^2/day for the second. Analysis of the recovery data indicated a transmissivity of 14.6 m^2/day.

During the first test, groundwater levels in monitoring bore MAC2, located 90 metres from the pumping bore, were monitored. Analysis of the data using the Gringarten-Witherspoon method (vertical fracture model) indicated a transmissivity of 96 m^2/day

A specific storage value of 1×10^{-4} was calculated from the observation bore data.

MAC3P

Bore MAC3P was pumped at a constant discharge of 393 kL/day (Figure 7). The bore began to recover (becoming more efficient due to pumping development?) after 10 minutes and this continued to 600 minutes, when a normal drawdown response commenced. Aquifer parameters from the pumping bore cannot be determined, however the recovery data indicated a transmissivity of 785 m^2/day using the Theis method.

Groundwater levels in monitoring bore GWM103 (partially penetrating, sand and gravel aquifer) located 10.9 metres from the pumping bore were monitored during the test. Analysis of the data, using the Theis method, indicated a transmissivity of 631 m^2/day. Analysis of the recovery data, using the Cooper-Jacob method, indicated a transmissivity of 753 m^2/day.

Groundwater levels in monitoring bore GWPB01c (partially penetrating, sand aquifer) located 17.2 metres from the pumping bore were also measured during the test. Analysis of the data using the Theis and Papadopulos-Cooper methods indicated a transmissivity of 530 m^2/day and 574 m^2/day, respectively.

Confined storage values of 1×10^{-3} and 2×10^{-3} were obtained from the observation bore data.

The Cooper-Jacob ("straight-line") method of analysis is a modification of the Theis equation and the data must meet certain requirements in order to use the method. These requirements are derived using the following equation:

$$u = \frac{r^2 S}{4KDt}$$

Where:

$r =$ Radial distance between the observation bore and the production bore (m)

$S =$ Storativity value obtained from the analysis (-)

$K =$ Hydraulic Conductivity (m/day), [also referred to as permeability in this report]

$D =$ Thickness of the aquifer (m)

$t =$ Time (days)

For the straight-line method to be applicable, the value of u must generally be < 0.01. When applying this to the first 1 minute of the data for GWM103, $u = 0.16$ and when applying to 10 minutes of the data for GWM103, $u = 0.016$. Therefore, the straight-line method is only applicable after 10 minutes of pumping and analysis of the early time (< 10 minutes) test data using the straight-line method is invalid and gives erroneous results.

4.1 Geological Setting

4.1.1 Regional Geology and Structure

The McArthur Basin comprises Carpentarian and Adelaidean rocks extending from the Alligator River in the Northern Territory to the Queensland border and includes a large part of Arnhem Land and the Gulf of Carpentaria drainage region.

The dominant relief is low escarpments, plateaux and ridges (Figure 8). Limestone and dolomitic rocks of Palaeozoic age or older occur in the western part of the McArthur River catchment upstream of the project site. Sandstone and conglomeratic rocks occur in the eastern sub-catchments, including the Kilgour and Glyde Rivers (Figure 9).

4.1.2 Geology of the Open Pit Area

The sediment-hosted stratiform HYC deposit (Figure 10) has similarities with ore-bodies at Mount Isa and Hilton in Queensland. It is about 1.5 km long and 1.0 km wide with an average thickness of 55 m.

The HYC deposit occurs near the base of the HYC pyritic shale member, within the Middle Proterozoic McArthur Group (Figure 10). The member comprises a sequence of inter-bedded pyritic bituminous dolomitic siltstones, sedimentary breccias and volcanic tuffs.

The HYC deposit has been folded and eroded along its western margin, which is covered with about 30 m of alluvium and soil. The western margin contains the Hinge Ore Zone, which is sub-vertical with a strike length of 1.0 km and vertical height of 200 m. The northern margins inter-finger with sedimentary breccias and the southern margin grades into thinned nodular barren pyritic siltstone. On the eastern margin, the ore-body thickens and is folded to form the Fold Zone, which has a strike length of at least 600 m (Figure 10). The southeastern corner is down faulted by about 110 m along the northeasterly trending Woyzbun Fault.

4.2 Hydrology and Hydrogeology

4.2.1 Site Hydrology

The mine site is situated adjacent to the McArthur River, in the middle reaches of the river catchment, between the confluences of the Kilgour and Glyde Rivers. The 100-year ARI flood level at the mine site is 39.5 m AHD. All major infrastructure on the site is located above this elevation. With the exception of some spring fed tributaries, most of the flow in the McArthur River comes from wet season rains (Figure 11). The river ceases to flow in some dry seasons, and most stretches, particularly near the mine area, usually dry to a series of large isolated pools.

During the wet season, the river can become extremely turbid when in flood. Flow data for the McArthur River in terms of ARI are 7,250 m^3/s for a 1 in 100 year event (40 m AHD) and 1,000 m^3/s for a 1 in 2 year event.

The main creek systems, which bound the tailings and mine site, are Barney and Surprise Creeks. Barney Creek has a catchment area of 600 km^2 at the mine site. The creeks are dry throughout most of the year. This is particularly the case for Surprise Creek, which has a catchment size of only 85 km^2, and normally flows for only a few days each wet season.

A stream gauging study was undertaken to measure stream flows in June, a dry time of year, and use these data to characterise stream flow arising from groundwater. Stream flow and water quality (electrical conductivity and pH) measurements at a number of sites along the McArthur River were undertaken along a 14 km length of the River, extending from south west of the proposed pit to just above the confluence with the Glyde River. Details are presented in Appendix B.

4.2.2 Groundwater Geology and Aquifer Occurrence

Current knowledge about the hydrogeology of the mining area is based on a network of groundwater production and monitoring bores installed since 1995 (Figure 12).

Aquifers in the mining area occur locally in both the surficial deposits and the bedrock. These aquifers are a result of both intergranular and secondary permeability.

Extensive aquifers with intergranular permeability in the mine area are rare and are generally limited to the alluvium that occurs in the drainage channels of the major rivers. However, based on limited data, only the basal few metres of the alluvium contain permeable sand and gravel deposits. The majority of the upper sediments are a heterogeneous mixture of silt, sand and gravel with only a moderate permeability. These alluvial channels are important aquifers as they support groundwater dependent ecosystems (GDEs) during the dry season when there is limited surface water flow and drainage channels comprise a series of isolated pools.

In general, aquifers occur in the weathered and fresh bedrock in the mine area due to the presence of secondary structures such as faults, shear zones, vugs and fractures. Historically, groundwater has been abstracted from many of these aquifers in the numerous borefields that have been constructed in the mine area to supplement process water supply.

Alluvium

The alluvium near the proposed open pit occurs predominantly in the McArthur River channel and associated floodplain. The alluvium comprises mainly a low permeability mixture of silts, clays, and fine-grained sands. However, a higher permeability basal section of coarse-grained sands, gravels and cobbles/boulders occurs along the deepest portion of the channel.

The deepest part of the alluvium is offset to the southeast of the present day McArthur River channel and is represented by a palaeochannel of the former river location (Figures 3 and 12). The base of this palaeochannel is up to 34 m below ground surface (5 m AHD) and this represents the thickest known occurrence of the alluvium in the immediate mine area.

The palaeochannel is approximately 800 m wide across the southern perimeter of the proposed levee bank with a 200 m wide, 6 metre thick section of highly permeable gravel at the base. The palaeochannel gravel and sand could represent a significant source of groundwater inflows to the open pit, where it intersects the open pit walls.

Weathered and Partially Weathered Bedrock

The hydrogeology of the weathered and fresh bedrock is significantly more complex than that of the alluvium.

Aquifers occur locally in both the weathered and partially weathered bedrock underlying the alluvium in the open pit area. The near-surface geology east of the pit is predominantly weathered dolomite (Cooley Dolomite), and to the west, dolomitic siltstones, shale and dolomite (Teena Dolomite). The most significant aquifer occurs within the weathered dolomite, which appears to have a low to moderate permeability.

Faults that intersect the weathered and partially weathered zones are probably transmissive. These will contribute groundwater flows to the proposed open pit, where they intersect the wall (Figures 3, 12 and 13).

Generally, the base of weathered bedrock ranges between 5 and 22 m AHD (URS, 2003). The deepest zone of weathering is between 5 and 8 m AHD, associated with the McArthur River palaeochannel.

During heavy precipitation events, the main decline for the underground mine (approx 100 m from the portal) discharges water at a rate of 2,420 kL/day. This implies that permeable sections of the weathered bedrock at shallow depths can be significant aquifers that receive rapid recharge from ground surface and extend locally downwards into the fresh bedrock.

Bedrock

Groundwater can occur in open vugs or solution channels (collectively referred to as karst and weathered/vuggy dolomite), fractures, joints and faults within the fresh bedrock.

Based on core photography, open vugs and solution channels extend below the zone of weathering to depths in excess of 300 m (-270 m AHD, MRM Mine Geology Department). These structures are predominantly in dolomite, located near the Mt Stubbs Fault north of the pit (Figures 3, 12 and 13). In addition, production bore WEMU 5PB (EMU 5) intersects vuggy dolomite from 64 m to 65 m (about -35 m AHD) and produced a yield of 864 kL/day. Similarly, the recently constructed test production bore

(MAC1P) yielded about 432 kL/day from vuggy dolomite along this fault trace. The intersections of major faults and vuggy dolomite are very prospective aquifer zones.

Open joints and fractures can also allow the transmission of groundwater and were observed (in core photography) within the open pit area between depths of 23 m (7 m AHD) and 152 m (-122 m AHD), predominantly in dolomite and brecciated units, but occasionally in shales.

Joints and fractures in most rock types appear to decrease in permeability with depth and therefore transmit only minor amounts of groundwater. From the core viewed, these structures were apparent between depths of 10 m and 240 m (20 m AHD and -210 m AHD). Open joints were most predominant above a depth of 100 m (-70 m AHD).

The underground mine water balance provided by MRM in May 2003 indicates that the primary groundwater inflows to the underground mine are relatively small (2,420 kL/day or 28 L/sec). The sources of this measured inflow comprise the following faults and structures.

- Hinge Zone – 864 kL/day (10 L/sec)
- Eastern Vent Rise – 605 kL/day (7 L/sec)
- Northern Fault – 605 kL/day (7 L/sec)
- Other sources including joints and combined seepages – 346 kL/day (4 L/sec)

MRM staff also noted that mine groundwater inflows varied with rainfall events, however measurements of outflows from the mine are sporadic and no seasonal variations in flow have yet been established.

Interpreted regional fault systems, together with bore locations, are presented in Figures 3 and 13. These faults are considered potentially prospective aquifers and have been included in the groundwater model (Section 5).

4.2.3 Groundwater Levels and Flow

Since 1995, a network (including both regional and local locations) of groundwater monitoring bores has been established by MRM to monitor any potential impacts of the current mining operations on the groundwater resources of the area (Figure 12).

The monitoring bores in the regional network are located both to the west and east of the mine area. The local monitoring bores (GW 1 to 17) are located in the plant area and around the tailings facility (Figure 12). Six groundwater monitoring bores were installed around the plant site area in 1995 and 10 groundwater monitoring bores were installed around the perimeter of the TSF in 1997 (except for GW4, installed in 1995). Three of the TSF monitoring bores (GW4, GW6 and GW 14) are located near the tailings runoff dam (TRD).

Groundwater levels across the mining area, for the end of the dry season in 2004, are presented in Figure 14. There is an easterly flow of groundwater from high elevations around the tailings dam (40 m AHD) to lower elevations near the McArthur River (20 m AHD). The regional groundwater flow in the mining area is towards the low topography associated with the major river channels. Superimposed on this regional pattern appears to be a drawdown cone associated with EMU 5, where groundwater levels are depressed to an elevation of about 18 m AHD, presumably associated with groundwater abstraction from this bore. There is no obvious drawdown pattern associated with groundwater abstraction from the existing underground mine.

Wet season groundwater levels are 5 to 6 m higher than dry season groundwater levels (URS, 2003), suggesting this is about the magnitude of seasonal groundwater level fluctuations.

4.2.4 Groundwater Chemistry

MRM routinely completes a monthly sampling program in the local groundwater monitoring bores around the plant site and TSF. In addition, a recent (2003) program of groundwater sampling in monitoring bores near the proposed open pit and water supply production bores has been completed. The following discussion on groundwater chemistry is based on the results of all sampling programs and the associated analyses. The results of the most recent analyses are shown in the trilinear plot in Figure 15.

Mining Area

The groundwater in the upper weathered rock profile in the mining area is relatively saline with total dissolved solids (TDS) contents of 2,000 to 4,000 mg/L with a neutral pH. This groundwater has a very high hardness (derived from carbonate bedrock such as dolomite) and is a (Na-Ca-Mg)-Cl type with significant concentrations of HCO_3 and SO_4. The large concentrations of SO_4 are probably derived from the bedrock because of the common occurrence of sulphide minerals in the area.

Groundwater from the underground mine and vent raise is significantly fresher than the shallow groundwater, having TDS contents ranging from 700 to 1,100 mg/L. This may be the result of dilution by both runoff down the decline and from infiltrating rainfall recharge into the weathered zone moving down the vent raise and into the underground mine.

As for the shallow weathered zone groundwater in the mining area, the groundwater being discharged from the underground mine is a (Na-Ca-Mg)-Cl type with significant concentrations of HCO_3 and SO_4.

Based on groundwater samples from MAC3P, groundwater in the alluvium is generally of better quality than the bedrock/weathered zone groundwater. With a TDS content less than 1,000 mg/L, the alluvial groundwater can be classified as fresh to brackish and generally has a neutral pH. As with the bedrock, alluvial groundwater is hard and sodium, chloride and sulphate are the dominant ions. The largest amount of the groundwater in the alluvium is derived from infiltrating surface runoff associated with wet season flows in surface drainages.

In both the bedrock and alluvial groundwaters, lead and zinc appear to be elevated and these metals are probably derived from sulphides in the bedrock.

Tailings Area

Based on monitoring results since 1995, the groundwater (mainly in shallow weathered bedrock) around and under the TSF and TRD is very hard and is a (Na-Mg-Ca)-(SO_4-Cl) type with a TDS content of 2,000 to 3,000 mg/L. Groundwater quality in other monitoring bores around the TSF is similar although the combination of cations and anions varies and the TDS content shows a considerable variation. Since 1995, EC and SO_4 content have both increased.

Borefields

The groundwater from the Emu borefield is of very good quality with TDS in the range 300 to 500 mg/L and is derived from permeable shallow (< 100 m) bedrock. The groundwater is hard and is a (Ca-Mg) HCO_3 type with only minor Na and Cl. Most groundwater pumped from these bores is derived from the Emu Fault in vuggy permeable sections of the dolomitic bedrock. The low TDS content of this groundwater suggests that rapid recharge of infiltrating rainfall occurs into permeable zones within the Emu Fault and surrounding bedrock, especially in areas where such structures underlie major drainage channels.

The groundwater from Donkey Bore is a (Na-Ca-Mg) (Cl-HCO_3) type with significant SO_4 content. This chemistry is a result of sulphide minerals present in the rocks in the area of the proposed open pit where the bore is located.

Recent Groundwater Analyses

Groundwater samples were collected from MAC1P and MAC3P near the end of the test-pumping test. The samples were forwarded to NTEL[1] for detailed analysis (Table 4).

Table 4
Recent Groundwater Analyses

Analysis	**Unit**	**Bore Number**	
		MAC1P	**MAC3P**
pH Value		7.1	7.1
Conductivity @ 25'c	μS/cm	2,030	1,220
Total Dissolved Solids (TDS)	mg/L	1,130	720
Calcium - Filtered	mg/L	138	102
Magnesium- Filtered	mg/L	146	91.5

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[1] A NATA-registered laboratory.

Sodium -Filtered	mg/L	63.8	34.5
Potassium - Filtered	mg/L	10.3	9.5
Sulphate - Filtered	mg/L	80	86.4
Chloride	mg/L	382	72.9
Nitrite	mg/L	<0.005	<0.005
Nitrate	mg/L	0.215	0.305
Manganese-Filtered	mg/L	15.3	597
Bicarbonate	mg/L	535	533
Hardness	mg/L	946	632
Cadmium - Filtered	µg/L	0.06	0.06
Cadmium - Total	µg/L	0.1	0.1
Copper - Filtered	µg/L	2.15	0.68
Copper - Total	µg/L	6.26	2.77
Lead – Filtered	µg/L	2.48	10.4
Lead – Total	µg/L	13	15.4
Zinc – Filtered	µg/L	151	105
Zinc - Total	µg/L	181	139

The groundwater is fresh to weakly brackish with laboratory salinities ranging from 720 to 1,130 mg/L total dissolved solids (TDS). The electrical conductivity ranged from 1,220µS/cm (MAC3P) to 2,030 µS/cm (MAC1P). Conductivities measured from the start of the test and from the end of the test were similar.

Values of pH are similar at 7.1 indicating that the groundwaters are essentially neutral to weakly alkaline.

Sodium, chloride and sulphate are the dominant ions, with sodium ranging from 34.5 mg/L (MAC3P) to 63.8 mg/L (MAC1P); chloride from 72.9 (MAC3P) to 382 mg/L (MAC1P) and sulphate from 80 (MAC1P) to 86.4 mg/L (MAC3P).

The groundwater is hard, with hardness concentrations of 632 (MAC3P) and 946 mg/L (MAC1P).

Lead and zinc concentrations are elevated and are presumably derived from sulphides in the bedrock.

5.1 Conceptual Hydrogeology Model

Based on the interpreted geology, the conceptual hydrogeological model of the area (used to construct the groundwater flow model) is complex and comprises the following features:

- The general groundwater flow direction is towards the southeast, from the higher topography near the TSF into the lower topography associated with major river drainages on the eastern and southern sides of the mining area.
- Groundwater levels are generally shallow and are within 15 m of ground surface.
- Major rivers occur in the area (McArthur and Glyde) and drain towards the north and north-east. Surface runoff in these river channels is assumed to be in direct hydraulic connection with groundwater in the underlying alluvium and major permeable structures in the bedrock. This implies that the major dry-season pools in the rivers are largely supported by groundwater during the dry season.
- Away from the major river channels, the surficial cover is generally thin and does not contain significant aquifer zones. The model assumes that the superficial deposits (mainly alluvial sand and lacustrine clay) are extensive, uniform in thickness and cover the entire model domain except in areas of bedrock outcrop.
- A palaeochannel (sub-parallel to the McArthur river) that drains to the north-east occurs on the south-eastern side of the current McArthur River channel. In the palaeochannel, the alluvium is 3 to 34 metres thick and comprises mixtures of: (i) near-surface sand, gravel, and silt; (ii) underlying lacustrine and palaeochannel clay; and (iii) a very permeable basal sand and gravel unit. Each of these “units” has distinct hydraulic characteristics and hence they are represented as individual model layers.
- The bedrock in the mining area comprises steeply-dipping Barney Creek Formation (shale, breccia, lead-zinc orebody) and dolomite. These rocks have little intergranular permeability and are only permeable locally, where major structures such as steeply-dipping folded bedrock, faults, shear zones and fractures occur. Large vugs and cavities can form aquifer zones in the dolomite near major fault zones, especially in the weathered zone and shallow bedrock. In general, the permeability of the bedrock is enhanced in the weathered zone.
- The site is dominated by north and north-west trending faults. These structures create horizontal permeability anisotropy in the bedrock. This anisotropy will generally redirect groundwater flow along the least resistant flow path and this results in preferential flow along these structures. Horizontal permeability anisotropy in the bedrock has been simulated by modelling major faults as different, more permeable, material types.

- The regional topographic model (Figure 8) was used to calculate a shaded relief image map (Figure 13) to aid interpretation of regional fault systems in addition to those mapped in the regional geology (Figure 9).
- The detailed geology beyond the mining area is generally unknown because of a lack of mineral exploration holes. Therefore, the modelled geology in regional areas is based on large-scale mapping (Figure 9).
- Seepage from the TSF is small and generally occurs through small permeable structures in the weathered bedrock.

5.2 Groundwater Flow Model Details

5.2.1 Model Code

The model code selected was MODFLOW. MODFLOW is a three-dimensional block-centred finite-difference code developed by the USGS to simulate groundwater flow in the saturated subsurface. MODFLOW-SURFACT with Visual MODFLOW Pro Version 4 was used as the pre- and post-processors. Several flow packages have also been used that complement/supplement the widely used USGS MODFLOW by enhancing the schemes for performing unconfined simulations to rigorously model desaturation/re-saturation of aquifers.

5.2.2 Model Domain

The model domain measures 20 km east-west and 22 km north-south (Figure 16), and was discretised into 537,765 model cells (389 columns x 277 rows x 5 layers) with variable grid sizes. Each cell block represents a homogeneous hydrogeologic sub-unit of the hydrostratigraphic unit. Finer grids (25 m x 25 m) were used around the proposed open-pit and in areas of specific interest.

5.2.3 Model Setup and Layering

In order to capture the regional and local flow of groundwater and physical changes caused by mining, the numerical model has to include the major groundwater flow domains. Five layers, identified in the conceptual model, were modelled as individual layers (Table 5).

Table 5
Model Layers

Layer	Descriptions
1	Palaeochannel CLAY
2	Alluvial SAND/SILT/CLAY
3	Palaeochannel SAND/GRAVEL
4	Weathered BEDROCK
5	Fresh BEDROCK

5.2.4 Distribution of Hydraulic Properties

Uniform hydraulic conductivities (permeabilities) were assigned to layers 1, 2, 3, 4 and 5. Layers 4 and 5 were sub-zoned based on the interpreted distributions of: (i) weathered dolomite; (ii) sandstone units in the eastern half of the model; and (iii) vertical faults. Figure 17 shows the distribution of permeability in the model on a regional scale and Figure 18 shows the distribution near the proposed open-pit.

For all faults modelled, the horizontal permeability was made isotropic (Ky, north-south = Kx, east-west). All superficial alluvial materials (basal palaeochannel gravels, sand and clay) have been assigned a vertical anisotropic (vertical permeability less than horizontal permeability) to represent the sub-horizontal depositional mode.

5.2.5 Boundary Conditions

Since the presence of physical boundaries to groundwater flow within the model domain is largely unknown, the hydraulic boundaries were arbitrarily selected at the model perimeter, a significant distance from the areas where groundwater is removed from the model to simulate open-pit dewatering.

Recharge has been defined using an average rate of 10 or 20 mm/year (Figure 19), depending on the geological materials at the upper model surface. Palaeochannel clay outcrops at ground surface east of McArthur River and recharge is considered small in this area. Recharge of 100 mm/year was applied directly over the tailings storage facility to simulate groundwater mounding underneath the facility.

River cells (Figure 20), with a conductance equal to the vertical permeability of the underlying material were used to simulate the McArthur River. This value implies a good connection between surface water and groundwater in major drainages. Drain cells were used in the Glyde River and minor creeks (set at ground surface) to promote groundwater flow towards these smaller drainages.

To simulate groundwater abstraction from the pit, drain cells were used in the model and these become activated when mining occurs below the water table. The drain cells in MODFLOW act as groundwater sinks when the specified drain elevations are below the water table. By scheduling the drain elevations according to the mining schedule, the model removes groundwater that is above the mining floor at each drain cell. Included in the drain cell specification is the drain conductance, which regulates flow into the drain cell. A value equal to the vertical permeability of the nearest geological unit was set for each drain cell.

5.2.6 Simplifying Assumptions for Modelling

Simplifying assumptions were made in order to discretise the groundwater flow conditions into a manageable package, without sacrificing the ability to simulate features which significantly contribute to the groundwater flow regime. The assumptions used are summarised below:

Aquifer Base

The bedrock below -500 m AHD does not yield water and is impermeable to groundwater flow.

Top of Model

The top of the model is the current topography from the digital elevation model (Figure 8), with the uppermost layer being unconfined.

Boundary Conditions

No rainfall recharge occurs into river cells, as these cells account for recharge from surface flows in major drainages. Other recharge as described above.

Hydraulic Parameters and Material Types

- The calibrated hydraulic parameters are representative beyond the calibrated domain of the model;
- The permeability zoning, which is based on the published bedrock geology of the area, can broadly represent the hydrogeology;
- The alluvial sand and lacustrine clay is relatively uniform in thickness beyond the immediate mining area and covers the entire model domain except for outcropping bedrock;
- A palaeochannel clay is present east of the McArthur River; this unit is underlain by palaeochannel sand;
- Gravel is present beneath the palaeochannel sand for a width of 200 m; and
- The configuration of the palaeochannel, based on one cross-section, is acceptable.
- Only major faults and permeable zones of weathered bedrock are represented in the model. The faults extend to the base of the model and are the only aquifers in fresh bedrock. In general, the

fresh bedrock in the mine area has a very small permeability and contains no aquifers, other than the faults.

Mine Development

- The quarterly mining schedules provided can be equally sub-divided into monthly schedules;
- The progressive lowering of the drain elevations in the pit has the same effects as progressive mining and dewatering; and
- The use of the nearest vertical permeability for drain conductance (to simulate ease of groundwater flow into the pit) is acceptable.

Model Code

MODFLOW is a groundwater flow model code for fully saturated conditions. Hydraulic conductivity does not change with the change in water content. The reduction in hydraulic conductivity in unsaturated conditions is approximated by correcting the transmissivity for changes in the saturated thickness.

5.2.7 Limitations of the Model

The developed groundwater flow model has limitations. These limitations result from generalisations, interpretations and assumptions made in attempting to simulate the interpreted hydrogeology. The model limitations include:

- MODFLOW is a fully saturated groundwater flow model code, which can lead to an overestimation of the dewatered areas; and
- The use of the vertical permeability of the nearest rock unit for the drain conductance was arbitrarily selected to allow ease of flow into the pit.
- The area is largely underlain by fractured rock environment, where the only major aquifers in the bedrock are secondary structures, such as faults and karst development in the weathered zones of dolomites. The model only represents the major secondary structures (faults and karst) in the area.
- There are large tracts of saturated alluvium along the current McArthur River valley in hydraulic connection with streamflow. A palaeochannel of the river also occurs in the valley. The geometry and extent of these alluvial deposits is not well known.

The complexities of the hydrogeological regime at MRM mean that this model should only be used as a guide to determine impact areas and the likely groundwater abstraction rates required for dewatering. The interpretation of predictive simulations should be based on the assumptions made.

5.3 Model Calibration

The purpose of calibration is to establish that the model can reproduce measured groundwater levels and flows, both regionally and during aquifer tests, i.e. the model can reasonably represent the conceptual hydrogeological model of the deposit and environs.

Calibration of the model occurs in two steps and these are described below.

5.3.1 Steady State Calibration

A steady state calibration was completed by:

- Assigning estimated hydraulic properties to the various material types in the model;
- Assigning assumed groundwater levels to the model boundaries, based on topography and known groundwater levels in the modelled area; and
- Running the model under current known hydraulic conditions for an infinite time (i.e., steady-state) to establish the regional groundwater flow gradient, flow pattern and groundwater elevations in the area.

5.3.2 Transient Calibration

The groundwater elevations resulting from the steady-state calibration were used as initial conditions for all transient simulations. Whenever the transient calibration involved significant changes to the hydraulic conductivity, the steady state calibration was repeated with the new set of hydraulic conductivity values to obtain a new set of initial conditions.

During the transient calibration process, the hydraulic parameters were varied slightly in order to get the best fit of modelled drawdown to actual drawdown measured in observation bores during aquifer tests. The transient calibration was repeated for each of the aquifer tests in the test production bores with simulated groundwater levels tracked at the observation bore locations.

This process involved adjusting the hydraulic parameters, within realistic ranges, so that the simulated groundwater levels in each of the observation bores during testing of the two test production bores (MAC1P and MAC3P) closely matched the observed groundwater levels in the monitored observation bores (MAC2 and GWM103). Graphs of simulated drawdown were compared with observed data points.

The model is assumed calibrated when a set of hydraulic parameters closely reproduces the observed drawdown responses in each of the observation bores during the aquifer test.

5.4 Predictive Simulations

With the calibrated model, simulations of the open-pit dewatering system were completed to help assess the potential impacts of dewatering on regional groundwater levels and the hydrological environment.

In order to model the dewatering of the open-pit and to assess the environmental impacts, the model was run in transient mode with the mining schedules (elevation versus time) included in the model. The pumping rate required to dewater each mining level was calculated using the drain cells that simulate groundwater abstraction for dewatering.

The dewatering scenario investigated was a staged mining schedule (*"MRM Open Pit project, 1.8Mtpa LOM Mining Scenario, March 2005*), in order to quantify dewatering rates in line with proposed mining schedule.

6.1 Steady-State Calibration

The steady-state calibration is presented in Figure 21 and shows:

- Groundwater levels generally correlating with topography;
- A regional groundwater flow pattern towards the east-south-east, similar to that found in the current mining area (Figure 14);
- Simulated groundwater elevations that generally correlate with measured groundwater levels in the area (Figure 14);
- An acceptable correlation of modelled versus actual conditions.

6.2 Transient Calibration

6.2.1 MAC1P Aquifer Test (Bedrock)

There was only one observation bore (MAC2) with which to calibrate the model in the bedrock fault zone pumped during the MAC1P aquifer test. Unfortunately, this results in a very tenuous calibration as the aquifer parameters calculated for this bore represent only one point in the fault and this may not be representative of the entire fault.

Figure 22 shows the simulated drawdown in MAC2 from the model and the observed drawdown recorded in this bore during the aquifer testing of MAC1P. The model shows slightly less drawdown at this observation bore, but in both cases the total drawdown is very small. With only one data point to calibrate against there are probably local variations in aquifer parameters that are not reflected by the model. However, given the data available, this may be the best match that can be obtained for the model calibration in this bedrock fault zone.

During the calibration process for the bedrock aquifer test, variations of the vertical permeability of the overlying alluvial deposits in the McArthur River channel and palaeochannel had a significant effect on the drawdown in the production bore. This implies that the overlying alluvium does recharge permeable bedrock aquifers where they subcrop under present day drainages.

Table 6 shows the final observed drawdown in MAC1P and that simulated from the model. The broad agreement in these values and the plots (Figure 22) suggests that the hydraulic parameters derived from the calibrated model are representative of the site.

Table 6
Final Drawdown in MAC2 during Pumping from MAC1P

Observation Bore	Observed Drawdown (m)	Simulated Drawdown (m)
MAC2	0.58	0.59

Actual drawdown in the test production bore MAC1P was not compared to the simulated drawdown (Figure 22) because the model does not account for bore efficiency and the modelled cell size is much larger than the test production bore.

6.2.2 MAC3P Aquifer Test (Alluvium)

For the MAC3P aquifer test in the basal sand and gravel unit of the palaeochannel, two geotechnical bores (GWM103, GWPB01c), converted to observation bores, were used to measure groundwater levels. As with the bedrock aquifer test, the small number of observation bores does not produce a completely satisfactory calibration.

Figure 23 shows the simulated drawdown against observed values recorded in observation bore GWM103 while pumping from MAC3P. GWPB01c (failed production bore with questionable construction details) was not used for calibration due to the lack of hydraulic connection (reduced drawdown) compared to GWM103. During the test, the measured drawdown in GWM103 was small and showed small variations after 1 day of pumping, probably due to small variations in the pumping rate. However, the simulated drawdown does not have such fluctuations due to the constant pumping rate used in the model. In general, the simulated drawdown matches the observed drawdown reasonably closely. Both the observation bores were drilled as part of the geotechnical program to study the proposed river diversion around the open-pit and construction details are poorly known. As explained earlier, GWPB01c, a failed test production bore, is a partially penetrating bore, which may account for its smaller drawdown response.

Table 7 shows the final drawdown in observation bores GWM103 from pumping MAC3P and those simulated from the model. The broad agreement in these values and the plots referred to above show that the hydraulic parameters derived from the calibrated model can be considered broadly representative of the MAC3P area.

Table 7
Final Drawdown in Observation Bores during Pumping from MAC3P

Observation Bore	Observed Drawdown (m)	Simulated Drawdown (m)
GWM103	0.76	0.80

Due to the complexities (unknowns and spatial variability) of the aquifer systems, the calibration achieved is considered adequately representative of the site and should provide a reasonable guide for the dewatering design.

6.3 Derived Hydraulic Parameters

Ten transient calibration runs were completed in order to match simulated aquifer test drawdown to actual and this produced a reasonably satisfactory calibration, given the lack of data. Table 8 summarises the hydraulic parameters derived from the calibrated model that broadly correspond with the values derived from the aquifer tests.

Table 8
Hydraulic Parameters Derived from the Calibrated Model

Material Type	Model Layer	Descriptions	Hydraulic Conductivity (Permeability)			Specific Storage	Specific Yield
			Kx	Ky	Kz		
			(m/d)	(m/d)	(m/d)	(1/m)	(-)
2	1	Palaeochannel Clay	1.00E-04	1.00E-04	1.00E-05	1.00E-06	0.001
3	2	Alluvial Sand/Silt/Clay	2.0	2.0	0.5	1.00E-04	0.05
4	3	Palaeochannel Sand/Gravel	50	50	10	1.00E-04	0.10
5	5	Fresh Bedrock (Dolomite)	0.0001	0.0001	0.0001	5.00E-06	1.00E-03
6	5	Fresh Bedrock (Sandstone)	0.0001	0.0001	0.0001	5.00E-06	1.00E-03
7	4,5	North-South Bedrock Faults	2.0	2.0	0.1	5.00E-04	0.10
8	4	Weathered Bedrock (Teena Dolomite)	1.5	1.5	0.5	1.00E-05	5.00E-03
9	4	Weathered Bedrock	0.10	0.10	0.10	3.00E-04	5.00E-03
10	4,5	East-West Bedrock Faults	2.0	2.0	0.1	5.00E-04	0.10

6.4 Predictive Simulations

6.4.1 Pit Inflow Rates

To simulate groundwater inflows to the pit, the staged pit design was emplaced within the model with the groundwater head in the drain cells being set equal to the elevation of the active pit surface. As these elevations are below the initial water table, this simulates drawdown and promotes groundwater flow into the drain cells, which is analogous to groundwater pumping to achieve dewatering. Figure 24 shows the calculated groundwater abstraction from the drain cells up to year 25 from: (i) alluvium and weathered bedrock; and (ii) bedrock. Estimated total groundwater inflow is low in the first 6 months of mining at 1,270 kL/day, increasing to 1,990 kL/day after 1 year. After year 4 of mining, estimated inflow increases to 4,450 kL/day. Estimated inflows progressively increase to about 6,220 kL/day at year 17 and slightly decrease to 6,040 kL/day at year 25. Proportionally, estimated groundwater inflows from weathered bedrock and alluvium are smaller than bedrock. After 25 years, estimated inflows from alluvium and weathered bedrock are about 2,590 kL/day and 3,450 kL/day from bedrock.

6.4.2 Scheduled Open-Pit Mining

The Xstrata mining schedule (Section 5.4) is included in the model to realistically simulate the development of the open-pit and groundwater abstraction from the mine dewatering system. In simple terms, the drain cells simulate dewatering bores placed around the perimeter of each progressive pit shell. These drain cells "pump" groundwater from the model, if they are artificially set to a lower groundwater elevation than the model cells surrounding them. Currently, the mine life is 25 years and this duration has been assumed for the groundwater modelling simulations.

Including the mining schedule in the model (to set the elevations of the drain cells to the required dewatering level) provides an insight into the development of the cone of depression (caused by the pumping groundwater from faults in the bedrock) with time as the open-pit expands. The simulation shows that the drawdown is initially localised but gradually expands. Figures 25 to 28 show the development of the cone of depression with time and the associated groundwater level drawdown that occurs for the palaeochannel aquifer (layer 3 in the groundwater model) and fresh bedrock and faults (layer 5). As there is good hydraulic connection between layers 2 and 3 in the groundwater model, the simulated drawdown results between these layers have produced similar results, therefore layer 3 drawdown has been used for display purposes only.

Abstraction from the dewatering bores decreases in the later stages of mining as groundwater levels in the faults in fresh bedrock are lowered, largely due to the pit dewatering bores (simulated by drain cells) becoming less productive.

The predictive simulations generated mass balance discrepancy errors of about 1.5 %, which was considered acceptable.

6.4.3 Flooding - 1 in 50 Year Event

Other consultants undertook predictive surface water flood modelling and the results are presented in Figure 29 and Figures 29a to 29 d for a 1 in 50 year food event. The extent and stage height was included in a modelling scenario, simulated in 6-hour intervals by river cells covering the extent of the flooded area in 6-hour intervals. After the peak flood event, the flooded area gradually reduced over 30 days back to the original river flow conditions. The flooding scenario assumed that mining and dewatering have been occurring for 6 years (at which time the pit extends considerably into the alluvium) and dewatering continues throughout the flood event.

Recharge (negative drawdown) plots for day 1, 5, 10, 12 and 15 are presented in Figure 30 and Figures 30a to 30d. They show minor recovery of groundwater levels (less than 0.5 m) within the levee wall perimeter between days 5 to 15. Groundwater inflows into the pit (Figure 31) show a delayed response after the initial flood peak (after 4.5 days), with inflows increasing after 5 days within the alluvium and weathered bedrock. Inflows from the alluvium and weathered bedrock increase about 80 kL/day during this event. Groundwater inflow from the bedrock shows a continuing decline (associated with dewatering) up until day 20. After this time, recharge from the flood event slightly increases the groundwater inflow rate from the bedrock.

6.4.4 Flooding – 1 in 500 Year Event

Other consultants undertook predictive surface water flood modelling and the results are presented in Figure 32 and Figures 32a to 32d for a 1 in 500 year food event. The extent and stage height of flooding was included in a modelling scenario, simulated in 6 hour intervals by river cells covering the extent of the flooded area. After the peak flood event, floodwaters gradually receded over a 30 day period. The flooding scenario assumed that mining and dewatering have been occurring for 6 years, at which time the pit extends considerably into the alluvium and dewatering continues throughout the flood event.

Recharge (negative drawdown) plots for day 1, 5, 10, 12 and 15 are presented in Figure 33 and Figures 33a to 33d. They show moderate recovery of groundwater levels (up to 6 m) within the levee wall perimeter between days 5 to 15. Groundwater inflows into the pit (Figure 34) show a delayed response after the initial flood peak, with inflows increasing after 3 days within the alluvium and weathered bedrock. Groundwater inflows from the alluvium and weathered bedrock increase by about 550 kL/day during this event. Groundwater inflows from the bedrock show a continuing decline (associated with dewatering) up until day 10, when recharge from the flood event increases the flow rate.

6.4.5 Alluvium Cut-Off Trench

Scheduled Open-Pit Mining

A palaeochannel cut-off trench was simulated to determine the quantitative effects of placing an impermeable barrier on the southern bund wall perimeter on: (i) groundwater inflows into the pit; and (ii) the magnitude of drawdown. A 1,200 m long, 0.6 m wide cut-off trench was modelled across the McArthur River to cut-off groundwater flow into the pit area from the palaeochannel. The cut-off trench had a permeability of 0.000864 m/day and was installed from ground surface to the base of the palaeochannel.

Figures 35 to 38 show the development of the cone of depression with time and the associated groundwater level drawdown that occurs in the palaeochannel aquifer (layer 3 in the groundwater model) and in the fresh bedrock and faults (layer 5). Reduced drawdown is shown south of the cut-off trench compared to simulations without the trench (Figures 25 to 28).

Figure 39 shows estimated groundwater inflows for the alluvium cut-off trench scenario. Compared to the no-trench scenario, it shows similar groundwater inflow from bedrock sources and a small reduction of groundwater inflow from alluvium and weathered bedrock. Estimated groundwater inflow from the alluvium and weathered bedrock without the cut-off trench after year 20 is about 2,600 kL/day. Estimated groundwater inflow from alluvium with the emplacement of a cut-off trench after year 20 is about 2,250 kL/day; a 13% reduction in inflow. The effectiveness of the cut-off trench will be limited by the permeability of the weathered bedrock (allowing underflow), but more importantly by the groundwater inflow from the northern area of the pit as induced drawdown from the pit will also draw groundwater from the northern (downstream) portion of the palaeochannel. The diversion channel will re-direct surface water around the pit, however this will still supply recharge to the alluvium downstream of the pit and this groundwater will be drawn back towards the pit by the cone of depression caused by dewatering.

Flooding – 1 in 50 Year Event

Simulations of the 1 in 50 year flooding event as described in Section 6.4.3 were undertaken with the alluvium cut-off trench in place. Figures 40 and Figures 40a to 40d show similar recoveries in groundwater level (recharge) compared to the simulation without the cut-off trench (Figures 30 and 30a to 30d). Groundwater inflow associated with the flood event is presented in Figure 41. The increase of groundwater inflow associated with the flooding in the alluvium/weathered bedrock is similar to that of the simulation without the cut-off trench, at about 80 kL/day.

Flooding – 1 in 500 Year Event

Simulations of the 1 in 500 year flooding event as described in Section 6.4.4 were undertaken with the alluvium cut-off trench in place. Figures 42 and 42a to 42d show similar recovery in groundwater level compared to the simulation without the cut-off trench (Figures 33 and 33a to 33d). Groundwater inflow associated with the flood event is presented in Figure 43. The increase of groundwater inflow associated with the flooding in the alluvium/weathered bedrock is reduced compared to the scenario without the cut-off trench in place. The estimated increase in inflow to the pit with the trench in place is about 470 kL/day, a reduction of about 14% compared to simulations without the trench in place.

6.4.6 Groundwater Inflow Summary

A summary of the various modelling scenarios and associated groundwater response to dewatering of the McArthur River Pit are detailed in Table 9.

Table 9
Predictive Scenario Results - Maximum Estimated Inflows (kL/day)

Aquifer	**Mining Schedule (Year 17)**		**Flooding Simulation (Year 6)**			
			1 in 50 Year Event		**1 in 500 Year Event**	
	Without Cut-Off Trench Trench	**With Cut-Off Trench**	**Without Cut-Off Trench**	**With Cut-Off Trench**	**Without Cut-Off Trench**	**With Cut-Off Trench**
Alluvium/Weathered Bedrock	2,655	2,300	2,480	2,220	2,960	2,630
Bedrock/Faults	3,565	3,560	2,160	2,160	2,340	2,210
Total	**6,220**	**5,860**	**4,640**	**4,380**	**5,300**	**4,840**
Change	**-**	**470**	**220**	**90**	**740**	**540**

6.5 Potential Environmental Impacts Associated with Dewatering

6.5.1 Magnitude of Regional Drawdown

During Scheduled Open-Pit Mining

Based on the results of the groundwater modelling, bedrock/fault groundwater levels will be lowered significantly in the immediate area of the open-pit because of the groundwater abstraction required for mine dewatering. Most of this abstraction will occur from: (i) faults in both the fresh and weathered bedrock; and (ii) the permeable sections of the weathered bedrock (i.e. karst development in weathered dolomite).

By the end of mining, the depth to groundwater in the fresh bedrock/faults will be approximately 230 - 240 m – slightly deeper than the open-pit (ultimate depth 215 m) due to the required depth of dewatering bores. This will result in a total drawdown in the fresh bedrock/faults (model layer 5) of about 210 to 220 m below the initial static groundwater level.

However, the detailed distribution of drawdown in the bedrock/faults is complex and cannot be accurately represented by the model. Because of the generally low horizontal and vertical permeability of the bedrock surrounding the open-pit, the drawdown cone will only migrate significant lateral distances along the more permeable structures (faults) that intersect the pit. The unstructured fresh bedrock between the faults has a very low permeability and probably contains very little recoverable groundwater. Any groundwater in the unstructured fresh bedrock will drain slowly towards the faults, which will have lowered groundwater levels due to pumping. Therefore, there could be large areas of fresh bedrock in which groundwater levels are highly variable with very little drawdown and steep vertical hydraulic gradients. In-pit horizontal drains may be required to reduce pore pressures associated with slow-draining fresh bedrock.

Due to the resulting steep vertical hydraulic gradients in the fresh bedrock, the very large drawdown that occurs around the open pit will reduce vertically upwards, resulting in less drawdown in the upper sections of the fresh bedrock, the weathered bedrock and the alluvial sediments. Where the weathered bedrock is permeable and intersected by the faults, it will contribute groundwater flows to the faults during dewatering and groundwater levels will potentially decline. However, in any areas where faults and permeable weathered rock extend below major river channels they probably receive recharge from wet season streamflow, which will tend to limit the drawdown in these features. The modelling results indicate that the cone of depression migrates along the major fault systems in the bedrock during mining and model calibration suggests that the hydraulic parameters of the river alluvium (especially a large vertical permeability) have a significant effect in reducing drawdown in the upper weathered bedrock because of vertical leakage and the resulting recharge. To date, the most important fault system studied as part of the current work is the Mt Stubbs system (an important historical groundwater supply aquifer) that was tested by the pumping of MAC1P.

Drawdown caused by dewatering of the fresh bedrock/faults has the potential to lower groundwater levels in the superficial sediments around the pit and in the alluvium associated with both the current McArthur River channel and the palaeochannel. However recharge from surface water streamflow will probably significantly reduce this potential drawdown. Groundwater levels in the superficial sediments over most of the area (away from the major drainages) are already reasonably deep (10 to 15 m below ground surface) and in some areas, these sediments are largely unsaturated. Lowering of groundwater levels in these sediments, therefore, cannot have a significant environmental impact on vegetation as most flora in the area probably rely on shallow soil moisture (rather than the water table) for survival.

One of the most important potential impacts from groundwater level lowering is on dry season pools in the McArthur River. In the area of the Billabong pool ("Djirrinmini"), located in the current river channel, the model predicts that about 0.5 m of drawdown in the weathered bedrock and alluvium will occur after 25 years of mining. Although the river pools and alluvium are recharged by streamflow on a seasonal basis, this magnitude of drawdown has the potential to affect both the level and longevity of the pools, if the pools are dependent on groundwater during the dry season. The downstream end of the Billabong pool is located on low permeability weathered bedrock but its banks at the upstream end are in the alluvium. The low permeability bedrock and lateral leakage from the alluvium will assist in reducing any potential drawdown under the pool, caused by lowering of groundwater levels in the fresh bedrock/faults, by attenuating the upward migration of the drawdown. In addition, the pool appears to be located far enough from the pit to be on the edge of the cone of depression developed in both the palaeochannel sand and the weathered bedrock (Figures 28 and 28a).

Bores MAC4 and MAC5 are located near the Billabong. At the end of the 2004 dry season, the Billabong invert level was measured at 18.35 m AHD with a river level of 19.85 m AHD (1.5 m deep). Groundwater elevations at the same time in MAC4 and MAC5 (both in weathered bedrock) were slightly higher at 22.23 m AHD and 23.27 m AHD, respectively. This distribution of surface water and groundwater elevations suggests that groundwater is discharging laterally into both the river and the pool. The Billabong pool probably receives this groundwater discharge laterally, but it doubtful whether the pool receives any significant vertical recharge from the underlying low permeability bedrock.

A reduction in groundwater level of 0.5 m in both the weathered bedrock and alluvial aquifers can be expected to result in a reduced lateral flow into the waterhole. This may result in a decrease in the depth and extent of the waterhole at the end of the dry season prior to it being replenished in the following wet season.

It should be noted that the predicted drawdown of 0.5 m is a maximum which will not occur until after 25 years of mining. Prior to that, the drawdown will be less. During the initial years of mining, a program for monitoring groundwater levels in both the weathered bedrock and the alluvial aquifers at the waterhole should be implemented to confirm the accuracy of the predicted effects.

Alluvium Cut-Off Trench

In the McArthur River alluvium and palaeochannel alluvium closest to the proposed open-pit, the model predicts about 0.4 m of drawdown after 25 years of mining with the cut-off trench installed, slightly less than the scenario without the cut-off trench in place (near bores MAC4 and MAC5). The drawdown is associated mainly with bedrock/fault dewatering, inducing some vertical downward leakage from the alluvium to the lowered groundwater levels in the bedrock/faults.

6.5.2 Potential Impacts on Other Groundwater Users

Extensive groundwater level lowering associated with mine dewatering can cause drawdown in groundwater supply bores (stock wells, private domestic supply bores and industrial supply bores) in the surrounding area, depending on distance from the pit operations. Such drawdown can increase pumping lifts, cause reduction of available drawdown, reduce the pumping rates from bores and in extreme instances completely stop the supply of groundwater from a bore.

Based on current knowledge and a NT Government database search, other (non-Xstrata) groundwater bores in the mining area do not exist. However, if stock wells are located within the cone of depression resulting from the open-pit dewatering, reduced yields could occur. It is suggested that Xstrata incorporate any nearby stock wells into the groundwater monitoring network for the mining area.

6.5.3 Potential Impacts to Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of groundwater resources. For the purposes of defining ecosystem dependence on groundwater, groundwater is defined as that water, which has been below ground and would be unavailable to plants or animals were it to be abstracted by pumping. Ecological water requirements are defined as the water regime needed to maintain ecological values of water dependent ecosystems.

Towards the end of the dry season, the Djirrinmini Waterhole becomes a GDE as river flows reduce and it depends on groundwater to assist in maintaining water levels. The modelling results discussed in Section 6.5.1 indicate that due to mine dewatering, a reduction in groundwater level in both the weathered bedrock and alluvial aquifers can be expected to result in a reduced lateral flow of groundwater into the waterhole. This may result in a decrease in the depth and extent of the waterhole at the end of the dry season prior to it being replenished in the following wet season. The biological implications of this are reported in the EIS for the open cut project.

6.5.4 Potential Reduction in Streamflow

If surface water flow in major rivers is in hydraulic connection with groundwater, there is a potential to reduce annual streamflow if groundwater levels under drainages are significantly lowered. Obviously during peak flooding periods in the wet season, this is not an issue, however at low-flow times early or late in the wet season significant loss to groundwater recharge could alter flow amounts and duration.

The loss of surface water flow into underlying aquifer zones (mainly into alluvium, palaeochannel alluvium or fault zones) is directly proportional to:

- The difference in head between the groundwater level and the river level;
- The vertical permeability of the strata underlying the river channel; and
- The thickness of the strata between the base of the river and the top of the underlying aquifer.

The vertical flow per unit area of river channel is therefore:

$$Q' = K' (dh/dl); \text{ where:}$$

K' = vertical permeability (m/day);

dh = head difference (m); and

dl = thickness of strata (m) between the river bed and the underlying aquifer.

In order to determine the total leakage, Q' is multiplied by the surface area of the alluvium.

The groundwater model can automatically calculate such leakage through the river cell and zone budget facilities. Based on the modelling results, the initial loss in the first year of dewatering to the strata underlying the river (in the immediate mining area) is 60 kL/day, by the end of mining the drawdown in the bedrock under the river in the same area has caused an increase of vertical leakage to 170 kL/day.

Based on the hydrology of the mine site area, the historical flow during the wet season in the McArthur River varies significantly (Figure 11). The increase in leakage (170 kL/day) to aquifers underlying the river is obviously insignificant during the height of the wet season. During September, the river flow has declined to about 23,000 kL/day (median value) but the increase in vertical leakage is still less than 1 %.

6.5.5 Groundwater Disposal

Based on the modelling, the order-of-magnitude groundwater inflows to the open-pit range from 420 to 6,220 kL/day during the mining period. This water will require disposal or use of some type.

The exact quality of this discharge is unknown, but it will probably be a “blend” of the different bedrock and alluvial groundwaters. The discharge will probably: (i) be moderately saline with a TDS content of 1,000 to 4,000 mg/L and a neutral pH; (ii) have a very high hardness (derived from carbonate bedrock such as dolomite) (iii) be a (Na-Ca-Mg)-Cl type with significant concentrations of HCO_3 and SO_4; and (iv) have a significant metal content.

The disposal of water of this quality to the environment could be problematic without treatment or a temporary storage facility, depending on the regulatory requirements. A significant amount of environmental monitoring could be required as part of the licensing of such disposal. Therefore, using as much of this water as possible in mineral processing and dust suppression would be advantageous to reduce potential environmental impacts and the costs of disposal.

6.5.6 Induced Leakage from Tailings Storage Facility

The modelling results indicate that the drawdown cone associated with open-pit dewatering will not migrate as far as the TSF. Based on this result, the drawdown resulting from the dewatering should not increase the leakage of contaminated tailings dam water into the subsurface.

6.5.7 Groundwater and Environmental Monitoring Requirements

The current groundwater monitoring network will need to be expanded to meet environmental licensing guidelines associated with the dewatering.

Additional requirements for groundwater monitoring could include:

- Incorporation of selected stock wells into the monitoring network.
- Monitoring fluctuations in groundwater levels adjacent to Djirrinmini Waterhole.
- Monitoring drawdown effects around the open cut to assess the efficiency of the dewatering system.

Environmental monitoring requirements could also increase because of open cut dewatering. Monitoring of identified GDEs may be required to assess any impacts of the dewatering system, especially in areas where a lowered water table could occur. Baseline studies, annual environmental assessments, and flora and fauna surveys could be required.

Based on the results of this study, the pertinent conclusions and recommendations are summarised below.

7.1 Conclusions

- A groundwater drilling and testing program has been completed at MRM to assist in designing a groundwater flow model to predict the potential environmental impacts of proposed open-pit dewatering. This program has helped to elucidate the hydrogeological characteristics of: (i) fault zones around the open-pit area; and (ii) the alluvial deposits (present day and palaeochannel) associated with the McArthur River.

- The hydrogeology of the area is complex and groundwater occurrence away from the mining area is largely unknown. While the groundwater model has been designed to take account of the significant hydrogeological features in the mining area, regional groundwater flow and occurrence have been based only on regional geology. This includes the modelling of major faults and the occurrence of a palaeochannel, sub-parallel to the present-day channel of the McArthur River. There are presumably permeable secondary structures away from the mining area; such as faults shear zones, fractures and karst; which have not been included in the model.

- Because of the lack of regional groundwater data, the groundwater model is only approximate but can be used to obtain order-of-magnitude estimates of groundwater level lowering resulting from pit dewatering. In addition, calibration of the model has only been based on two aquifer tests, each with one or two observation bores, and the results of the model must therefore be considered only as approximate.

- The modelling results indicate that open cut dewatering will lower groundwater levels in the mining area, as described below.

  – In the fresh bedrock, the drawdown migrates away from the pit along permeable structures, such as faults, and results in up to 1 m of drawdown in these structures at distances of up to 2.3 km. However, the lateral extent of the cone of depression in the fresh bedrock/faults is reduced by vertical groundwater leakage from overlying strata, thus reducing the area of potential impact.

  – In the non-structured, low permeability, fresh bedrock the drawdown does not move far from the pit and large drawdowns only occur within 100 m of the open cut.

  – The pit dewatering also causes drawdown in the alluvium, via groundwater leakage from the alluvium into permeable structures in the weathered and fresh bedrock in which significant drawdown has occurred. Modelling results suggest that about 0.5 m of drawdown occurs under a 2 km reach of the McArthur River south of the open-pit. A Billabong pool is in this area and by the end of mining the projected drawdown (about 0.5 m). This may result in a decrease in the depth and extent of the pool at the end of the dry season prior to it being replenished in the following wet season.

- Theoretically, significant groundwater level drawdown under the McArthur River has the potential to reduce the relatively small streamflow during the latter part of the wet season. However, modelling shows that at the end of the dry season when river flows are at their lowest vertical leakage is less than 1 % of median flow rates.

- Because of the relatively poor quality of the dewatering discharge, the disposal of this discharge may be problematic, depending on regulatory requirements. Therefore, using as much of this water as possible in mineral processing and dust suppression would be advantageous to reduce potential environmental impacts and the costs of disposal.

- There will be a requirement for greater groundwater and environmental monitoring during (and perhaps after) the operation of the open-pit. Examples include monitoring at: (i) stock wells; (ii) significant environmental locations: and (iii) at regional locations around the open cut into the monitoring network. These additional facilities will be used to assess environmental impacts and dewatering system efficiency.

- Modelling simulations have indicated that 1 in 50 year and 1 in 500 year flooding events in the McArthur River have only a very small influence on the quantities of groundwater inflows to the open cut. Surface water recharge from such events is limited by the vertical permeability of the superficial deposits in the area.

- Based on modelling results, the use of a palaeocahnnel cut off trench to reduce groundwater inflows to the open cut appears questionable due to the relatively low reductions in inflow when simulated. For the cut off trench to be effective it needs to be keyed through the weathered bedrock to substantially reduce groundwater inflows.

7.2 Recommendations

- As more groundwater and ecological information becomes available in the future, the groundwater model should be refined, updated and re-run. This will allow the potential environmental impacts of the dewatering to be better quantified and will ensure that the model will be suitable to predict the required pumping quantities for future pit dewatering.

- In order to minimise environmental impacts and costs, dewatering discharge should be used to meet process water and dust suppression requirements.

- As part of the open cut dewatering system, additional groundwater and environmental monitoring will be required.

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URS, 2003, McArthur River Mine Expansion – Estimated Groundwater Inflows to Open Pit. Unpublished report to MIM Holdings Limited, Ref 598-F5695.0, May 2003.

URS Australia Pty Ltd (URS) has prepared this report for the use of Xstrata PLC and Macarthur River Mining Pty Ltd in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 27 August 2004.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 30 September 2004 and 29 April 2005 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The borehole logs indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of conditions as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

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Prep. By	CMAC	14 Oct '04
Chk'd By	RIJV	14 Oct '04
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

DRILLING OF BORE MAC1P

Plate 1

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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

AIRLIFTING BORE MAC1P

Plate 2

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Revision No.	1	

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

REGIONAL LOCALITY PLAN

Figure 1

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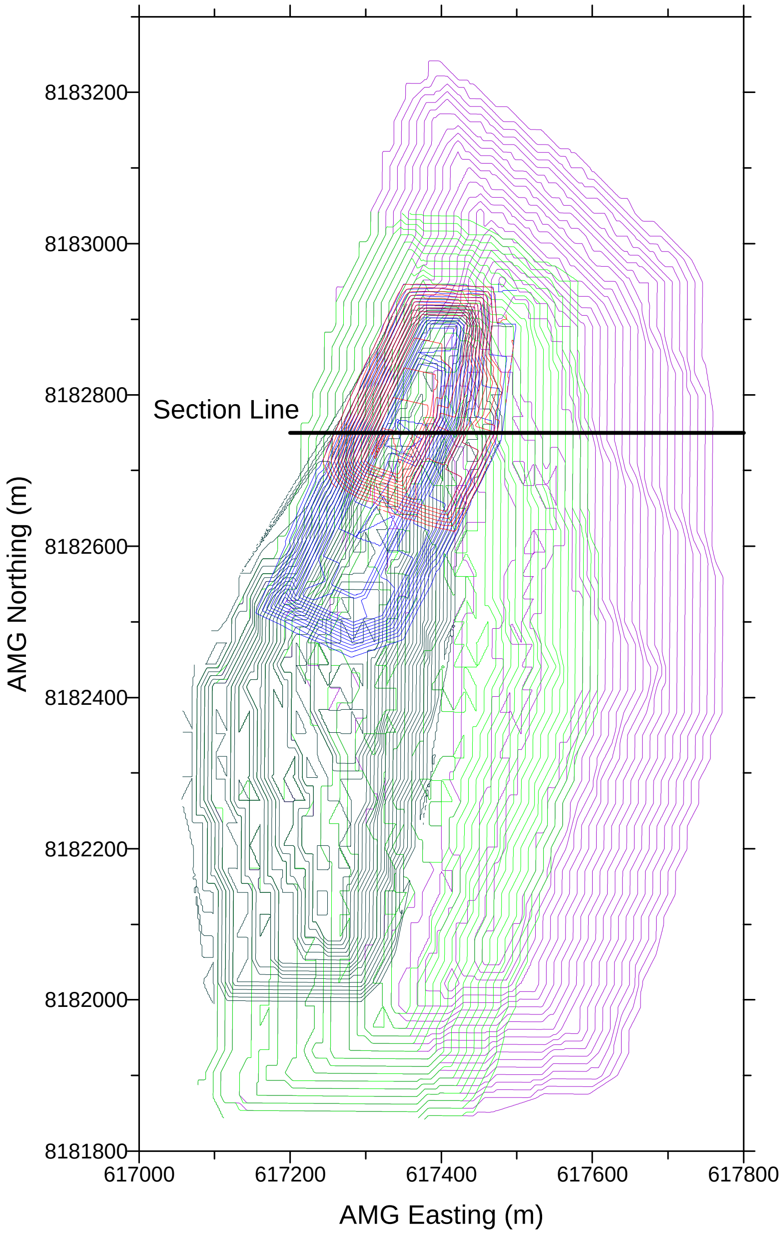
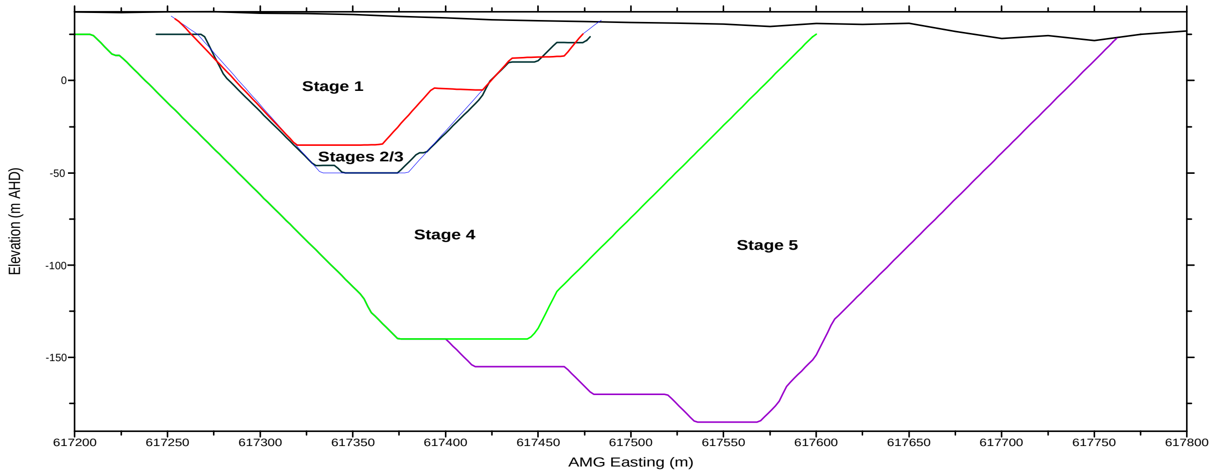
Figure 1.srf





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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

PROPOSED OPEN PIT MINING PLAN

Figure 2

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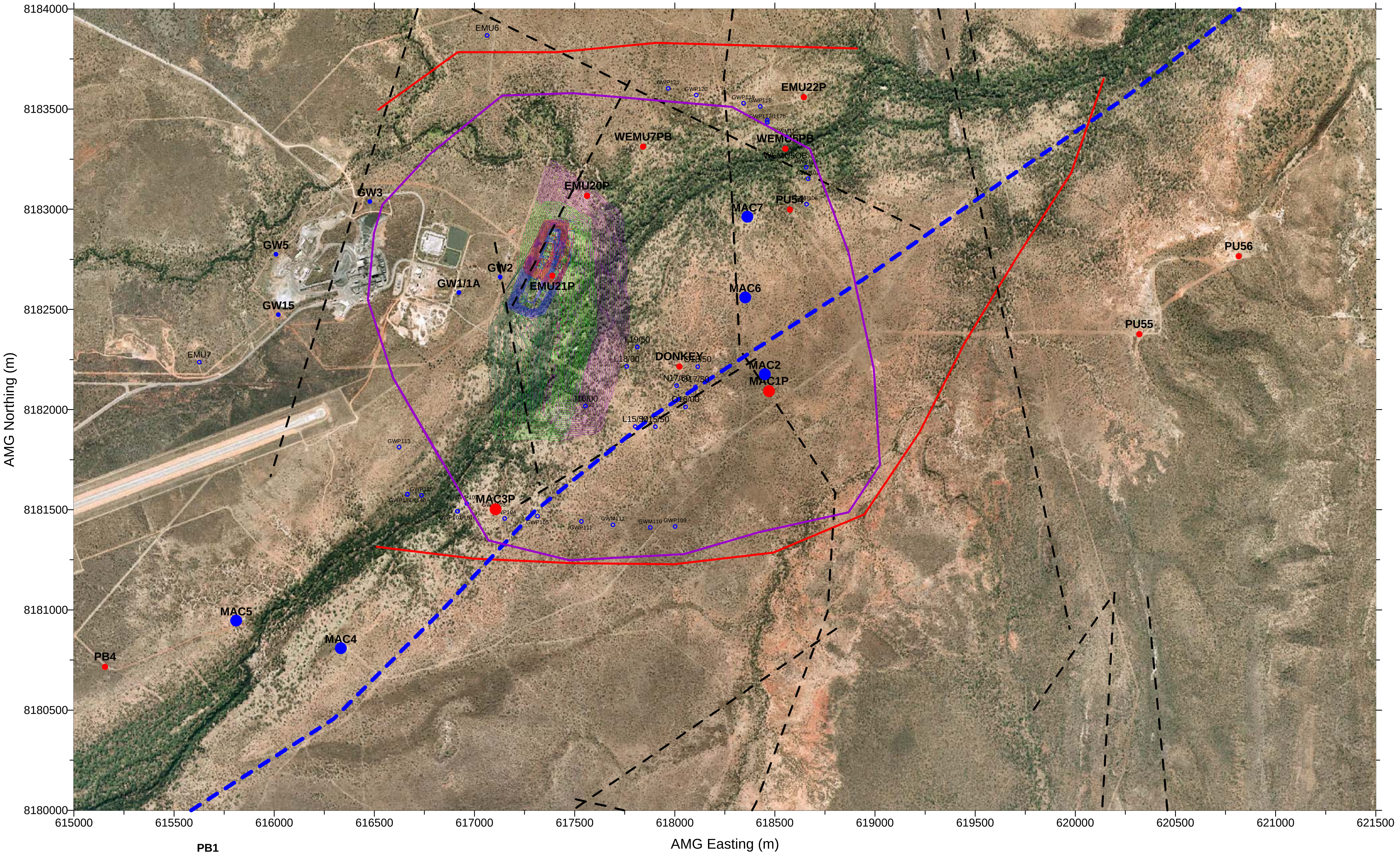

GW1 Existing Monitoring Bore

MAC4 ● New Monitoring Bore

Levee Wall

Channel

Faults (Approx)

PB1 Existing Production Bore

MAC1P ● New Production Bore

WEMU8 ○ Groundwater Exploration Bore

Palaeochannel (Approx)

0 500 1000m

Scale 1: 20,000

AGD 84

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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER DRILLING AND TESTING PROGRAM

Figure 3

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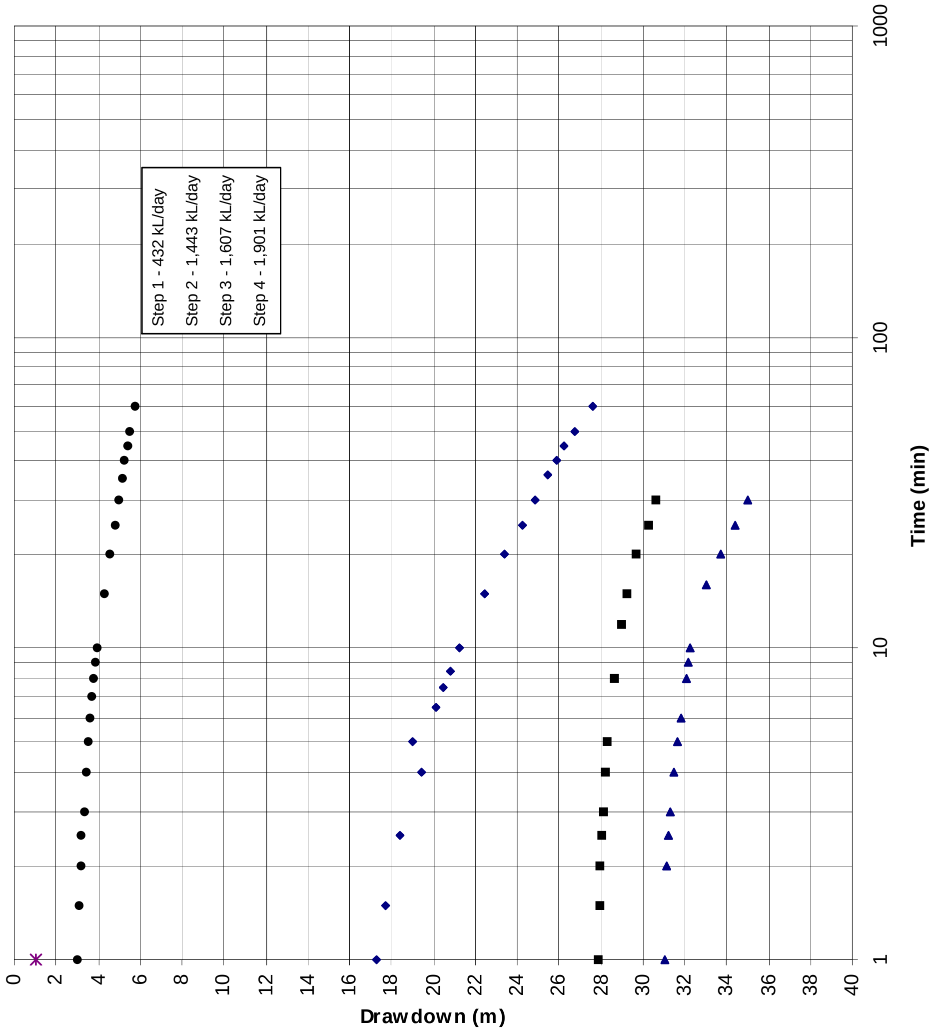
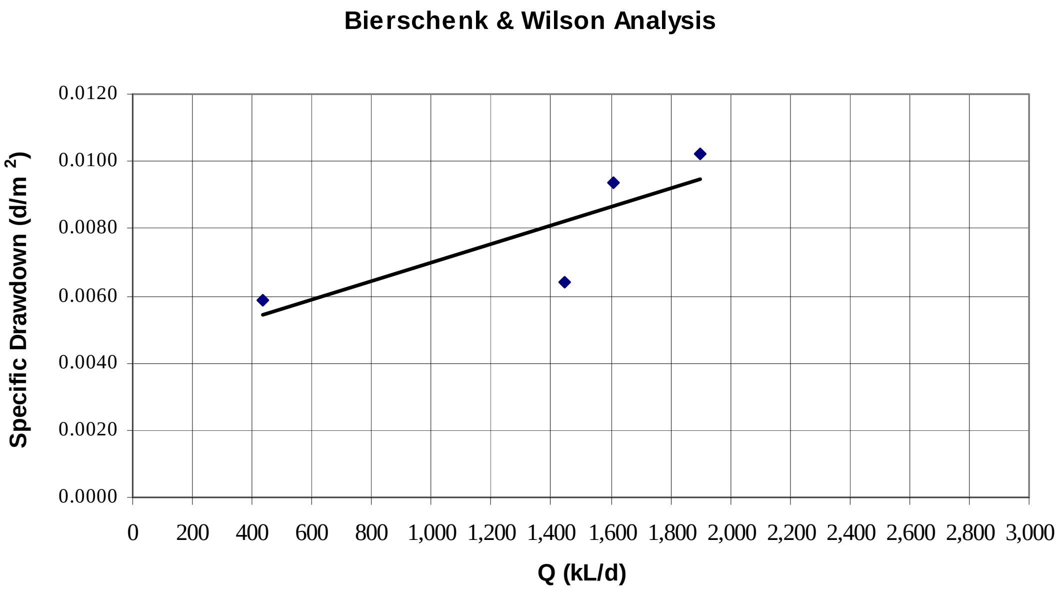
Figure 3.srf





Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		1

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAC1P BORE STEP - DRAWDOWN TEST

Figure 4

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Figure 4.srf

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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAC1P CONSTANT - RATE TEST No.1

Figure 5

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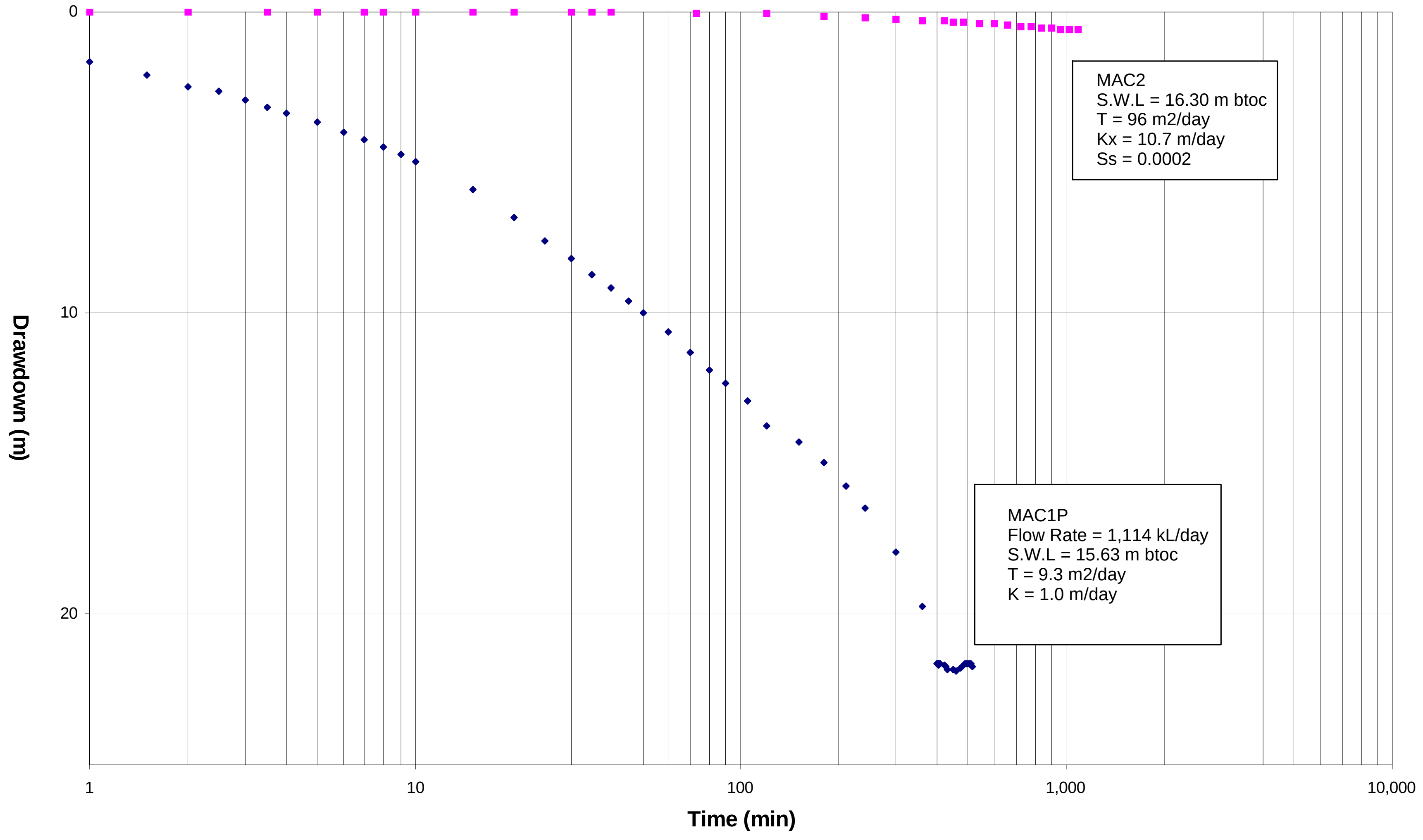

Figure 5.srf

Figure 6.srf

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Prep. By	CMAC 19 Apr '05
Chk'd By	RIJV 21 Apr '05
Revision No.	1

MAC1P CONSTANT - RATE TEST No.2

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

URS

Figure 6

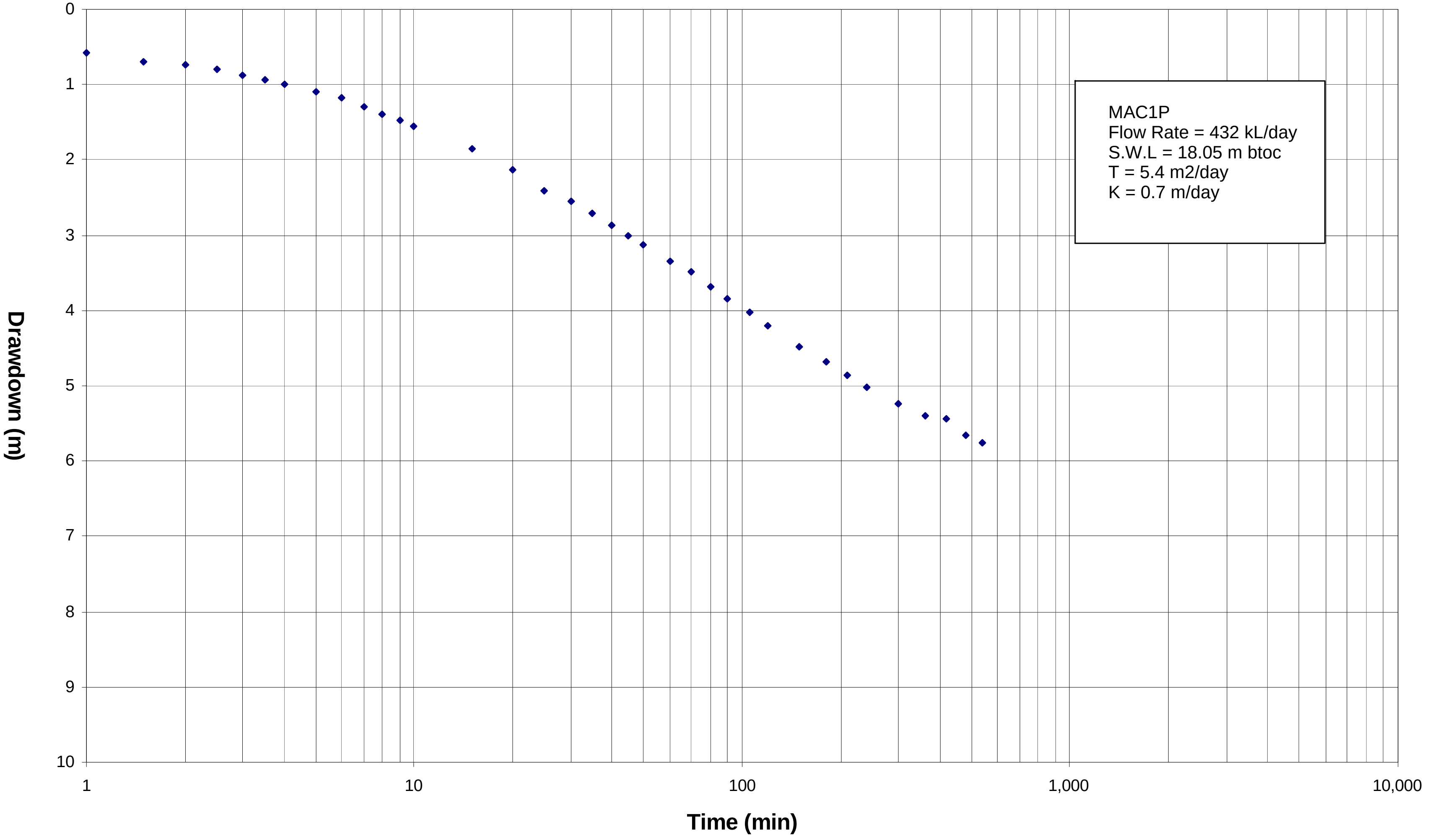

Figure 7.srf

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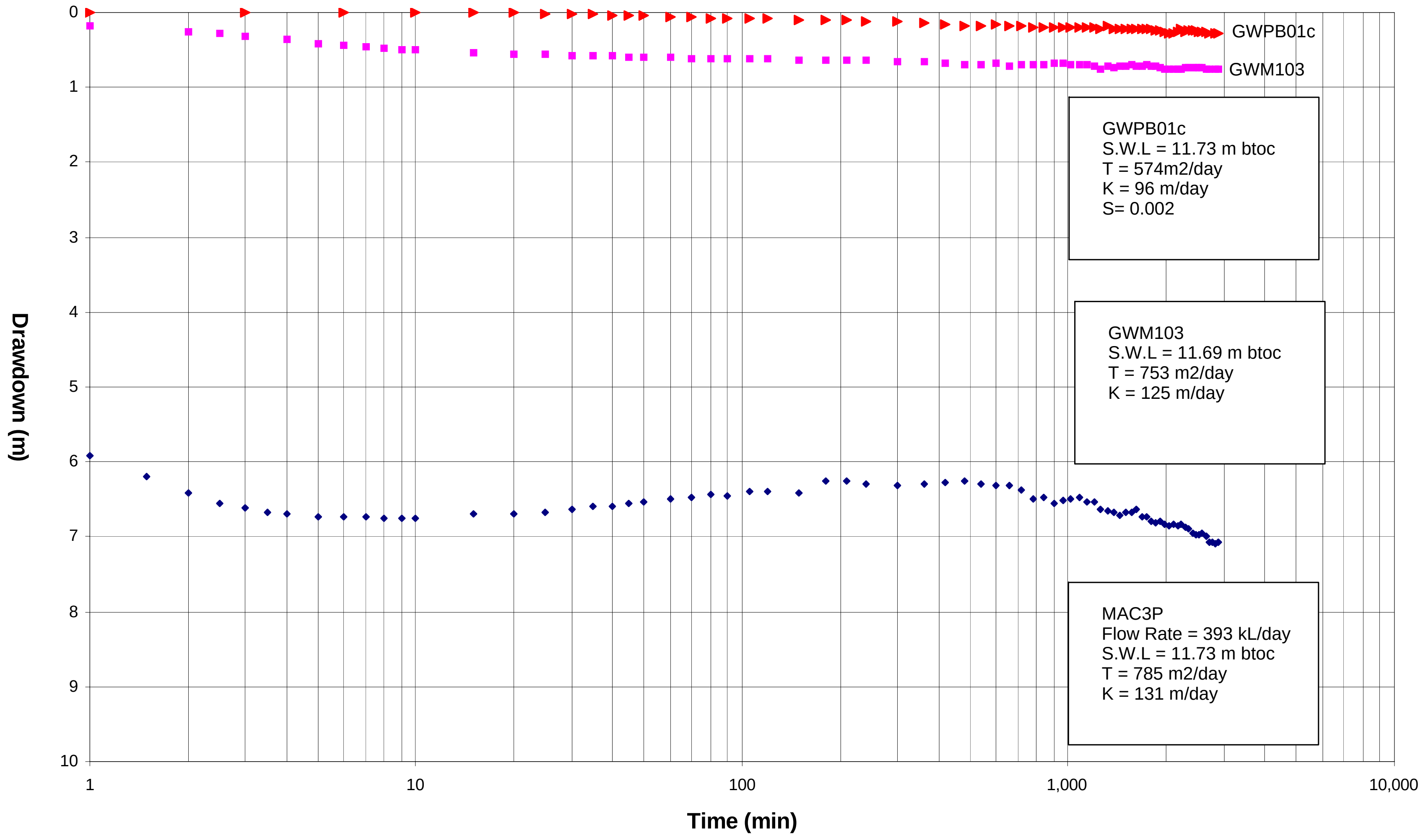
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAC3P CONSTANT - RATE TEST

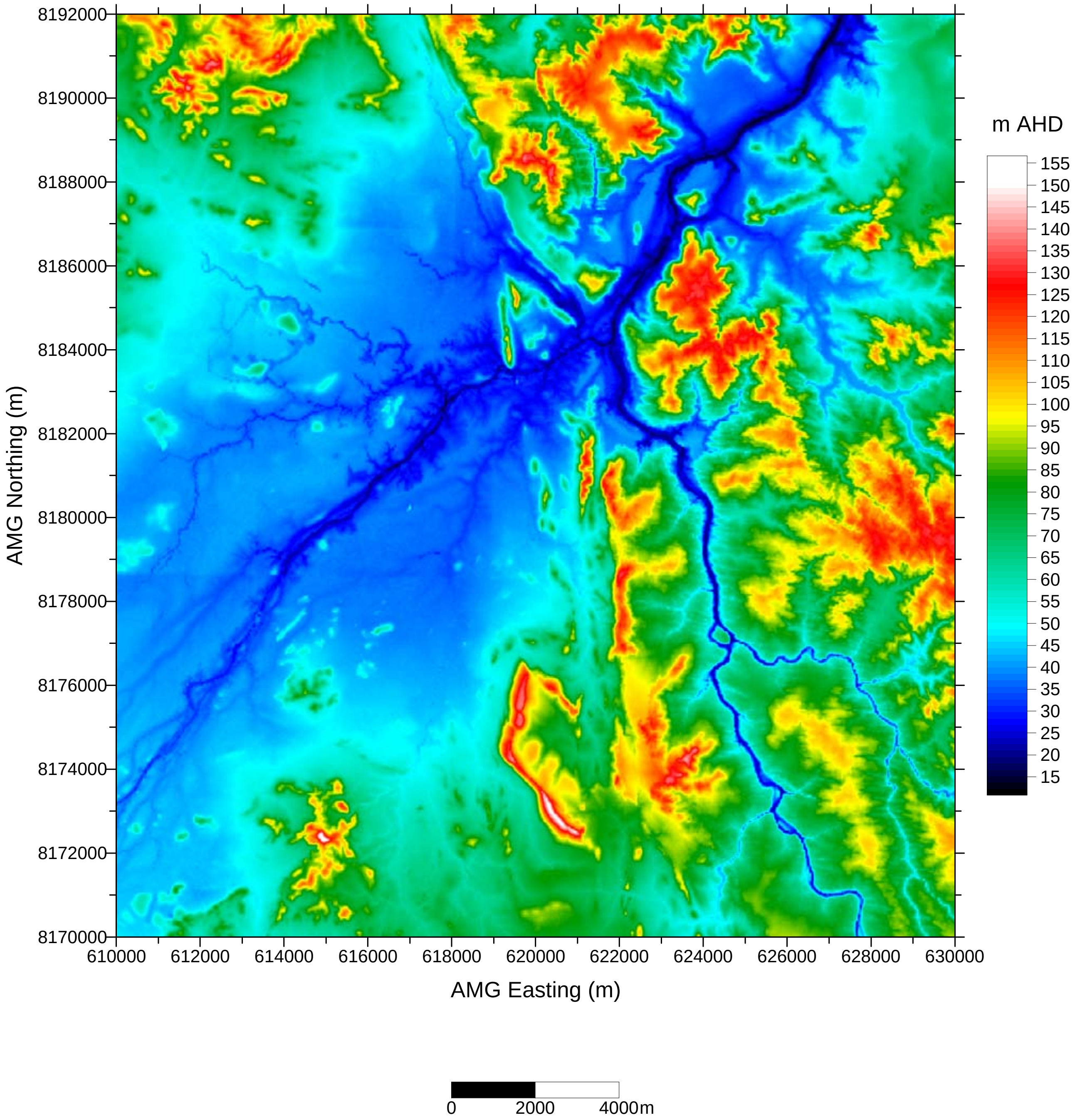
Figure 7



GWPB01c
S.W.L = 11.73 m btoc
T = 574m2/day
K = 96 m/day
S= 0.002

GWM103
S.W.L = 11.69 m btoc
T = 753 m2/day
K = 125 m/day

MAC3P
Flow Rate = 393 kL/day
S.W.L = 11.73 m btoc
T = 785 m2/day
K = 131 m/day



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

REGIONAL TOPOGRAPHY

Figure 8

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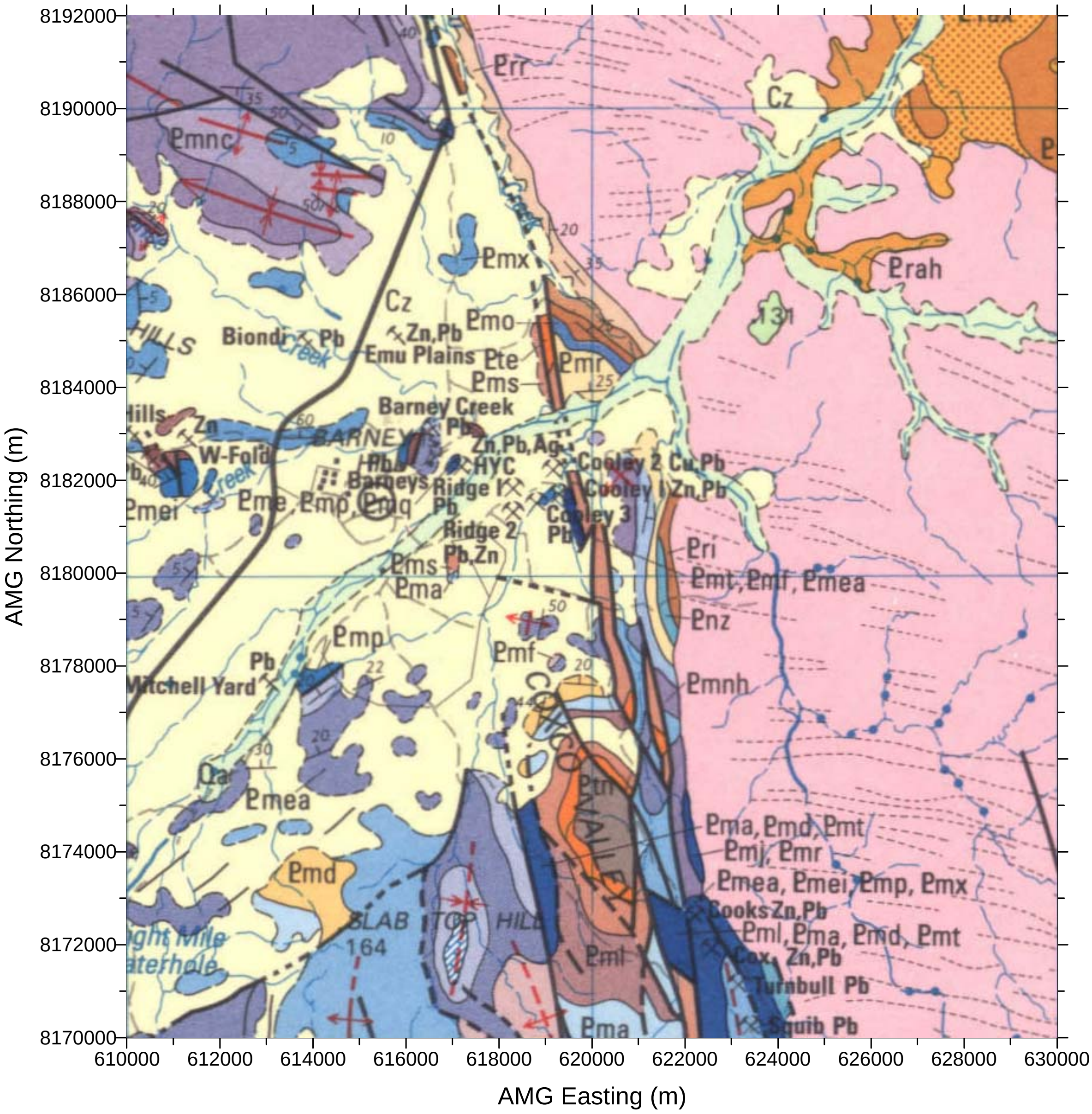
Figure 8.srf



Source: NTGS 1991, Bauhinia Downs
1:250,000 Map Sheet SE53-2

0 2000 4000m

Scale 1: 150,000

AGD 84

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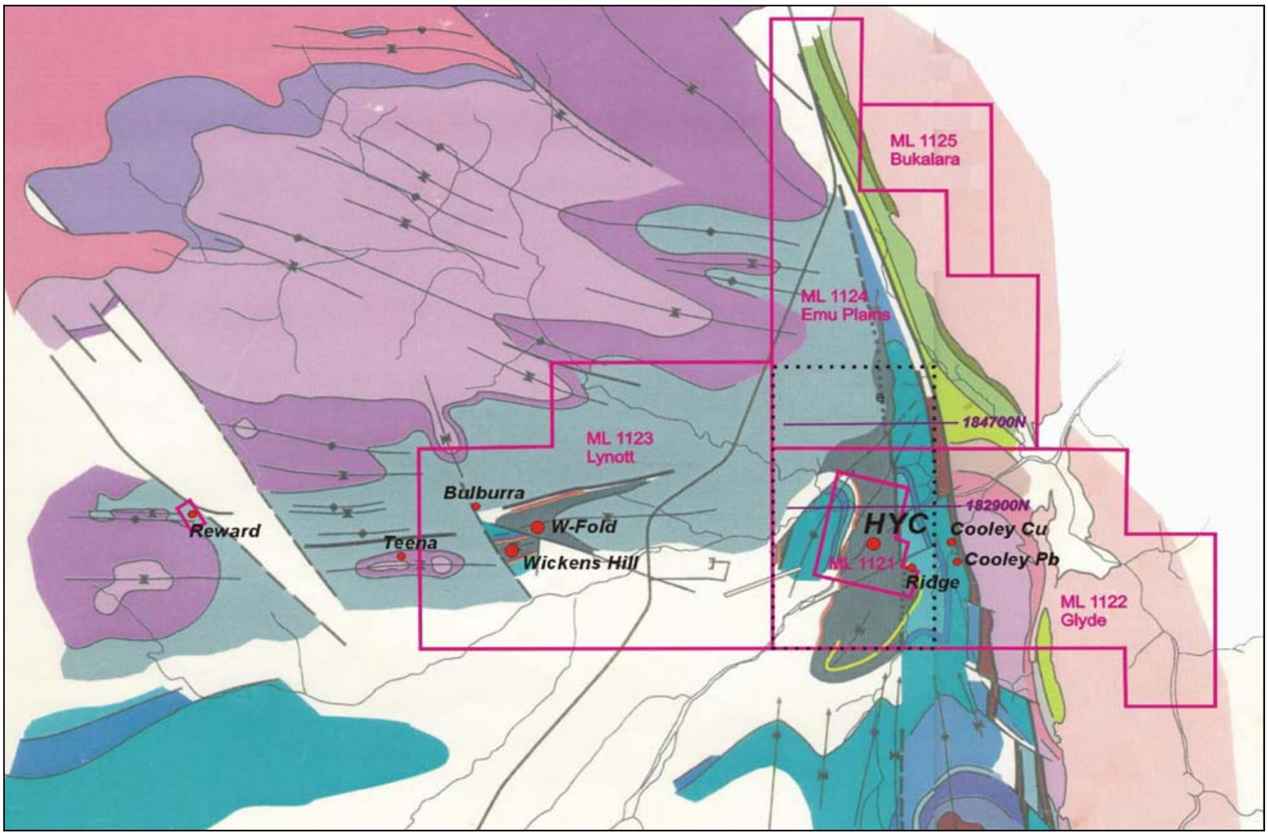
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

REGIONAL GEOLOGY

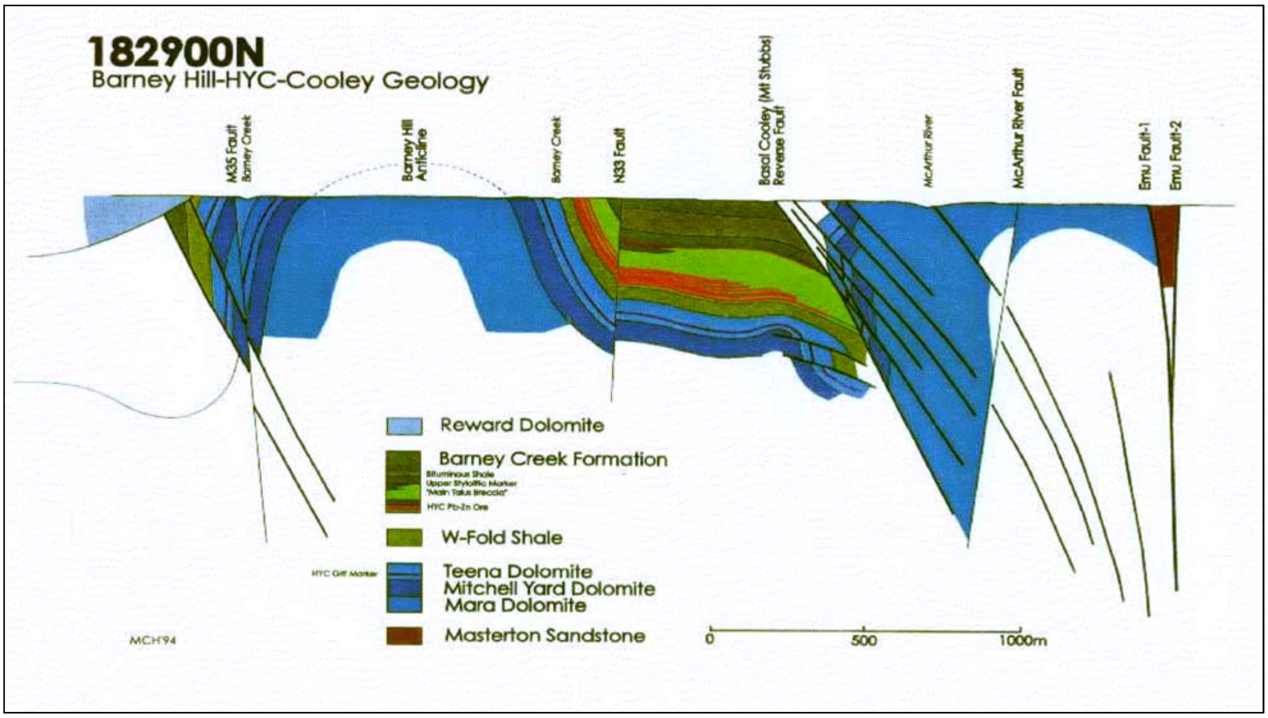
Figure 9

URS

McARTHUR RIVER GEOLOGY - PLAN VIEW



McARTHUR RIVER GEOLOGY - SECTION VIEW



Job No.	42905628	
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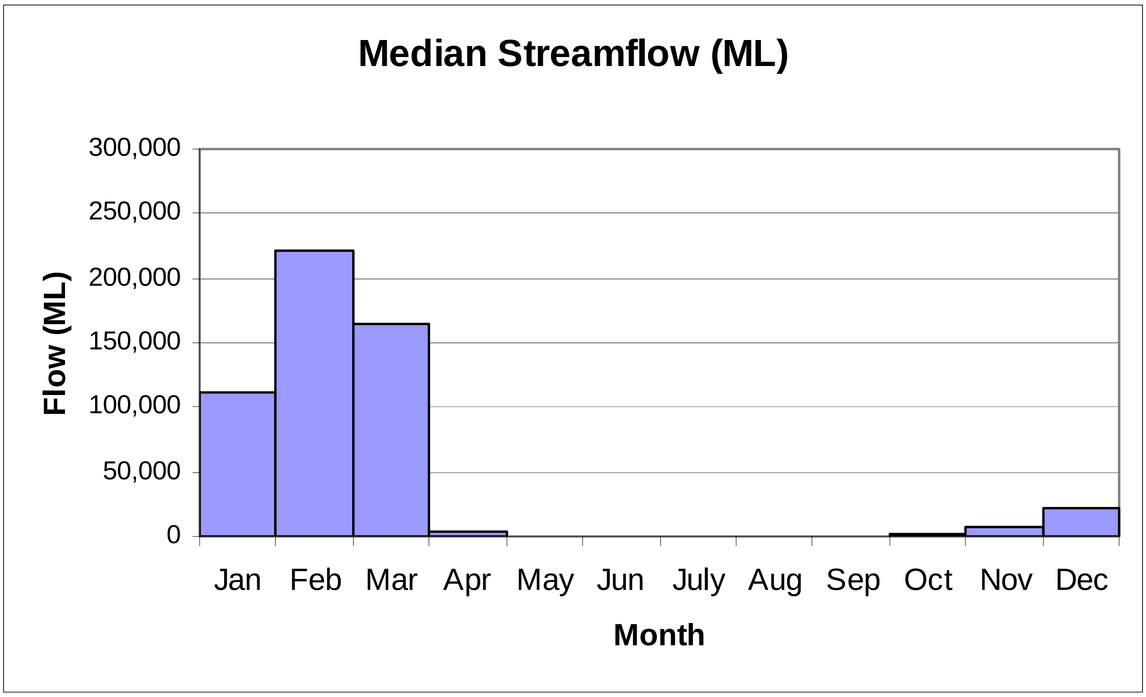
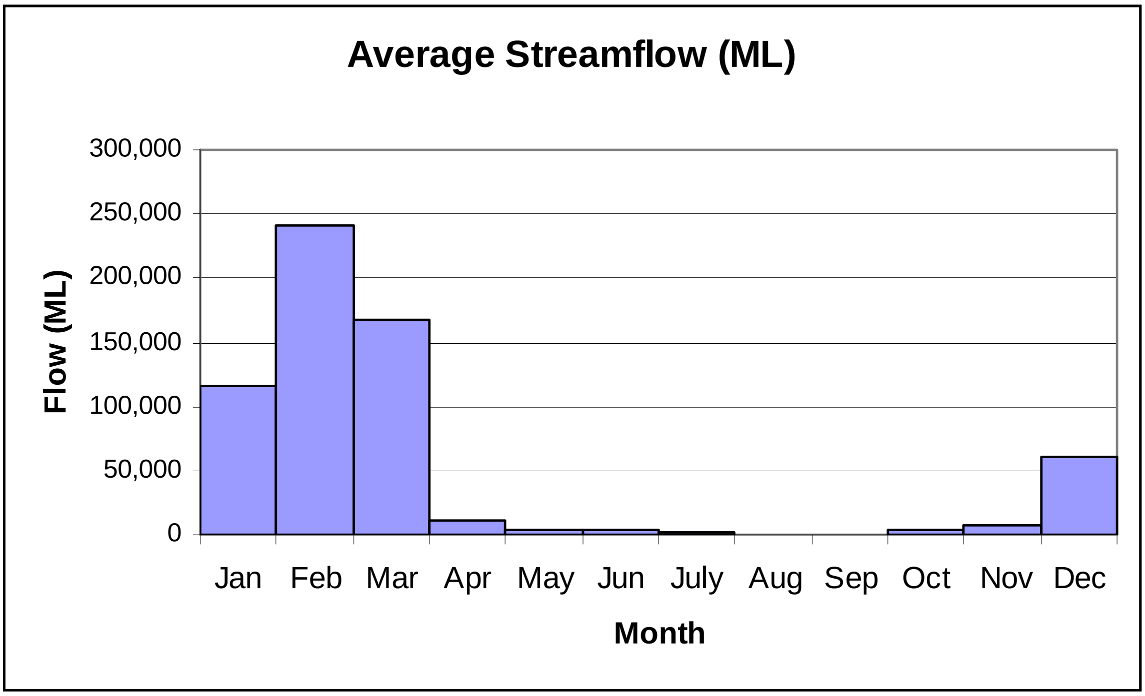
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

McARTHUR RIVER GEOLOGY

Figure 10

URS





McArther River at the mine Flow Weather Stn G9070132 Stn 014704

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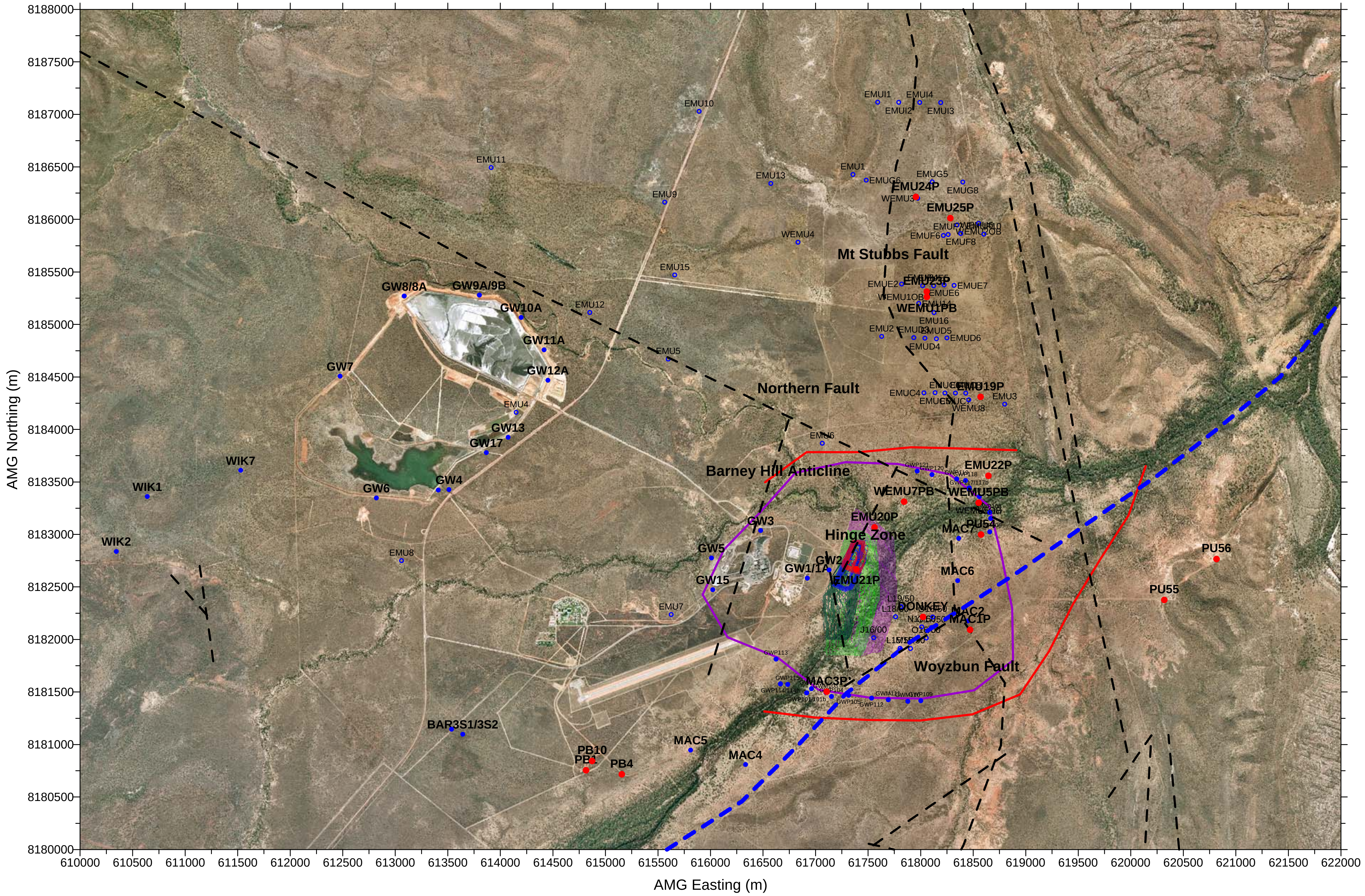
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

TYPICAL McARTHUR RIVER STREAMFLOW

Figure 11

URS



GW1 Monitoring Bore

PB1 Production Bore

Levee Wall

WEMU8 Groundwater Exploration Bore

Diversion Channel

Palaeochannel (Approx)

Faults (Approx)

0 1000 2000m

Scale 1: 40,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.	1	

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

REGIONAL GROUNDWATER PRODUCTION & MONITORING BORES

Figure 12

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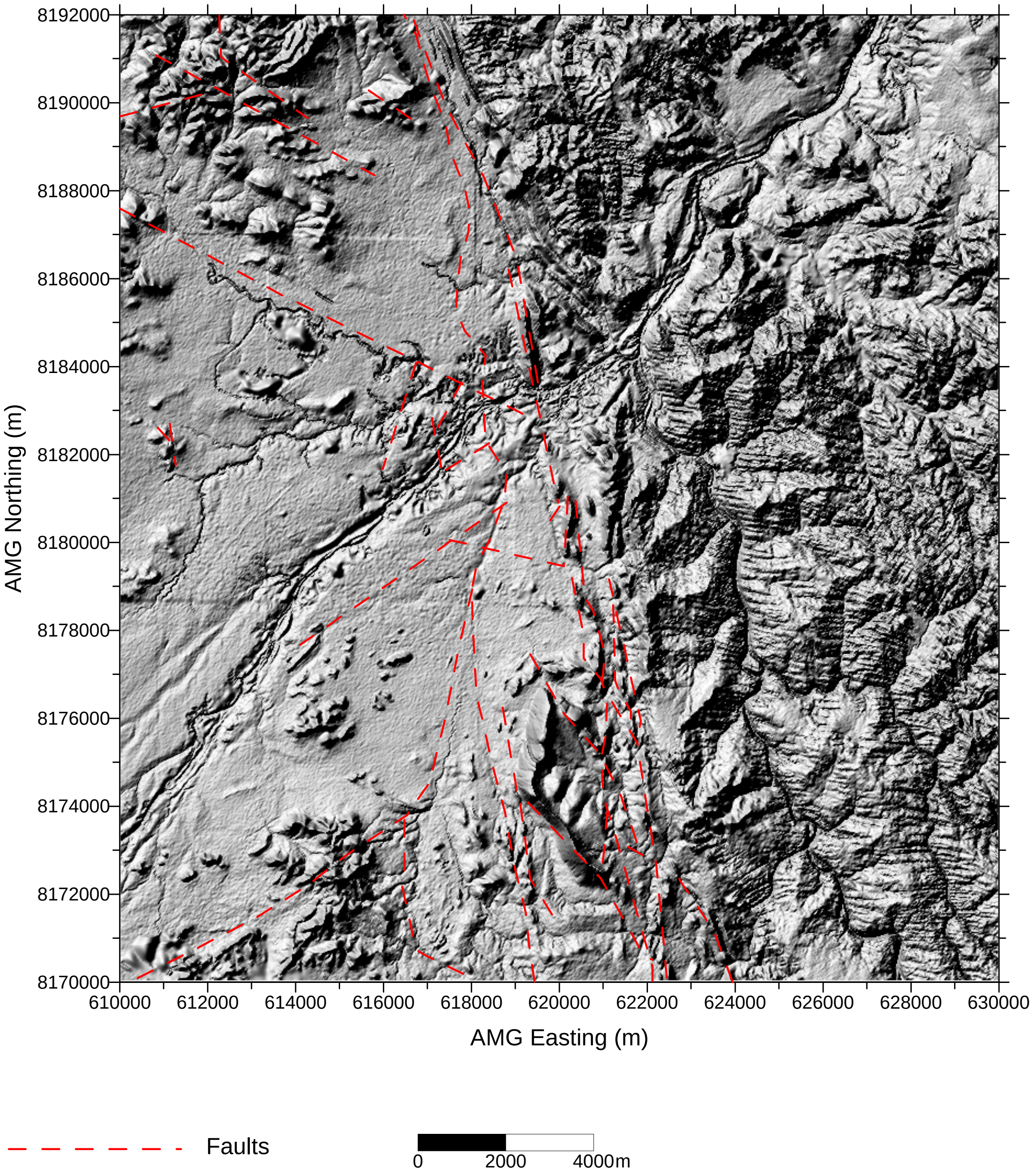
Figure 12.srf



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SHADED RELIEF TOPOGRAPHY WITH REGIONAL FAULTS

Figure 13

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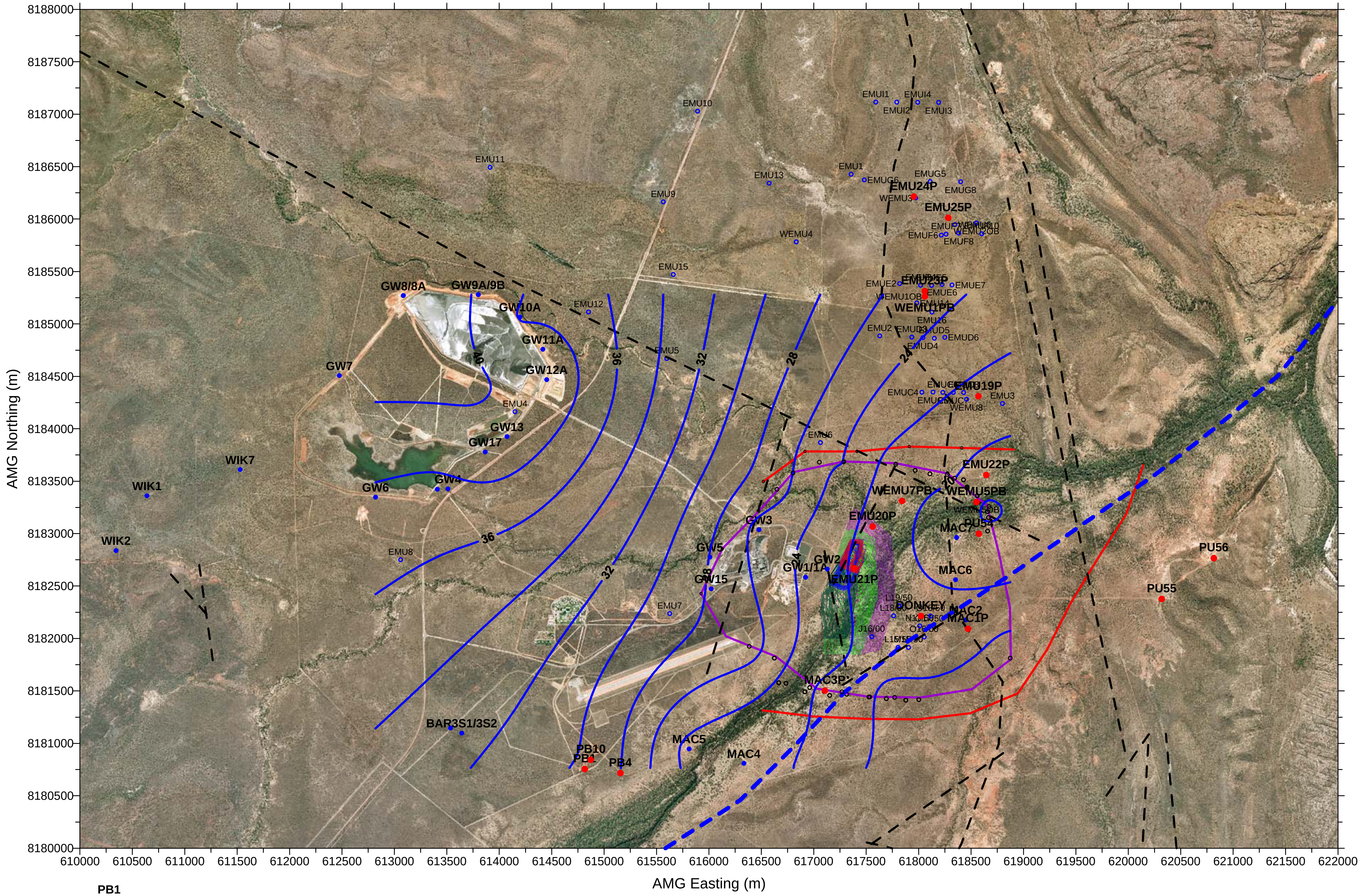
Figure 13.srf



GW1 ● Monitoring Bore

PB1 ● Production Bore

Levee Wall

WEMU8 ○ Groundwater Exploration Bore

Channel

Palaeochannel (Approx)

Faults (Approx)

Groundwater Level (m AHD)

° Geotechnical Hole

0 1000 2000m

Scale 1: 40,000

AGD 84

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Prep. By	CMAC	19 Apr '05
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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

REGIONAL GROUNDWATER LEVELS - END OF DRY SEASON 2004

Figure 14

URS

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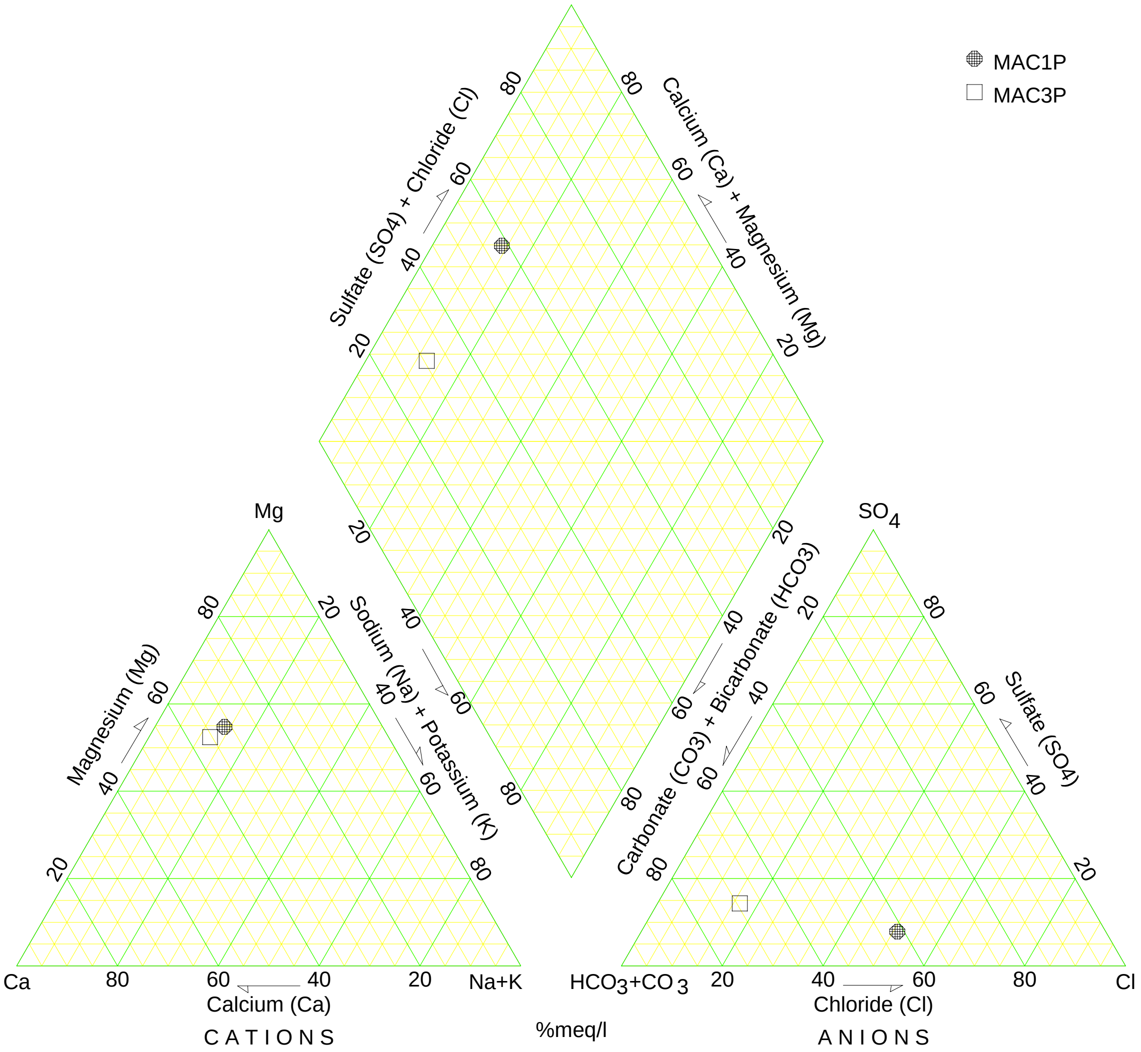
Figure 14.srf

Piper Diagram



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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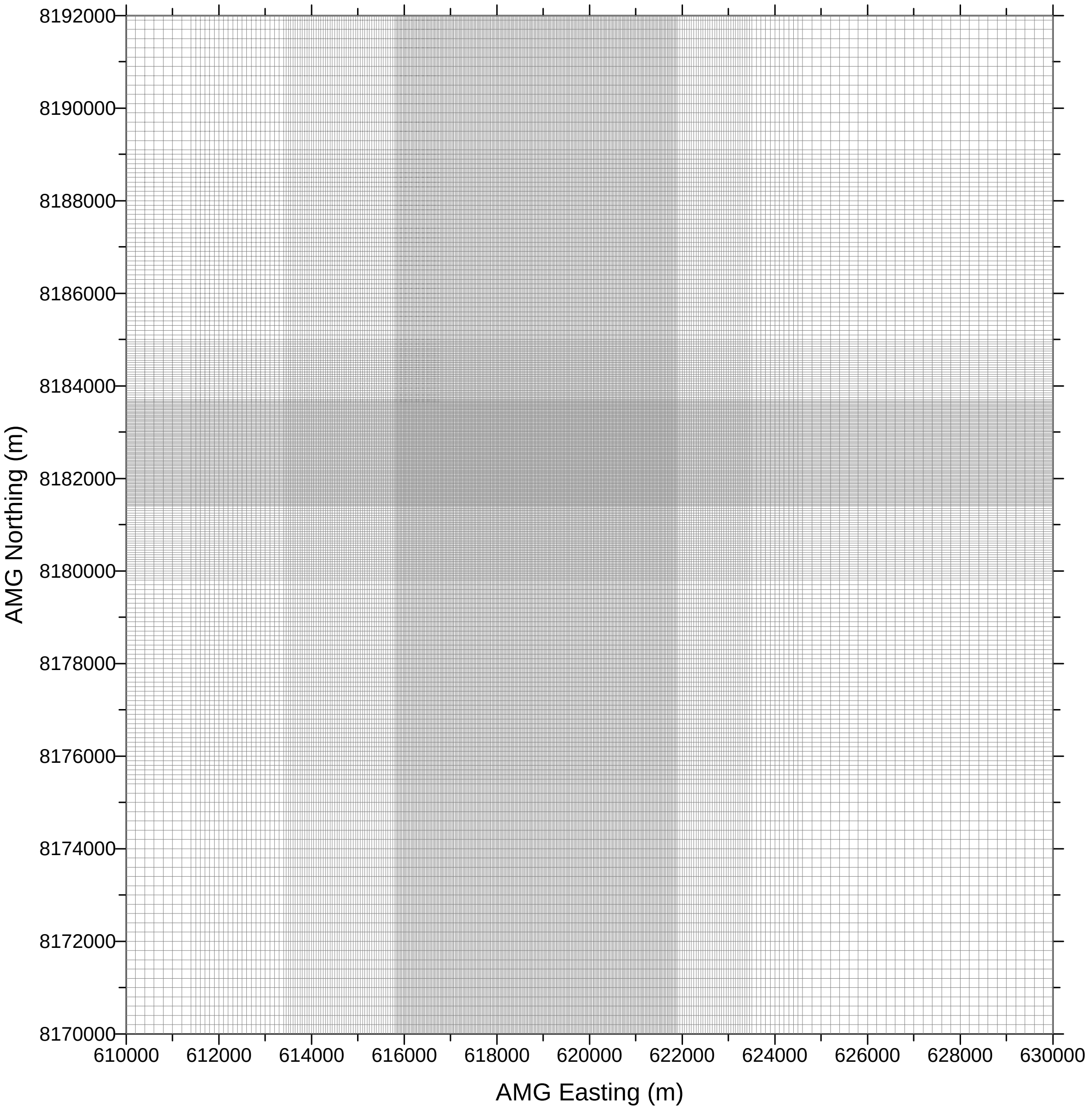
Revision No.	1	

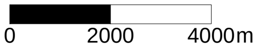
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER CHEMISTRY

Figure 15

URS





Scale 1: 150,000

AGD 84

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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MODEL GRID

Figure 16

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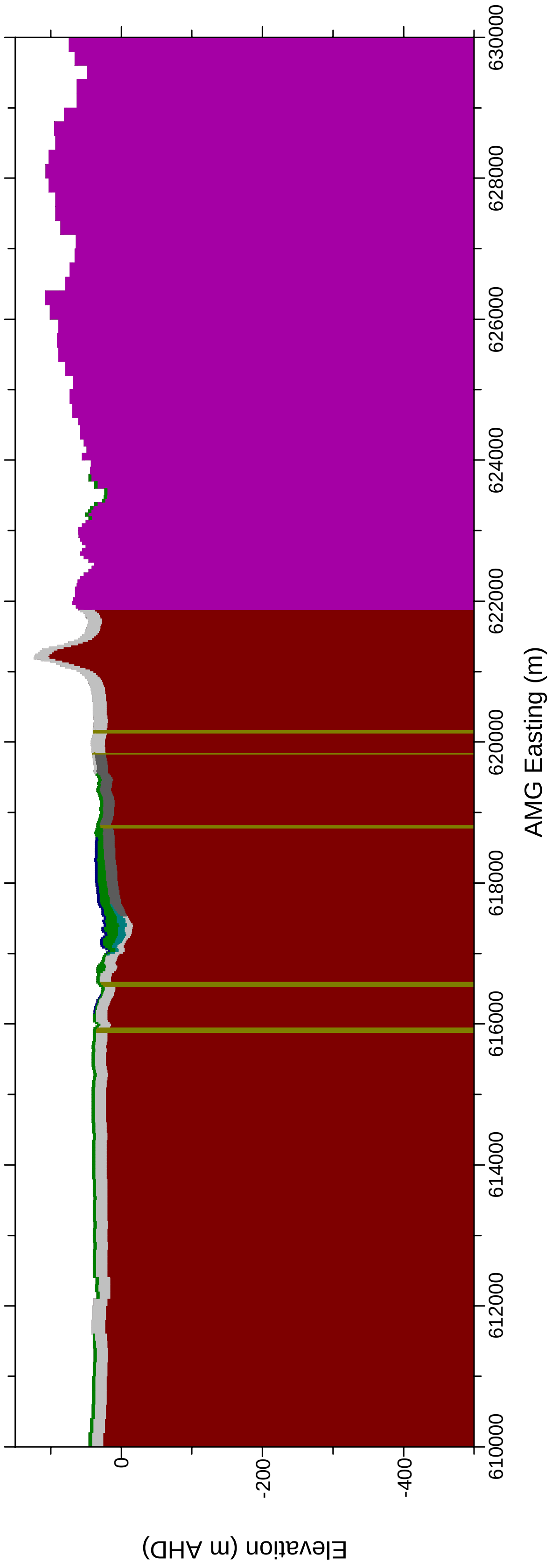
Figure 16.srf



Cross Section (East-West) taken through production bore MAC3P

Job No.	42905628	
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Revision No.		1

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MODEL CROSS SECTION (REGIONAL)

Figure 17

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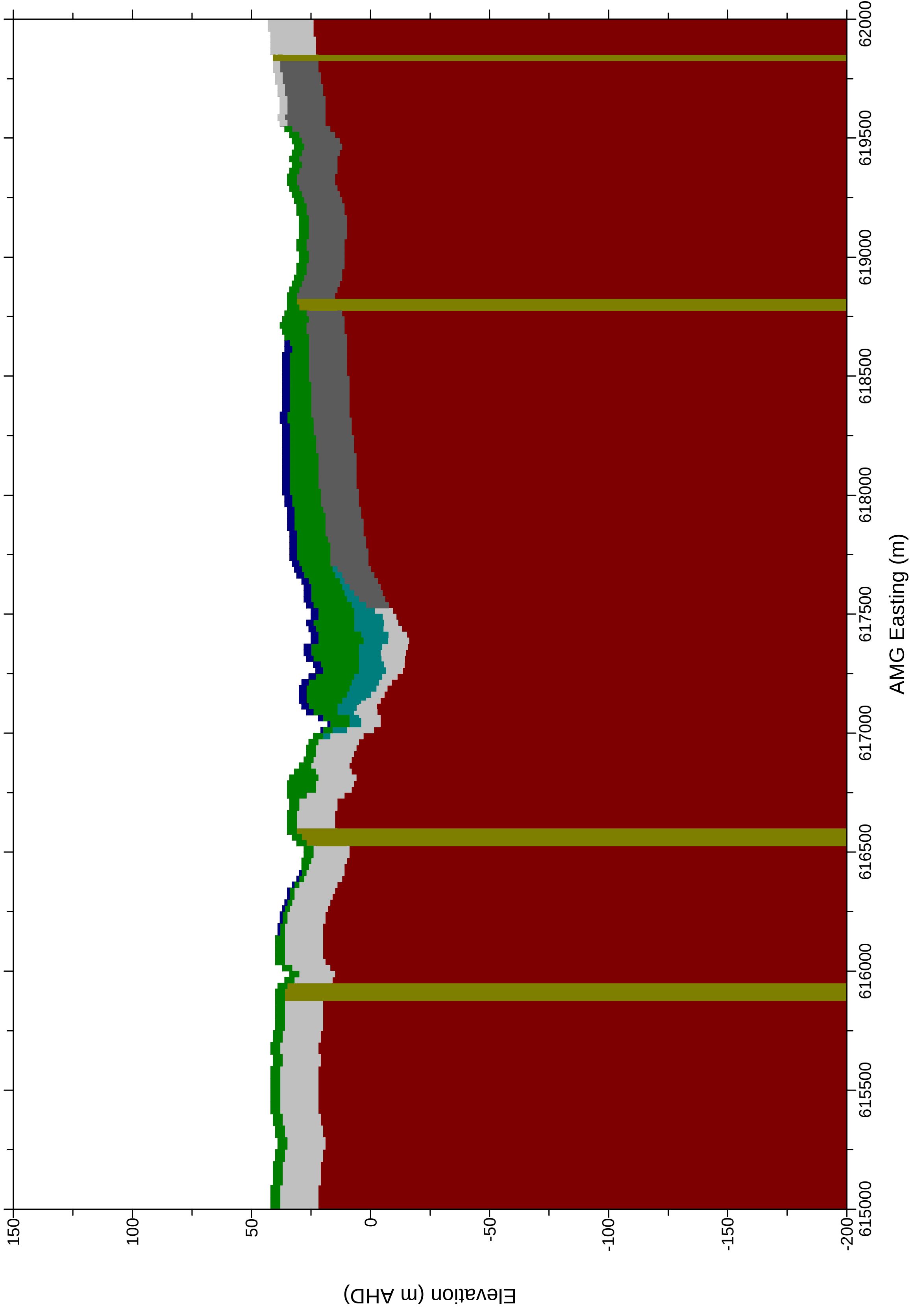

Cross Section (East-West) taken through production bore MAC3P

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MODEL CROSS SECTION (LOCAL)

Figure 18

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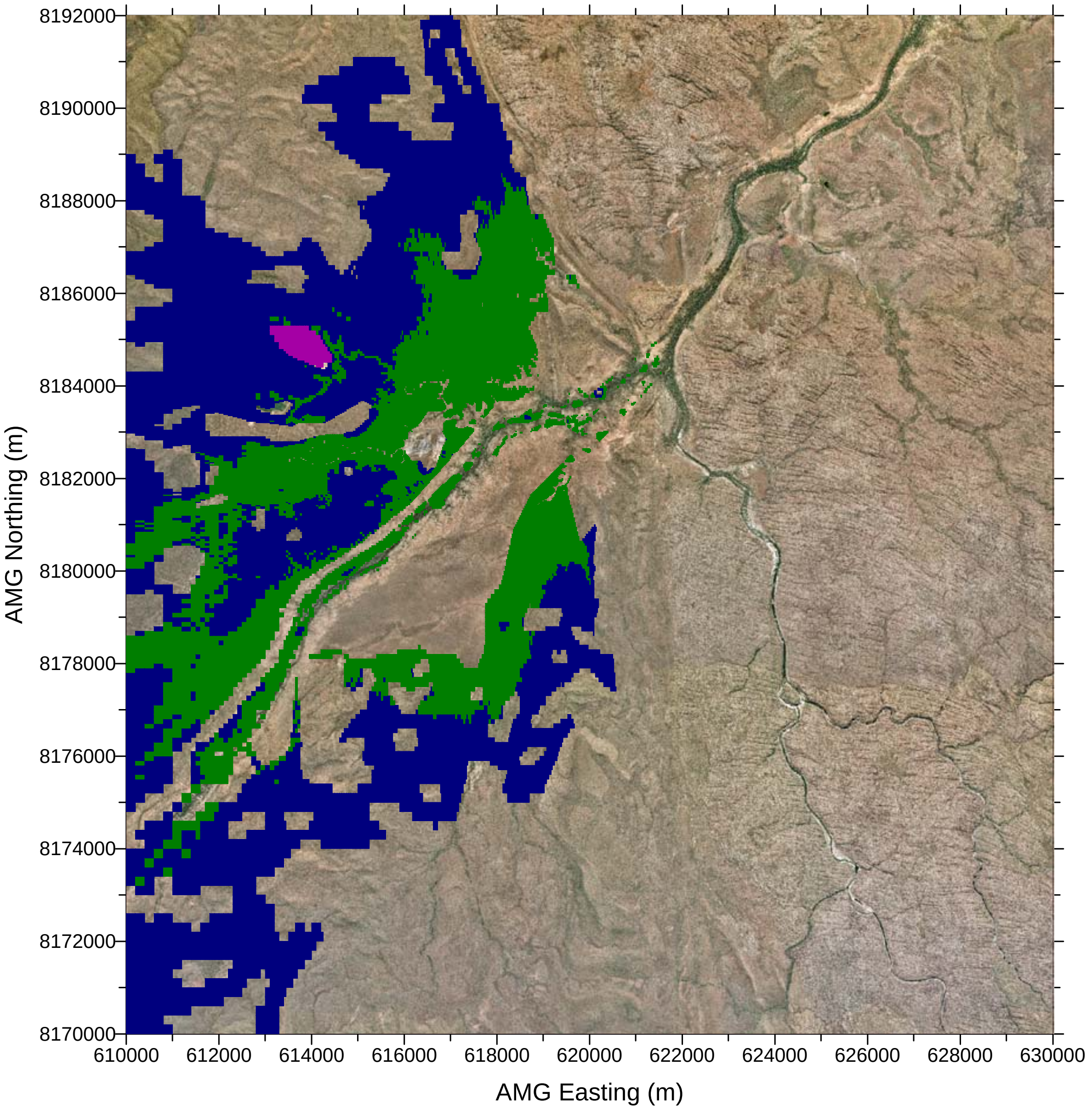
Figure 18.srf



Blue = 10 mm/yr

Green = 20 mm/yr

Purple = 100 mm/yr

0 2000 4000m

Scale 1: 150,000

AGD 84

Job No.	42905628	
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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MODEL RECHARGE

Figure 19

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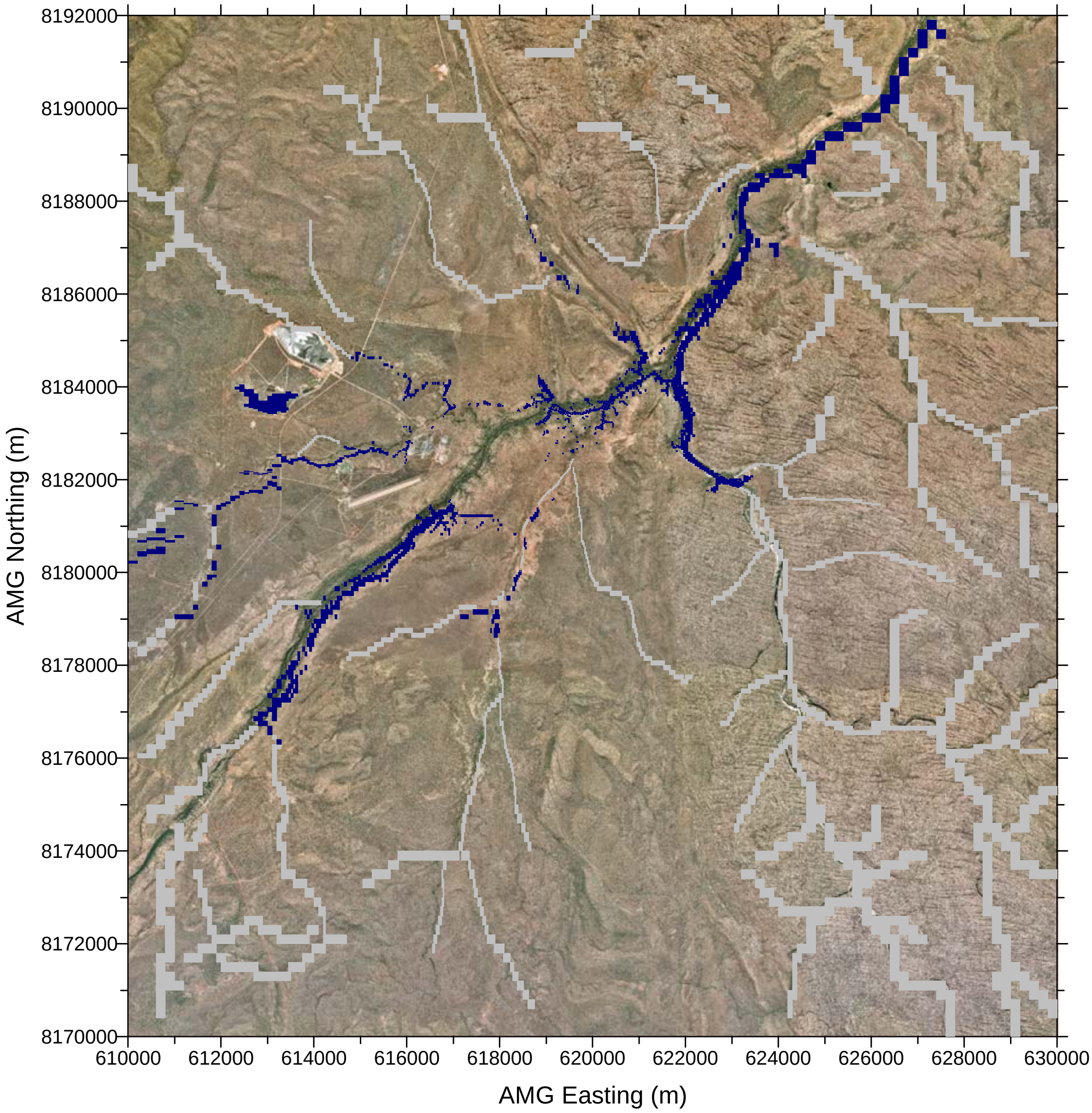
Figure 19.srf



Blue = Staged River Cells

Grey = Drain Cells

0 2000 4000 m

Scale 1: 150,000

AGD 84

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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MODEL RIVER CELLS

Figure 20

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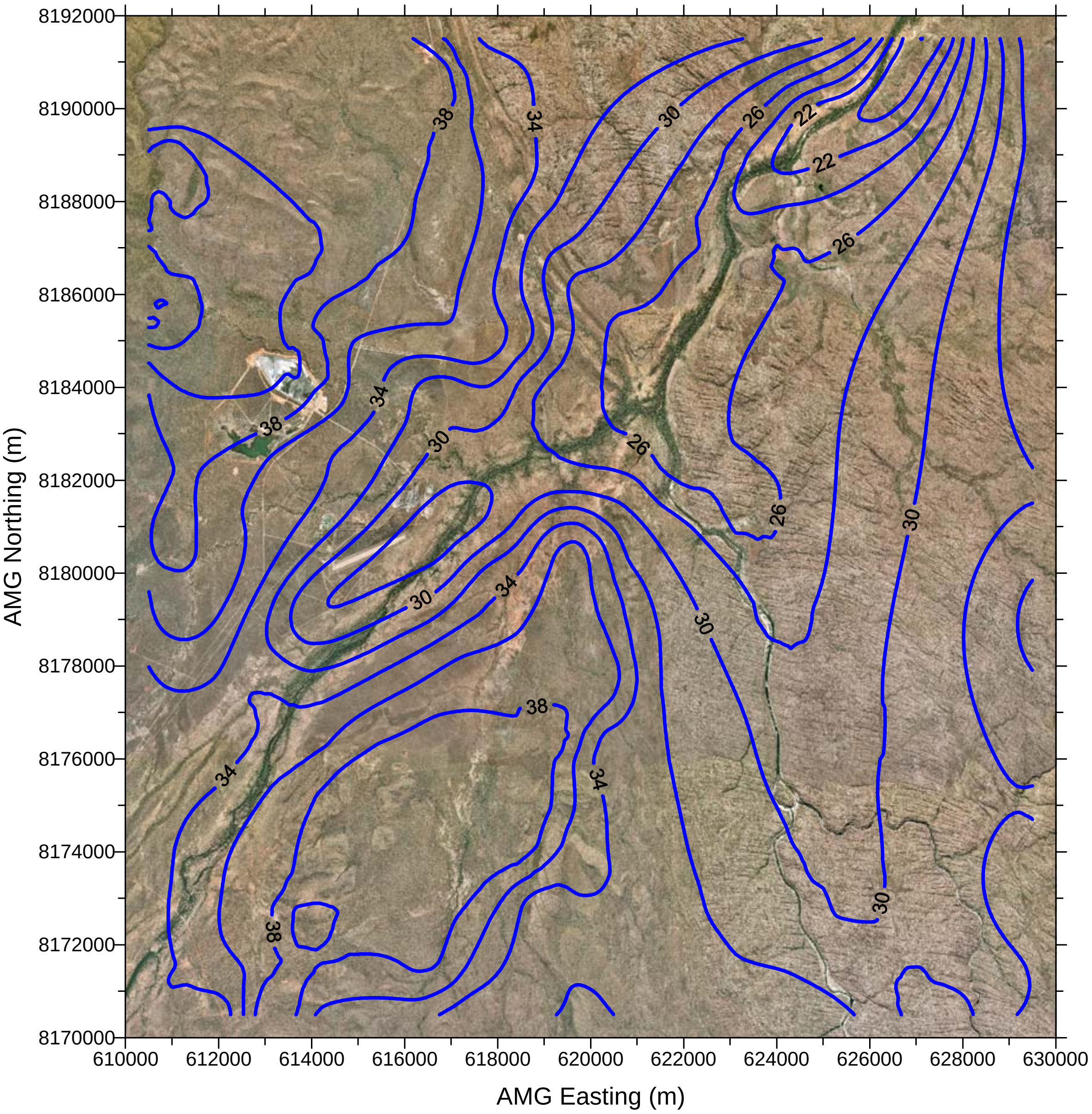
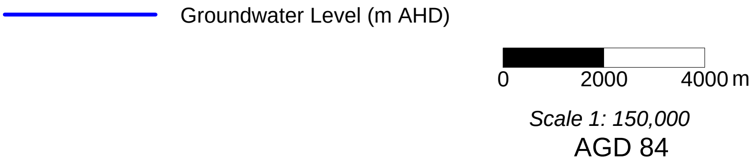
Figure 20.srf





Scale 1: 150,000

AGD 84

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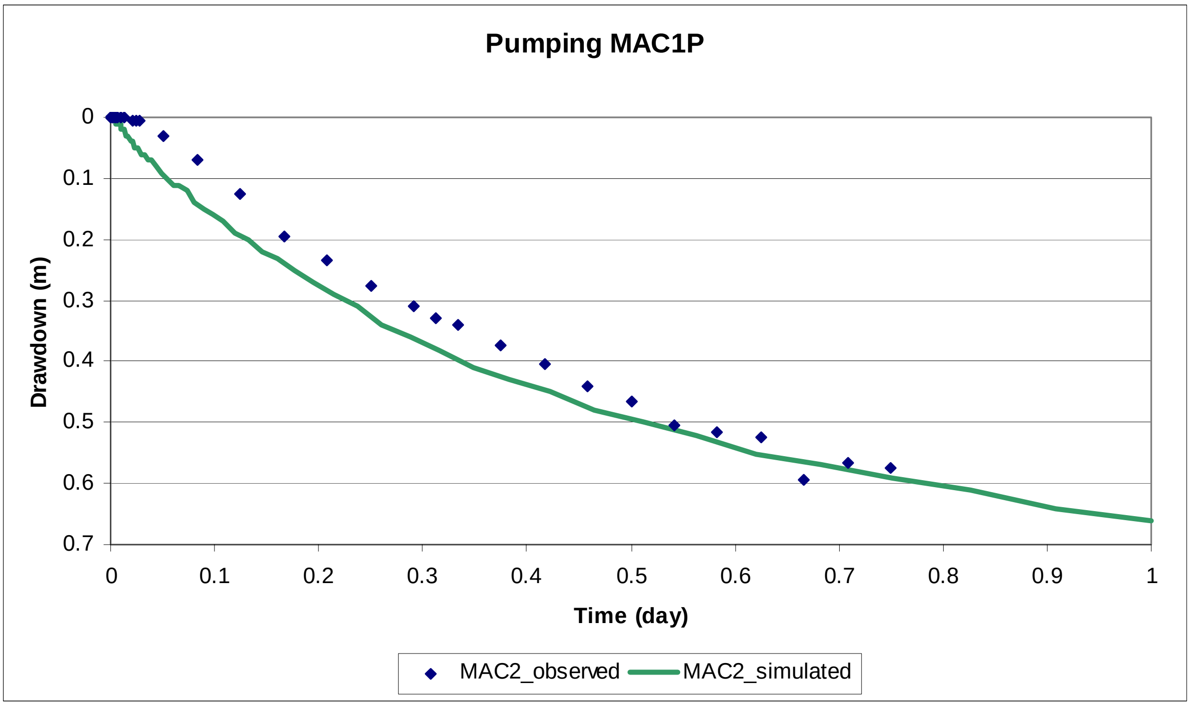
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

STEADY-STATE GROUNDWATER LEVELS

Figure 21

URS



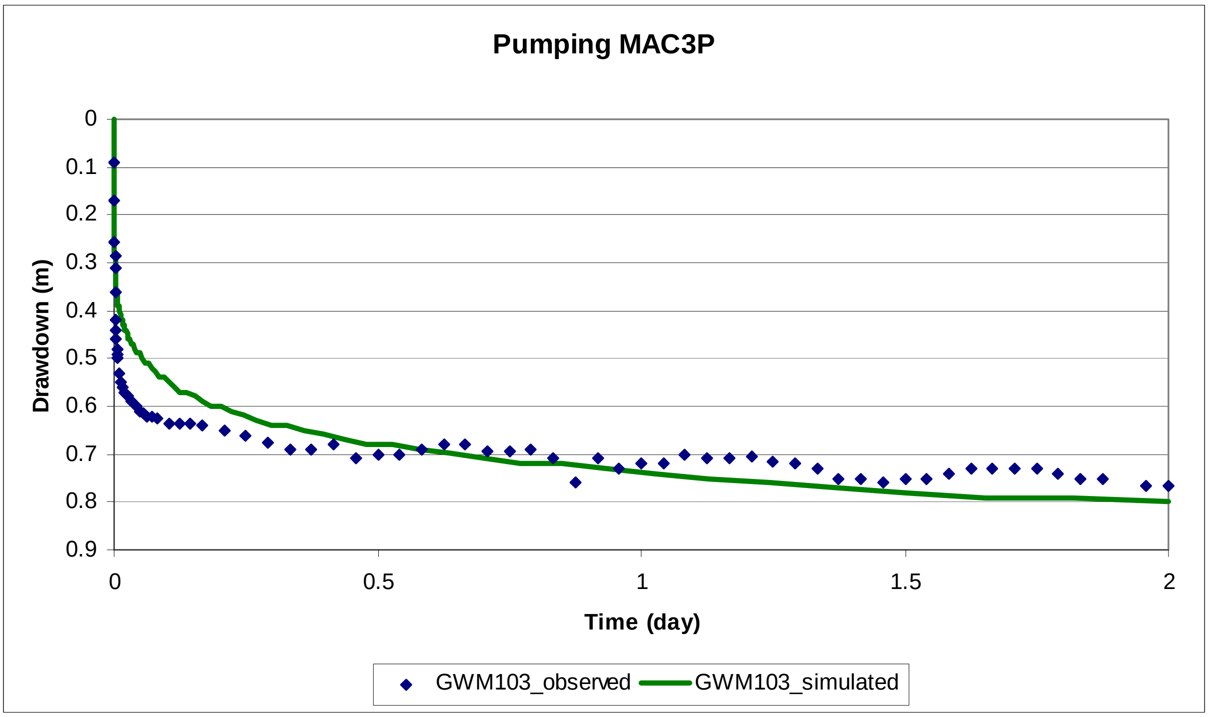
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

TRANSIENT CALIBRATION - BEDROCK

Figure 22

URS



Job No.	42905628	
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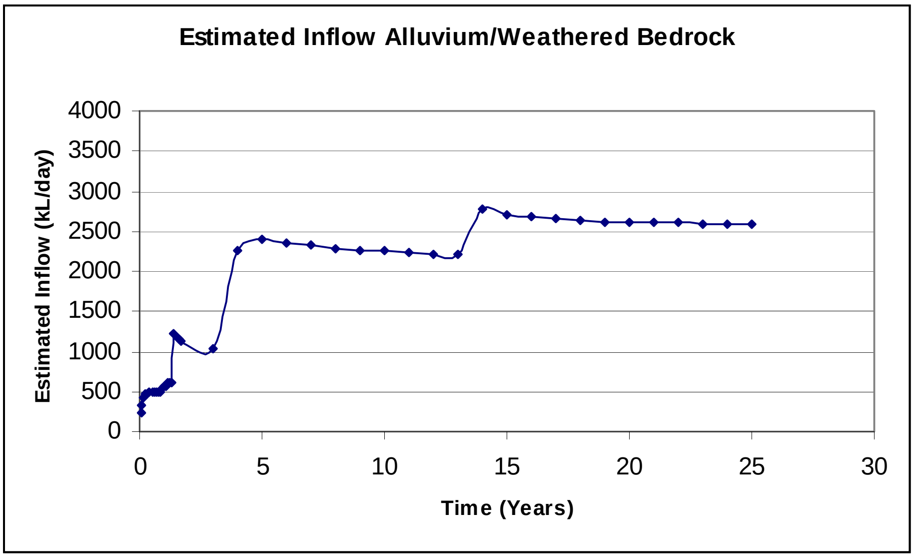
Revision No.		0

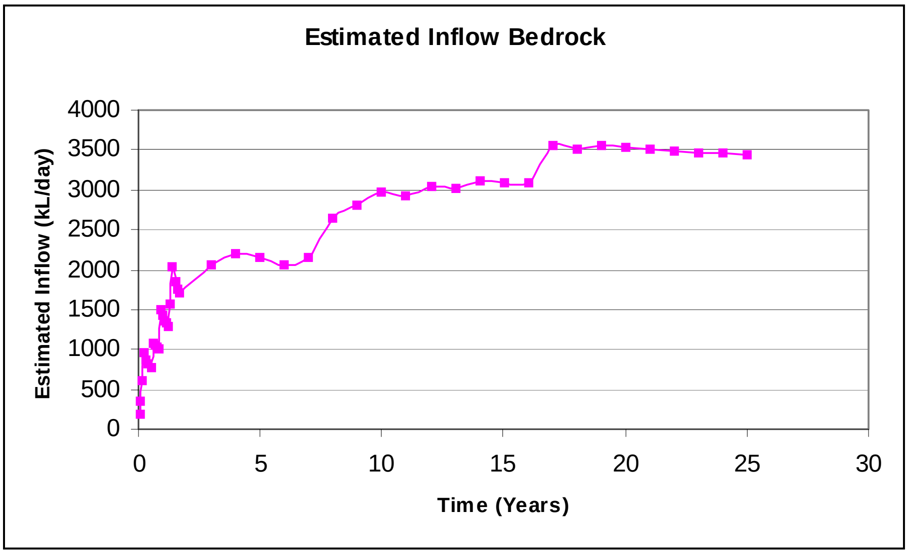
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

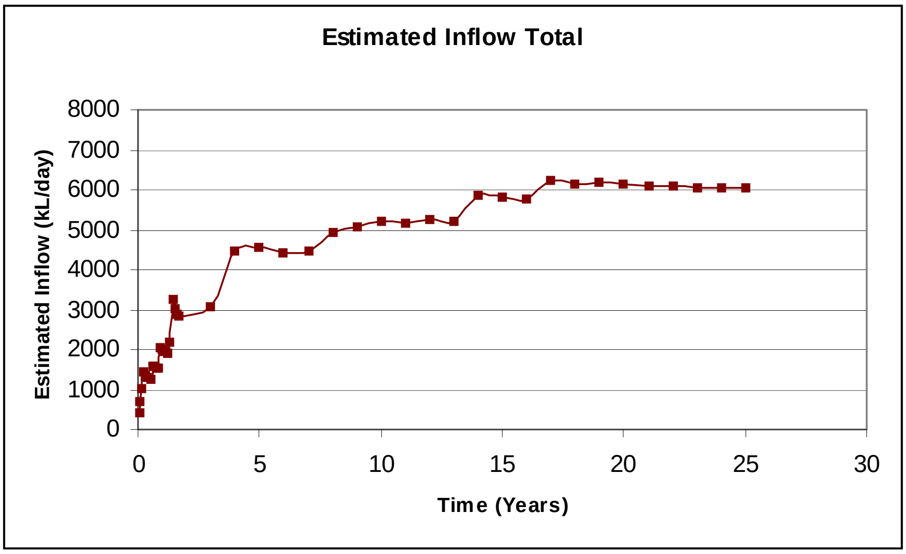
TRANSIENT CALIBRATION - ALLUVIUM

Figure 23

URS







Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

ESTIMATED GROUNDWATER INFLOW

Figure 24

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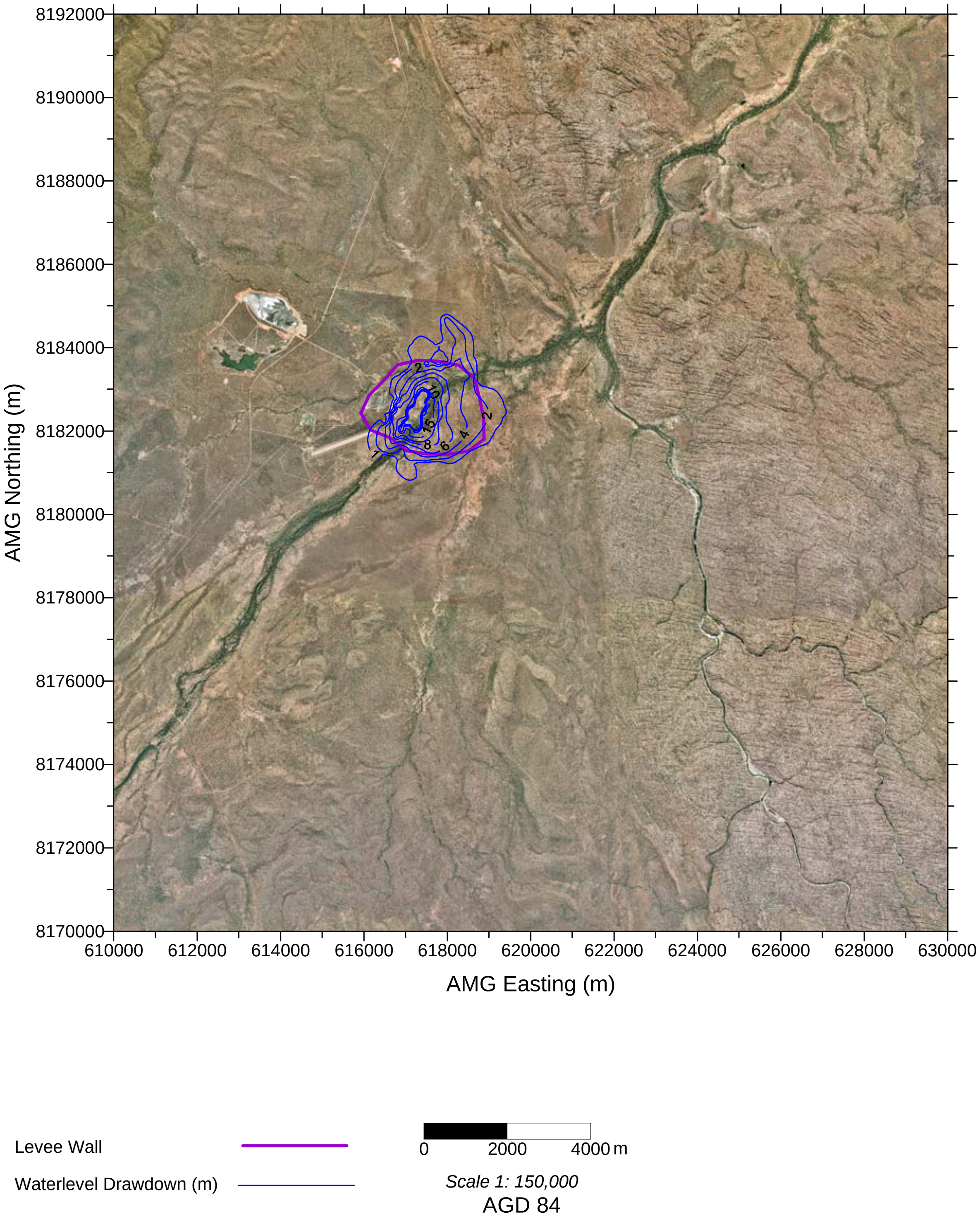
Figure 24.srf



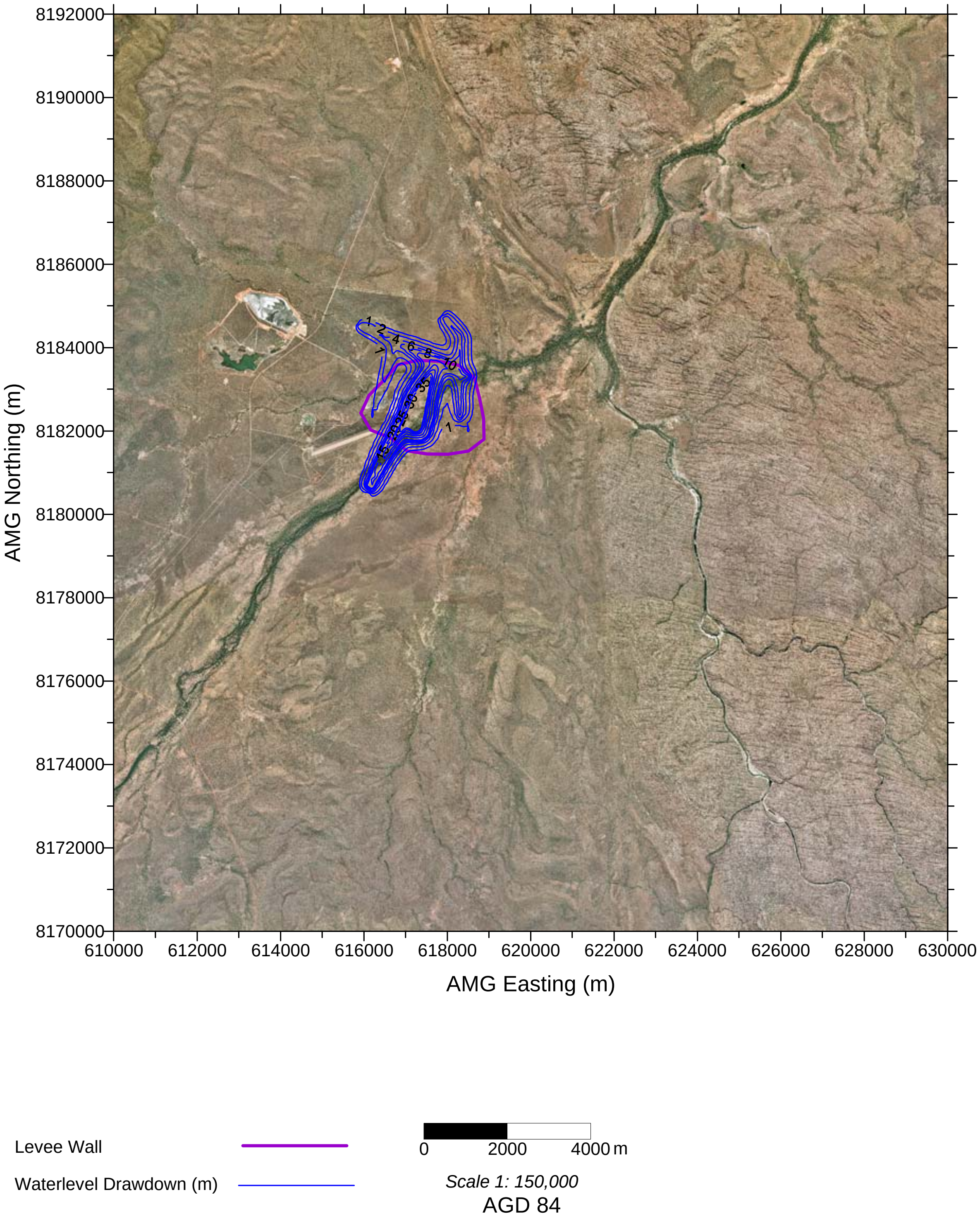
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 4
PALAEOCHANNEL GRAVEL (LAYER 3)

Figure 25

URS



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

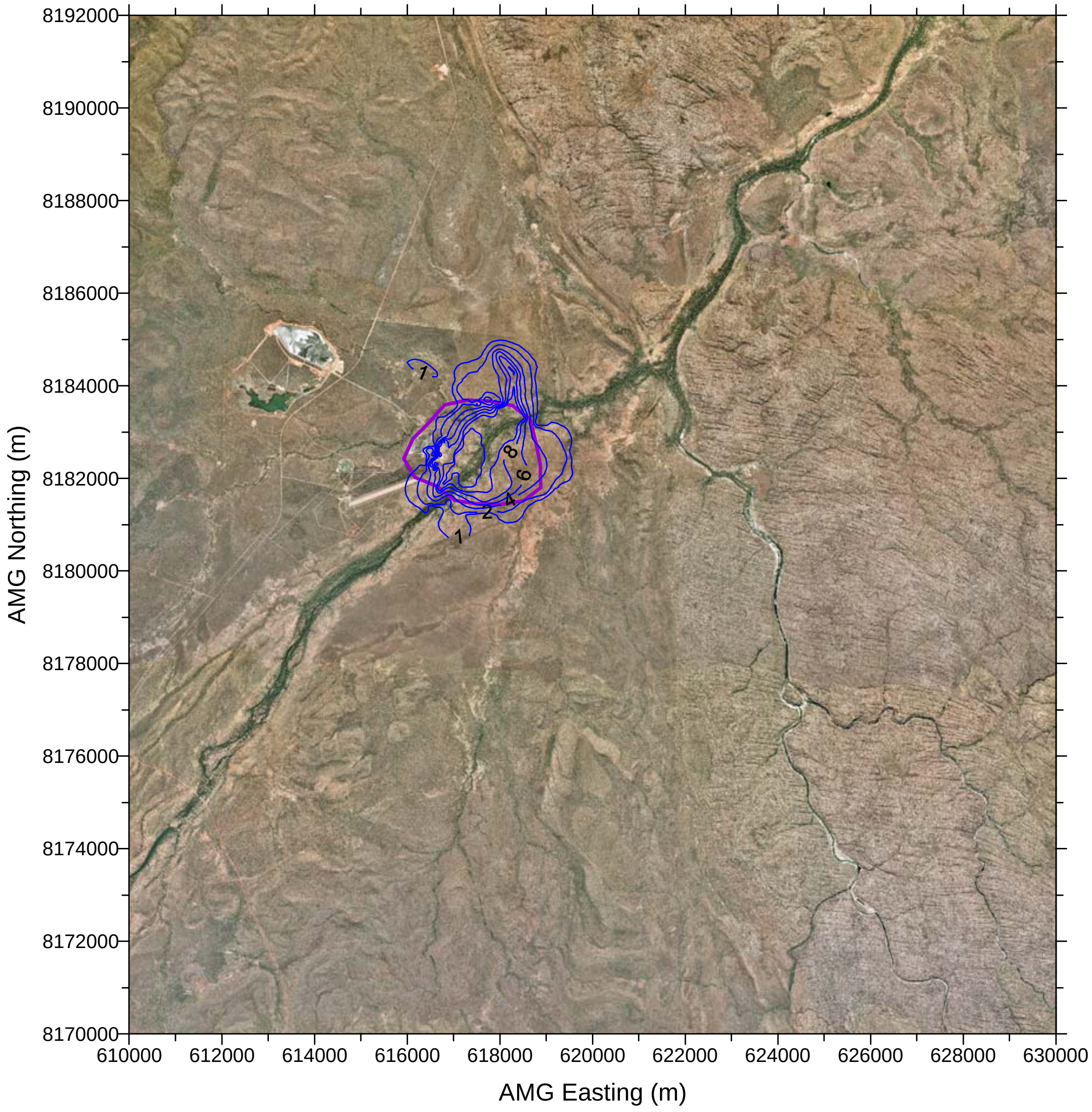
Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 4
BEDROCK (LAYER 5)

Figure 25a

URS



Levee Wall	▬
Waterlevel Drawdown (m)	―

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 10 PALAEOCHANNEL GRAVEL (LAYER 3)

Figure 26

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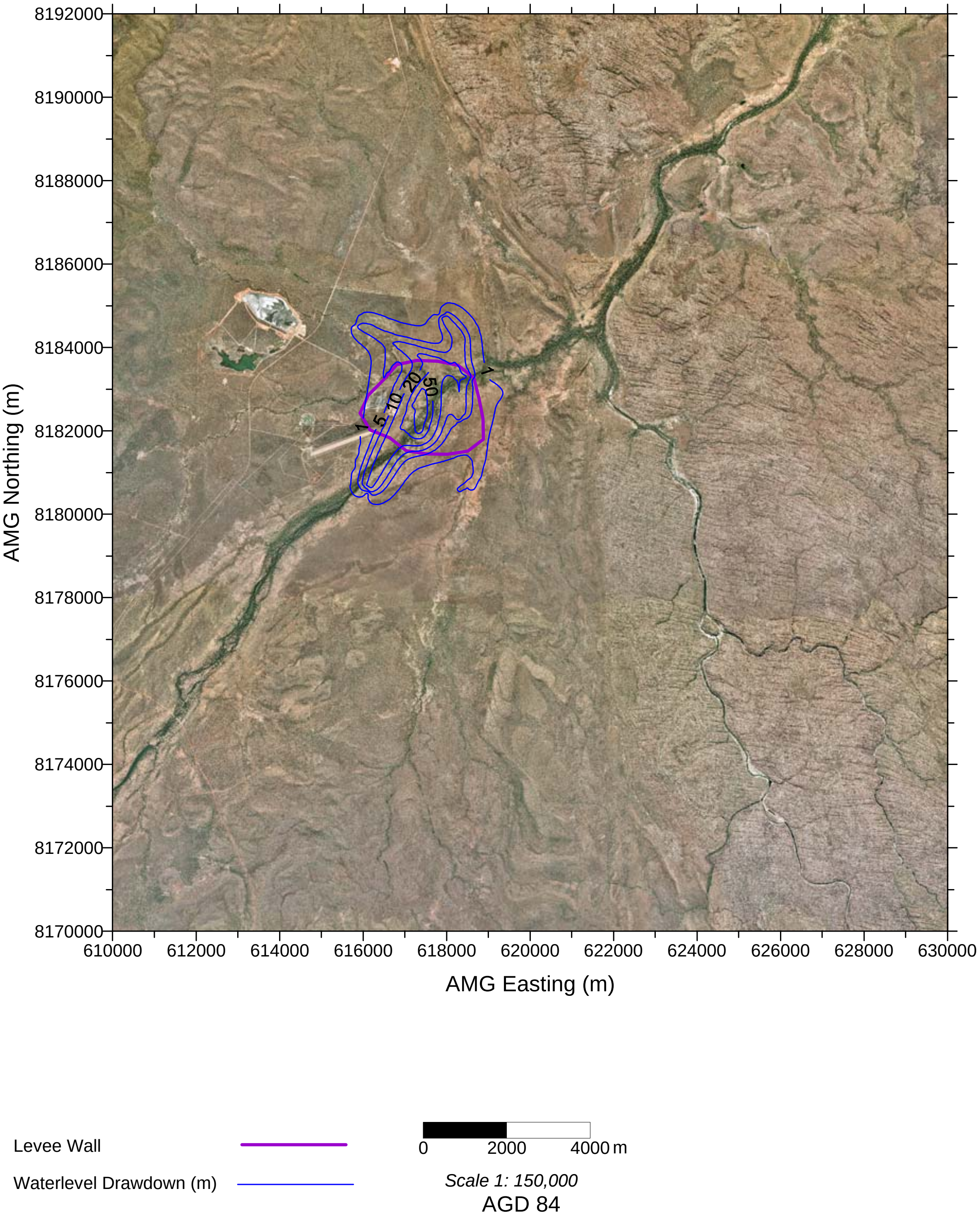
Figure 26.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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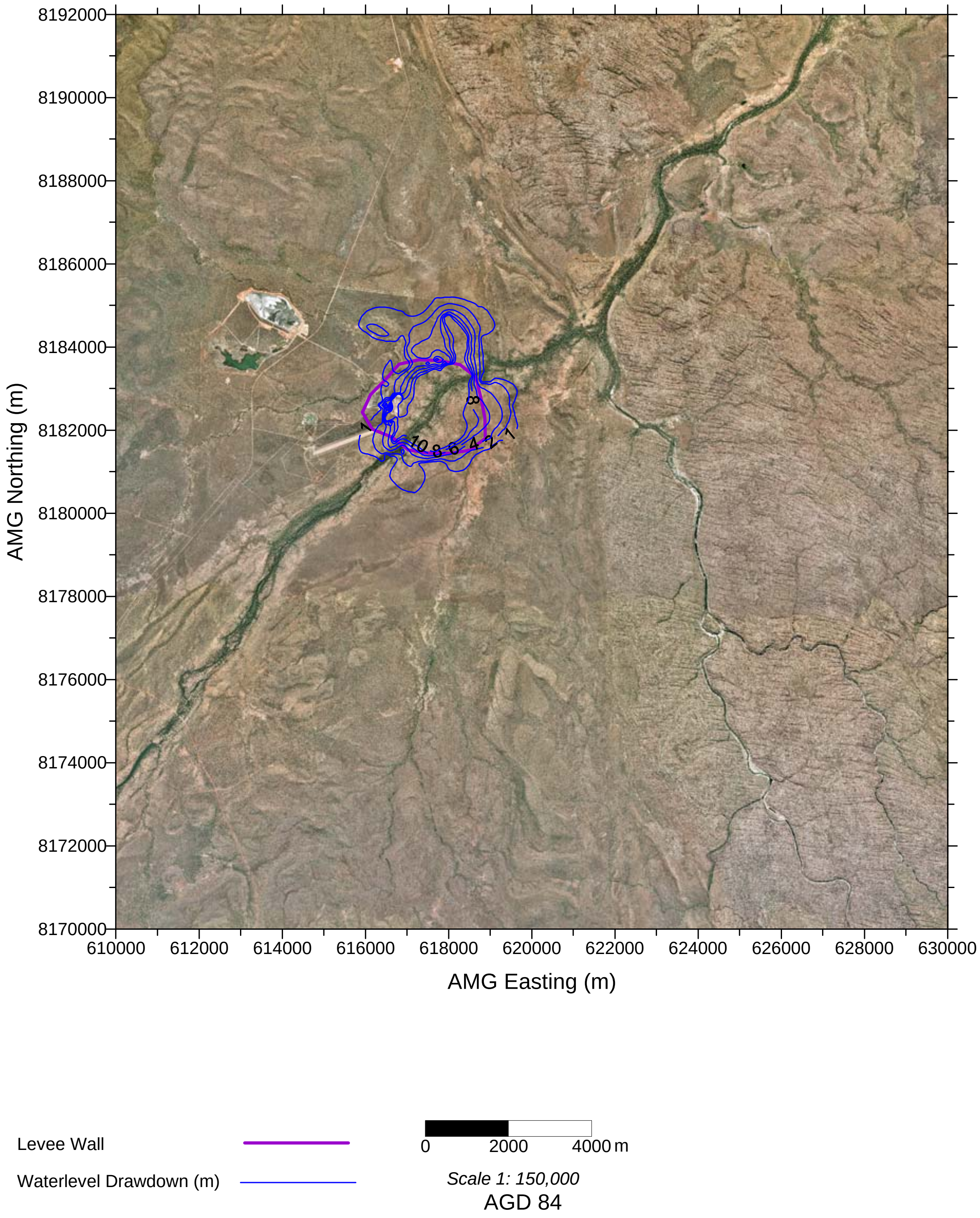
Revision No.	0	

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 10
BEDROCK (LAYER 5)

Figure 26a



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 20
PALAEOCHANNEL GRAVEL (LAYER 3)

Figure 27

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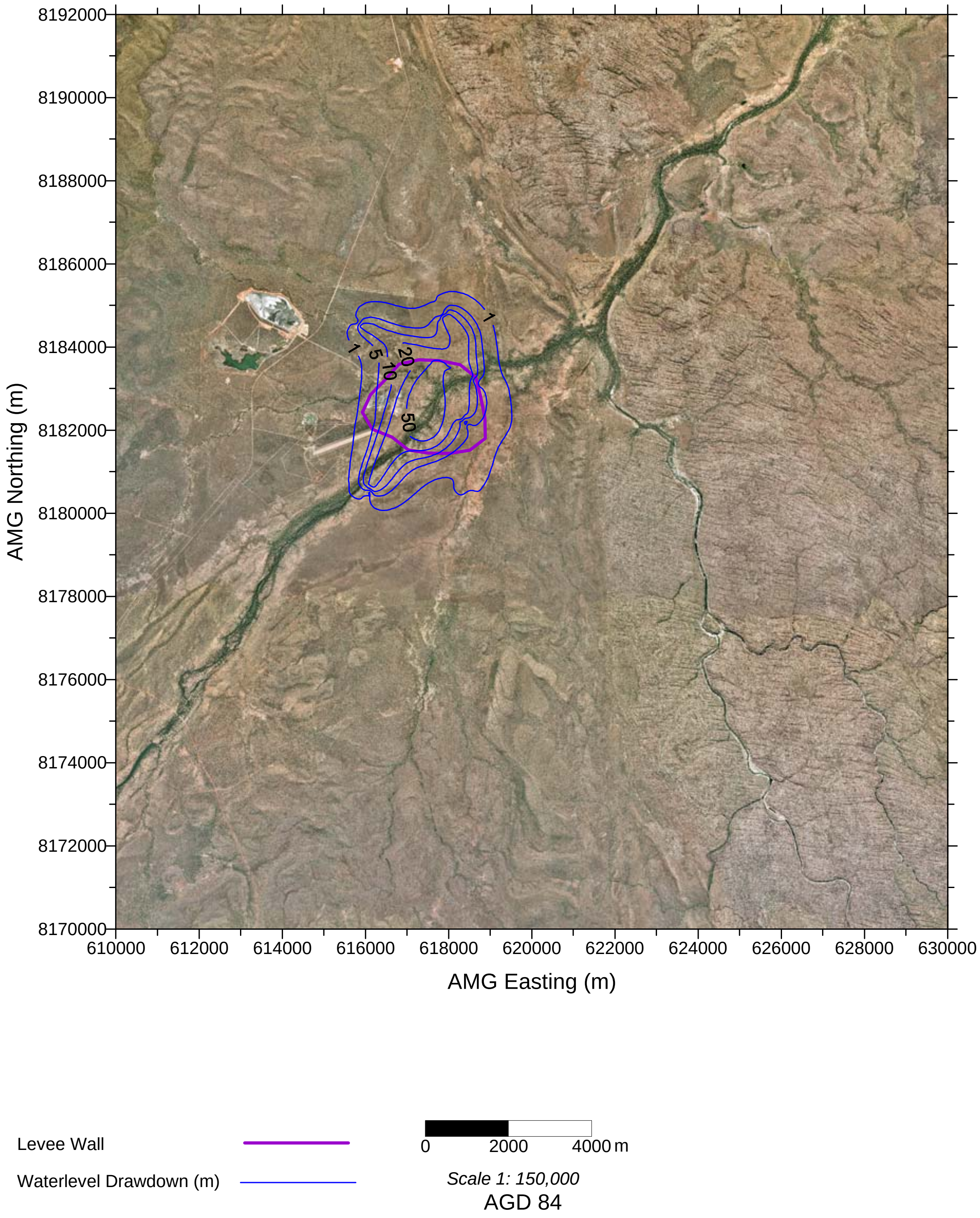
Figure 27.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

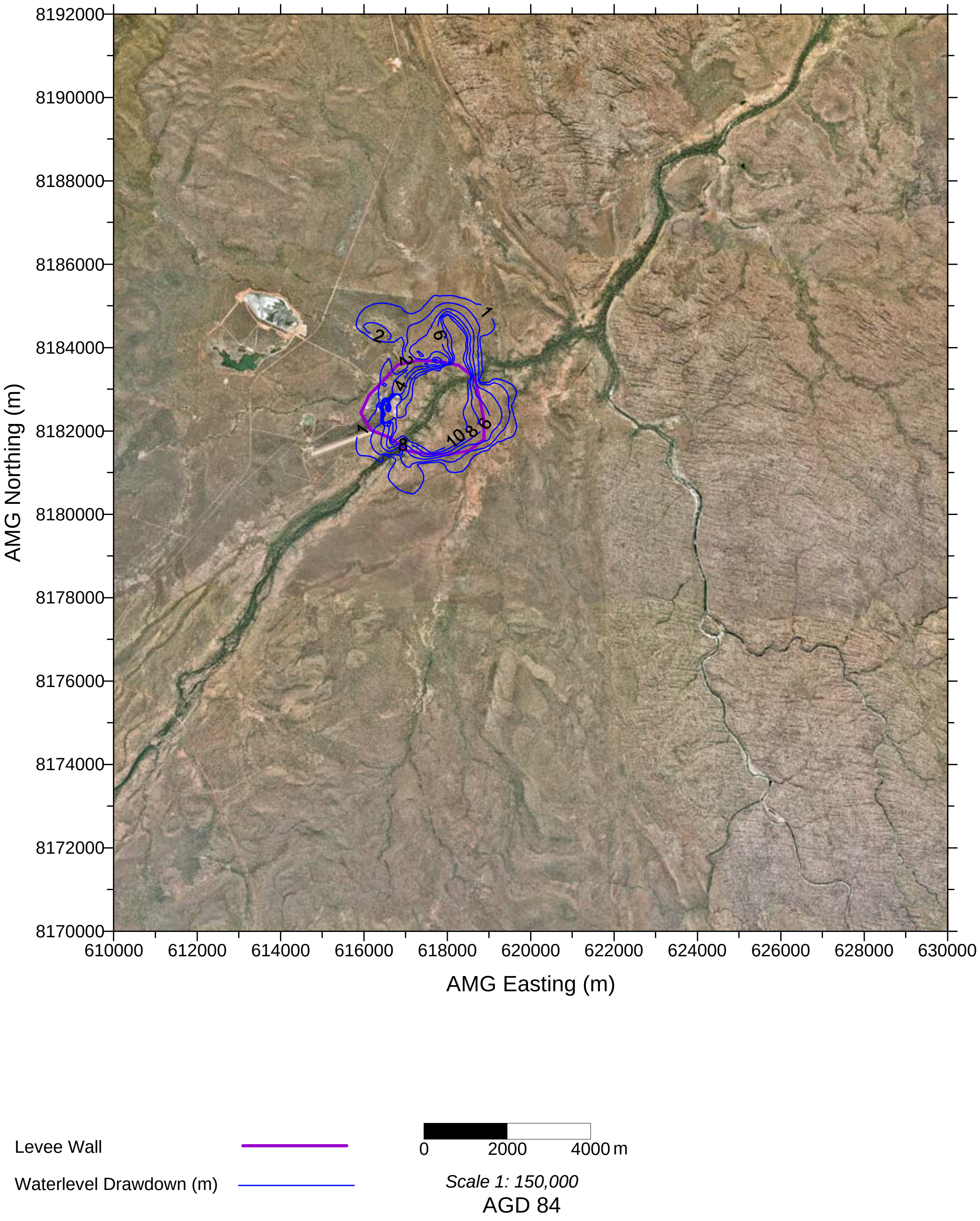
Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 20
BEDROCK (LAYER 5)

Figure 27a

URS



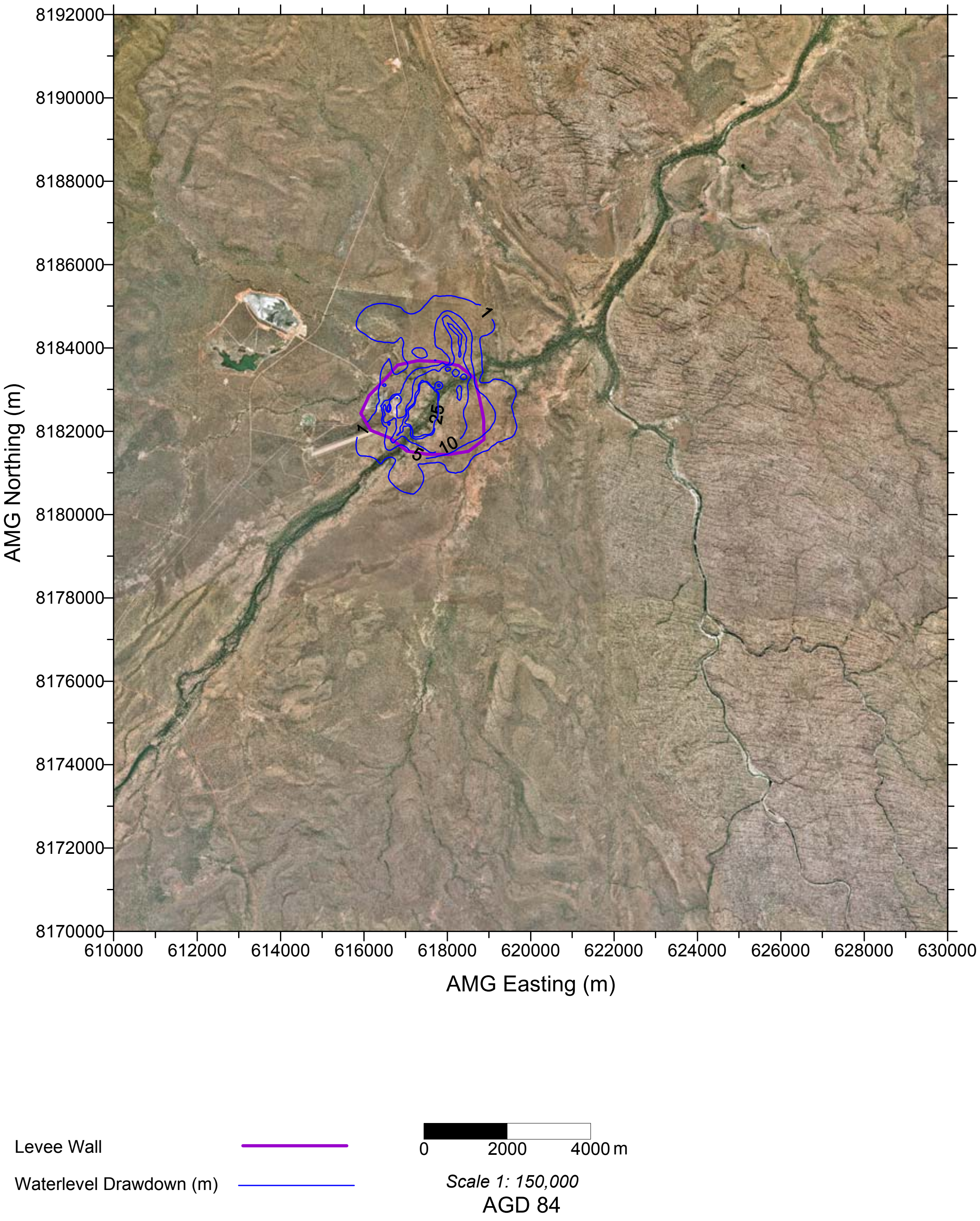
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 25 PALAEOCHANNEL GRAVEL (LAYER 3)

Figure 28

URS



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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Revision No.		0

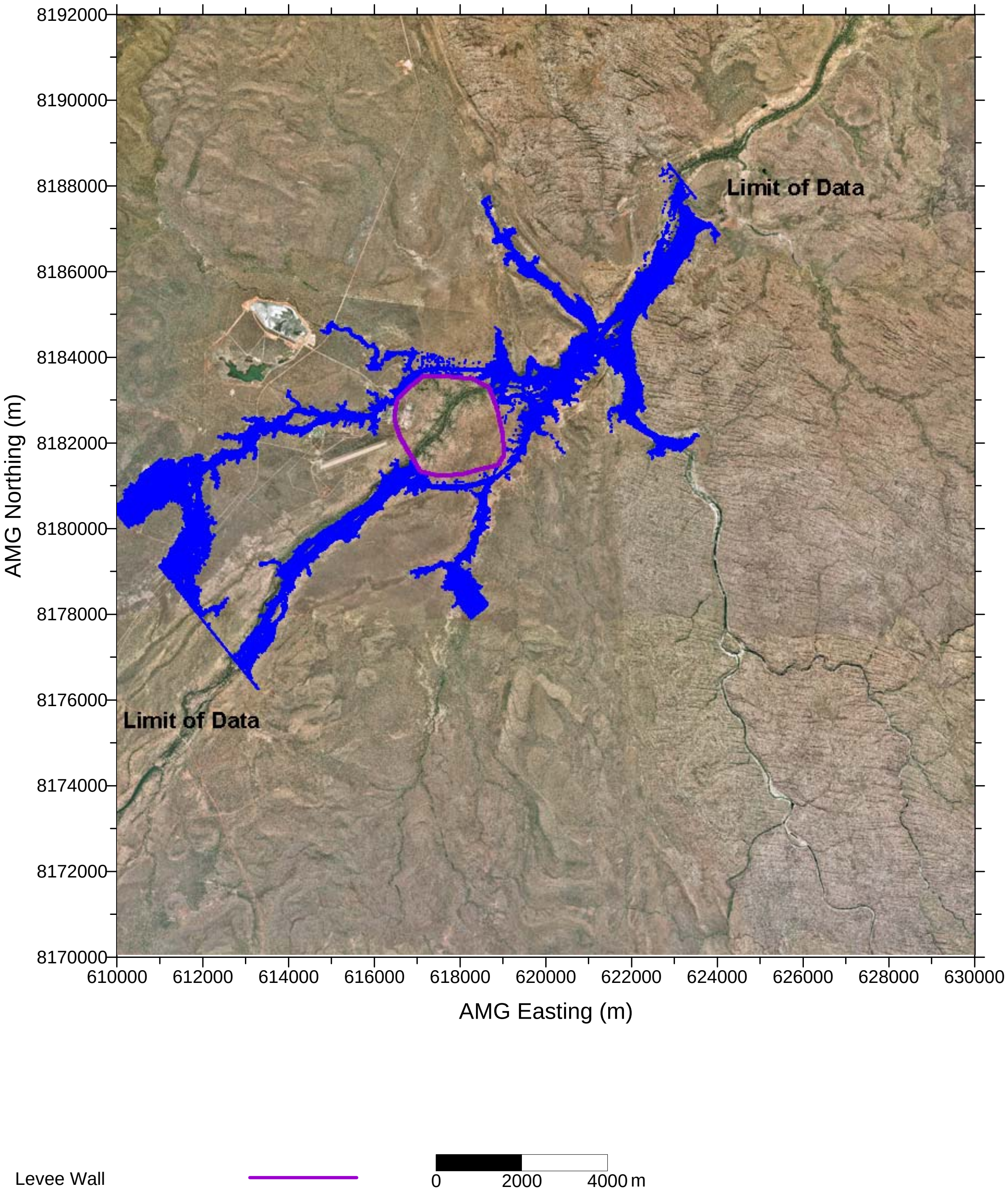
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 25 WEATHERED BEDROCK (LAYER 4)

Figure 28a

URS AUSTRALIA PTY LTD Perth Office +61 8 9221 1630

Figure 28a.srf



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 50 YEAR EVENT (DAY 1)

Figure 29

URS

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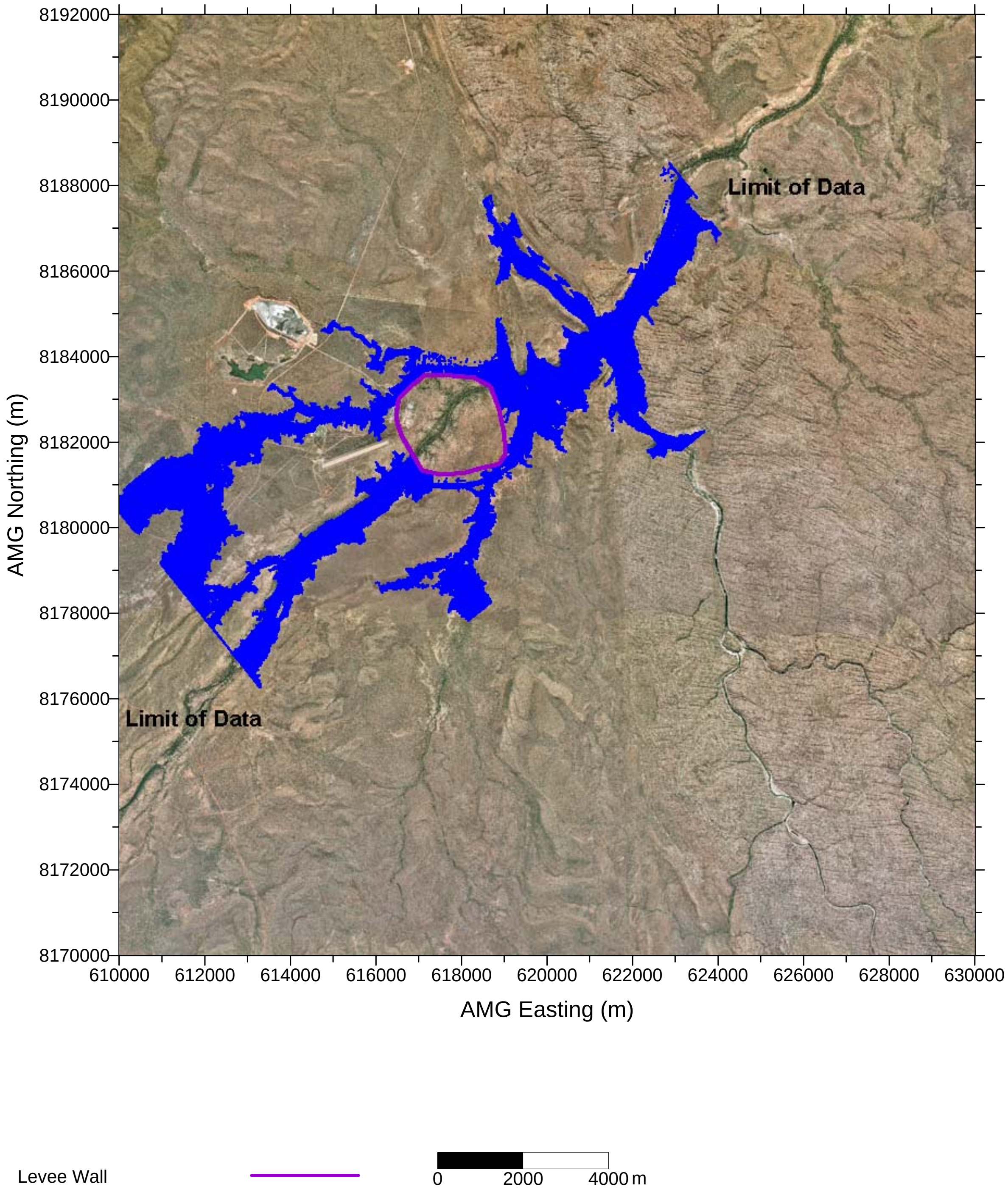
Figure 29.srf



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

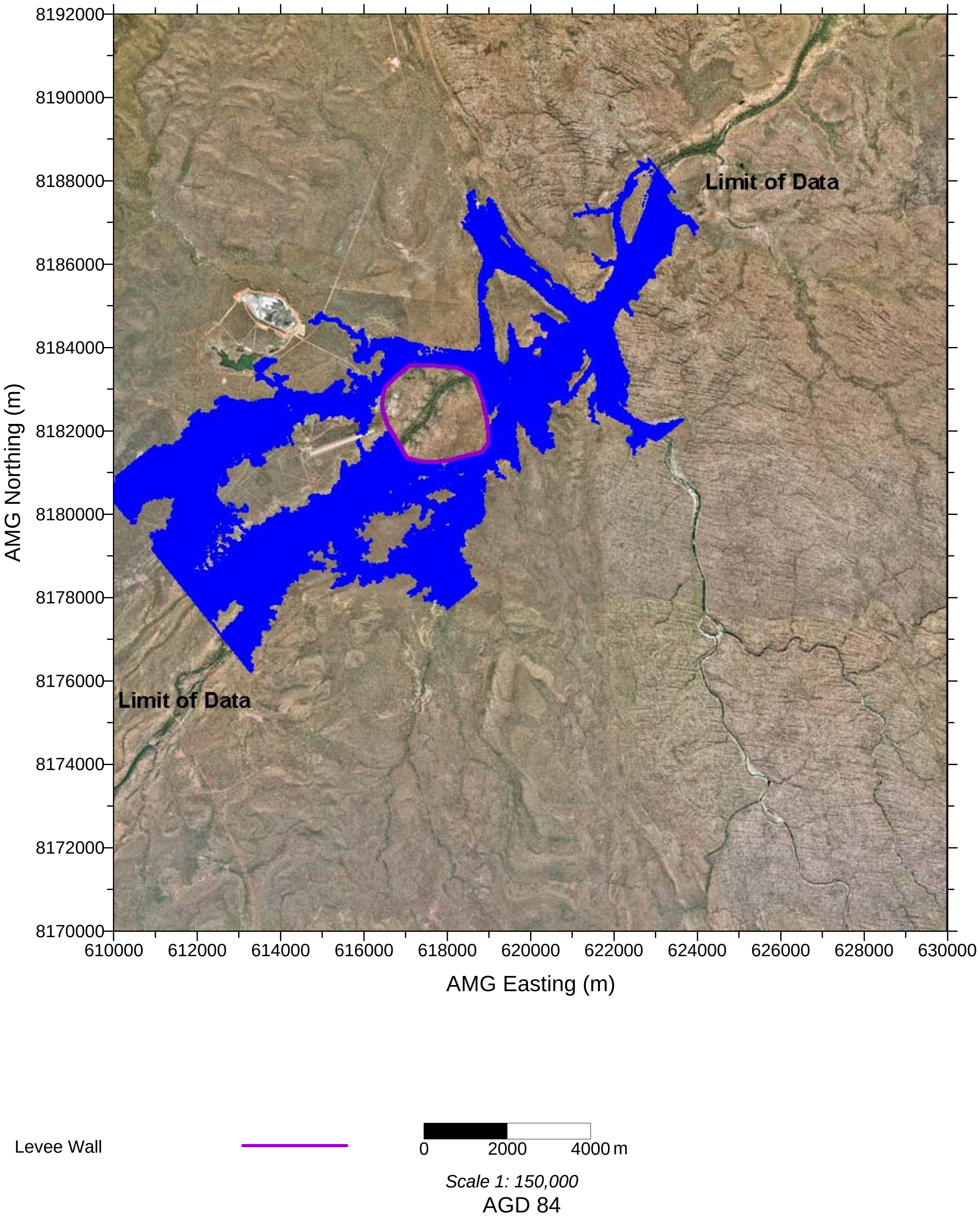
Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 50 YEAR EVENT (DAY 2)

Figure 29a

URS



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 50 YEAR EVENT (DAY 3)

Figure 29b

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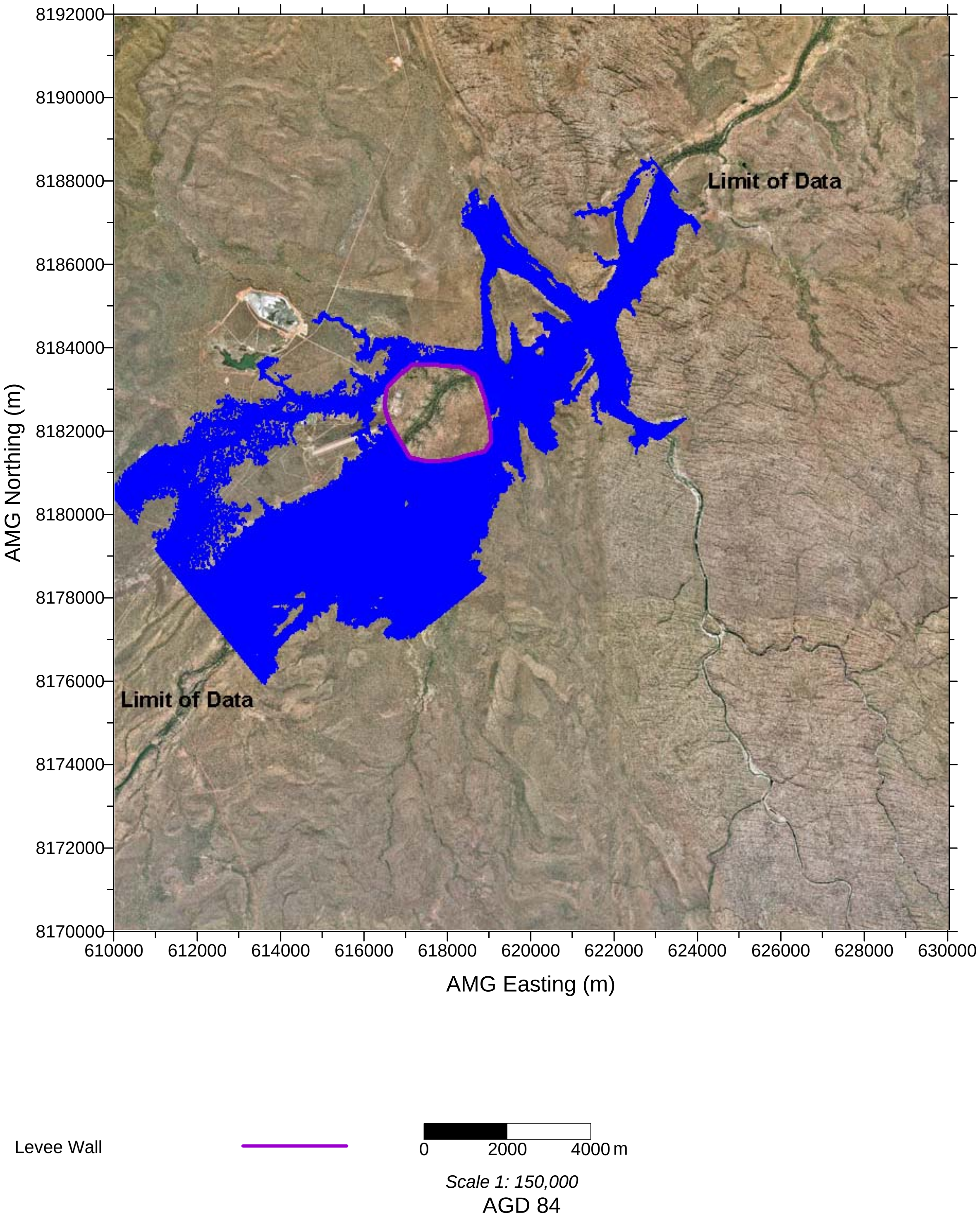
Figure 29b.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 50 YEAR EVENT (DAY 4)

Figure 29c

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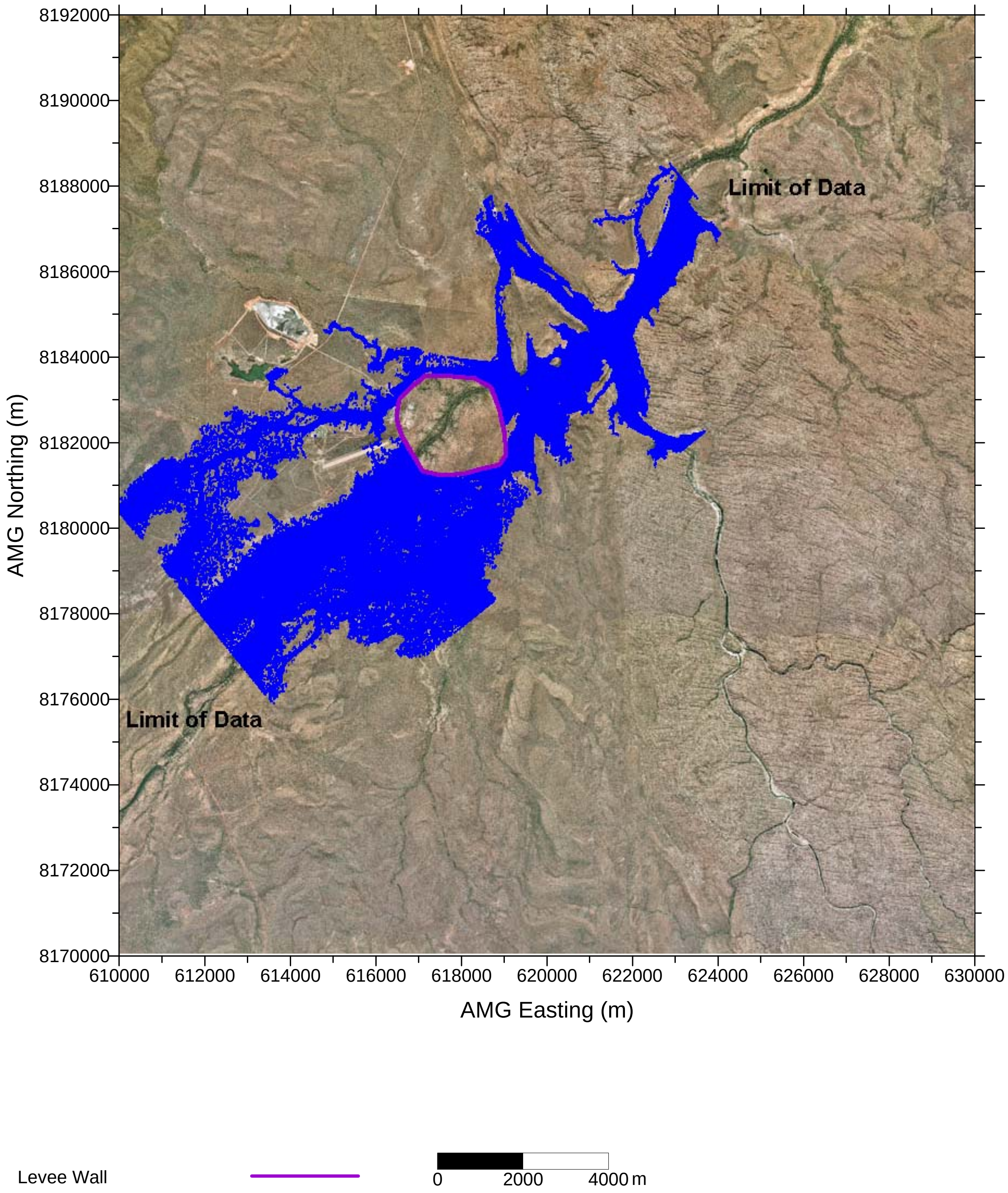
Figure 29c.srf



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 50 YEAR EVENT (DAY 4.5)

Figure 29d

URS

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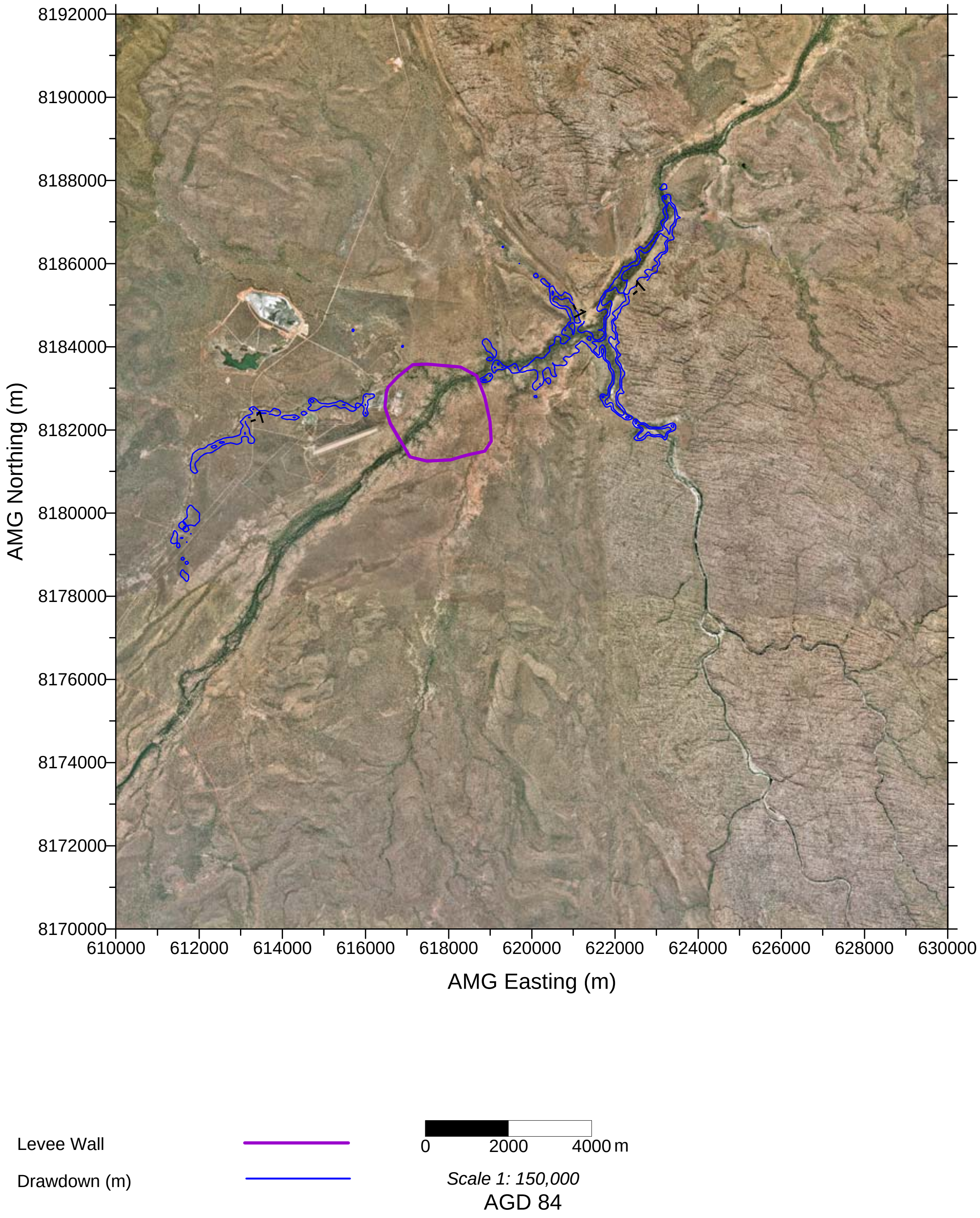
Figure 29d.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.	0	

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR FLOOD EVENT (DAY 1)

Figure 30

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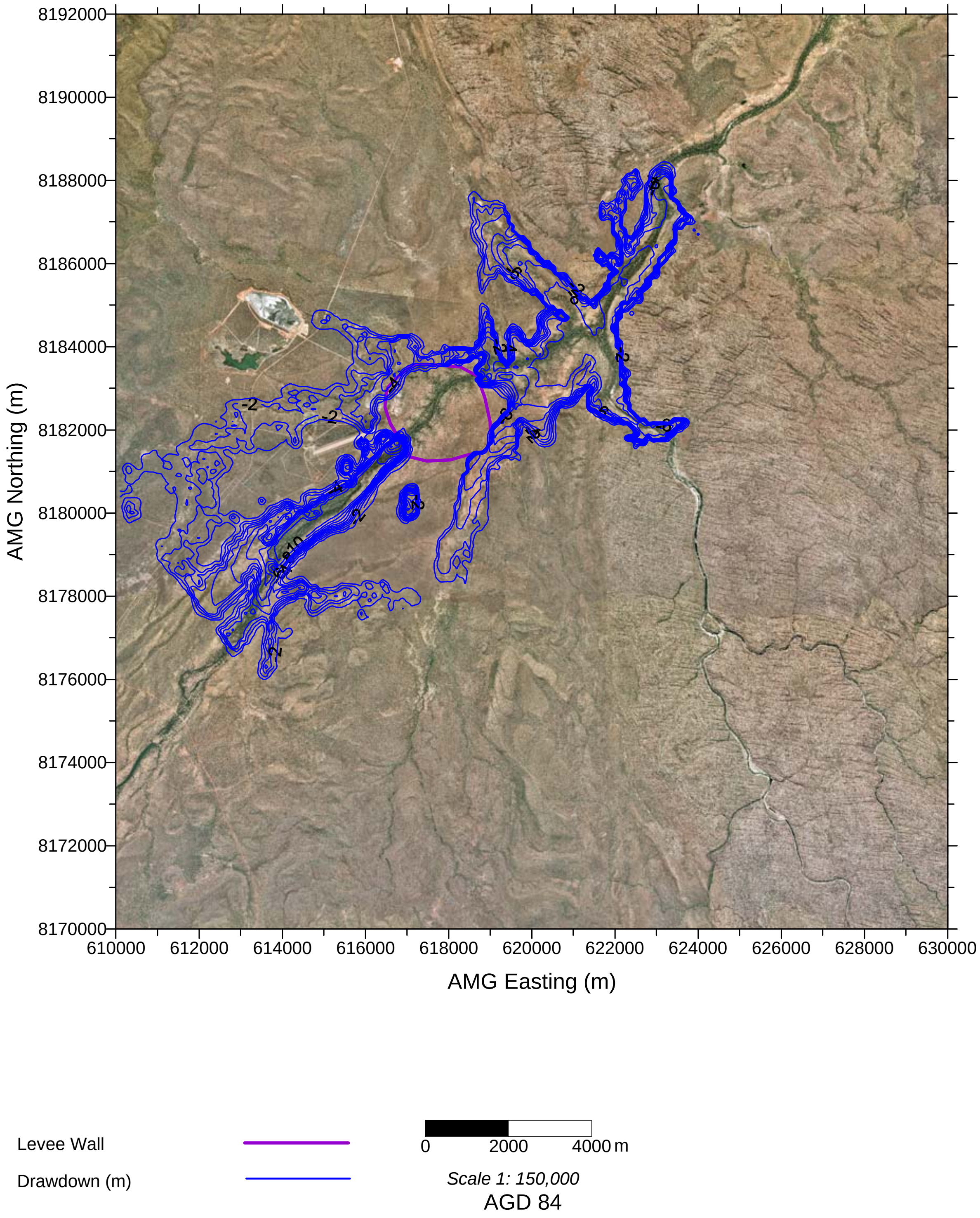
Figure 30.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.	0	

Xstrata PLC

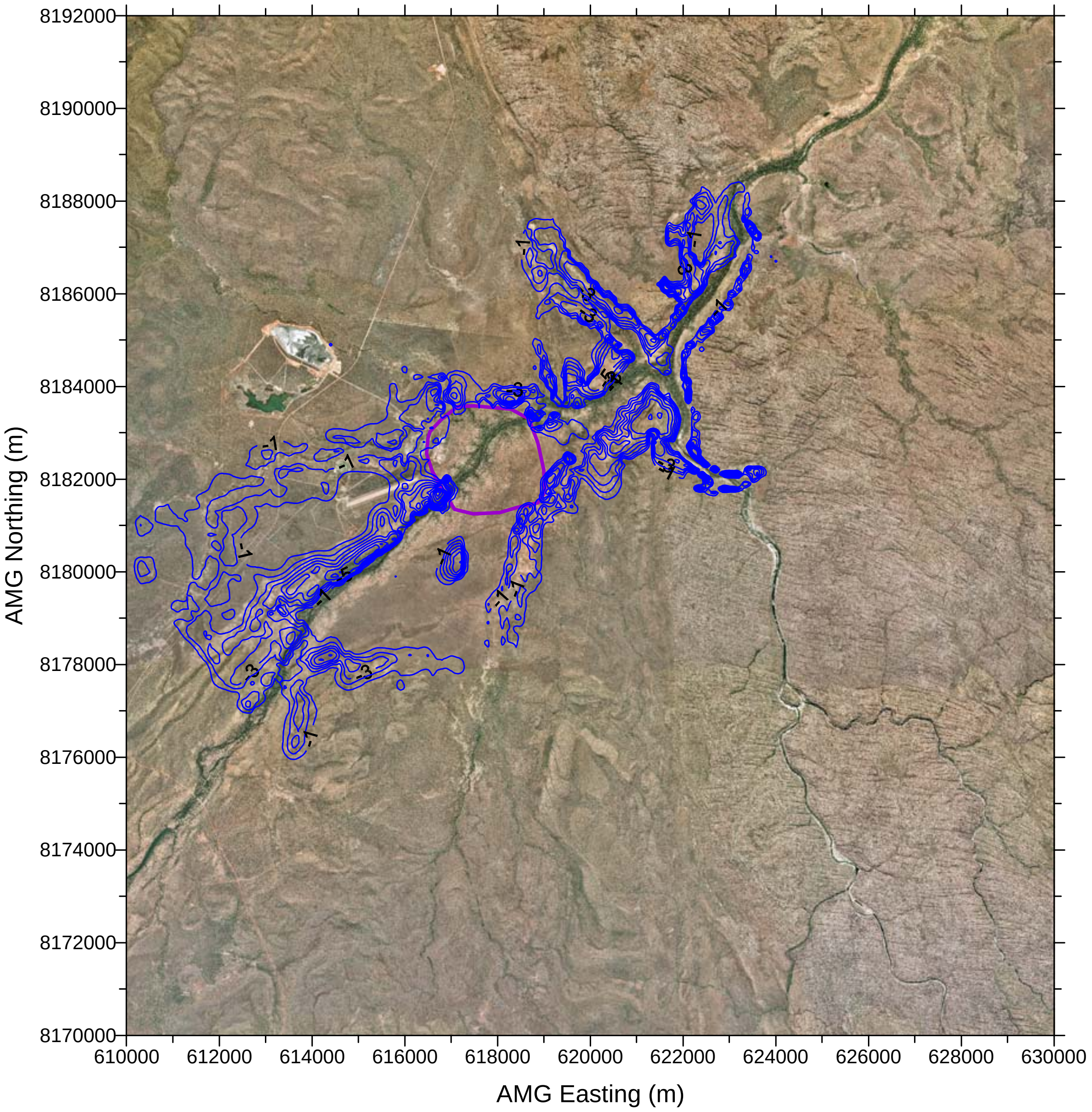
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR FLOOD EVENT (DAY 5)

Figure 30a

URS AUSTRALIA PTY LTD Perth Office +61 8 9221 1630

Figure 30a.srf



Levee Wall	🟪
Drawdown (m)	🟦

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

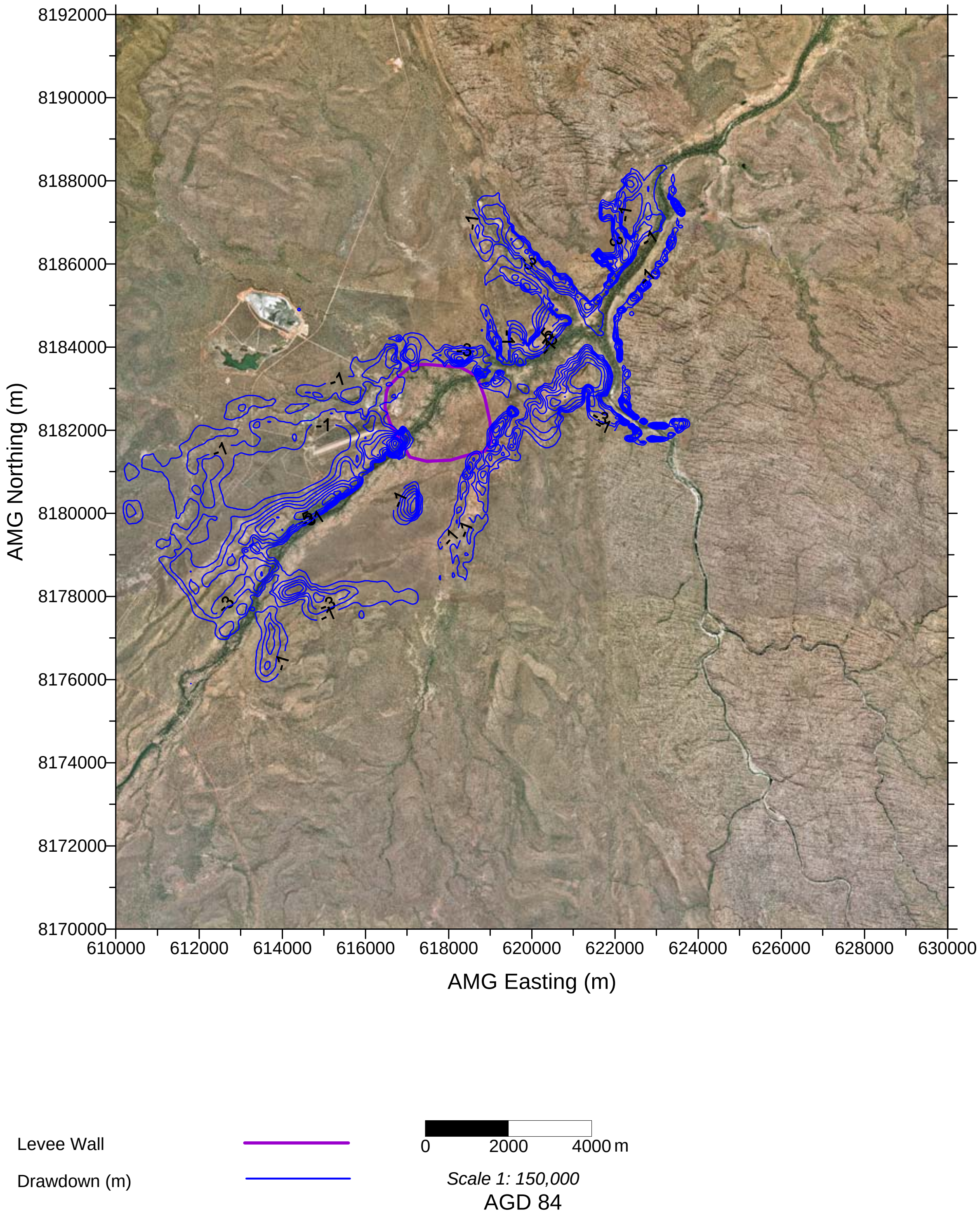
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR FLOOD EVENT (DAY 10)

Figure 30b

URS AUSTRALIA PTY LTD Perth Office +61 8 9221 1630

Figure 30b.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR FLOOD EVENT (DAY 12)

Figure 30c

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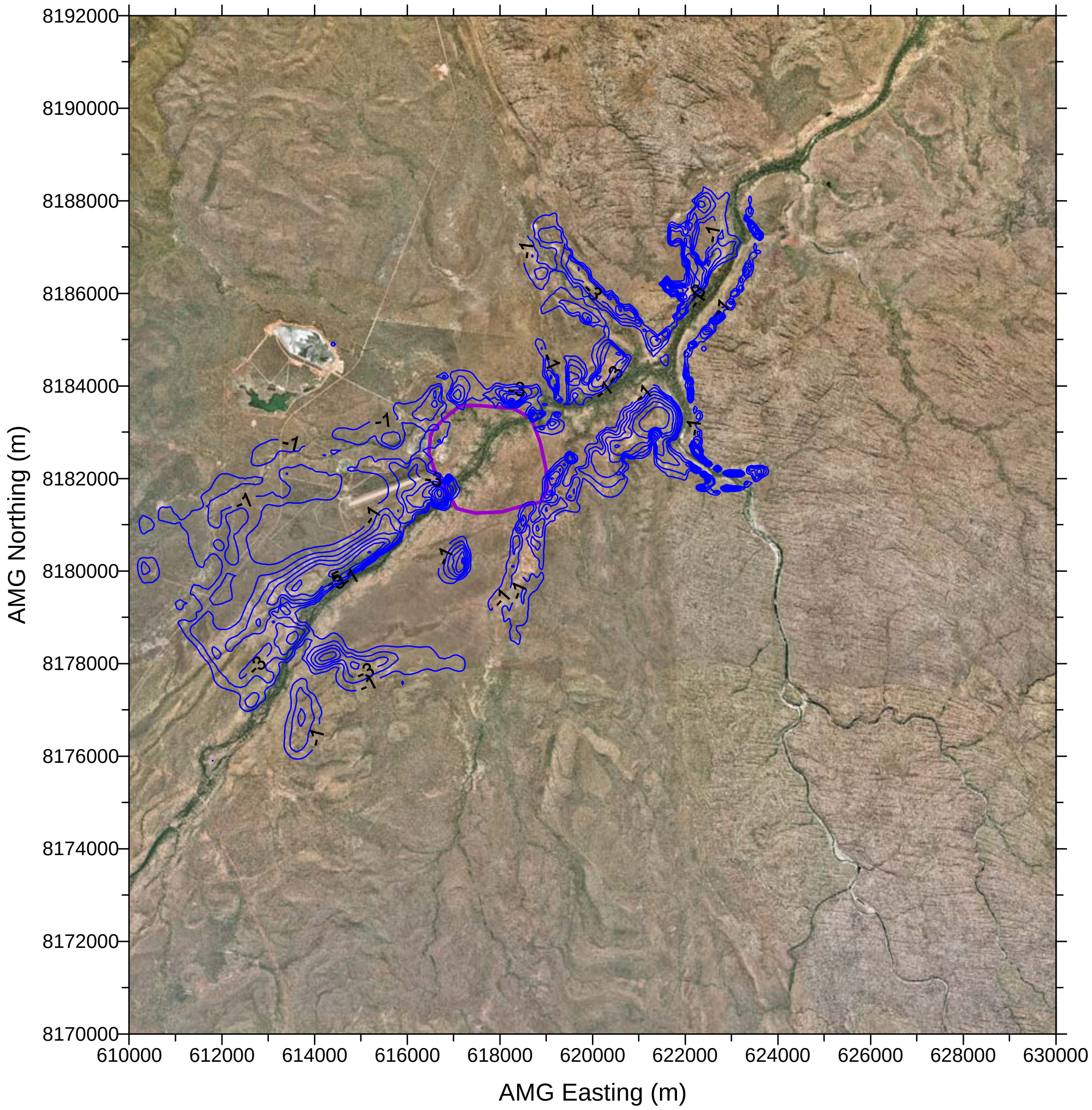
Figure 30c.srf



Levee Wall	▬
Drawdown (m)	▬

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR EVENT (DAY 15)

Figure 30d

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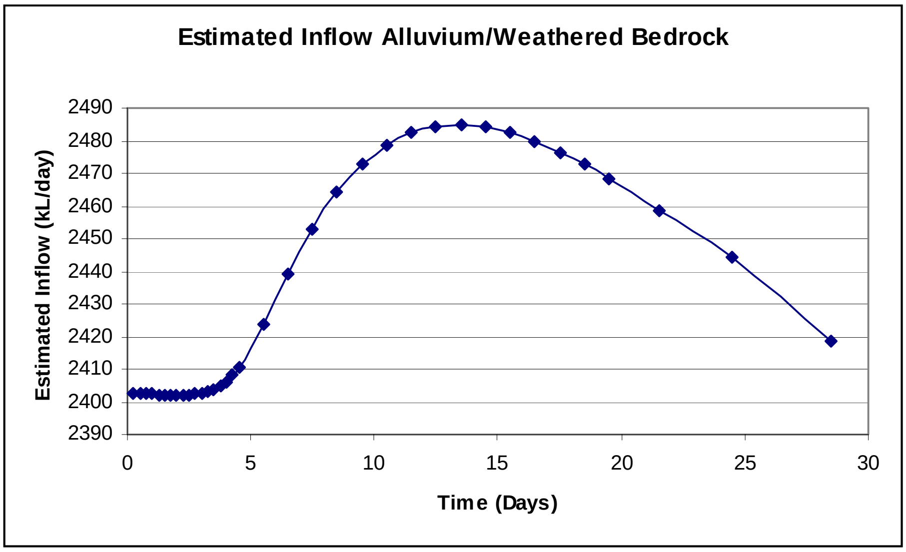
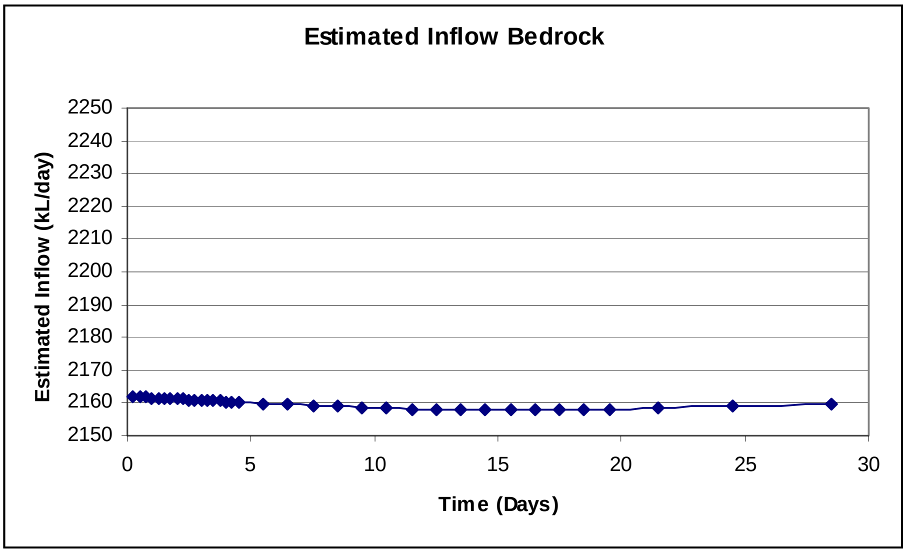
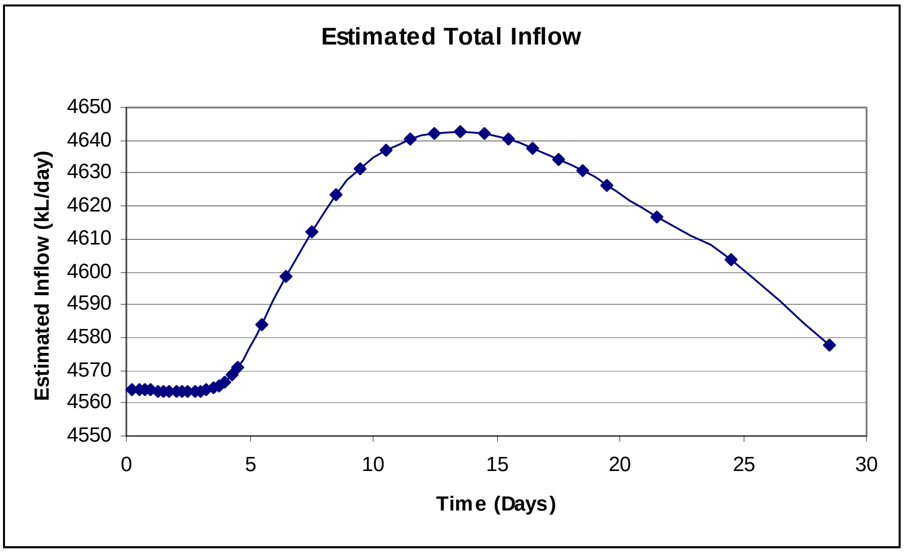
Figure 30d.srf



Estimated Inflow Alluvium/Weathered Bedrock



Estimated Inflow Bedrock



Estimated Total Inflow

Job No.	42905628	
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Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

ESTIMATED GROUNDWATER INFLOW DURING 1 IN 50 YEAR FLOOD EVENT

Figure 31

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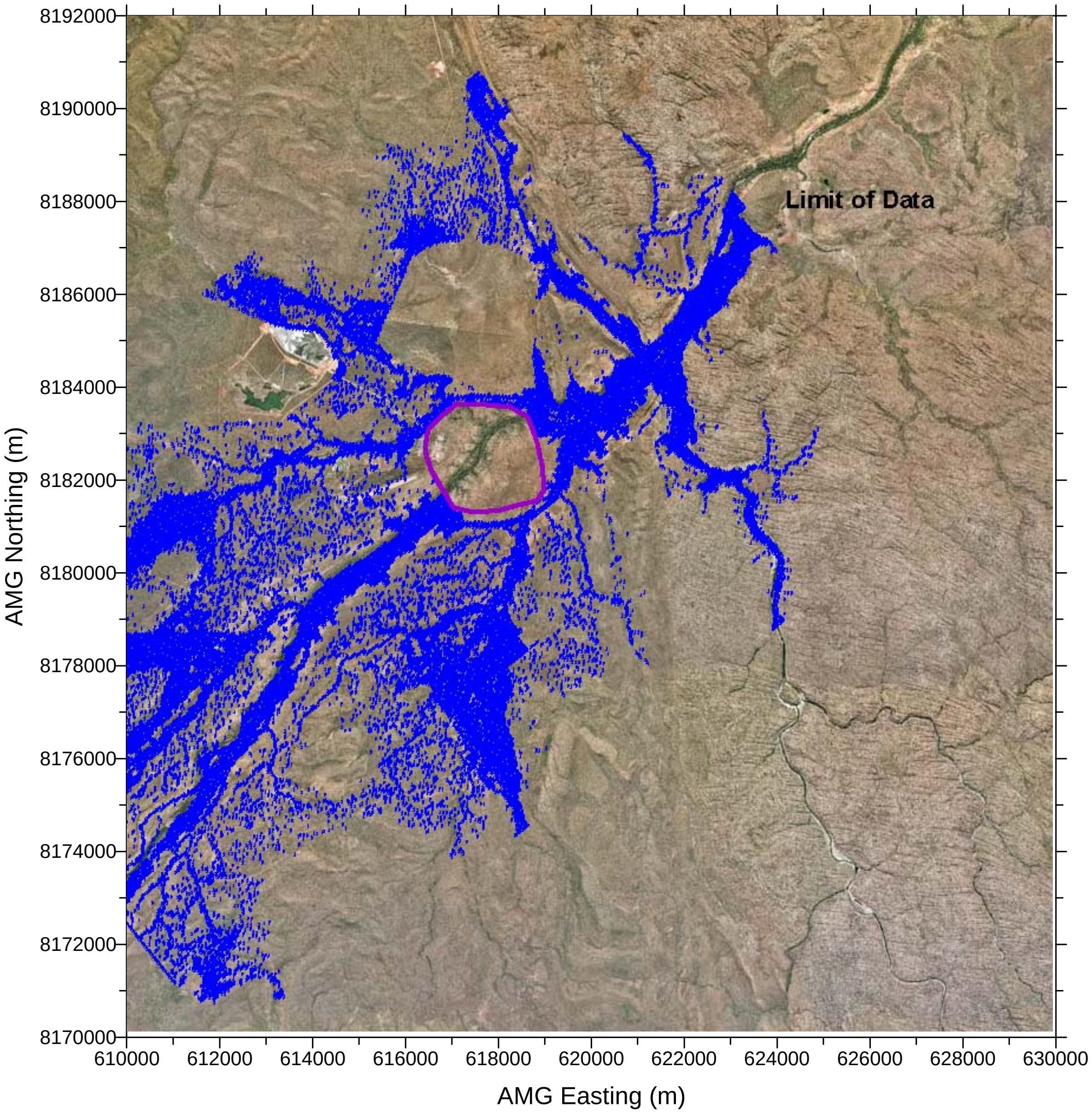
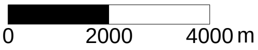


Levee Wall	🟪



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

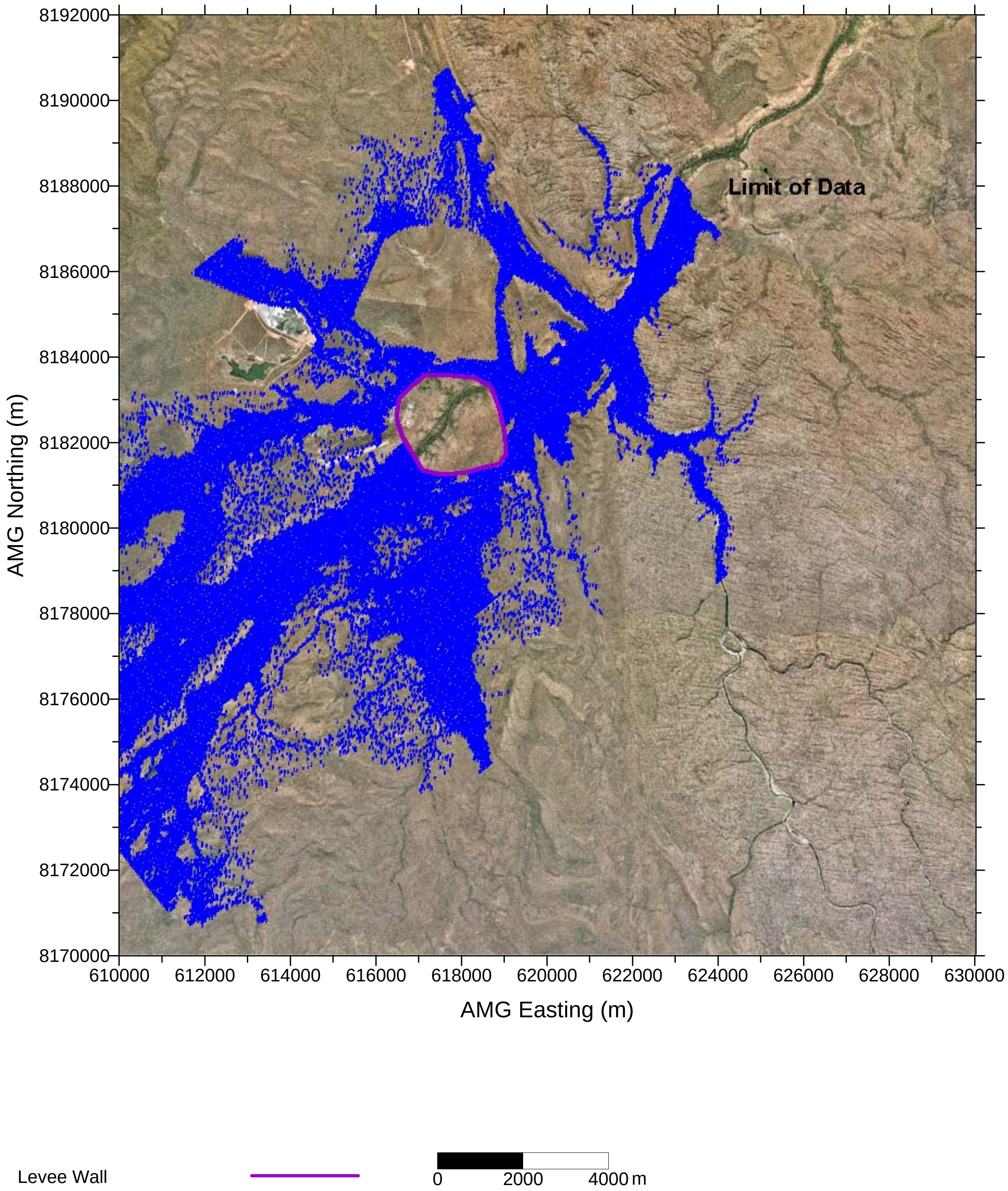
Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 500 YEAR EVENT (DAY 1)

Figure 32

URS



Scale 1: 150,000

AGD 84

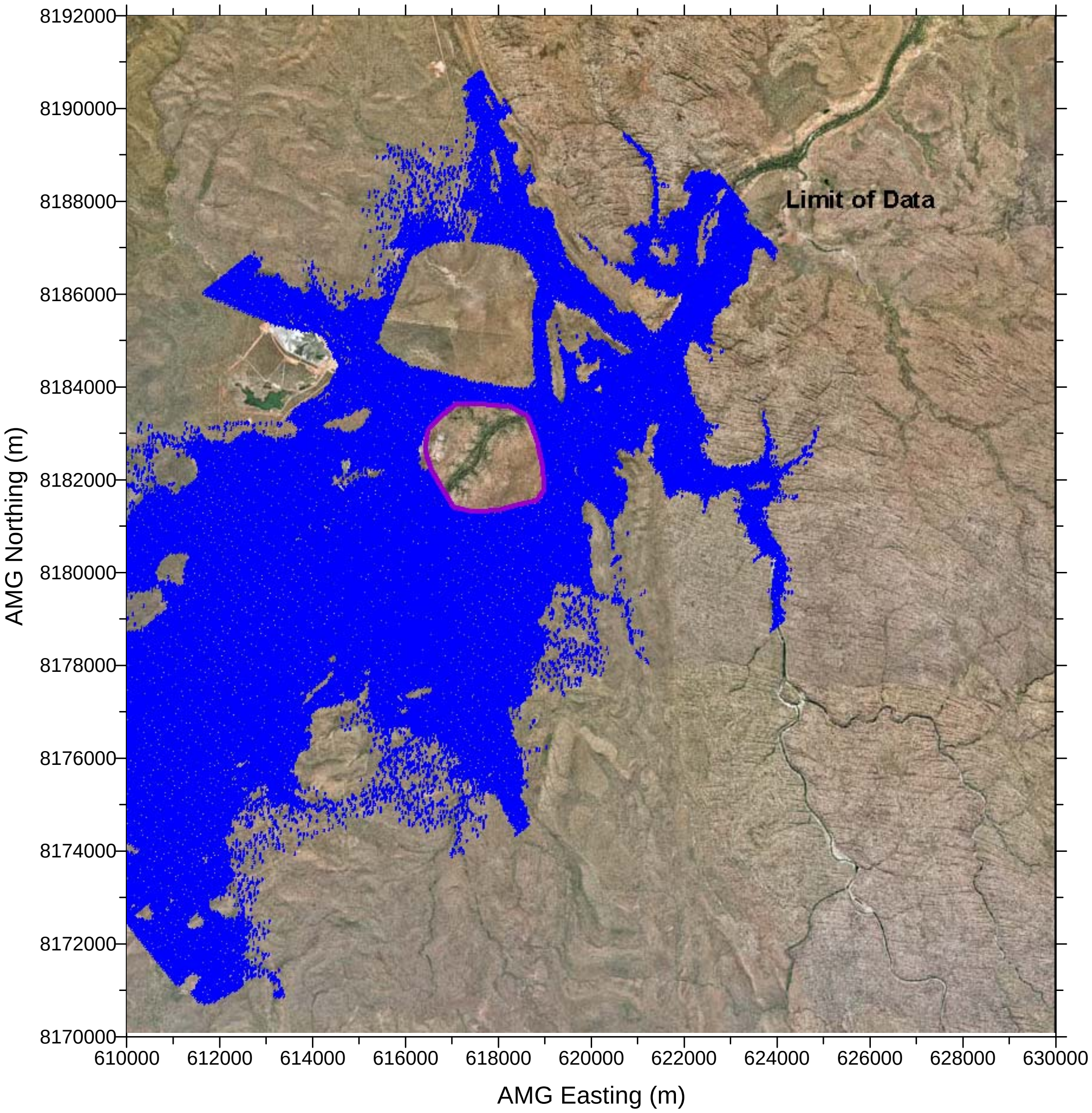
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 500 YEAR EVENT (DAY 2)

Figure 32a



Levee Wall

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

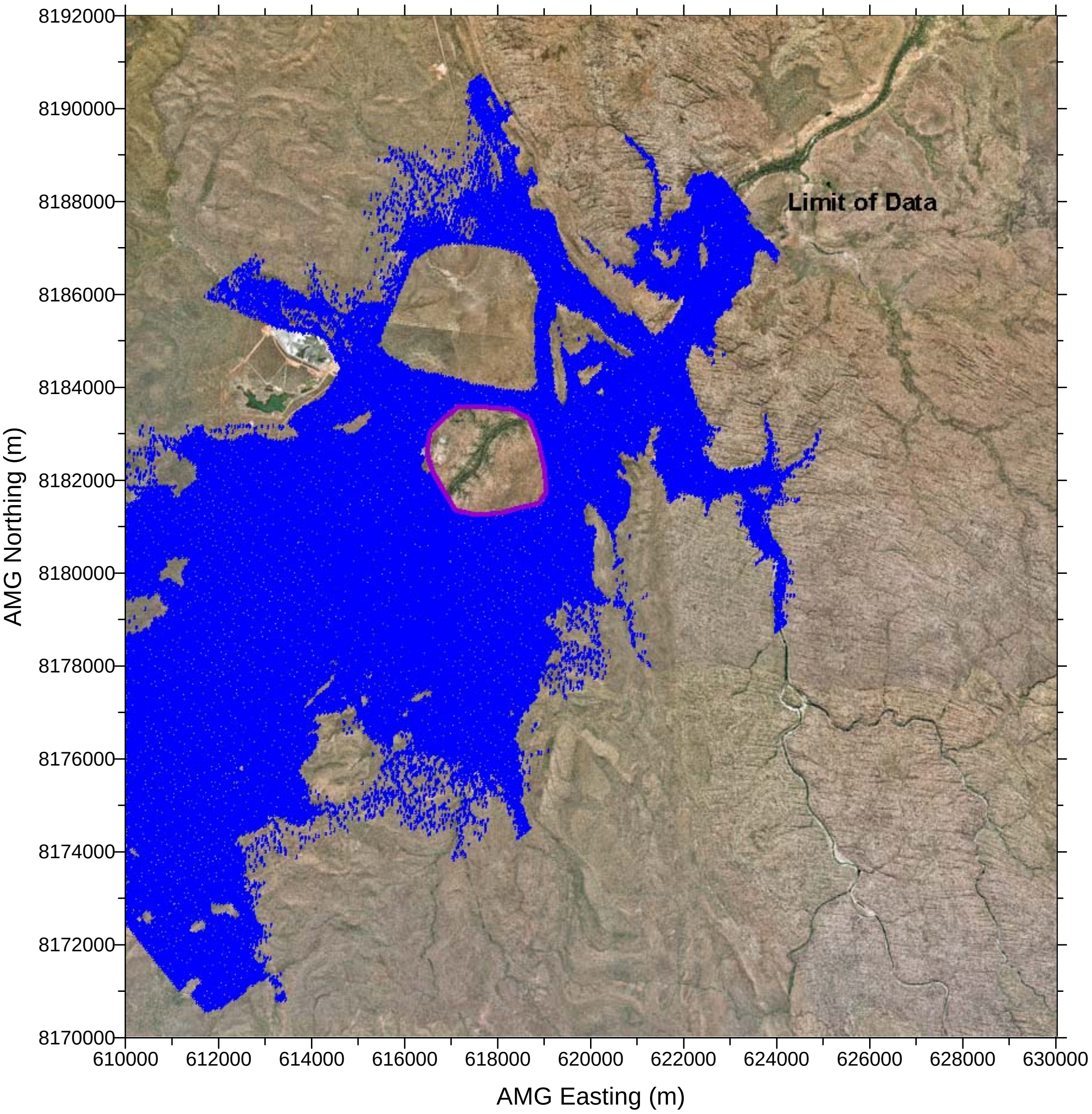
Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 500 YEAR EVENT (DAY 3)

Figure 32b

URS



Levee Wall	▬

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

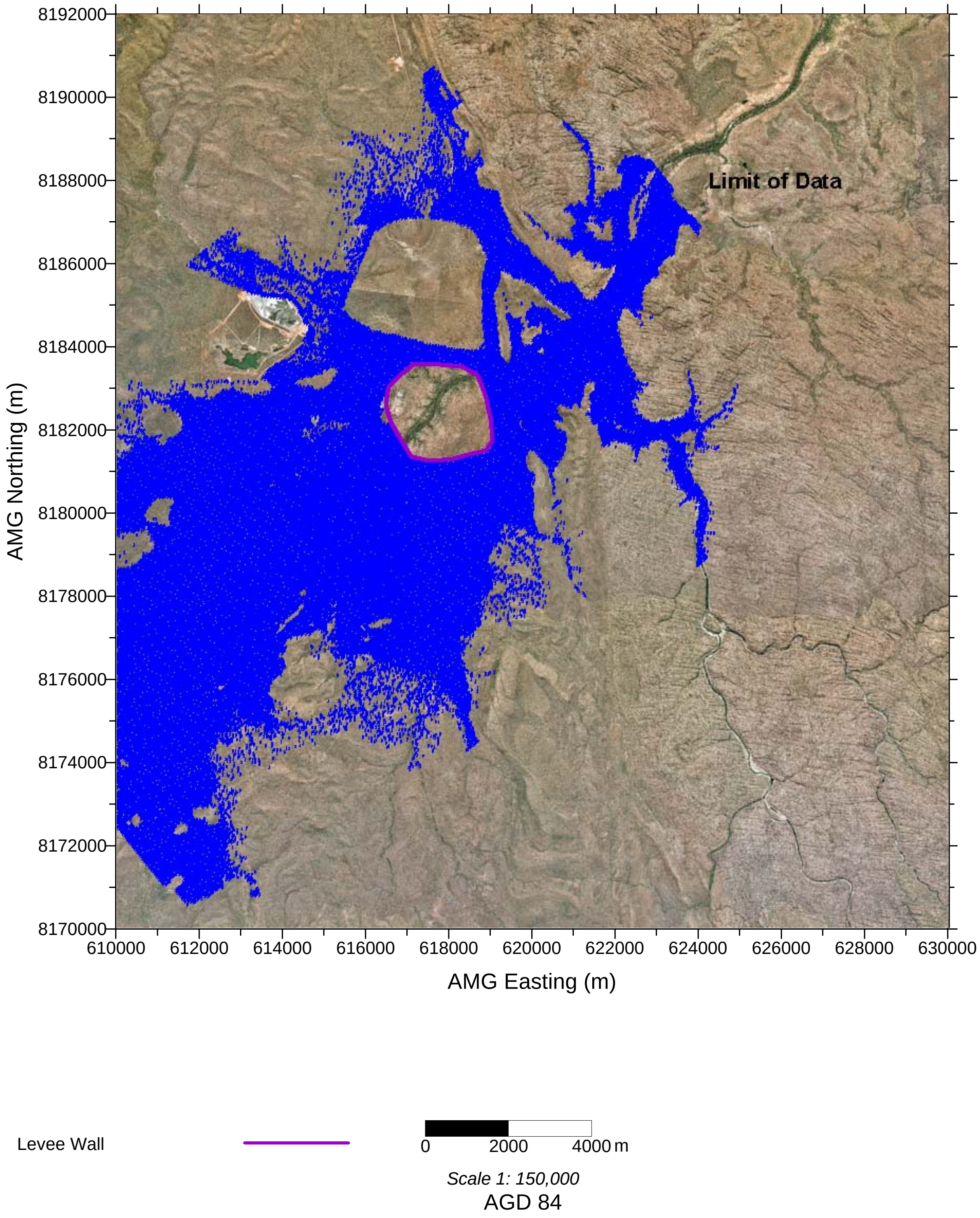
Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 500 YEAR EVENT (DAY 4)

Figure 32c

URS



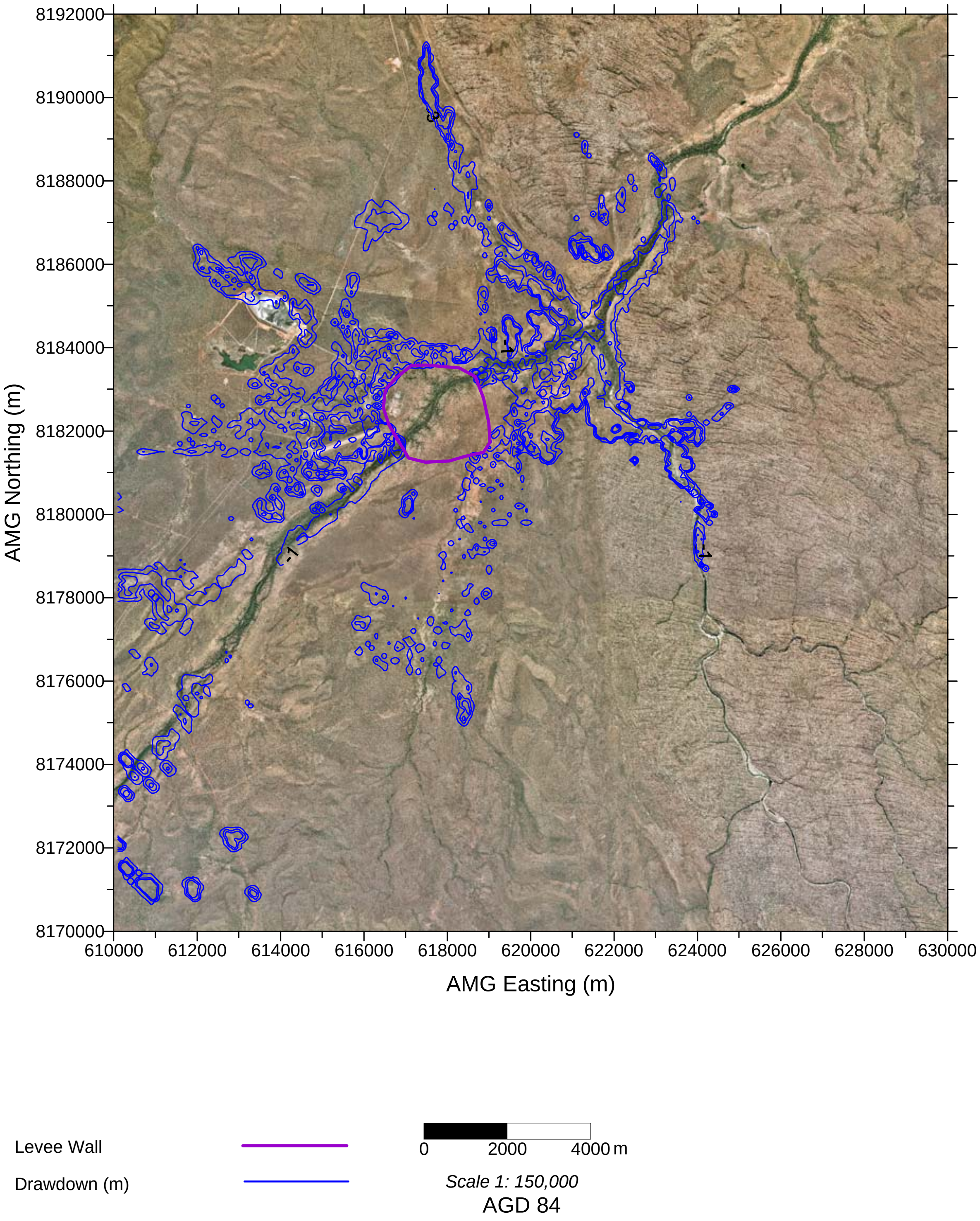
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

MAXIMUM FLOODING EXTENT
1 IN 500 YEAR EVENT (DAY 4.5)

Figure 32d



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 500 YEAR FLOOD EVENT (DAY 1)

Figure 33

URS

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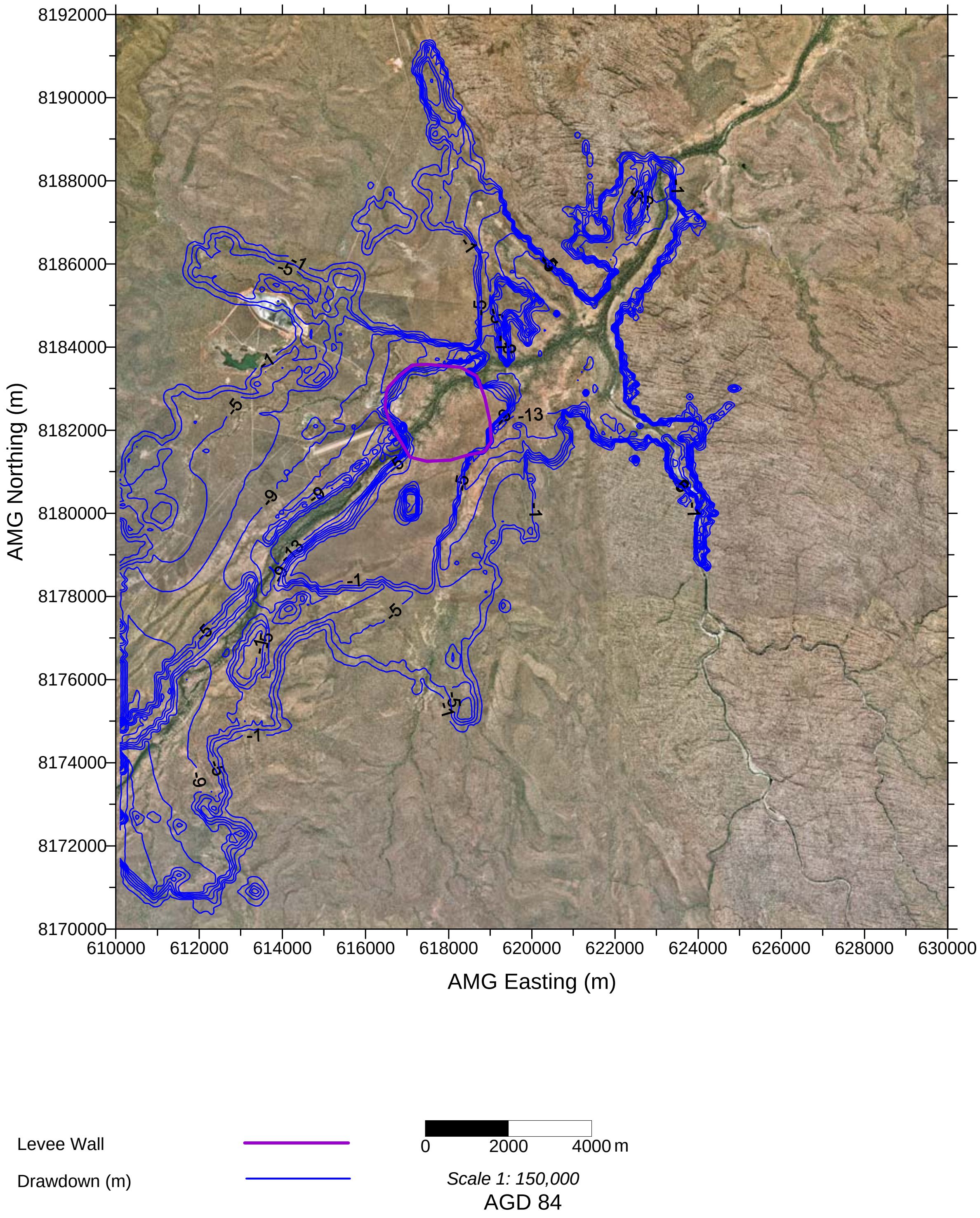
Figure 33.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 500 YEAR FLOOD EVENT (DAY 5)

Figure 33a

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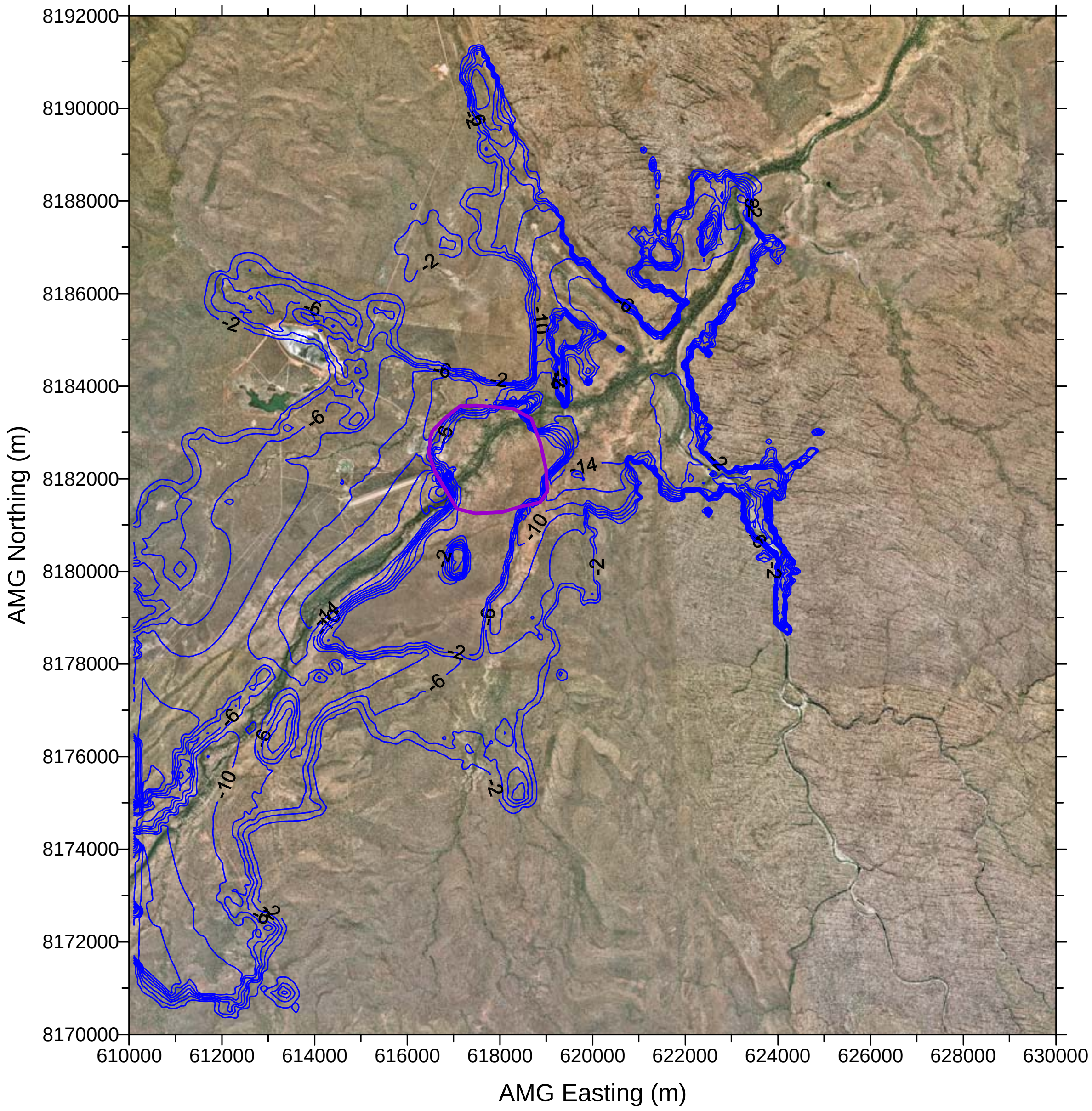
Figure 33a.srf



Levee Wall ▬

Drawdown (m) ▬

0 2000 4000 m

Scale 1: 150,000

AGD 84

			Xstrata PLC McARTHUR RIVER MINE EXPANSION MRM EIS GROUNDWATER MODELLING **GROUNDWATER LEVEL CHANGE** **1 IN 500 YEAR FLOOD EVENT (DAY 10)**	**Figure 33b** URS
Job No.	42905628			
Prep. By	CMAC	19 Apr '05		
Chk'd By	RIJV	21 Apr '05		
Revision No.		0		

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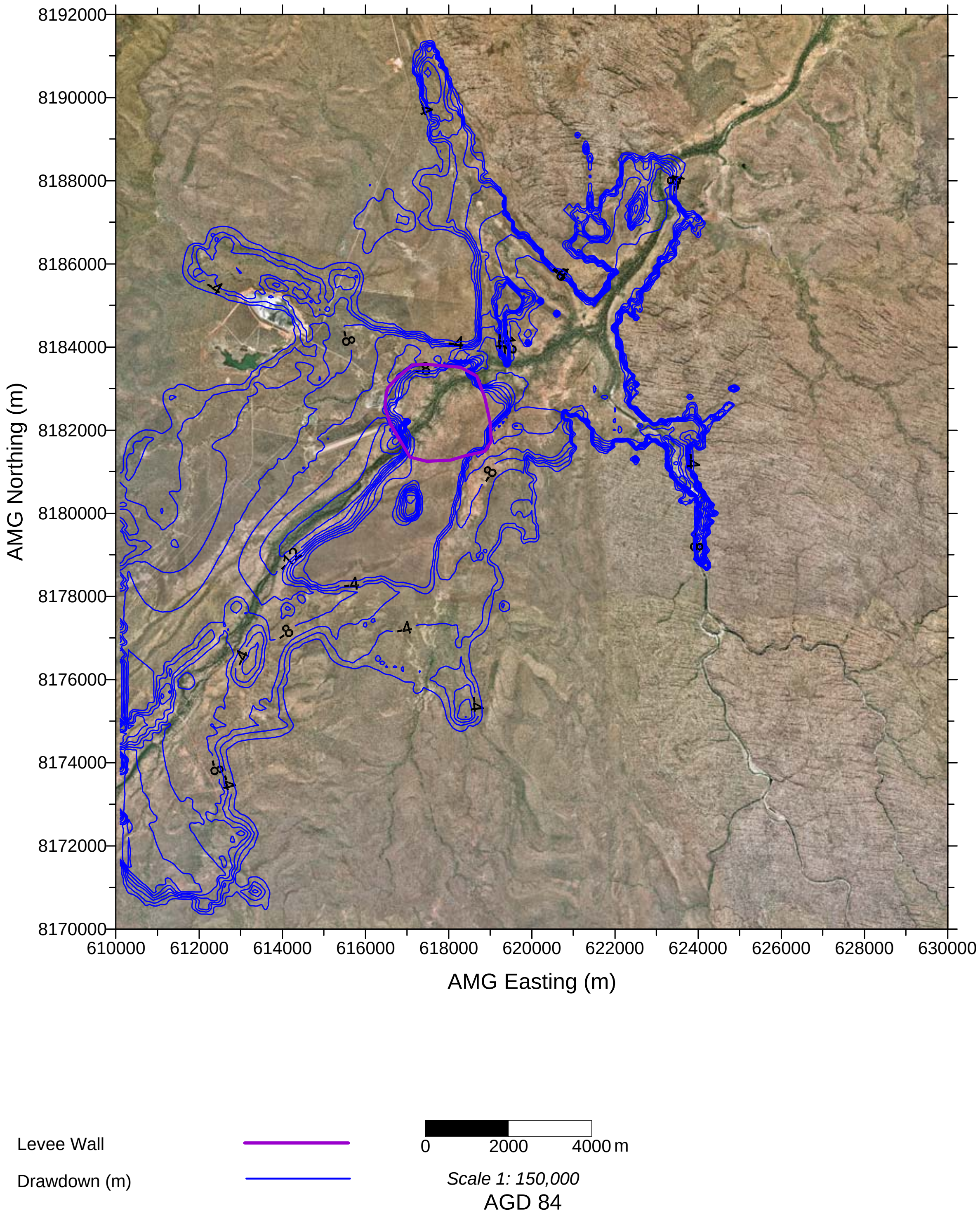
Figure 33b.srf



Job No.	42905628		
Prep. By	CMAC	19 Apr '05	
Chk'd By	RIJV	21 Apr '05	
Revision No.		0	

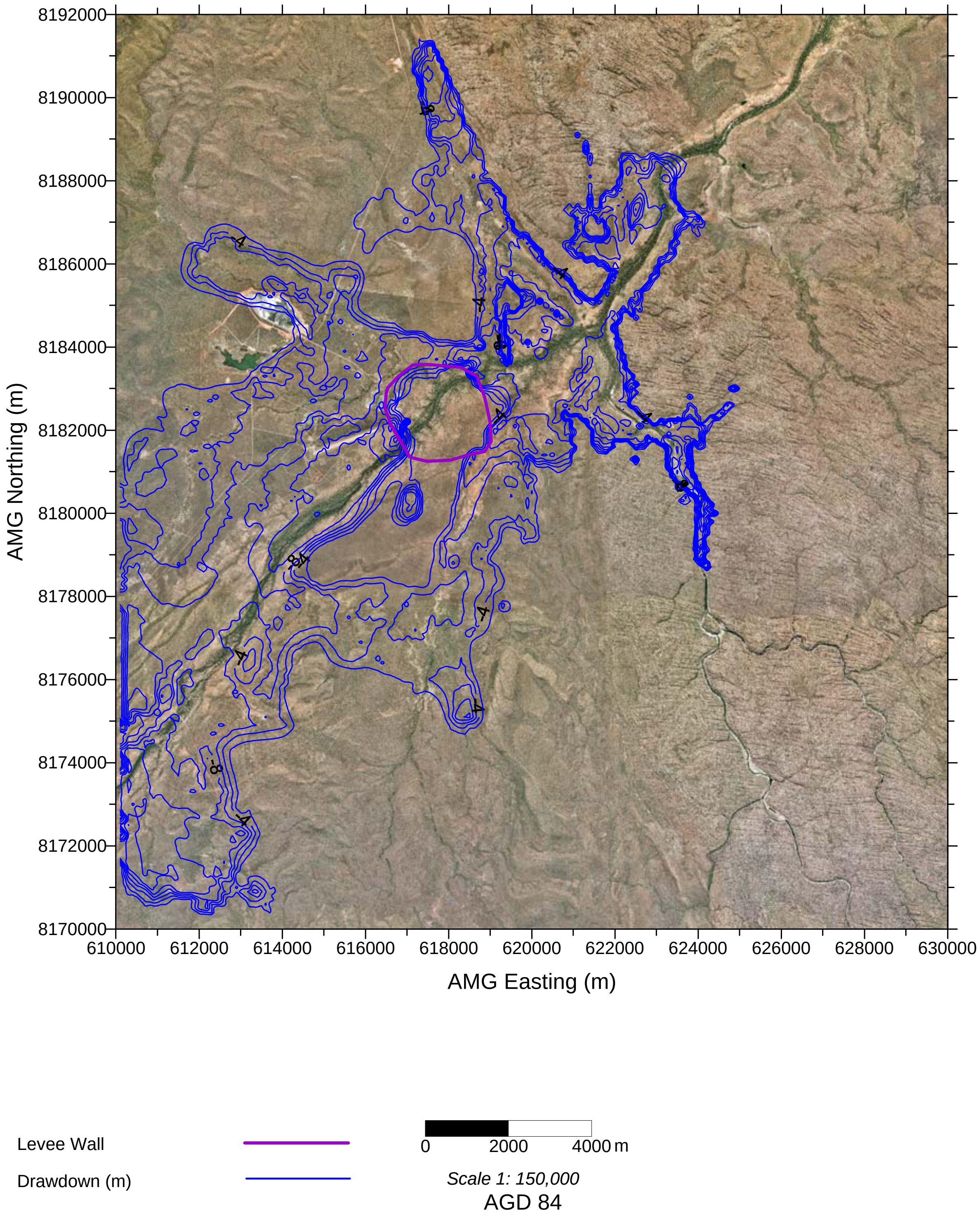
Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 500 YEAR FLOOD EVENT (DAY 12)

Figure 33c

URS



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC

McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 500 YEAR FLOOD EVENT (DAY 15)

Figure 33d

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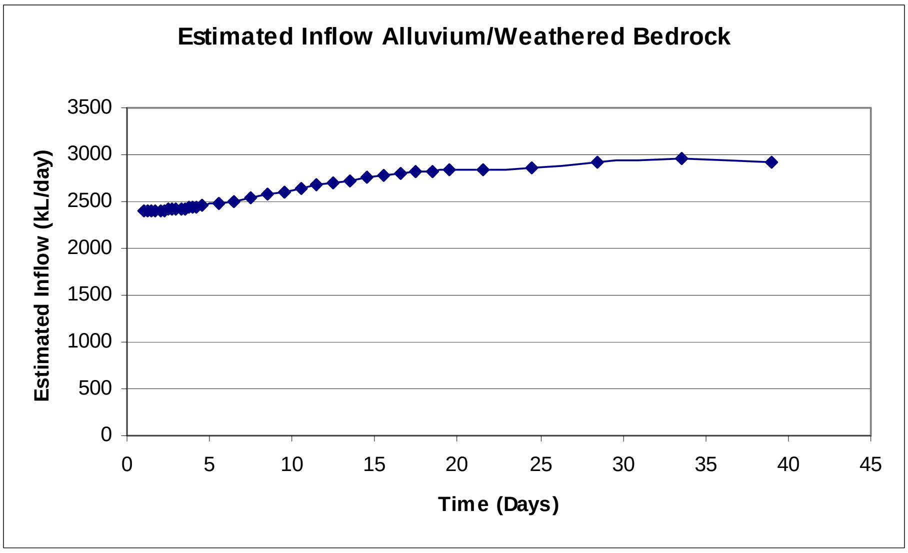
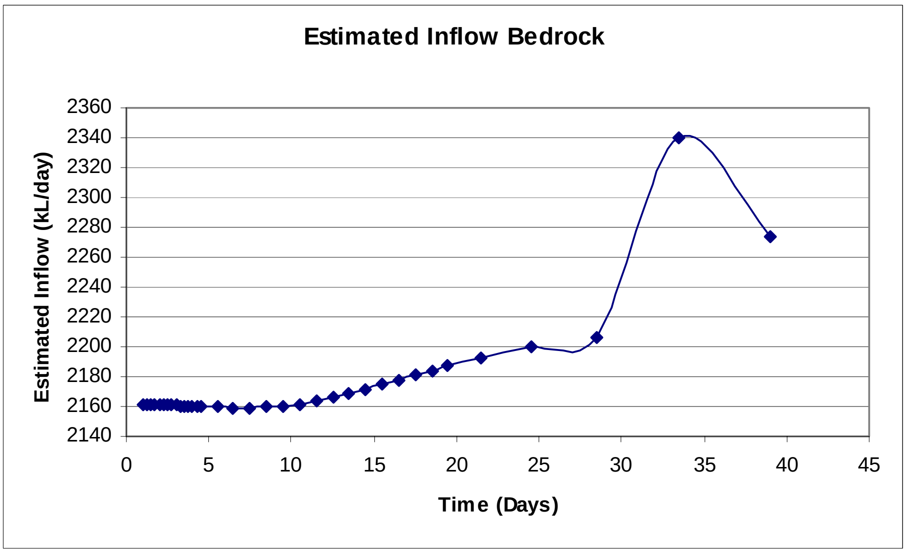
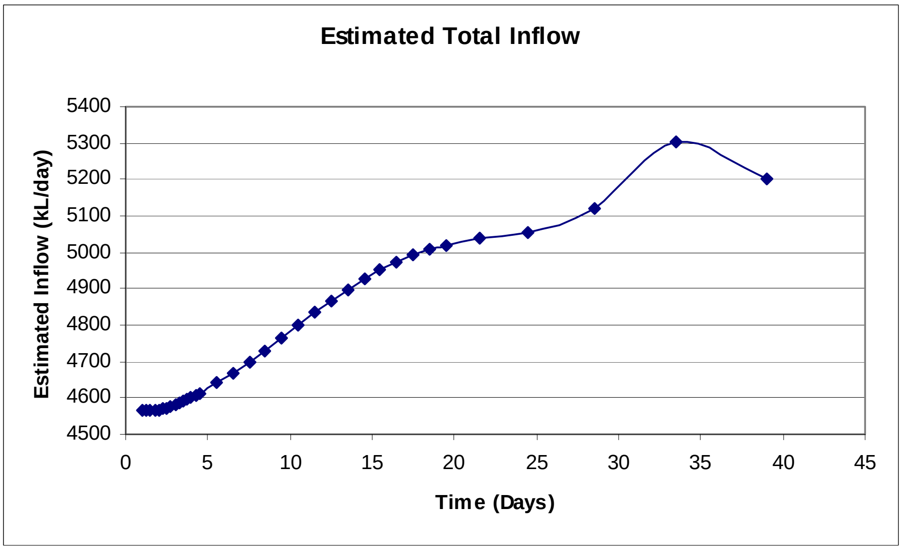
Figure 33d.srf





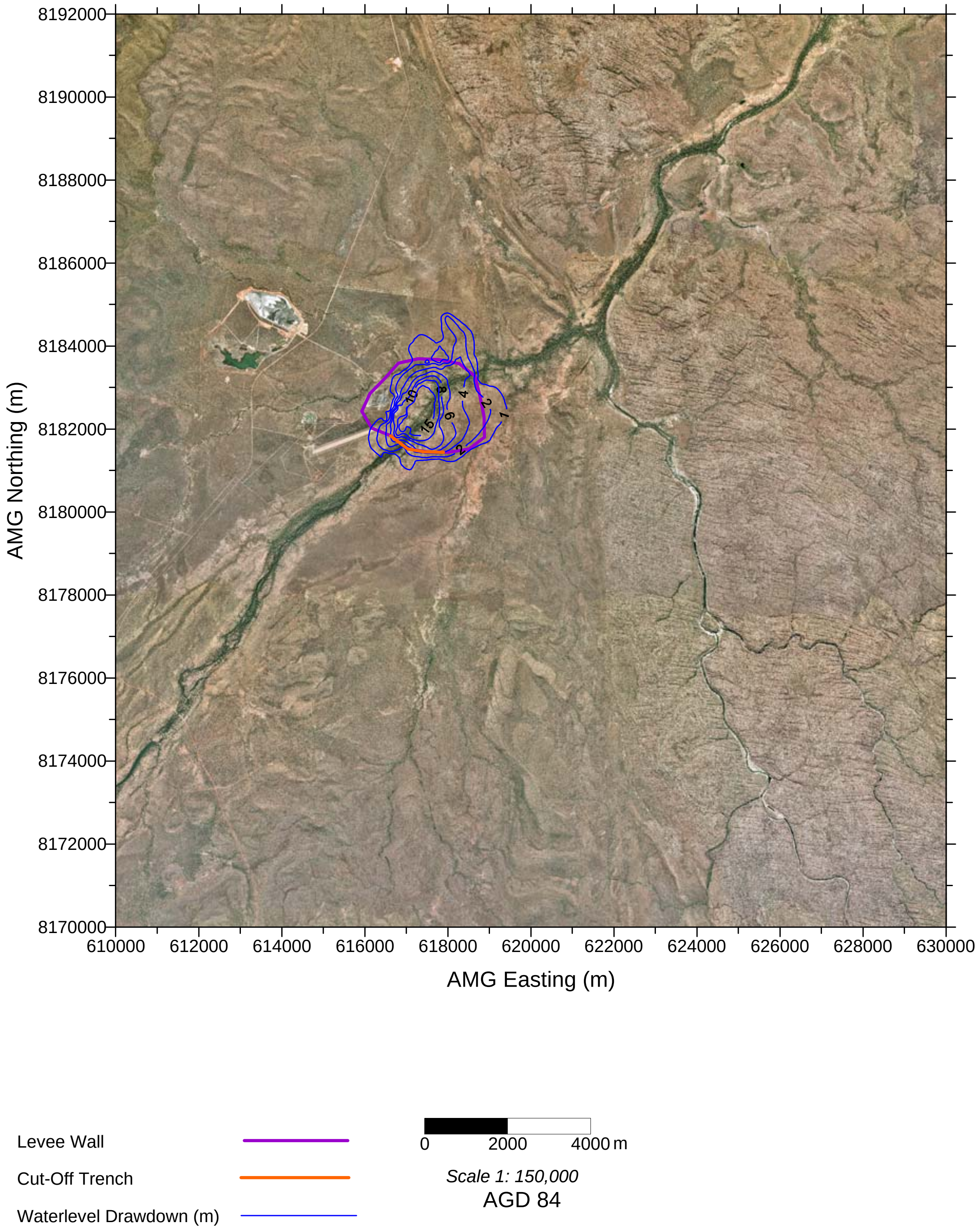


Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

ESTIMATED GROUNDWATER INFLOW DURING 1 IN 500 YEAR FLOOD EVENT

Figure 34



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 4 PALAEOCHANNEL GRAVEL (LAYER 3) WITH CUT-OFF TRENCH

Figure 35

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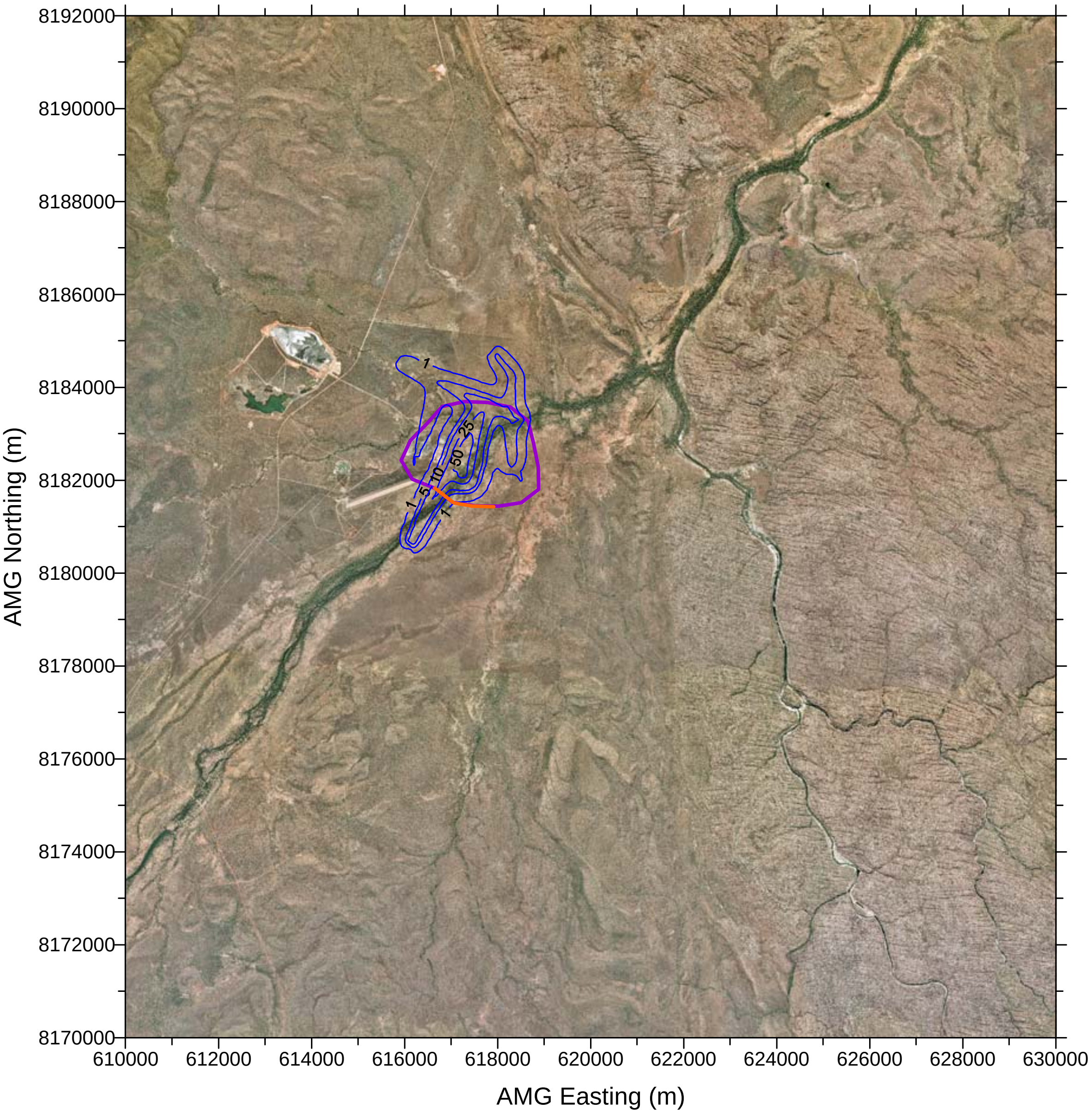
Figure 35.srf



Levee Wall	▬
Cut-Off Trench	▬
Waterlevel Drawdown (m)	▬

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 4 BEDROCK (LAYER 5) WITH CUT-OFF TRENCH

Figure 35a

URS

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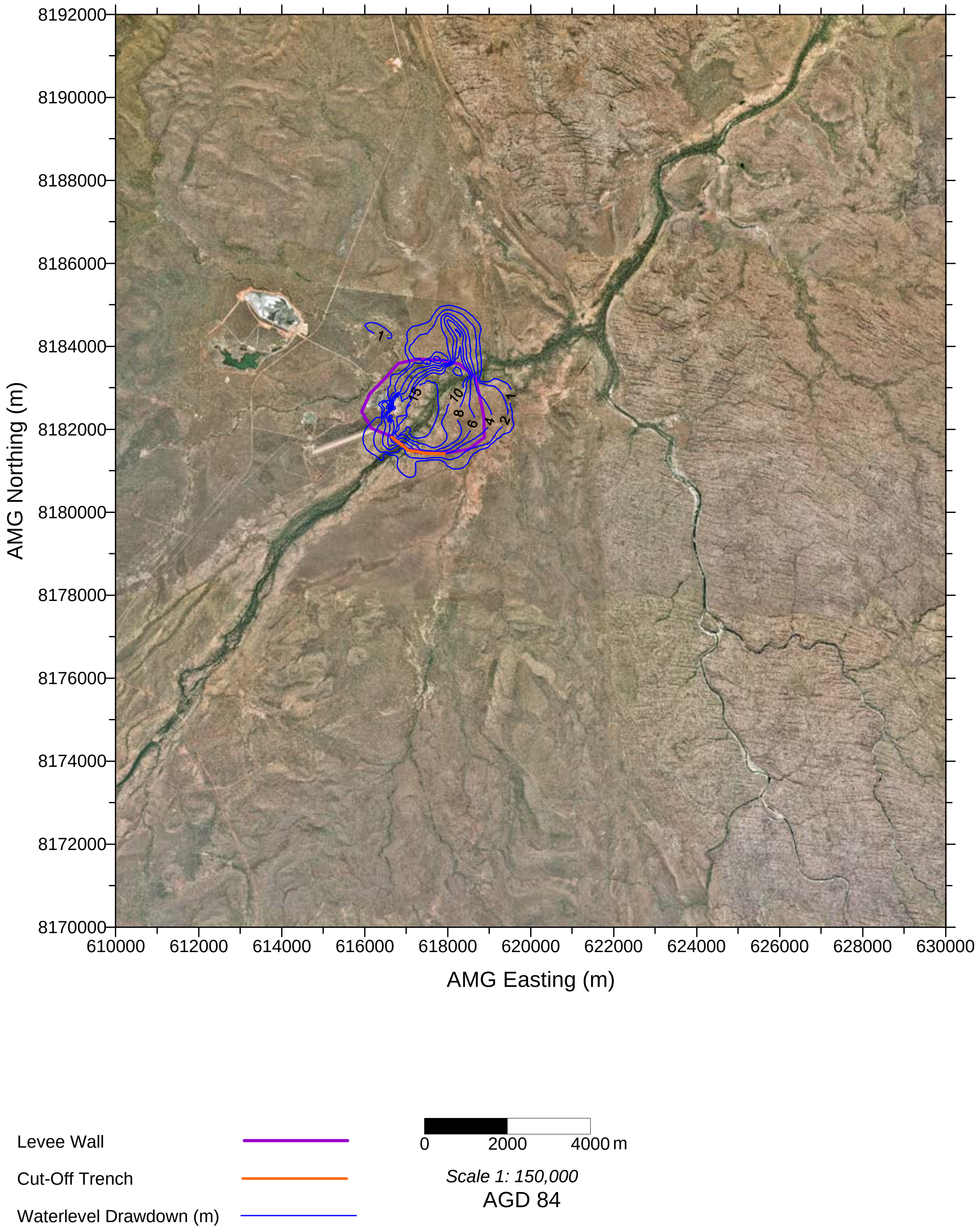
Figure 35a.srf



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Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

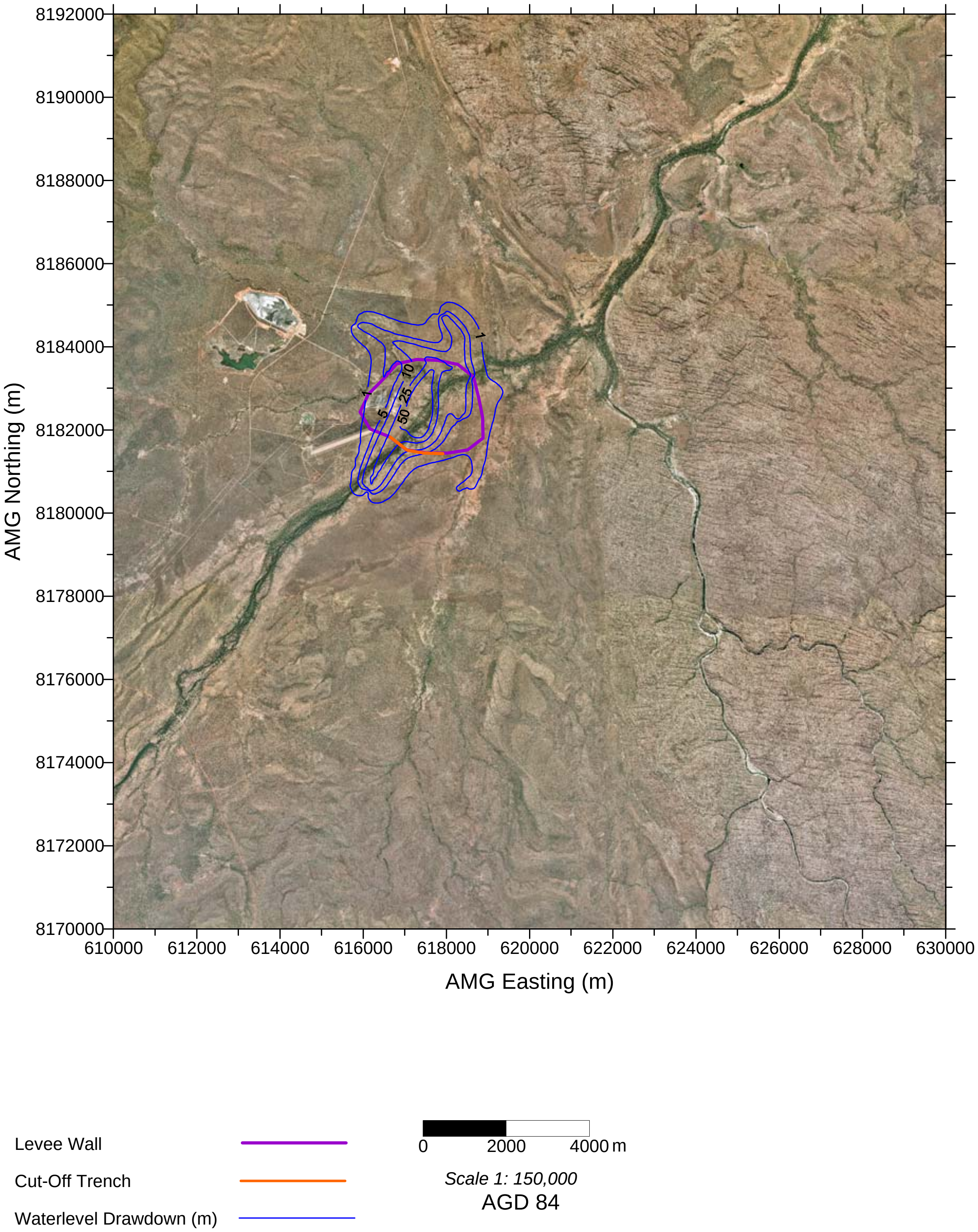
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 10 PALAEOCHANNEL GRAVEL (LAYER 3) WITH CUT-OFF TRENCH

Figure 36

URS

Figure 36.srf



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Job No.	42905628	
Prep. By	CMAC	19 Apr '05
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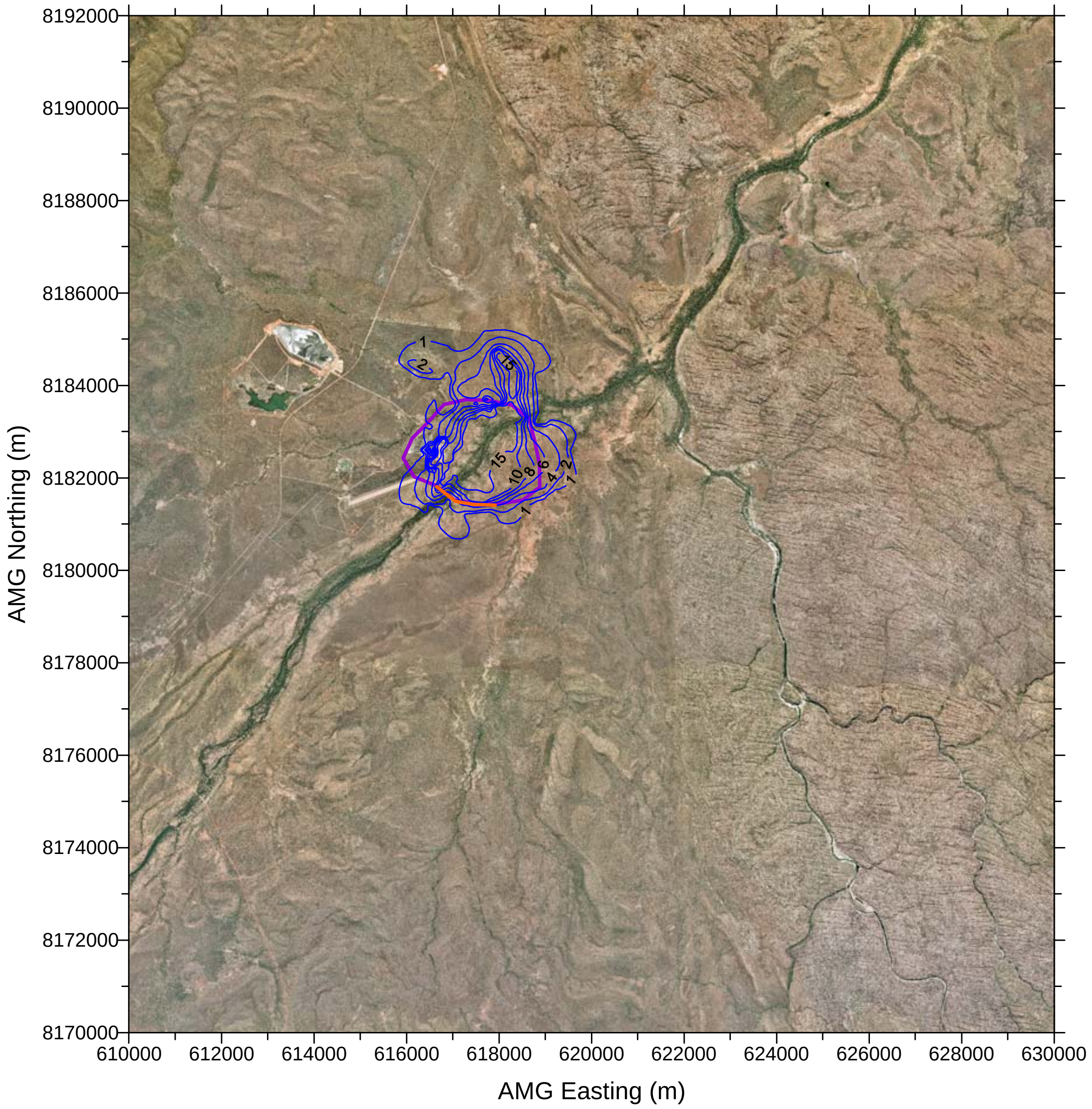
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 10 BEDROCK (LAYER 5) WITH CUT-OFF TRENCH

Figure 36a

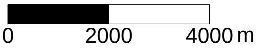
Figure 36a.srf



Levee Wall

Cut-Off Trench

Waterlevel Drawdown (m)



Scale 1: 150,000

AGD 84

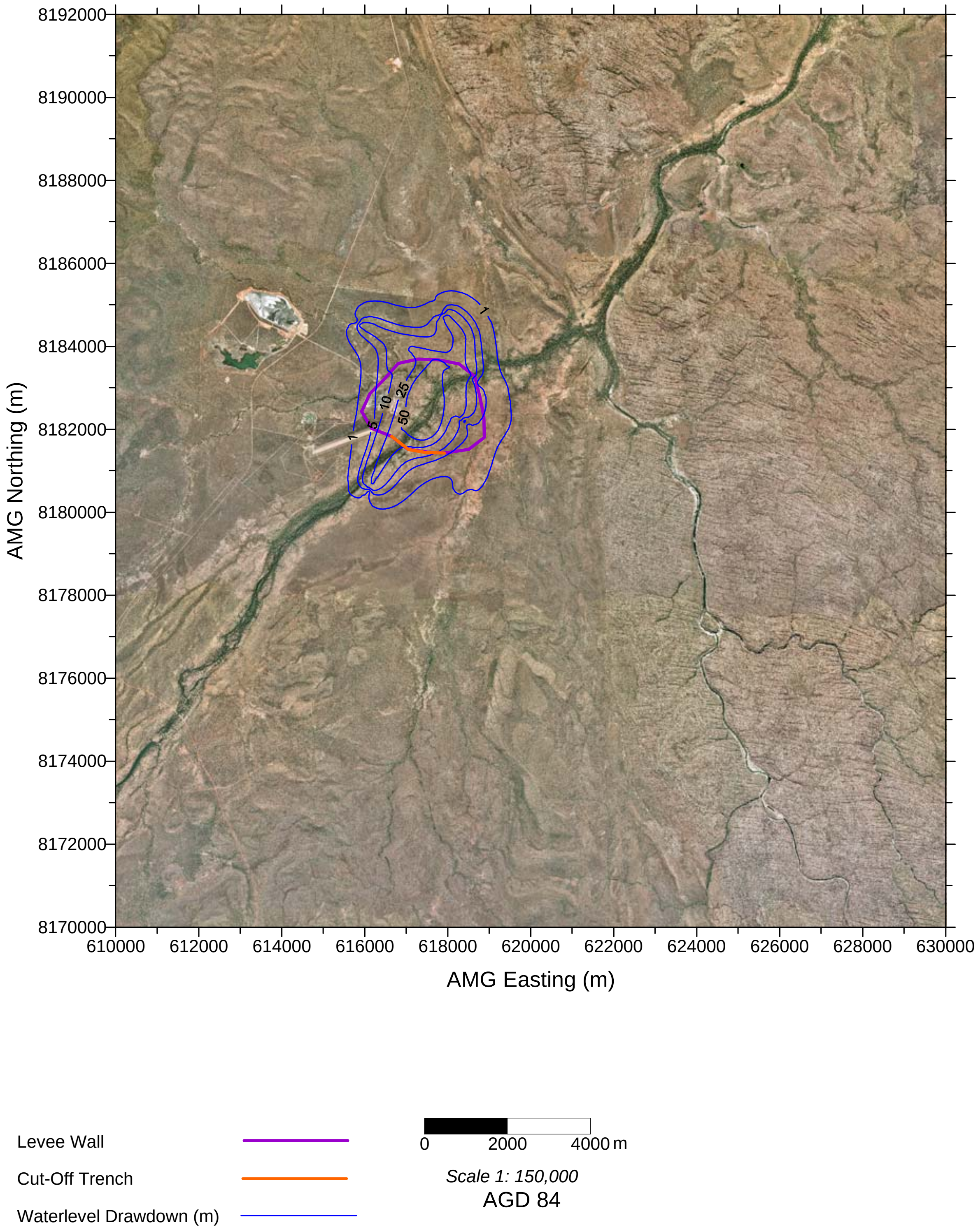
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 20 PALAEOCHANNEL GRAVEL (LAYER 3) WITH CUT-OFF TRENCH

Figure 37

URS



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

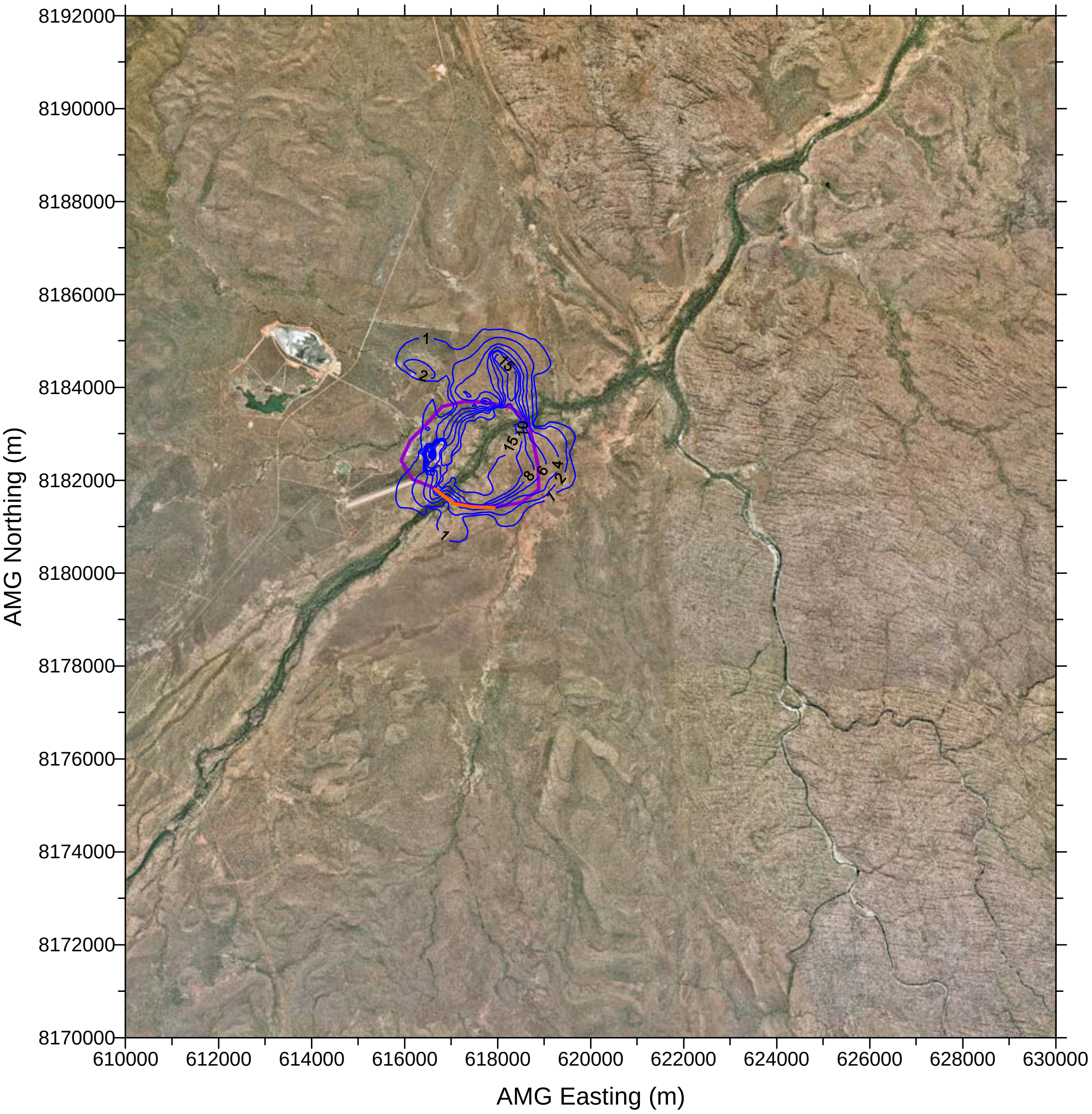
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 20 BEDROCK (LAYER 5) WITH CUT-OFF TRENCH

Figure 37a

URS AUSTRALIA PTY LTD Perth Office +61 8 9221 1630

Figure 37a.srf



Levee Wall	▬
Cut-Off Trench	▬
Waterlevel Drawdown (m)	―

0 2000 4000 m

Scale 1: 150,000

AGD 84

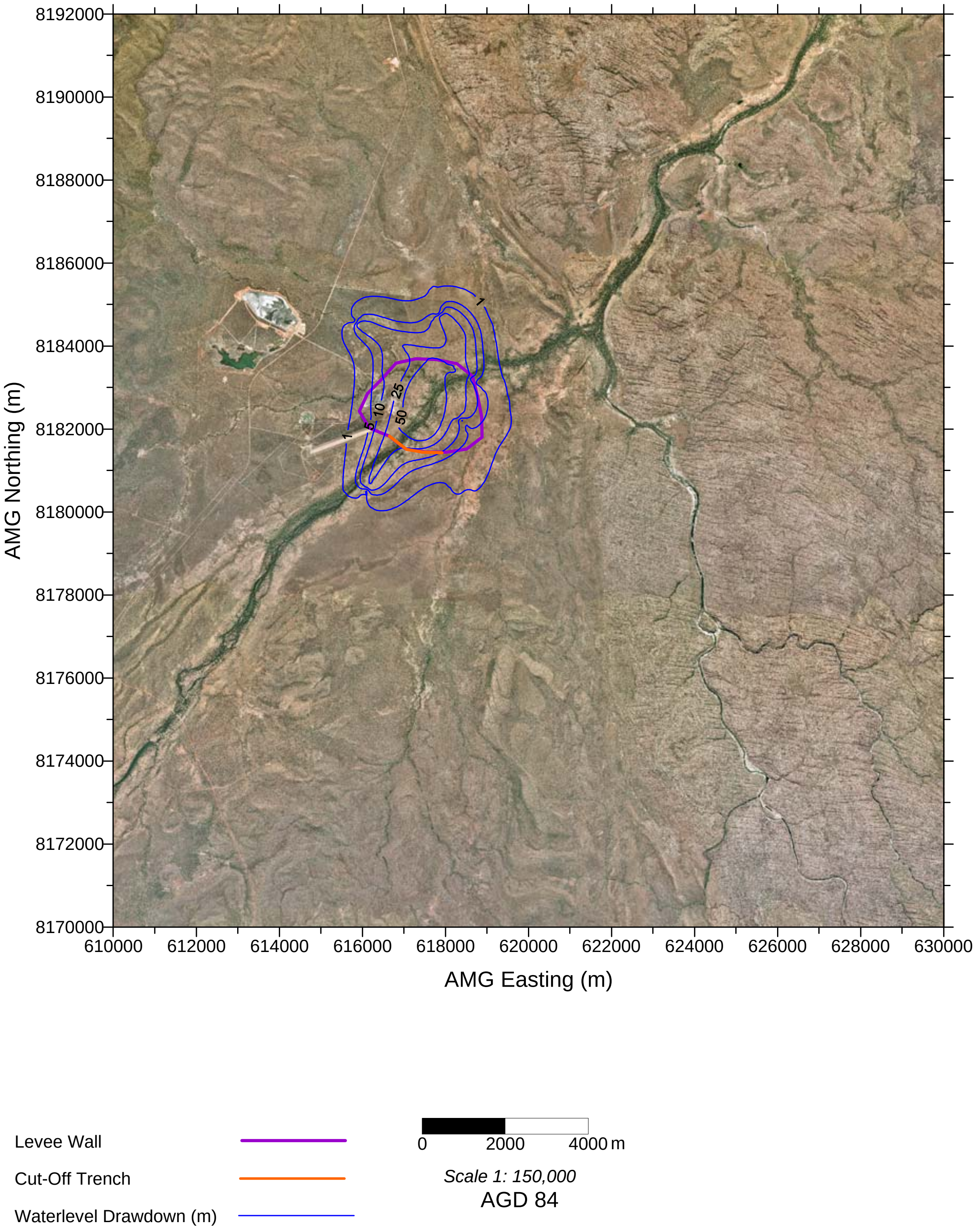
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.	0	

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 25 PALAEOCHANNEL GRAVEL (LAYER 3) WITH CUT-OFF TRENCH

Figure 38

URS



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

SIMULATED DRAWDOWN YEAR 25 BEDROCK (LAYER 5) WITH CUT-OFF TRENCH

Figure 38a

URS

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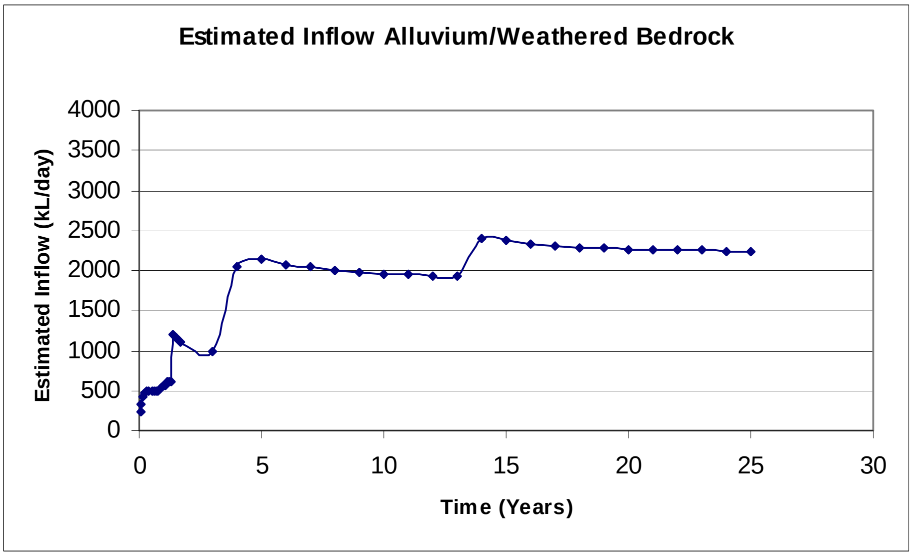
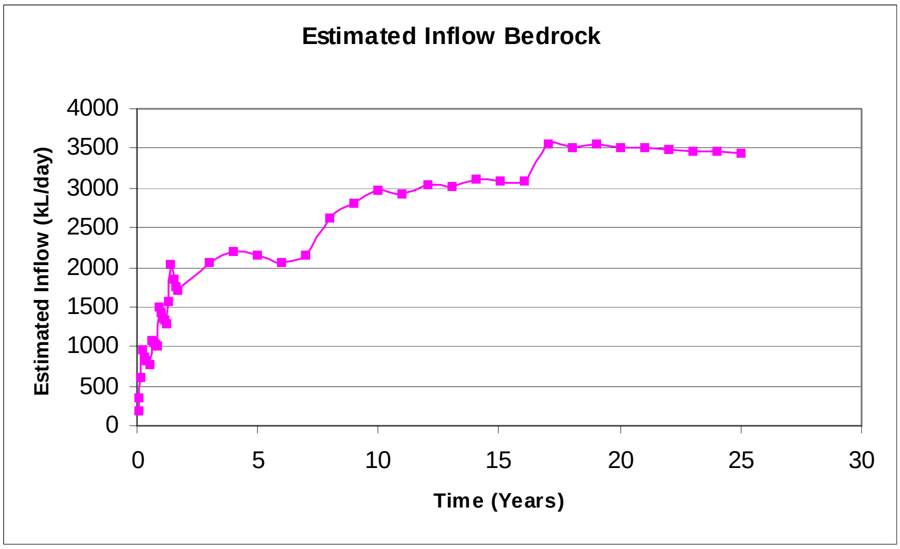
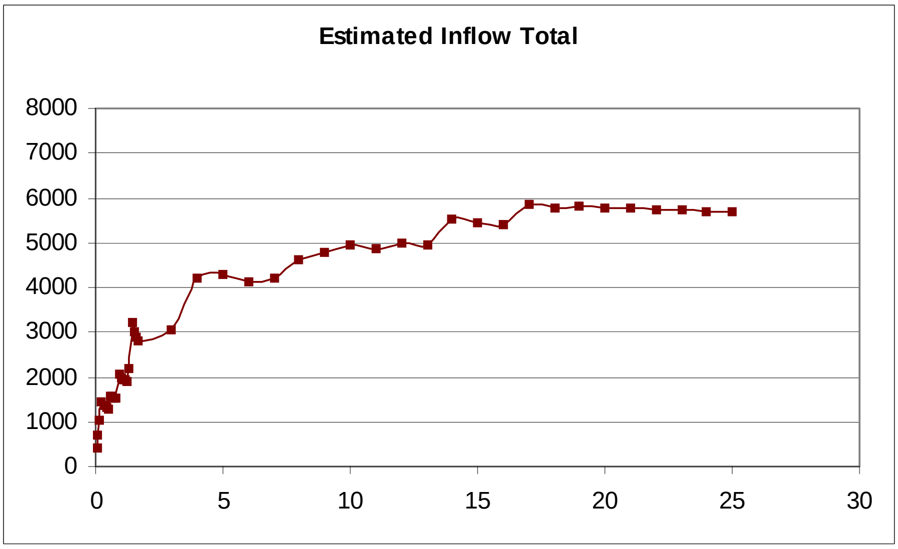
Figure 38a.srf







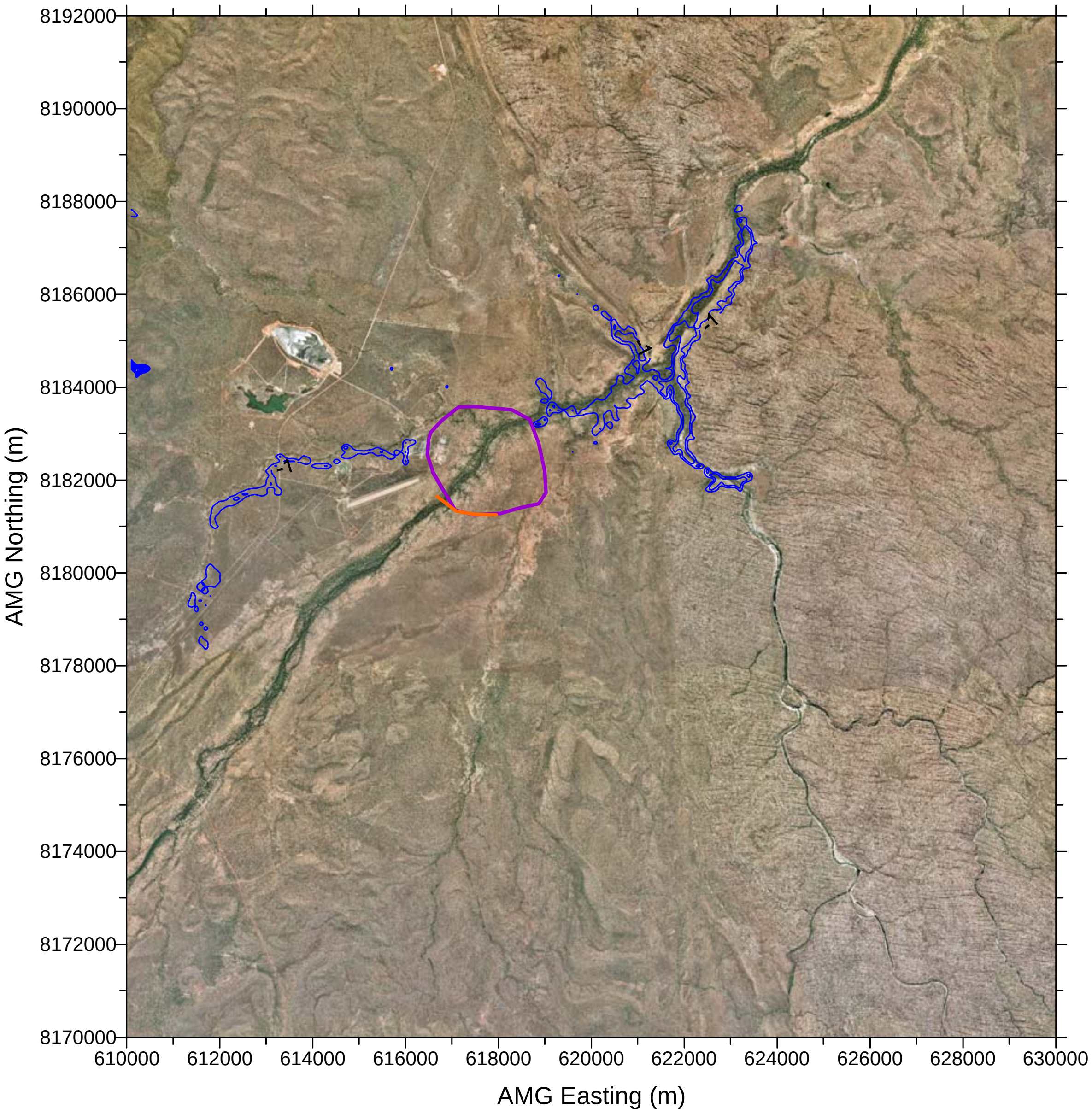
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

ESTIMATED GROUNDWATER INFLOW WITH CUT-OFF TRENCH

Figure 39

URS



Levee Wall	🟪
Cut-Off Trench	🟧
Waterlevel Drawdown (m)	🟦

Scale 1: 150,000

AGD 84

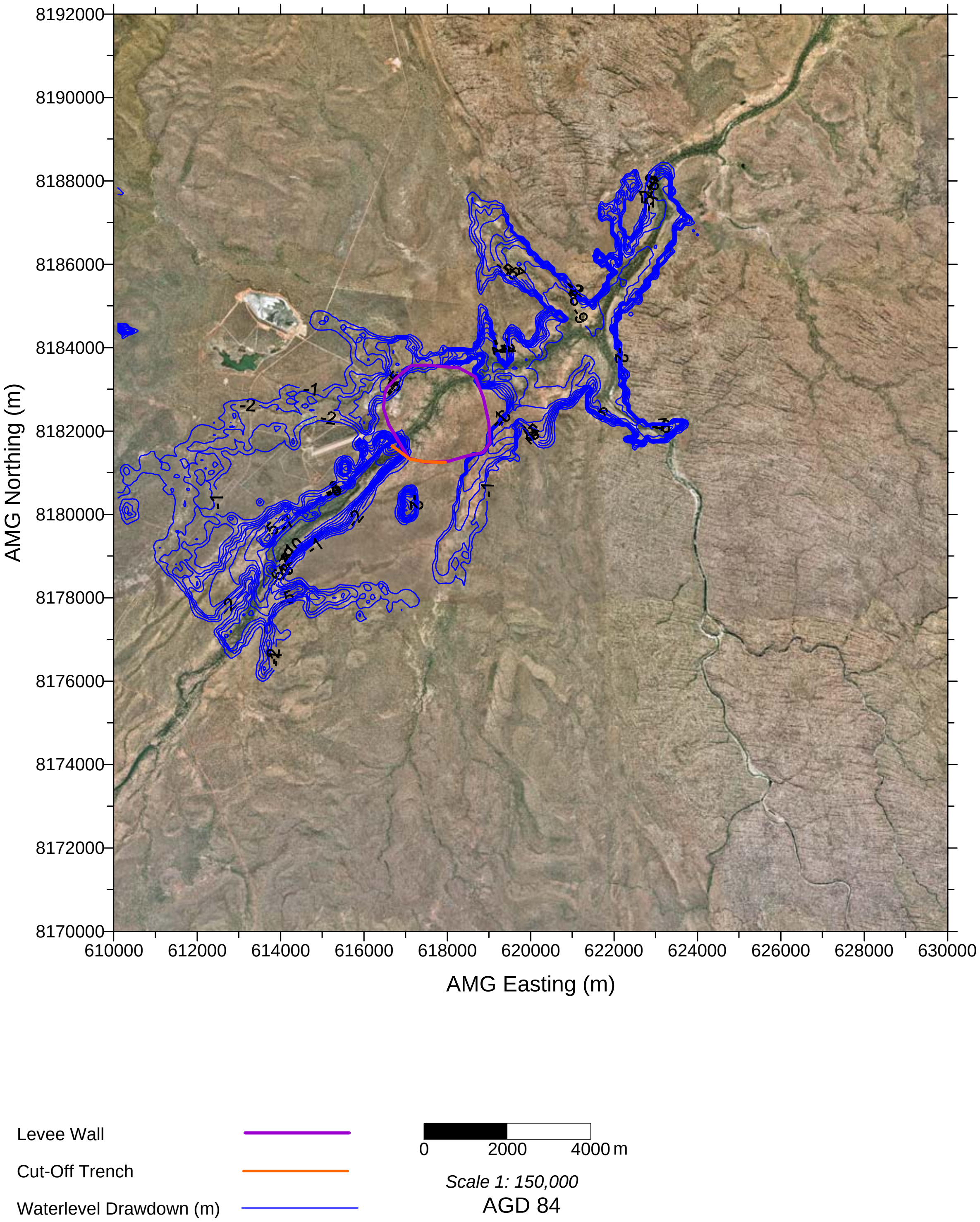
Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE 1 IN 50 YEAR FLOOD EVENT (DAY 1) WITH CUT-OFF TRENCH

Figure 40

URS



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE 1 IN 50 YEAR FLOOD EVENT (DAY 5) WITH CUT-OFF TRENCH

Figure 40a

URS

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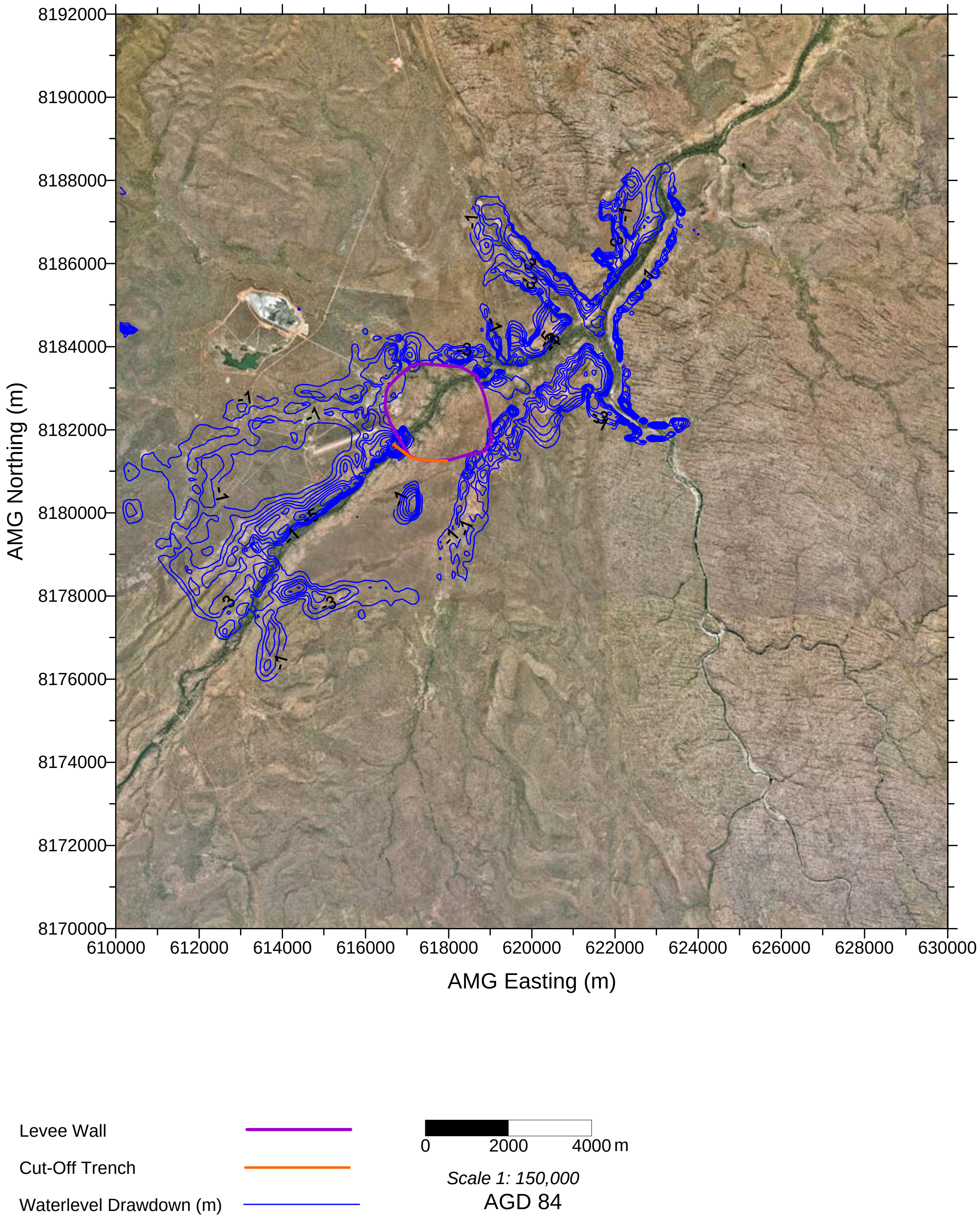
Figure 40a.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

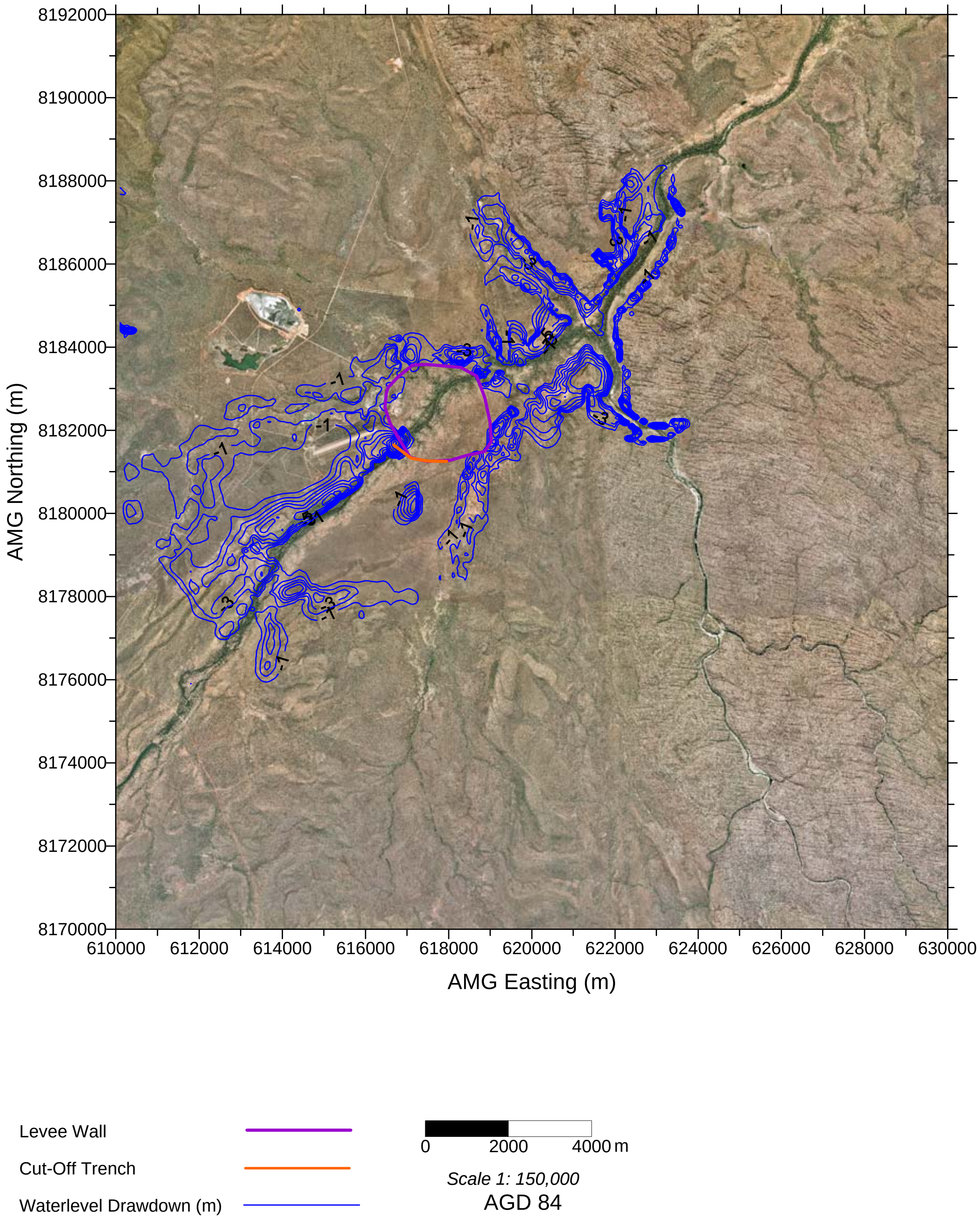
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR FLOOD EVENT (DAY 10)
WITH CUT-OFF TRENCH

Figure 40b

URS AUSTRALIA PTY LTD Perth Office +61 8 9221 1630

Figure 40b.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR FLOOD EVENT (DAY 12)
WITH CUT-OFF TRENCH

Figure 40c

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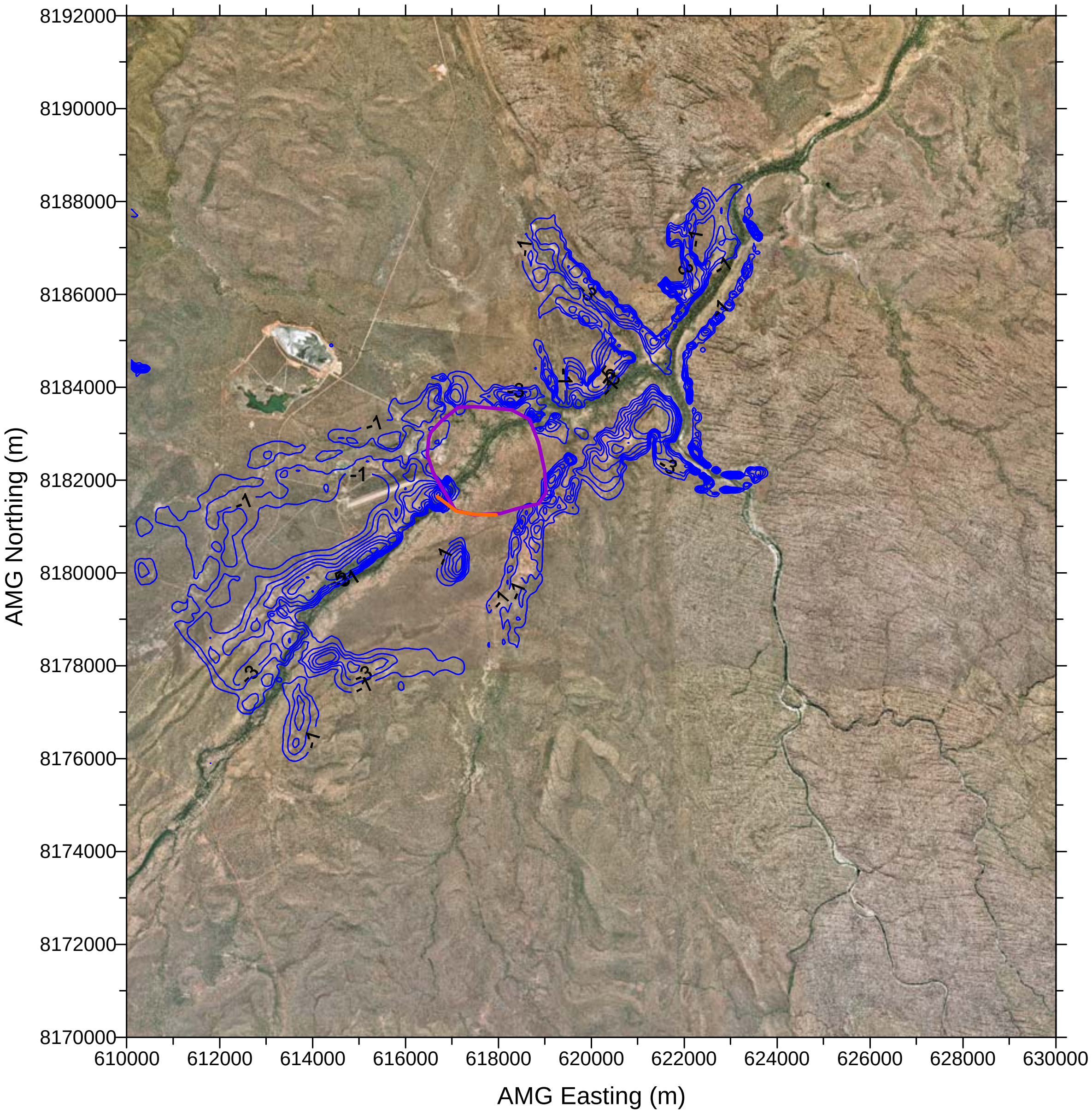
Figure 40c.srf



Levee Wall	▬
Cut-Off Trench	▬
Waterlevel Drawdown (m)	▬

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.	0	

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE
1 IN 50 YEAR FLOOD EVENT (DAY 15)
WITH CUT-OFF TRENCH

Figure 40d

URS

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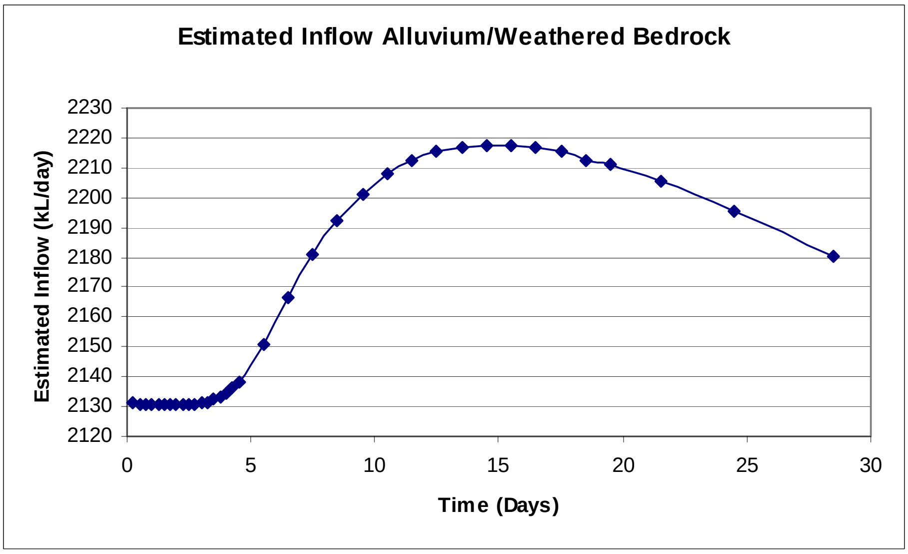
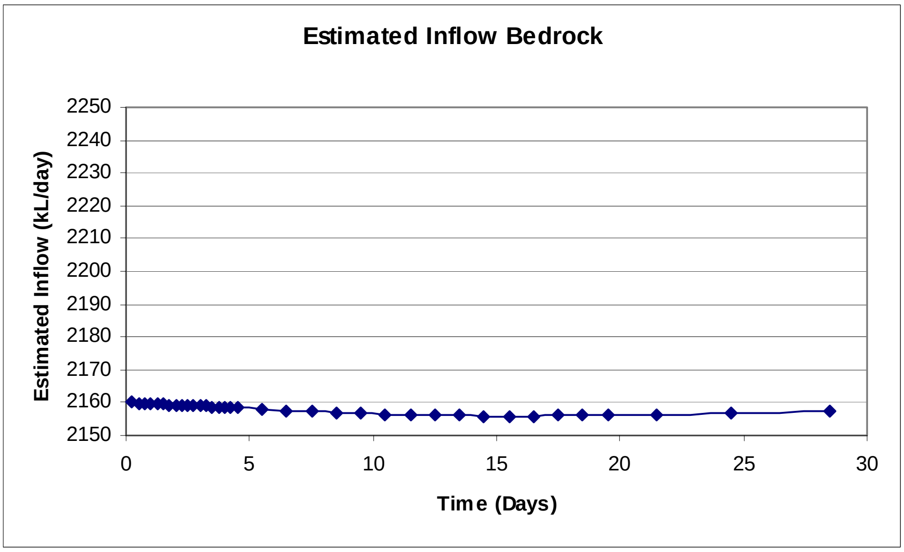
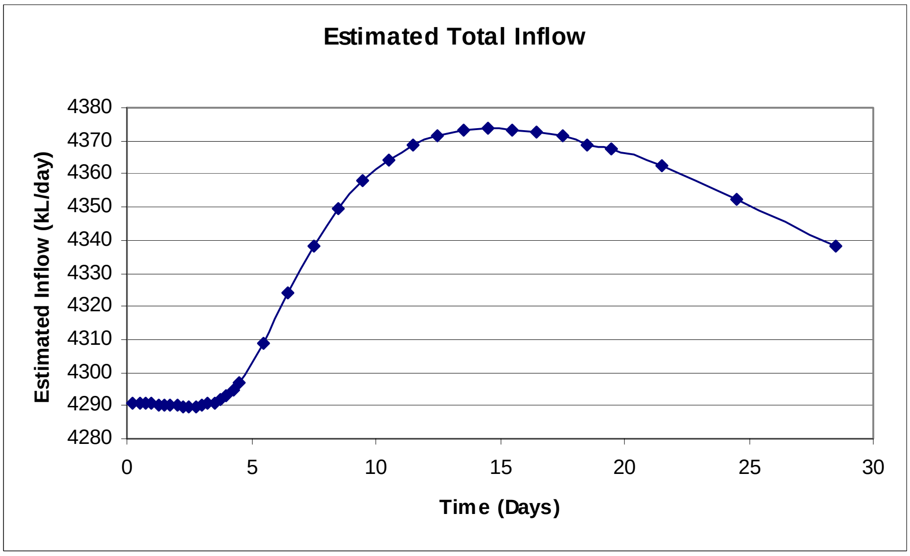
Figure 40d.srf


Estimated Inflow Alluvium/Weathered Bedrock


Estimated Inflow Bedrock


Estimated Total Inflow

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

ESTIMATED GROUNDWATER INFLOW DURING 1 IN 50 YEAR FLOOD EVENT WITH CUT-OFF TRENCH

Figure 41

URS

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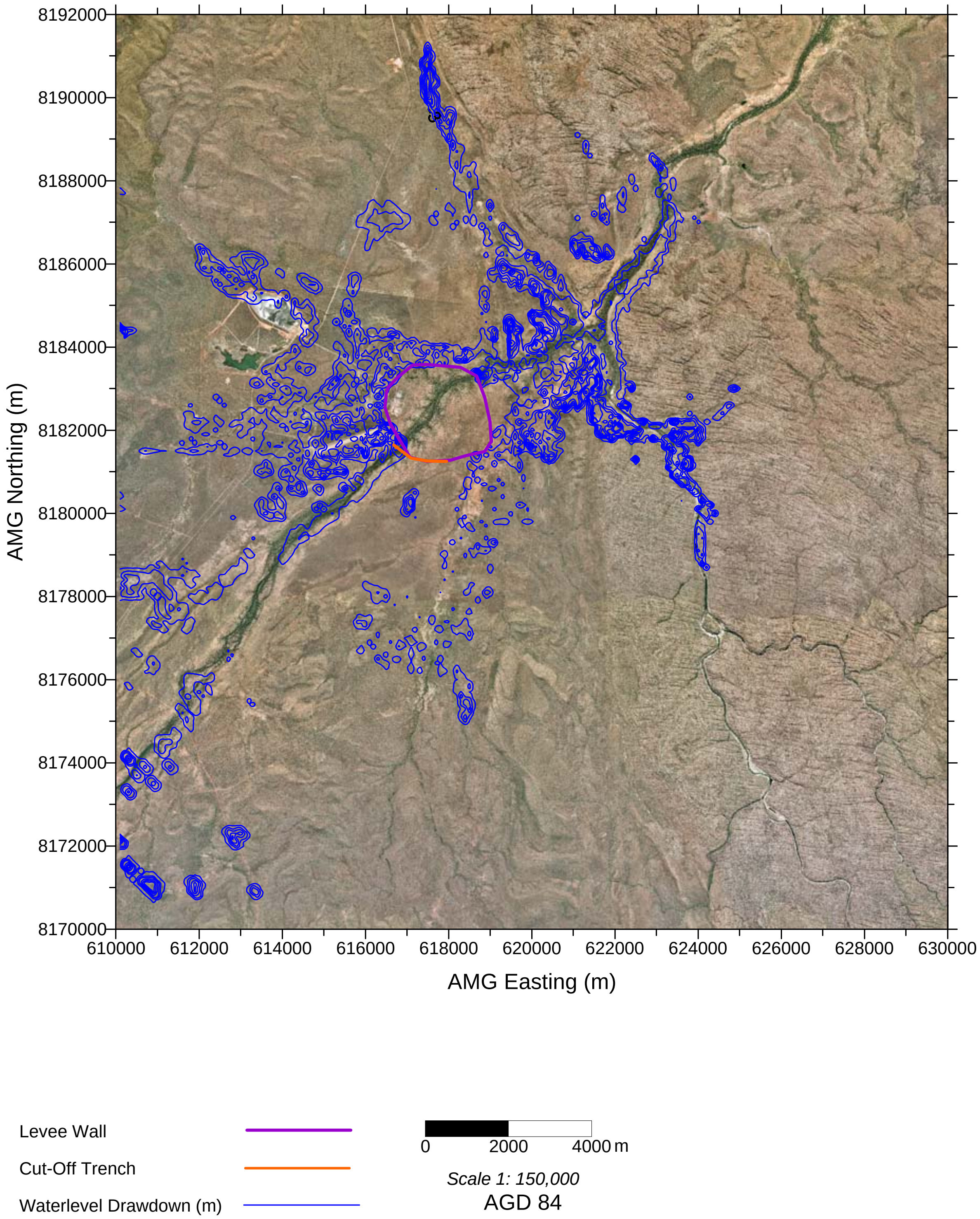
Figure 41.srf



Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE 1 IN 500 YEAR FLOOD EVENT (DAY 1) WITH CUT-OFF TRENCH

Figure 42

URS

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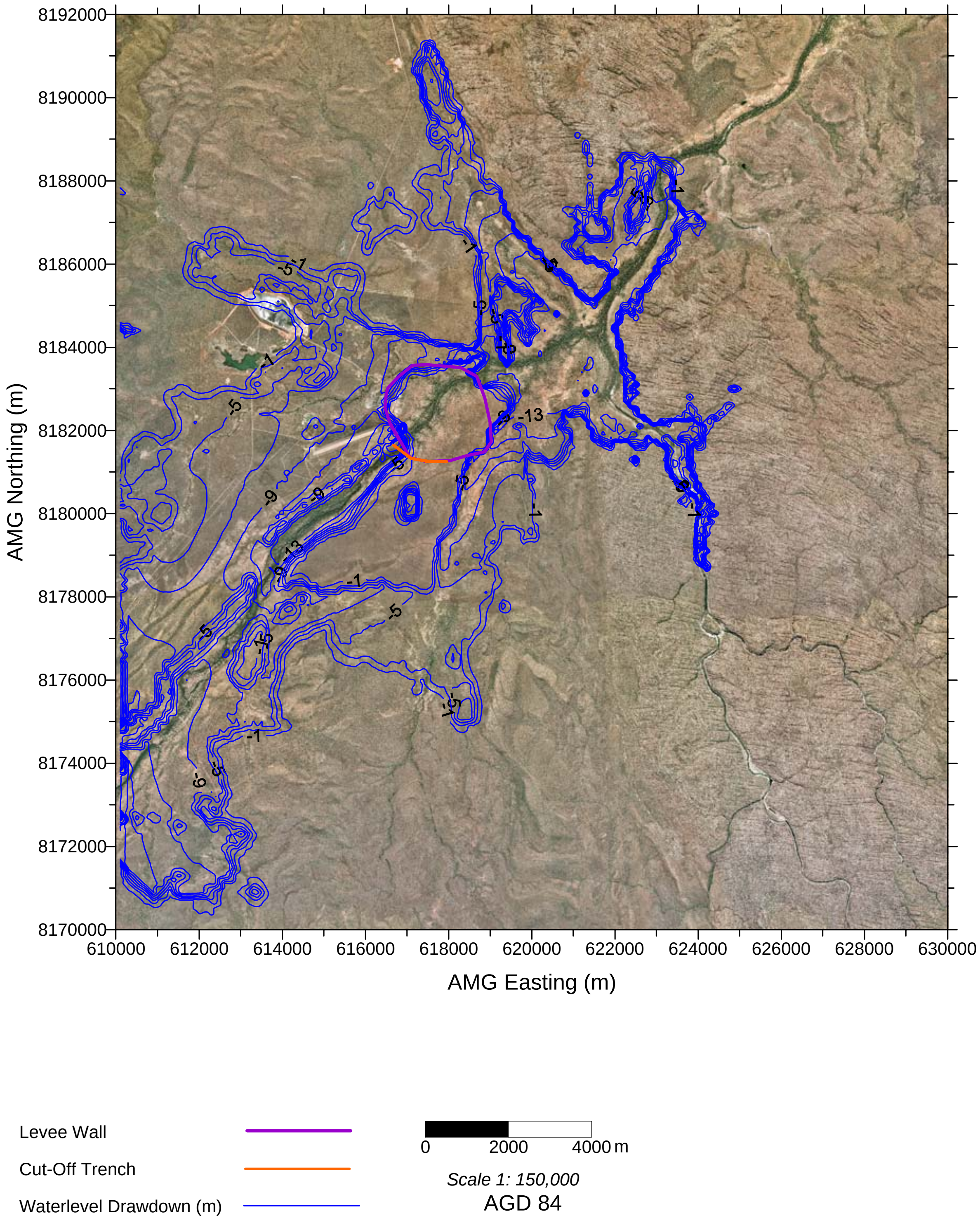
Figure 42.srf



Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

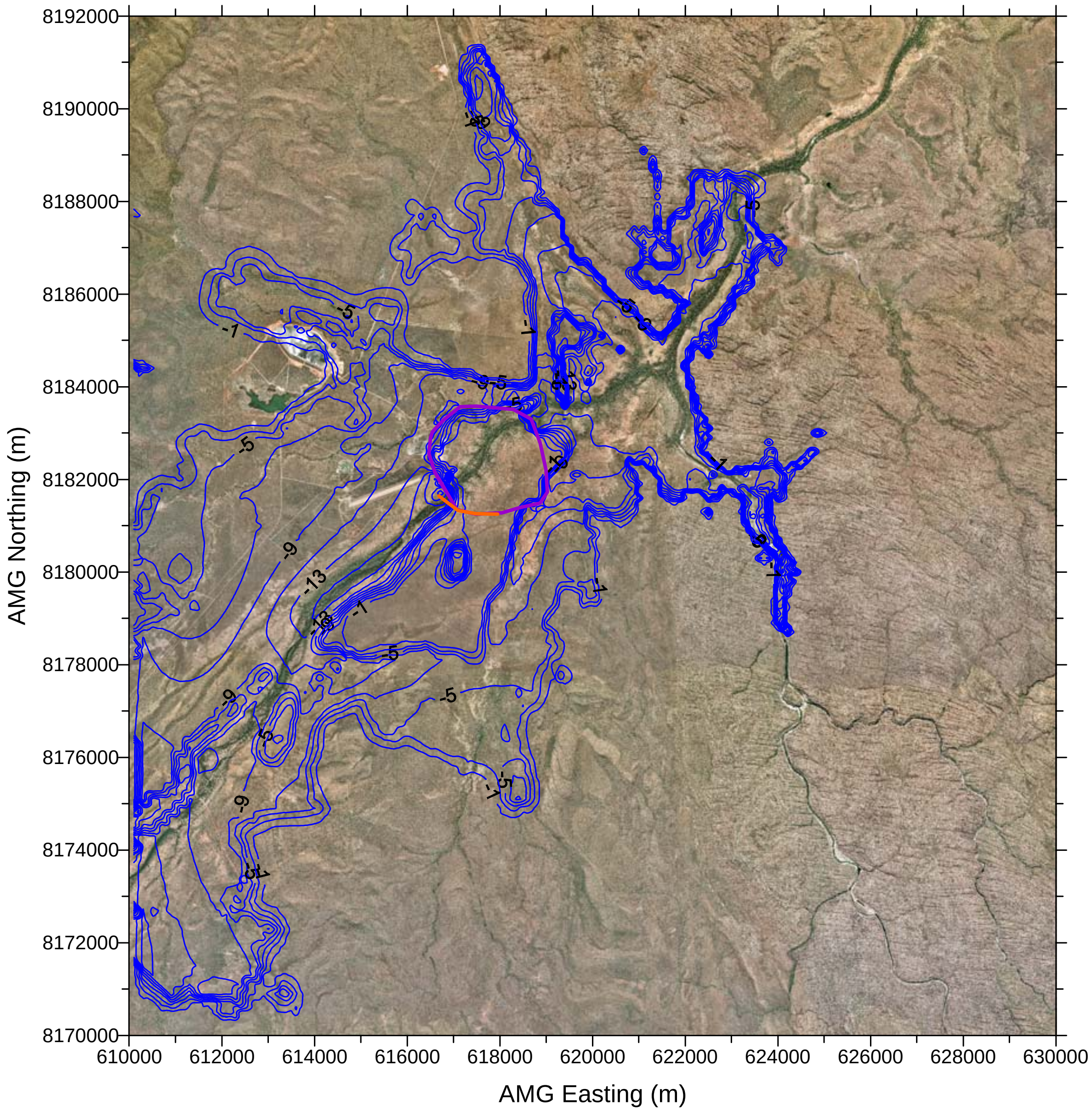
GROUNDWATER LEVEL CHANGE 1 IN 500 YEAR FLOOD EVENT (DAY 5) WITH CUT-OFF TRENCH

Figure 42a

URS

URS AUSTRALIA PTY LTD Perth Office +61 8 9221 1630

Figure 42a.srf



Levee Wall

Cut-Off Trench

Waterlevel Drawdown (m)

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE 1 IN 500 YEAR FLOOD EVENT (DAY 10) WITH CUT-OFF TRENCH

Figure 42b

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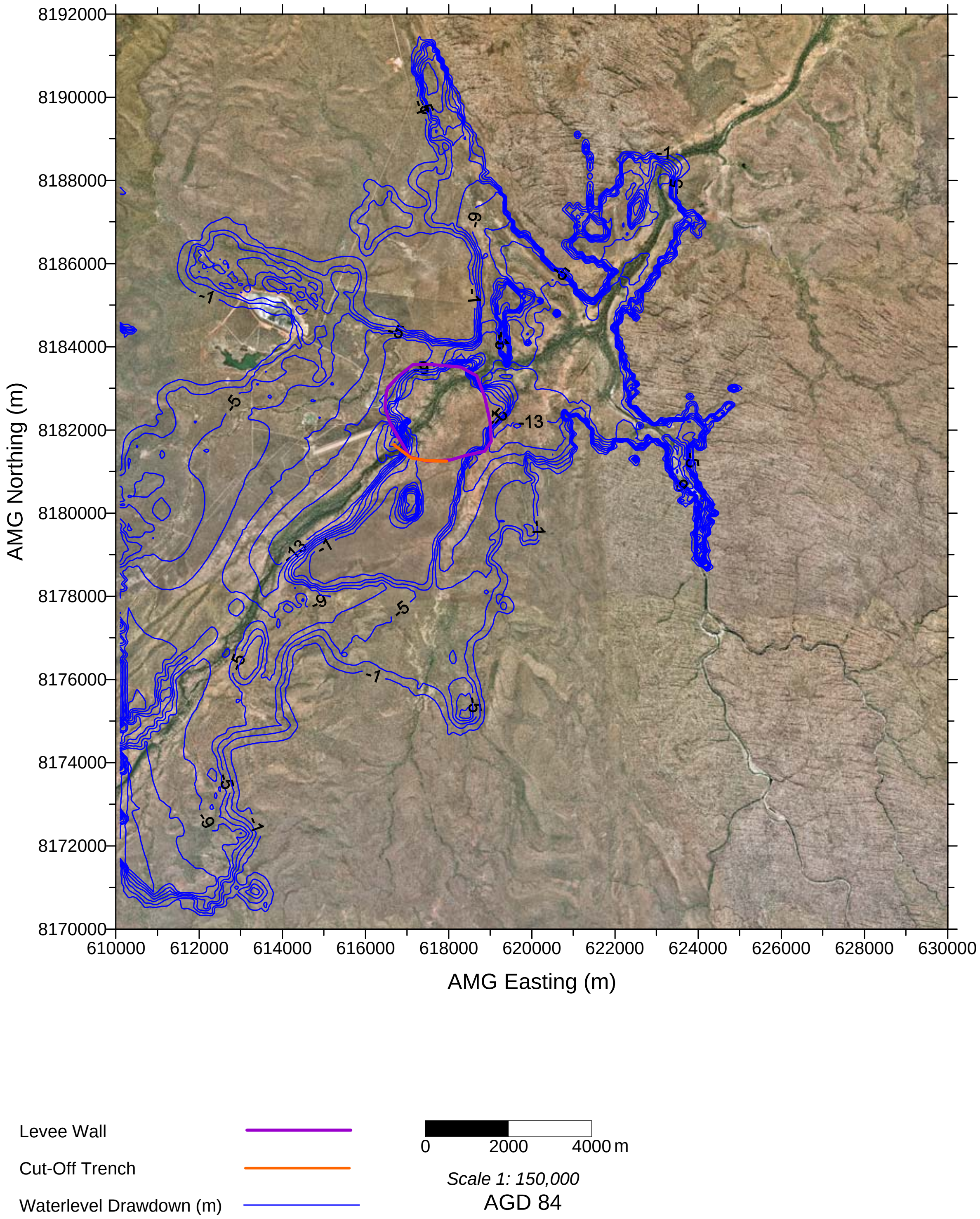
URS AUSTRALIA PTY LTD Perth Office +61 8 9221 1630

Figure 42b.srf



Scale 1: 150,000

AGD 84

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Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.	0	

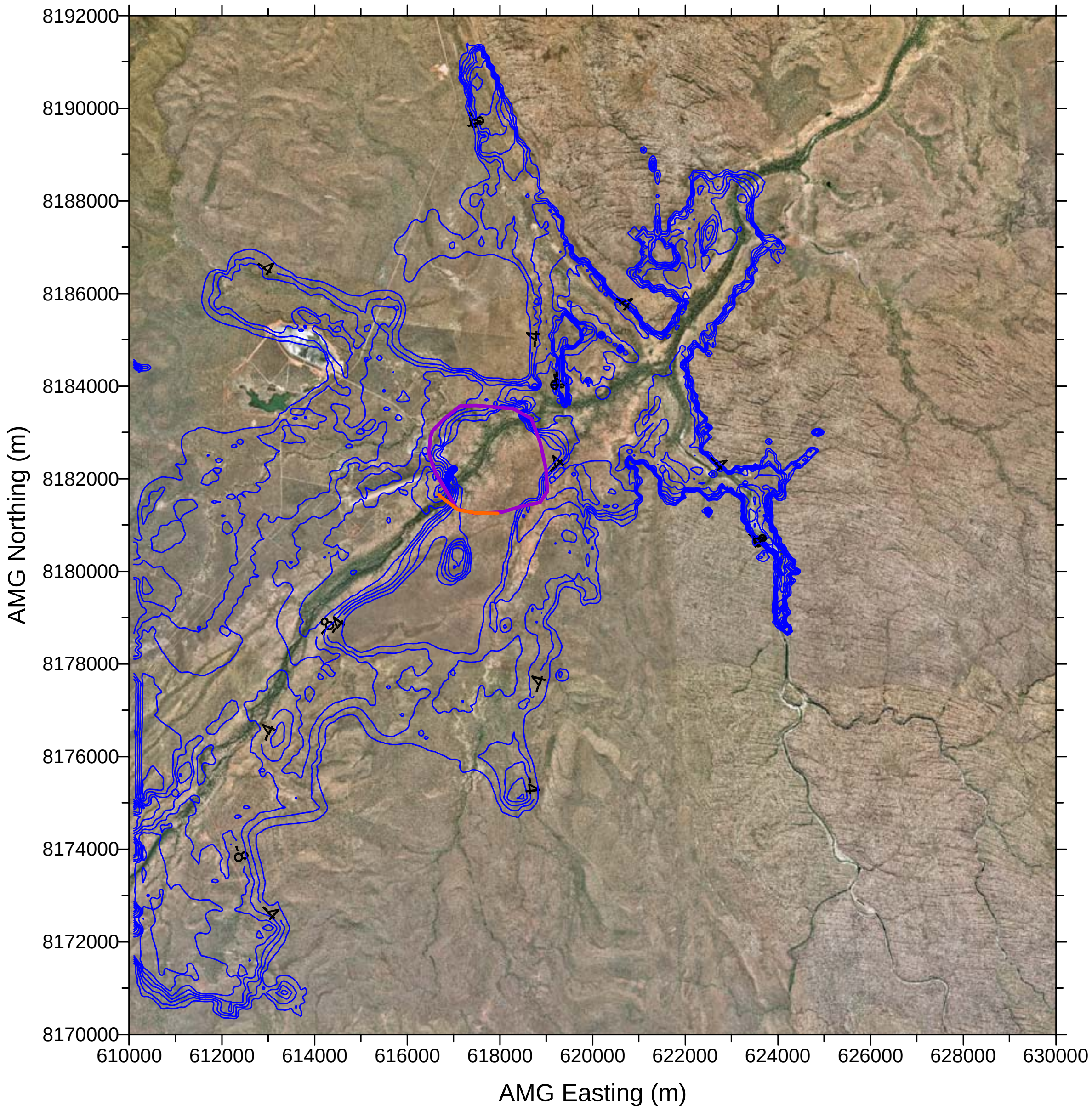
Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE 1 IN 500 YEAR FLOOD EVENT (DAY 12) WITH CUT-OFF TRENCH

Figure 42c

URS

Figure 42c.srf



Levee Wall	🟪
Cut-Off Trench	🟧
Waterlevel Drawdown (m)	🟦

0 2000 4000 m

Scale 1: 150,000

AGD 84

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

GROUNDWATER LEVEL CHANGE 1 IN 500 YEAR FLOOD EVENT (DAY 15) WITH CUT-OFF TRENCH

Figure 42d

URS

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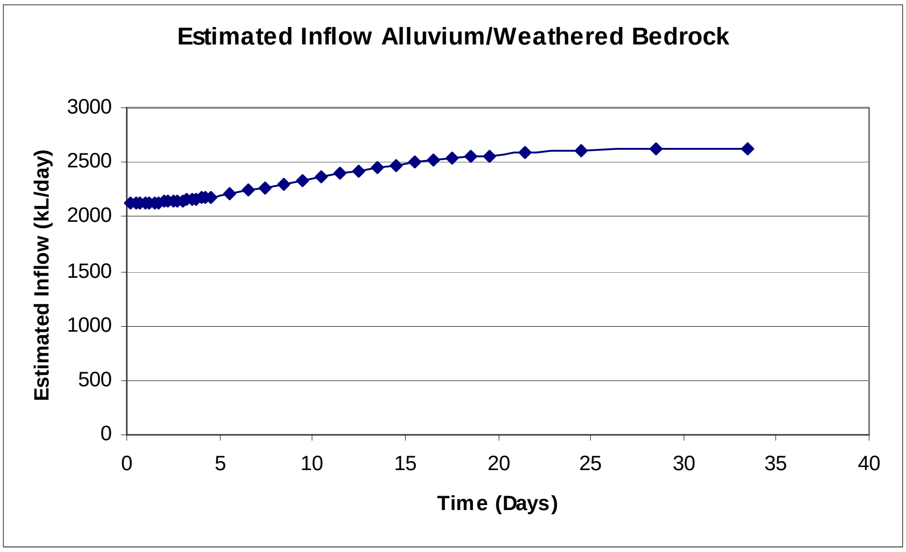

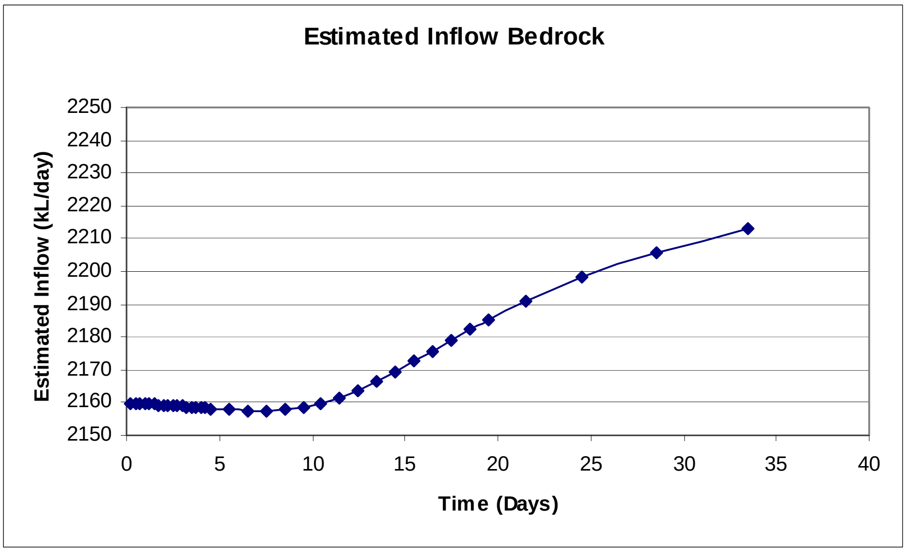

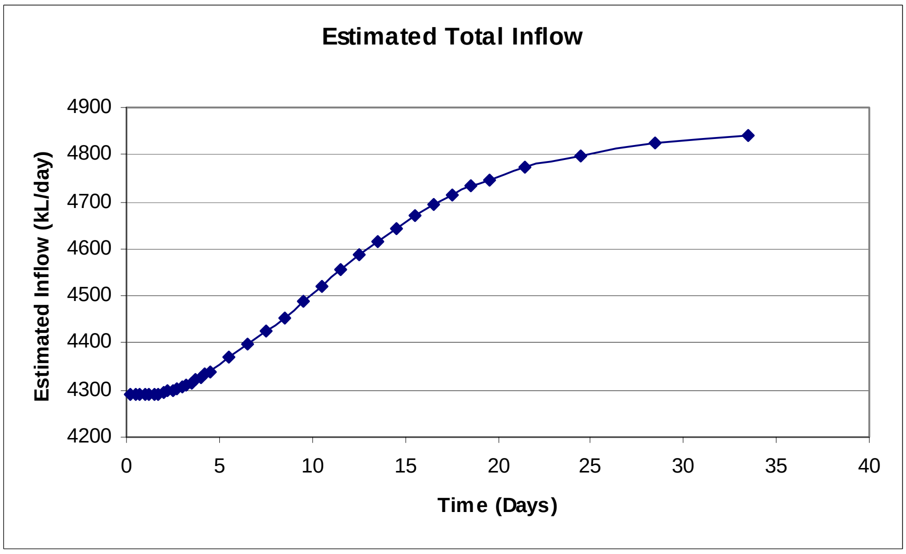

Job No.	42905628	
Prep. By	CMAC	19 Apr '05
Chk'd By	RIJV	21 Apr '05
Revision No.		0

Xstrata PLC
McARTHUR RIVER MINE EXPANSION
MRM EIS GROUNDWATER MODELLING

ESTIMATED GROUNDWATER INFLOW DURING 1 IN 500 YEAR FLOOD EVENT WITH CUT-OFF TRENCH

Figure 43

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Figure 41.srf

BORE COMPLETION REPORT

BOREHOLE: **MAC1P**

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

DRILLING CO: **H20 Drilling**
DRILL METHOD: **Mud-rotary, Air-hammer**

PROJECT NAME: **MRM EIS Groundwater Modelling**
PROJECT NUMBER: **42905628**
CLIENT: **Xstrata PLC**
LOCATION: **McArthur River Mine**

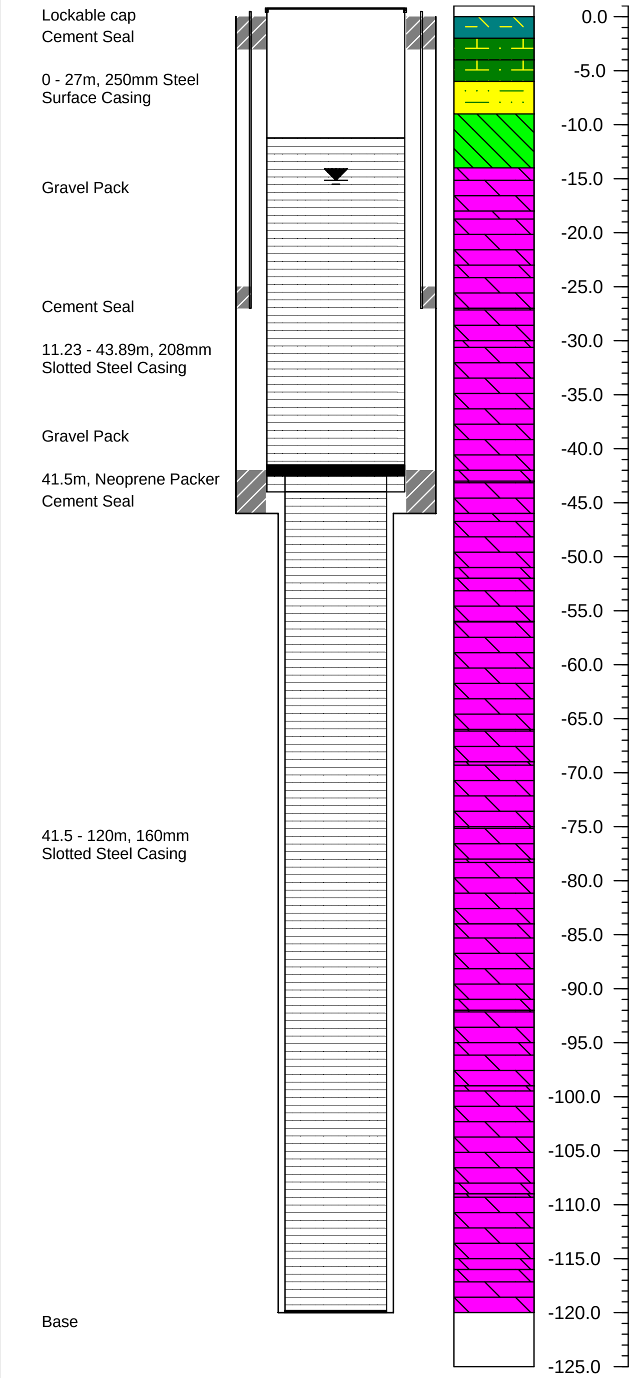
TOTAL DRILLED DEPTH: **46m**
TOTAL CASED DEPTH: **43.89**
CASING DIAMETER: **160mm, 208mm**
SCREEN DIAMETER: **160mm, 208mm**

OPEN INTERVAL: **11.23 - 43.89m**
STATIC WATER LEVEL (mbgs): **14.88 mbtc**
DATE OF MEASUREMENT: **17/11/04**
PUMPING TEST: **9hrs @ 433kL/day**
FINAL SALINITY: **1130mg/L**

R.L OF COLLAR: **36.1 (AHD)**
COORDINATES: **618470.68**
8182092.13
DATUM: **AMG Zone 53**

START DATE: **26/10/04**
FINISH DATE: **6/11/04**
LOGGED BY: **CM**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FORMATION | AIRLIFT YIELD (L/sec) | pH | FIELD EC (uS/cm)



DESCRIPTION

- CLAY AND SAND: Dark, brown.
- CLAY AND SILT: Light brown, fine grained sand, sub-angular to sub rounded quartz.
- CLAY AND SILT: Light brown, fine grained sand, sub-angular to sub rounded quartz.
- CLAYEY SAND: Light brown, clay, firm, brittle. Sand, silty. fine grained sub-angular to sub-rounded quartz, dry, occasional river shingle.
- CLAY: Moderately light brown, firm, slightly silty, sandy, fine grained, completely weathered bedrock.
- DOLOMITE: Cream, completely weathered bedrock. Iron stained, rubbly.
- DOLOMITE: Cream/brown, slightly weathered.
- DOLOMITE: Cream/brown, non-fractured.
- DOLOMITE: Brown slightly fractured, minor shale at 29m depth.
- DOLOMITE: Shale, black, hard, non-fractured.
- DOLOMITE: Grey/brown, hard, non-fractured.
- DOLOMITE: Broken, highly fractured.
- DOLOMITE: Grey/brown, non-fractured.
- DOLOMITE: Slightly fractured.
- DOLOMITE: Grey, non-fractured, hard drilling, minor iron oxide stained fracture surfaces.
- DOLOMITE: Grey/brown, slightly fractured, moderately hard drilling.
- DOLOMITE: Slightly fractured, grey/brown, slightly weathered.
- DOLOMITE: Grey/brown, non-fractured.
- DOLOMITE: Grey/brown, slightly to moderately weathered, iron oxide stained fracture surfaces.
- DOLOMITE: Slightly weathered, iron oxide stained fracture surfaces.
- DOLOMITE: Grey, slightly clayey, non-fractured.
- DOLOMITE: Grey, slightly fractured, hard drilling.
- DOLOMITE: Grey, hard, non-fractured.
- DOLOMITE: Grey, slightly fractured, minor iron oxide stained fracture surfaces.
- DOLOMITE: Grey, non-fractured, hard.
- DOLOMITE: Grey, non-fractured, hard, with calcite veining, hard slow drilling.
- DOLOMITE: Grey, hard, non-fractured.
- DOLOMITE: Grey, slightly to moderately fractured.
- DOLOMITE: Grey, non-fractured.

FORMATION: Alluvium; Cooley Dolomite

AIRLIFT YIELD (L/sec): Trace; 1; 1.5; 1.5; 8-10; Reaming estimated yield 20-30

FIELD EC (uS/cm): 2019; 2250

DRAWN BY: CE DATE: 17/12/04
CHECKED BY: GRB DATE: 22/12/04

BORE COMPLETION REPORT

BOREHOLE: MAC2

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

PROJECT NAME: **MRM EIS Groundwater Modelling**
PROJECT NUMBER: **42905628**
CLIENT: **Xstrata PLC**
LOCATION: **McArthur River Mine**

DRILLING CO: **H20 Drilling**
DRILL METHOD: **Blade**

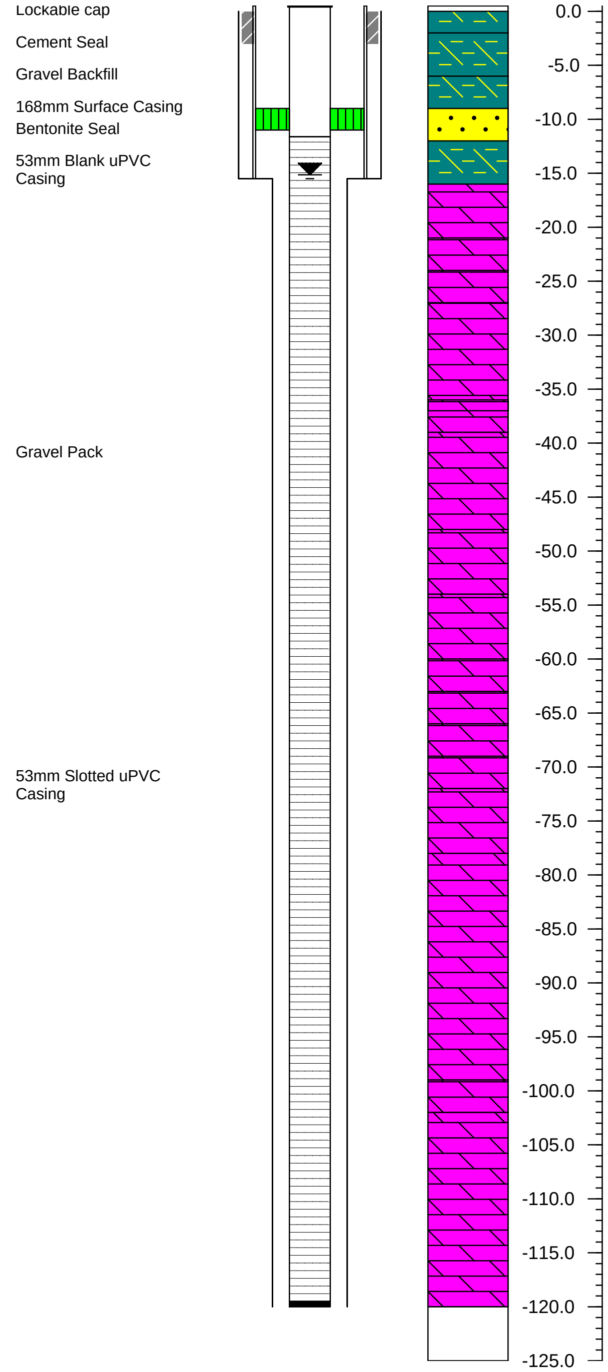
TOTAL DRILLED DEPTH: **120m**
TOTAL CASED DEPTH: **119.62m**
CASING DIAMETER: **53mm**
SCREEN DIAMETER: **53mm**

OPEN INTERVAL: **11.62 - 119.62m**
STATIC WATER LEVEL (mbtc): **16.08**
DATE OF MEASUREMENT: **17/11/04**

R.L OF COLLAR: **37.13 (mAHD)**
COORDINATES: **618449.61**
8182176.56
DATUM: **AMG Zone 53**

START DATE: **6/11/04**
FINISH DATE: **8/11/04**
LOGGED BY: **CM**

BORE CONSTRUCTION | LITHOLOGY | DEPTH (m) | DESCRIPTION | FORMATION | AIRLIFT YIELD (L/sec) | pH | FIELD EC (uS/cm)



DESCRIPTION

CLAY AND SAND: Dark grey, brittle.

CLAY AND SAND: Dark brown, sandy, very fine to fine grained, hard.

CLAY AND SAND: Light brown, fine to medium grained, well sorted.

SAND: Pale grey, fine to medium grained, sub-angular, moderately sorted, minor white clay nodules, soft.

CLAY AND SAND: Brown, firm, slightly sandy.

DOLOMITE: Brown, clayey bands, minor fractures, moderately weathered in part.

DOLOMITE: Grey, minor fractures, interbedded hard and soft clayeybands becoming damp, minor staining on fracture planes, weathered.

DOLOMITE: Grey, minor fractures, moderate to had, minor shale.

DOLOMITE: Grey non-fractured.

DOLOMITE: Grey to dark grey, minor fractures, minor quartz-veining.

DOLOMITE: Brown grey to dark grey, very minor fractures, minor quartz.

DOLOMITE: Dark grey, very minor fractures.

DOLOMITE: Dark grey, non-fractured.

DOLOMITE: Grey, non-fractured, minor brown weathered fragments - contamination from above?

DOLOMITE: Pale grey, minor fractures, hard.

DOLOMITE: Dark grey, non-fractured.

DOLOMITE: Mid to pale grey, non-fractured.

DOLOMITE: Pale grey to dark grey, minor fractures, hard.

DOLOMITE: Pale/mud grey, minor fractures, tight, hard.

DOLOMITE: Pale grey, non-fractured, hard.

DOLOMITE: Grey to black, moderately fractured, mineralisation of fracture planes, minor hard dark grey, non-fractured bands.

FORMATION

Alluvium

Coolie Dolomite

AIRLIFT YIELD (L/sec)

Trace
Minor
<1
<1
<1
<1
Est. 0.5 - 1

FIELD EC (uS/cm)

2000
1920
1865

DRAWN BY: CE
DATE: 17/12/04
CHECKED BY:GRB
DATE: 22/12/04

Page 1 of 1

BORE COMPLETION REPORT

BOREHOLE: **MAC3P**

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

DRILLING CO: **H20 Drilling**
DRILL METHOD: **Blade**

PROJECT NAME: **MRM EIS Groundwater modelling**
PROJECT NUMBER: **42905628**
CLIENT: **Xstrata PLC**
LOCATION: **McArthur River Mine**

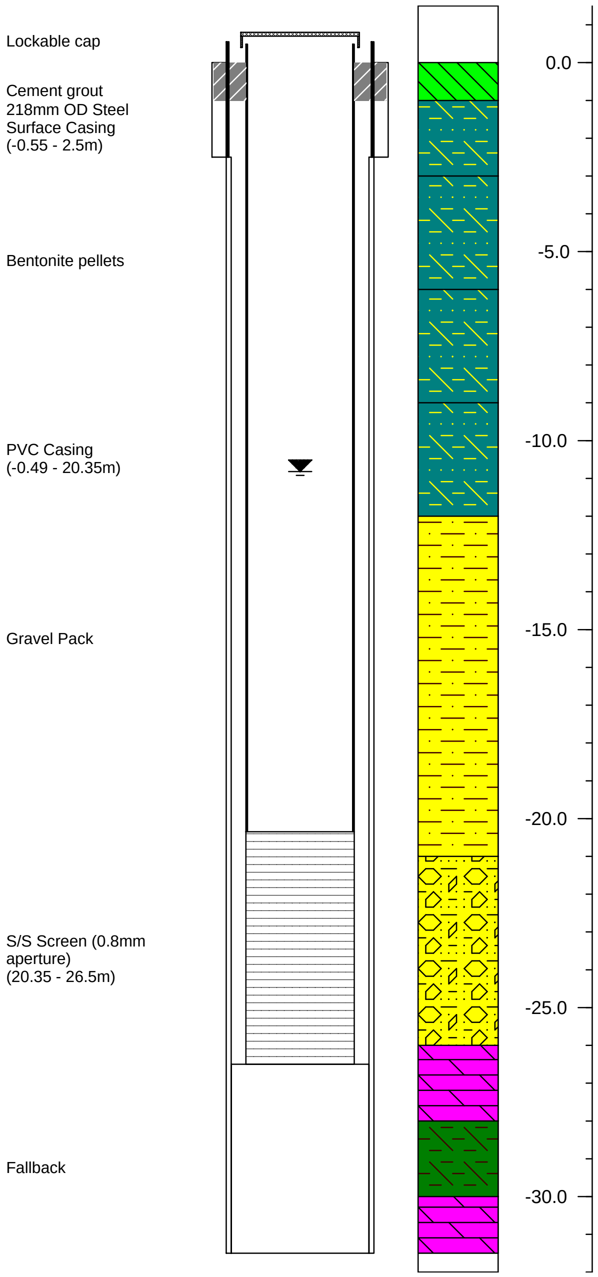
TOTAL DRILLED DEPTH: **31.5m**
TOTAL CASED DEPTH: **26.5m**
CASING DIAMETER: **147mm**
SCREEN DIAMETER: **0.8mm**

OPEN INTERVAL: **20.35 - 26.5m**
STATIC WATER LEVEL (mbgs): **11.37m**
DATE OF MEASUREMENT: **17/11/04**
PUMPING TEST: **48 hrs@393kL/day**
FINAL SALINITY: **720 mg/L**

R.L OF COLLAR: **32.93 (mAHD)**
COORDINATES: **617105.21**
8181502.23
DATUM: **AMG Zone 53**

START DATE: **10/11/04**
FINISH DATE: **11/1104**
LOGGED BY: **CM**

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FORMATION	AIRLIFT YIELD (L/sec)	pH	FIELD EC (uS/cm)



CLAY: Brown, brittle, sandy.

CLAY AND SAND: Brown, medium quartz sand, angular.

CLAY AND SAND: Dark grey, stiff gravelly, angular.

CLAY AND SAND: Grey, fine quartz sand, loose, interbedded with stiff clay.

CLAY AND SAND: Grey to brown, plastic.

SILT: Brown, clay interbedded with sand, some gravel, sub-angular to moderately rounded.

GRAVEL AND SAND: Brown, fine to course, poorly sorted, large boulders 21, 23 and 24m, well rounded.

DOLOMITE: Yellow brown, dolomite fragments, river sands/gravels, clayey, hard, dolomite?

SHALE/CLAYSTONE: Dark grey to yellow brown, interbedded shale and weathered bedrock.

DOLOMITE: Yellow brown, minor bands of hard dolomite.

FORMATION: Alluvium; Cooley Dolomite

AIRLIFT YIELD (L/sec): 1.5 - 2

FIELD EC (uS/cm): 1729

DRAWN BY: CE DATE: 17/12/04
CHECKED BY:GRB DATE: 22/12/04

BORE COMPLETION REPORT

BOREHOLE: MAC4

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

DRILLING CO: **H20 Drilling**
DRILL METHOD: **Rotary**

PROJECT NAME: **MRM EIS Groundwater modelling**
PROJECT NUMBER: **42905628**
CLIENT: **Xstrata PLC**
LOCATION: **McArthur River Mine**

TOTAL DRILLED DEPTH: **18m**
TOTAL CASED DEPTH: **15m**
CASING DIAMETER: **53mm**
SCREEN DIAMETER: **53mm**

OPEN INTERVAL: **3 - 15m**
STATIC WATER LEVEL (mbtc): **10.50**
DATE OF MEASUREMENT: **23/11/04**

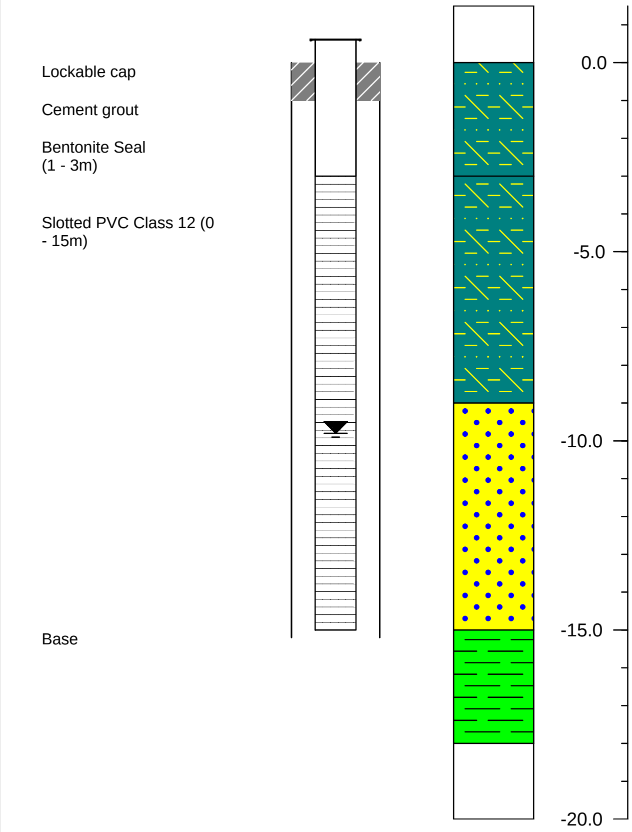
R.L OF COLLAR: **32.74 (AHD)**
COORDINATES: **616332.95**
8180808.62
DATUM: **AMG Zone 53**

START DATE: **17/11/04**
FINISH DATE: **18/11/04**
LOGGED BY: **CM**

BORE CONSTRUCTION

LITHOLOGY

DEPTH (m)



DESCRIPTION	FORMATION	AIRLIFT YIELD (L/sec)	pH	FIELD EC (uS/cm)
CLAY AND SAND: Moderate brown, firm, plastic.	Alluvium			
CLAY AND SAND: Cream/brown, soft, weathered bedrock, calcretised.				
SANDSTONE: Grey, slightly to moderately fractured, hard, fine to medium grained.	Coolie Dolomite	Trace 0.1		1465
SHALE: Black/grey, hard, non-fractured.				

DRAWN BY: CE
DATE: 17/12/04

CHECKED BY: GRB
DATE: 22/12/04

BORE COMPLETION REPORT

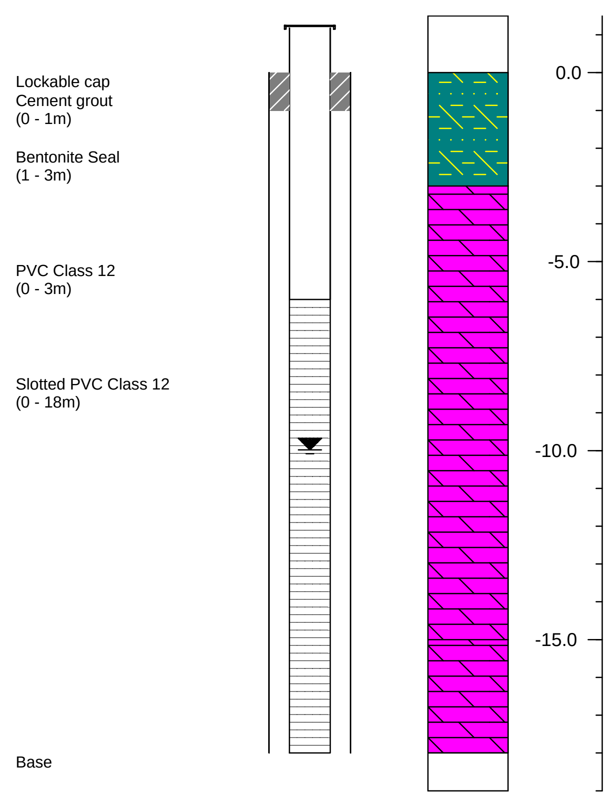
BOREHOLE: MAC5

URS Australia Pty Ltd — Phone 08 92211630
20 Terrace Rd, East Perth, 6004 — Fax 08 92211639

DRILLING CO:	**H20 Drilling**	PROJECT NAME:	**MRM EIS Groundwater modelling**
DRILL METHOD:	**Blade**	PROJECT NUMBER:	**42905628**
		CLIENT:	**Xstrata PLC**
		LOCATION:	**McArthur River Mine**

TOTAL DRILLED DEPTH:	**18m**	OPEN INTERVAL:	**6 - 18m**	R.L OF COLLAR:	**34.59 (mAHD)**
TOTAL CASED DEPTH:	**18m**	STATIC WATER LEVEL (mbtc):	**11.32**	COORDINATES:	**615809.99** **8180946.29**
CASING DIAMETER:	**53mm**	DATE OF MEASUREMENT:	**23/11/04**	DATUM:	**AMG Zone 53**
SCREEN DIAMETER:	**53mm**				

START DATE: **18/11/04** FINISH DATE: **18/11/04** LOGGED BY: **CM**



DESCRIPTION	FORMATION	AIRLIFT YIELD (L/sec)	pH	FIELD EC (uS/cm)
CLAY AND SAND: Brown, stiff.	Alluvium			
DOLOMITE: Cream, highly weathered, broken, minor sandstone beds, very fine grained, angular.	Cooley Dolomite			
DOLOMITE: Cream, hard, slightly fractured at 18m depth.		1		

DRAWN BY: CE DATE: 17/12/04

CHECKED BY: GRB DATE: 22/12/04

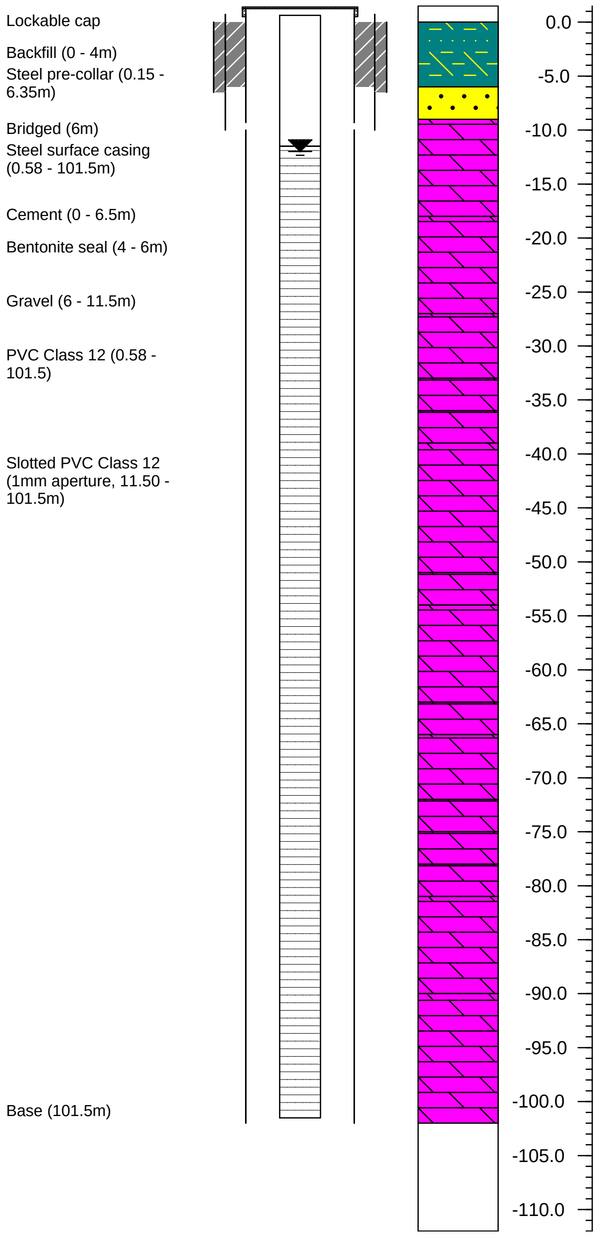
BORE COMPLETION REPORT

BOREHOLE: MAC6

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

PROJECT NAME:	**MRM EIS Groundwater modelling**
PROJECT NUMBER:	**42905628**
CLIENT:	**Xstrata PLC**
LOCATION:	**McArthur River Mine**
DRILLING CO:	**H20 Drilling**
DRILL METHOD:	**Blade**
TOTAL DRILLED DEPTH:	**102m**
TOTAL CASED DEPTH:	**101.5m**
CASING DIAMETER:	**53mm**
SCREEN DIAMETER:	**1mm**
OPEN INTERVAL:	**11.50 - 101.5m**
STATIC WATER LEVEL (mbtc):	**12.71**
DATE OF MEASUREMENT:	**17/11/04**
R.L OF COLLAR:	**32.39 (AHD)**
COORDINATES:	**618352.20** **8182559.93**
DATUM:	**AMG Zone 53**

START DATE: **12/11/04** FINISH DATE: **13/11/04** LOGGED BY: **CM**



DESCRIPTION	FORMATION	AIRLIFT YIELD (L/sec)	pH	FIELD EC (uS/cm)
CLAY AND SAND: Brown, sandy/silty, brittle.	Alluvium			
SAND: Red brown, very fine, well sorted, loose, slightly clayey.				
DOLOMITE: Light grey to yellow brown, slighty clayey, well fractured, moderate to hard and weathered.	Cooley Dolomite			
DOLOMITE: Pale grey minor fractures.				
DOLOMITE: Pale grey, minor fractures, iron stained fracture planes.				
DOLOMITE: Mid grey, minor fractures, iron staining.				
DOLOMITE: Mid grey, little fracturing.				
DOLOMITE: Dark grey, non-fractured, hard.				
DOLOMITE: Mid grey, minor fractures.		Trace		
DOLOMITE: Mid to pale grey, minor fractures, iron stained fracture planes, mottled dark grey in part.		<0.5		
DOLOMITE: Dark grey, non-fractured, hard.				
DOLOMITE: Mid to pale grey, minor fracture zone, iron staining, minor quartz		<0.5		4670
DOLOMITE: Dark grey, non-fractured.				
DOLOMITE: Mid grey, fractured, iron staining.				
DOLOMITE: Mid to pale grey, quartz veining, non-fractured.		<1		4600
DOLOMITE: Mid to dark grey, fractured in part, iron staining.				
DOLOMITE: Dark grey, non-fractured.		1		5690

DRAWN BY: CE DATE: 17/12/04
CHECKED BY:GRB DATE: 22/12/04

BORE COMPLETION REPORT

BOREHOLE: MAC7

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

DRILLING CO: **H20 Drilling**
DRILL METHOD: **Blade (0 - 13.5m), Hammer (13.5 - 121m)**

PROJECT NAME: **MRM EIS Groundwater modelling**
PROJECT NUMBER: **42905628**
CLIENT: **Xstrata PLC**
LOCATION: **McArthur River Mine**

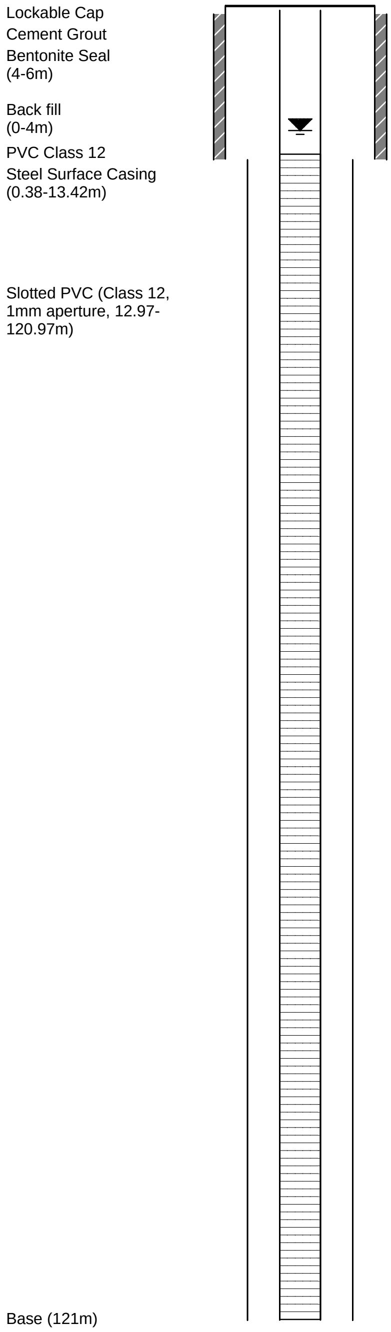
TOTAL DRILLED DEPTH: **121m**
TOTAL CASED DEPTH: **120.92m**
CASING DIAMETER: **53mm**
SCREEN DIAMETER: **1mm**

OPEN INTERVAL: **12.97 - 120.92m**
STATIC WATER LEVEL (mbtc): **11.19**
DATE OF MEASUREMENT: **17/11/04**

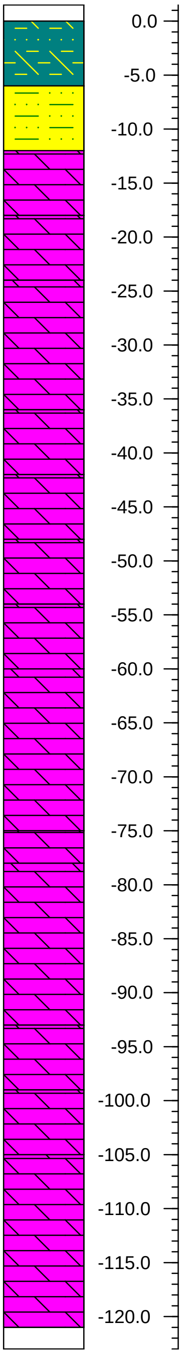
R.L OF COLLAR: **29.68 (AHD)**
COORDINATES: **618362.49**
8182962.61
DATUM: **AMG Zone 53**

START DATE: **13/11/04**
FINISH DATE: **15/11/04**
LOGGED BY: **CM**

BORE CONSTRUCTION



LITHOLOGY / DEPTH (m)



DESCRIPTION	FORMATION
CLAY AND SAND: Brown, very fine to medium sand with clay, minor dark olive green clay nodules.	Alluvium
CLAYEY SAND: Brown, minor to fine sand, soft.	
DOLOMITE: Yellow brown, clayey, very well fractured, highly weathered.	Coolie Dolomite
DOLOMITE: Yellow brown highly fractured, vuggy, becoming blue grey.	
DOLOMITE: Blue grey, fractured iron staining on fractures.	
DOLOMITE: Blue grey to yellow brown, highly fractured zones, vuggy, calcarenite, iron-staining.	
DOLOMITE: Grey, non-fractured.	
DOLOMITE: Mid to dark grey, minor fractures, iron-staining and fracture planes.	
DOLOMITE: Mid grey, very minor fractures.	
DOLOMITE: Pale grey, hard, minor quartz, very minor fractures, tight.	
DOLOMITE: Mid grey, very minor fractures, Breccia?, hard.	
DOLOMITE: Mid grey, as above, minor fractures with sugary fracture contents.	
DOLOMITE: Mid grey, hard, very minor tight fractures.	
DOLOMITE: Pale grey, non-fractured.	
DOLOMITE: Pale grey to mid grey, hard very minor fractures.	

AIRLIFT YIELD (L/sec)	pH	FIELD EC (uS/cm)
Trace		
1		40
2.2		9200
2.2		8960
3		7890
2.5		8260
3		8100
3.4		8100
5		7880
5		7740
5		7670

DRAWN BY: CE DATE: 17/12/04
CHECKED BY: GRB DATE: 22/12/04

REPORT

Summary of Stream Gauging at McArthur River

Prepared for

Xstrata PLC

12 July 2005

42213689/589-A1014.0

Project Manager: …………………………………..
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Robin Connolly
Associate Hydrologist

Date: **12 July 2005**
Reference: 589-A1014.0
Status: Final

Contents

List of Tables, Figures, Plates & Appendices

Tables

Figures

Introduction

SECTION 1

This section outlines the results of stream gauging in the MacArthur River, taken in June 2005 to characterise dry-season stream flow through the proposed expansion area of the McArthur River Mine.

The aim of this stream gauging study was to measure stream flows in June, a dry time of year, and use these data to characterise stream flow arising from groundwater.

2.1.1 Stream Gauging

Work involved measuring stream flow and water quality (electrical conductivity and pH) at a number of sites along the McArthur River. The location of sampling points is shown in Figure SG1. The gauging was undertaken on 29-30 June 2005 by URS (C Hughes and R Connolly) supported by Xstrata staff. Gaugings were taken along approximately a 14 km length of the River, extending from south west of the proposed pit to just above the confluence with the Glyde River.

Stream flow was calculated from measurements of flow velocity and the water cross-sectional area. Flow velocity was measured at intervals across the flow section using a Global FP101 water velocity meter. Water depth was measured at regular intervals across the section and flow area calculated for each velocity measurement. Flow was then calculated by multiplying velocity by area and summing for the section.

Stream flow could not be measured in ponds as the water velocity was lower than the effective resolution of the water meter.

Water quality was measured *in situ*. Electrical conductivity (a measure of salinity) was measured using a hand-held Cond315i meter and pH was measured using a pHScan1 meter. The reported electrical conductivity is temperature compensated.

2.1.2 Water Balance

A simple water balance for each river reach between cross-sections was used to account for evaporation losses. An average water width was assumed based on field observations – 20 m for “ponded” reaches of the river and 10 m for “flowing” reaches. The river upstream of the main McArthur River crossing (Section 7), opposite the airport, was considered to be continuously ponded. Downstream of this point the river was considered to be continuously flowing. Water surface area was calculated as the water width multiplied by the reach length.

An evaporation rate for the gauging period (29-30 June) of 5.9 mm/day multiplied by an evaporation factor of 0.9 was used (BOM 2005, Station 014714 McArthur River Mine), with evaporation assumed to occur over 12 h. Evaporation was calculated for each reach by multiplying the evaporation rate by the water surface area. Groundwater inflow/outflow in the reach was calculated by adding the evaporation loss to the change in stream flow.

Observed stream flow and water quality and calculated groundwater inflow is shown in Figure SG2 and Table SG1.

Groundwater inflow to the river occurs above and below the proposed pit area but there was little net inflow or outflow through the pit area itself. There is a reach with net outflow to groundwater just inside the western edge of the pit, between Sections 7a and 7c. The remainder of the river through the pit area has no or little net groundwater inflow or outflow. Groundwater inflow increases downstream of the pit area.

Accordingly, loss of this section of the river to the pit is likely to have little impact on dry season stream flows immediately downstream of the pit.

Observations of stream flow salinity show that pools south west of the proposed pit are fed by groundwater to varying degrees. Salinity and flows through Sections 1 to 6 indicate that, with the exception of Sections 2 and 3, groundwater inflows were greater than evaporation (between 2.3 and 4.9 L/s) and probably in the order of 10 L/s.

The pond at Section 2 had significantly higher salinity than the other ponds, suggesting that groundwater inflow was less than evaporation (3.7 L/s). Salinity was about 6 times the salinity at nearby sections, indicating considerable concentration since the end of the previous wet season.

At Section 3, the stream bed was dry between two ponds, but the groundwater level in the dry bed was close to the surface. Electrical conductivity of groundwater in the stream bed (measured in an excavated hole) was 314 µS/cm, less than flowing water at Section 1 (475 µS/cm). Electrical conductivity in a nearby pond was 950 µS/cm. It is possible that there is groundwater inflow to this pond from the base (despite the dry nearby stream bed), but the inflow rate is likely to be less than evaporation, or less than about 5 L/s.

In the sections with ponds with low salinity (Sections 1, 4, 5 and 6), there is likely to be enough groundwater inflow (in June) to maintain constant water levels and there is probably enough outflow from the ponds to minimise salt build up as a result of evaporation. Ponds with higher salinity (particularly at Section 3) probably also have groundwater inflow, but at lower rates.

Any impact of dewatering on groundwater inflow rates to these pools is likely to have a negative effect on pool water levels and salinities during the dry season.

The salinity of non-ponded water in Sections 1 and 3 (300-500 µS/cm) was lower than in the remaining downstream sections (800-900 µS/cm), indicating that groundwater here is derived from a different aquifer.

Observed pH was variable along the river, ranging around a value of 8. There appeared to be a general upward trend in ph with distance downstream.

Stream flows and groundwater inflows may vary during the remainder of this dry season and from year to year in response to varying groundwater levels and seasonal conditions. The stream gaugings were made as a once-off sampling in June 2005 after a relatively dry prior wet season. June also corresponds approximately to the seasonal low in local groundwater levels. Accordingly, the observed stream flows probably represent a value towards the lower end of what may be expected for June. Flows may vary (probably decrease) during the remainder of this dry season and may vary from year to year.

Table SG1

Stream Flow, Groundwater Inflow and Water Quality

Section	Location*		River Length, Downstream From Section 1	River Reach Length	Adopted Reach Width	Observed pH	Observed Electrical Conductivity	Observed Stream Flow	Calculated Evaporation	Calculated Groundwater Inflow	Comments
	(m E)	(m N)	(km)	(m)	(m)		(µS/cm)	(L/s)	(L/s)	(L/s)	
1	611466	8175057	0.0			8.5	475	8.0	0		
2	612097	8176256	1.6	1.6	20	8.6	2,660		3.3		Ponded, no stream flow observation possible.
3	613229	8177657	3.5	1.8	20	7.4	950	0.0	4.4		Stream bed dry between pools; moist sand in lower parts of the dry bed. Electrical conductivity of water in sand 314 µS/cm.
4	613653	8178497	4.4	0.9	20	8.3	737		2.3		Ponded, no stream flow observation possible.
5	614584	8179708	5.9	1.6	20	7.9	780		3.8		Ponded, no stream flow observation possible.
6	615323	8180083	6.7	0.8	20	8.3	837	8.6	2.0		Ponded, no stream flow observation possible.
7	616161	8181072	8.0	1.3	20	7.8	920	21.5	3.2	16.1	Main McArthur River crossing.
7a	616917	8181658	9.0	1.0	10	7.9	950	33.4	1.2	13.1	Western pit edge.
7c	617398	8182168	9.7	0.7	10	8.2	910	26.0	0.9	-6.5	
8	617460	8182230	9.8	0.1	10	8.2	970	26.5	0.1	0.6	Power line crossing.
9	618112	8183165	11.0	1.2	10	8.1	880	25.1	1.4	0.0	Eastern pit edge.
10	619151	8183720	12.2	1.3	10	8.2	810	35.5	1.4	11.8	
11	621206	8184382	14.5	2.3	10	8.3	800	36.8	2.7	4.0	Above confluence with the Glyde River

* AMG 84 grid 53, based on GPS UTM projection of AGD 84

Groundwater inflow to the river occurs above and below the proposed pit area but there is little net inflow or outflow through the pit area itself. Accordingly, loss of this section of the river to the pit is likely to have little impact on dry season stream flows immediately downstream of the pit.

It is likely that the pools south west of the proposed pit area are fed by groundwater and that water and salinity levels are maintained at relatively consistent levels. The existing outflow from the ponds (at 10-30 L/s) is important to maintain stable salinity levels.

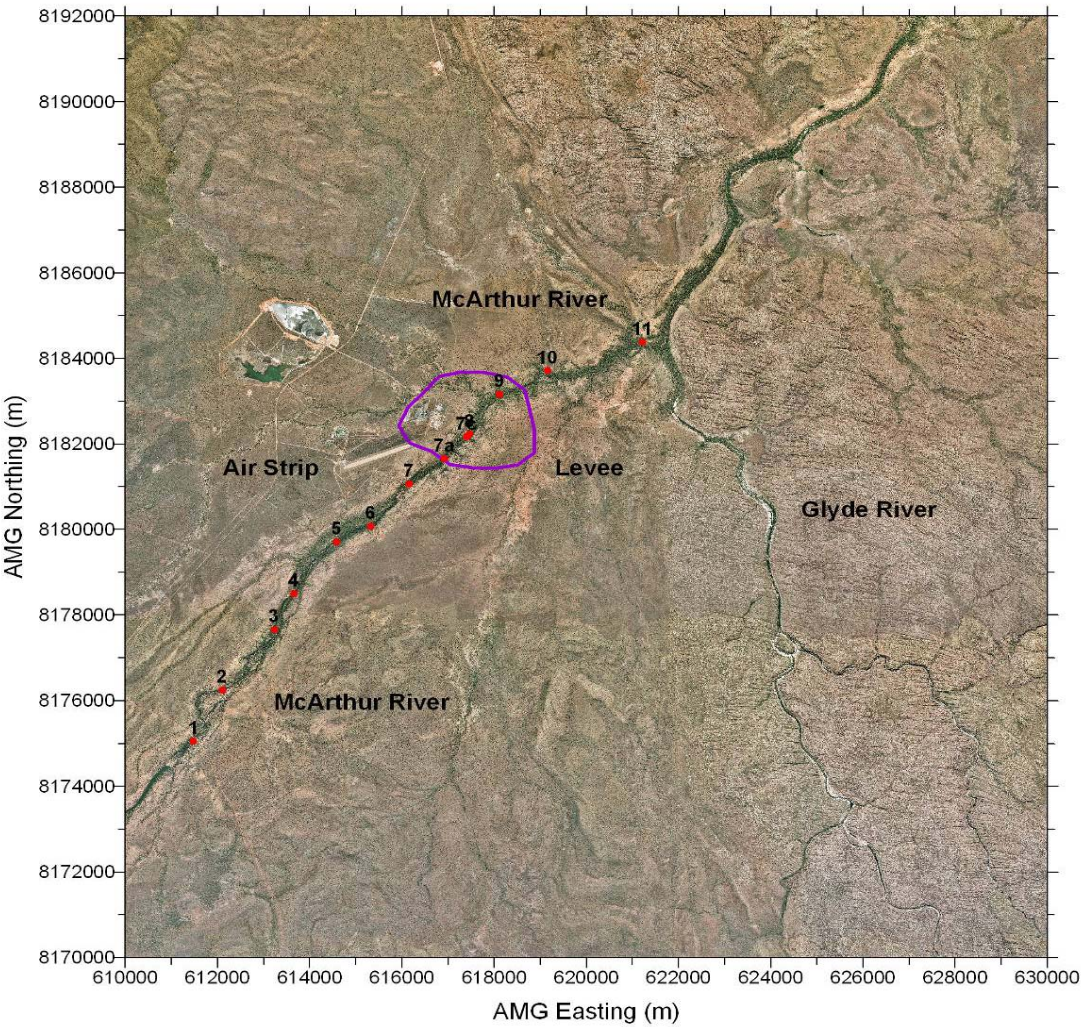
BOM (2005). Australian climate averages. http://www.bom.gov.au/climate/averages/. Bureau of Meteorology: Canberra.

URS Australia Pty Ltd (URS) has prepared this report for the use of Xstrata PLC in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 15 June 2005.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 5 and 12 July 2005 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.



URS Australia Ltd Perth Office +61 8 9221 1630

Job No.	42213689	
Prep. By	RC	13 Jul 05
Chk'd By	CM	14 Jul 05
Revision No.		0

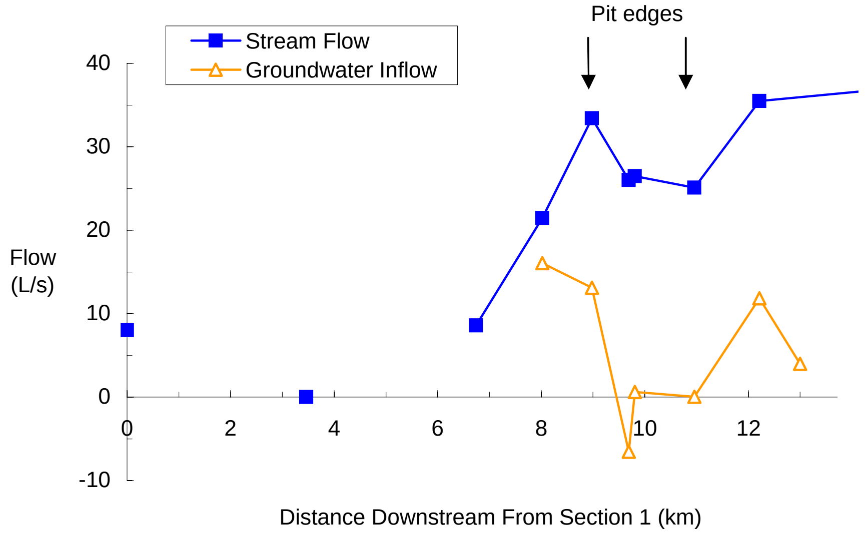
Xstrata Zinc
GROUNDWATER AND SURFACE WATER INVESTIGATIONS OF THE McARTHUR RIVER

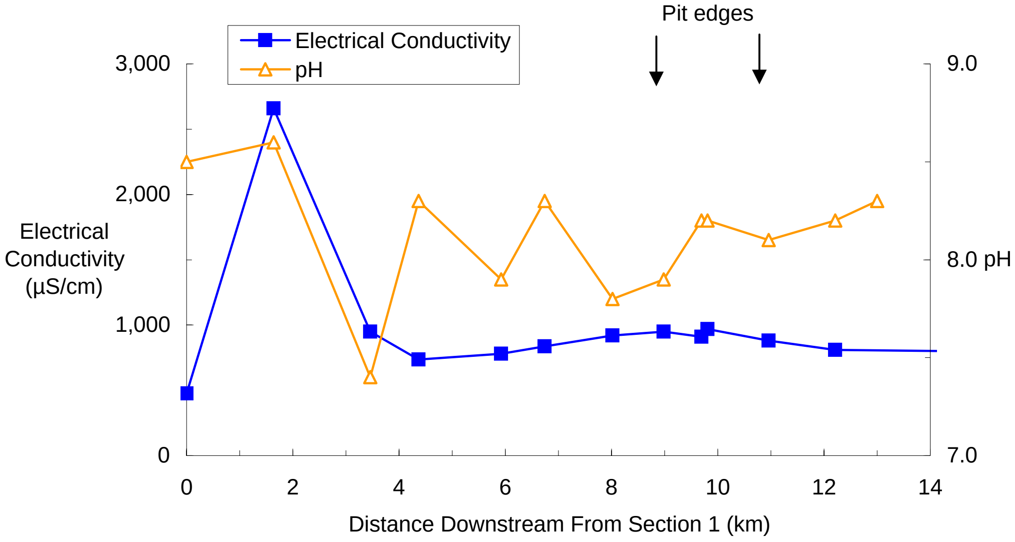
STREAM GAUGING STATIONS

Figure SG1

URS

Stream gauging figs&tbls.xls





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Revision No.	0	

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GROUNDWATER AND SURFACE WATER INVESTIGATIONS OF
THE MCARTHUR RIVER

FLOW AND WATER QUALITY

Figure SG2

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Stream gauging figs&tbls.xls

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