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FORTESCUE METALS GROUP LTD

EAST PILBARA IRON ORE PROJECT

HYDROGEOLOGY REPORT FOR THE CLOUD BREAK PUBLIC ENVIRONMENTAL REVIEW

JUNE 2005

Andrew Ball
Senior Hydrogeologist

Graham Smith
Principal Hydrogeologist

Prepared by:

Aquaterra Consulting Pty Ltd

ABN 49 082 286 708

Suite 4, 125 Melville Parade
Como, Western Australia, 6152

Tel: (08) 9368 4044
Fax: (08) 9368 4055

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EXECUTIVE SUMMARY

FMG are proposing the Cloud Break Project, which consists of an ore mine and associated infrastructure in the eastern Pilbara. Aquaterra has been commissioned to undertake hydrogeological investigations for the project including environmental impact assessment for the Public Environmental Review. This work follows on from previous studies undertaken by Aquaterra for FMG for the Stage A PER and Stage B PER Reports.

The proposed new Project is situated about 30km west-north-west of the proposed Christmas Creek pit (which was included in the Stage B PER) on the northern flank of the Fortescue Valley in Marra Mamba Iron Formation. Cloud Break consists of a series of separate ore bodies and will therefore be a series of individual pits.

The life of mining is approximately 12 years, with a further year for completion of back filling of the pits. The ore bodies in each of the pits are mostly below the water table, and dewatering will be required at each site. The ore extracted during mining years 1 to 6 will be high-grade ore (occasionally referred to as direct shippable ore or DSO); which does not require beneficiation. However water will be required for dust suppression and camp water supplies. In the first year the high-grade ore will be taken from above the water table, and will have a low moisture content. Water will be added to the ore to increase the moisture to 7%. In years 2 to 6 mining will extend to below the original groundwater table and the ore will be moist and no water will be required for moisture control. In years 6 to 12 low-grade ore will be mined which will require beneficiation. FMG proposes to use its proposed ore beneficiation plant at Christmas Creek (described in the Stage B PER) for this purpose. Some of the water abstracted from Cloud Break for dewatering will be piped to the process plant. Water will also be used for dust suppression and domestic supplies (with treatment). However the volume of water abstracted will exceed the demand, and therefore it will be necessary to dispose of the excess water. A number of options for disposal of the water (which is likely to become saline as dewatering progresses) have been considered and are presented in this report.

The Fortescue Marsh occupies a topographic depression and is an ephemeral surface water feature, which is approximately 100 km long and 10 km wide, and fills with surface run-off after significant rainfall events. Data suggests that at certain times the water table lies approximately 5 m below the base of the marsh reinforcing the concept that the surface water in the Fortescue Marsh forms as a result of rainfall rather than as a result of groundwater discharge. There is evidence of a groundwater catchment divide west of the project area at Goodiadarrie Hills, which effectively prevents any western migration of groundwater from the Fortescue Marsh area. During flooding events salts deposited during previous drying episodes are redissolved, and the freshwater entering the marsh becomes moderately saline.

Alluvium forms a flat-lying plain across the Fortescue Valley. The alluvium is generally fine-grained, but along creeks, has been shown to contain sands and gravels. The alluvium is underlain by Wittenoom Dolomite below the Marsh, and Marra Mamba in the vicinity of the proposed pits.

Following a flood event, a portion of the ponded surface water will infiltrate causing water levels to rise beneath the marsh, ultimately to ground (marsh bed) level. Continual evaporation will remove ponded surface water, after which the watertable in the marsh bed sediments will decline to its former position under the combined processed of direct evaporation and radial groundwater flow to the Fortescue valley. It is considered likely that the depth to water beneath the marsh is, or closely approximates, the extinction depth for direct evaporation.

With the above concept, any change in groundwater level beneath the marsh will have no impact on the occurrence of surface water ponding, or on the rate of seepage from the marsh bed into the water table. It is conceivable however that where the groundwater level is lowered significantly, an increased amount of water would be required to fully saturate the profile, and this could reduce the duration of surface water ponding. However, groundwater modelling indicates that the cone of depression from the dewatering of Cloud Break will not extend below the Fortescue Marsh, and therefore that the marsh will not be affected by drawdowns from the dewatering.

The larger scale groundwater abstraction from the dewatering of the proposed pits may have the potential to locally impact on phreatophytic vegetation. The impacts of the cones of depression from the mine dewatering on vegetation have been reviewed by Libby Mattiske for FMG and are reported separately.

Stygofauna have been detected in bores south of Cloud Break, close to the Fortescue Marsh in areas impacted by drawdown. However to date, none of the stygofauna recorded in the bores in the Project area are considered significant or restricted to the Project. FMG will implement a Stygofauna Management Plan to manage this risk.

To better understand the potential impacts of groundwater abstraction on the environment, and develop appropriate management measures, FMG proposes:

- Further development of groundwater impact models.
- Monitoring of regional groundwater levels.
- Monitoring of groundwater levels in the vicinity of operations.
- Monitoring of potentially impacted phreatophytic species and mitigation measures for decline in condition if identified.

Uncertainty exists with regard to prediction of water quality from the dewatering operations. Initially the salinity of the water will be <10,000 mg/L but will deteriorate as deeper saline water is induced. It is proposed that any excess water be discharged into shallow ponds, where the naturally occurring process of evaporation will be used to dispose of the water. Outline designs for the evaporation ponds have been prepared. In addition FMG proposes to continue to investigate alternative options for disposal of the water, which include re-injection of the excess water into the Marra Mamba aquifer via a series of bores, and in-pit disposal of water using soakaways installed in the base of one of the mined-out pits.

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SECTION 1 - INTRODUCTION

Fortescue Metals Group Ltd (FMG) is proposing to mine at a new site in the East Pilbara. The site is known as Cloud Break and consists of a series of separate ore bodies. The locations of the proposed pits are shown in Figure 1.1, along with the key features of the project area.

Aquaterra has been asked to undertake hydrogeological investigations within the project area to:

1. Determine dewatering requirements at the mine sites.
2. Identify disposal mechanisms for excess dewatering water.
3. Investigate the potential impacts of dewatering on the Fortescue Marsh.

This report is a summary of the investigations to date. It includes descriptions of the existing geology, climate and hydrogeology, and then details the methods used to determine the impacts of dewatering on the environment.

FMG and its consultants, Environ, have produced a Public Environmental Review (PER), which considers all likely environmental impacts from the mining operations on the environment. This report on the hydrogeology of the project area will be used within the PER in two ways. Firstly, the complete report forms part of the technical appendix to the PER report where it is designed for those relatively familiar with geological and hydrogeological terms. Secondly, a summary of information from this report has been included in the main body of the PER report.

In any groundwater study it is necessary to make a series of modelling assumptions regarding aquifer recharge, storage and permeability. For this project Aquaterra has used results from the groundwater investigations undertaken as well as knowledge obtained from other projects undertaken in the Pilbara and published data for the area.

An environmental risk assessment, facilitated by an independent analyst and conducted by a team of qualified experts, was undertaken for the Stage B PER Report, this Risk Assessment identified the potential impacts of mining, including dewatering, on the marsh. Whilst that risk assessment was undertaken for the Stage B PER report the results and analysis are also pertinent to the Cloud Break PER. The results of the risk assessment are presented under a separate report (minRISK, October 2004), but referred to within this report.

Aquaterra has also been commissioned to undertake a study on the impacts of the mine on the hydrology of the project area. The results of these investigations are in a separate report (Aquaterra, June 2005).

1.1 PREVIOUS EXPERIENCE

Aquaterra is a specialist hydrogeology and hydrology consultancy firm that has extensive experience in water resource investigation, development and management for mining projects.

Aquaterra has considerable experience of the geology and hydrogeology of the Pilbara region. Some of our clients operating in similar environments to the FMG project include:

- Hamersley Iron.
- BHP Billiton Iron Ore.

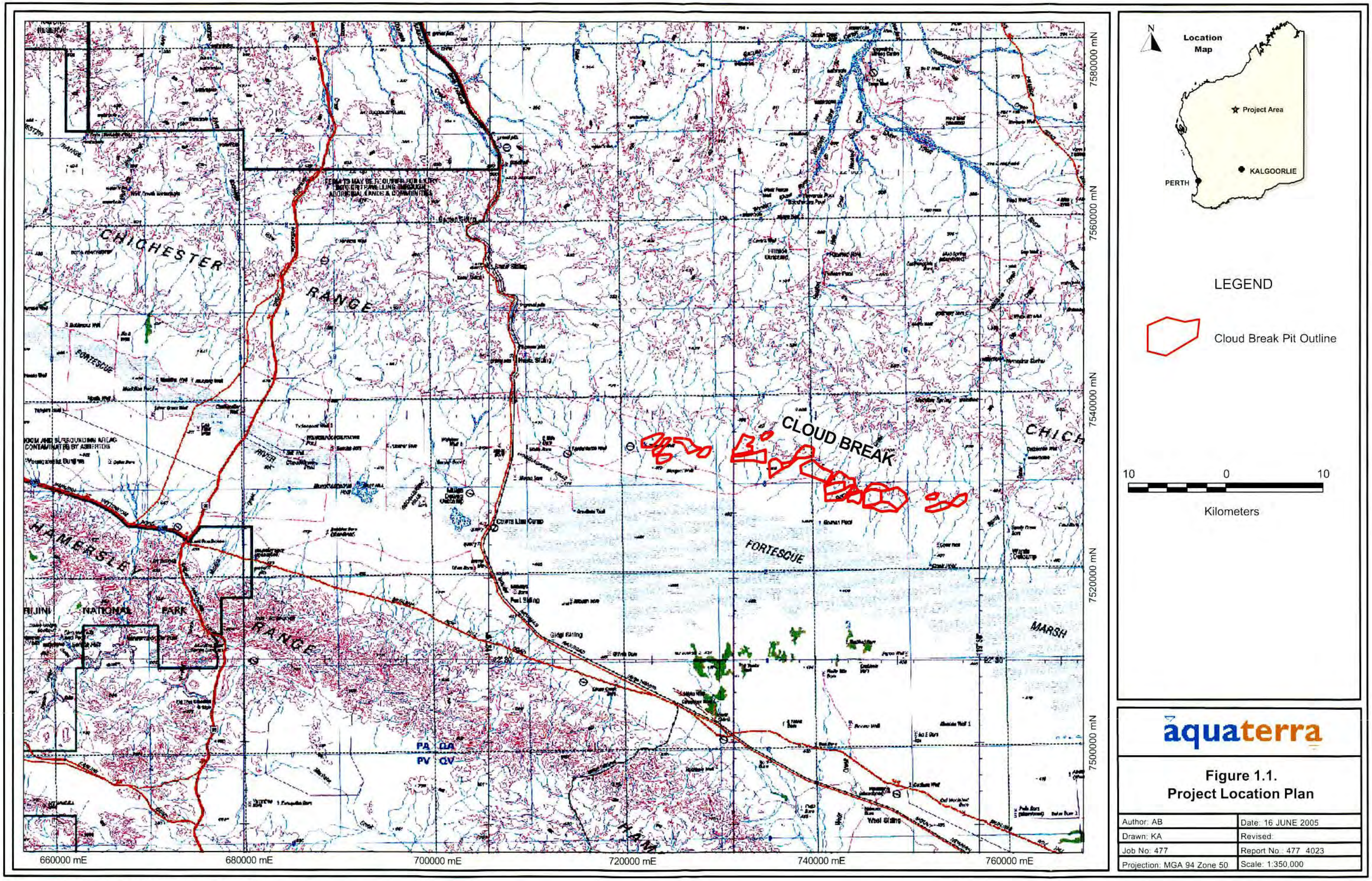


Figure 1.1.
Project Location Plan

F:\jobs\477\D1_Cloud Break\3000\3100 Maps and Plans\Figure 1.1 Project Location map

- Robe River Mining.
- Hope Downs.

Investigations have included the assessment and modelling of dewatering requirements and water supply in both channel iron deposits and the Marra Mamba Iron Formation. This experience has enabled Aquaterra to bring considerable relevant expertise and knowledge to the FMG hydrogeology study.

SECTION 2 - THE GEOLOGY OF THE PROJECT AREA

2.1 SUMMARY OF THE GEOLOGY OF THE PROJECT AREA

2.1.1 Regional Geology

The project area lies within the Hamersley Basin within the Pilbara region. A geological map of the area, with the mine locations superimposed is given in Figure 2.1. A summary of local stratigraphy relevant to this study is given in Table 2.1.

Table 2.1
Stratigraphy of the Project Area

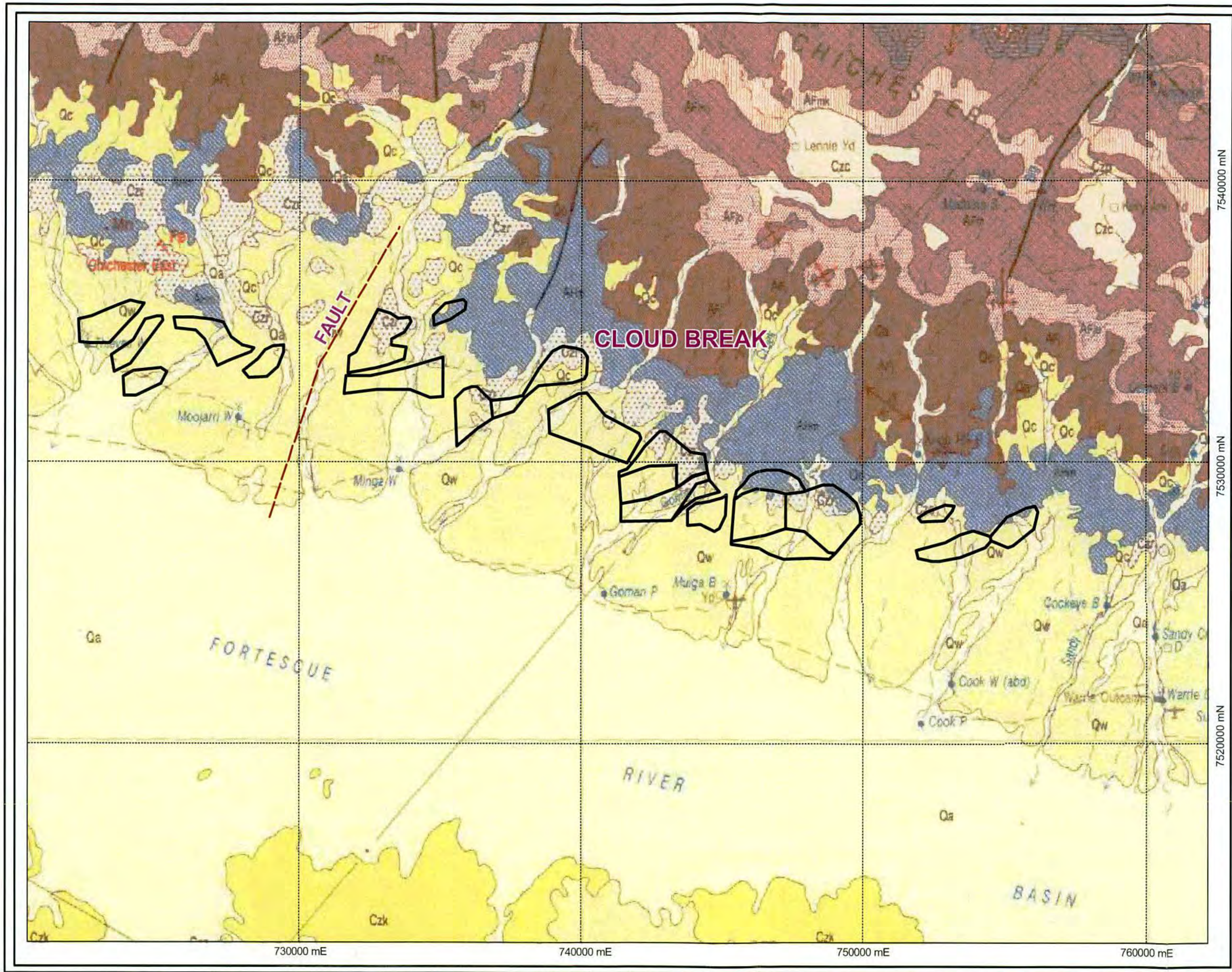
Group	Formation	Subdivision	Comments
Quaternary and Tertiary	Alluvium		Clay, silt, sands and gravel.
	Lacustrine Deposits		Clay and silt
	Colluvium and Alluvium		Clay, partly ferruginised silt, sand and gravel
	Ferruginous Duricrust		Overlying the Marra Mamba Iron Formation
	Channel Iron Deposits (CID)		Pisolitic Limonite developed along river channels.
Hamersley Group	Weeli Wolli Formation [1]		BIF [2], pelite and numerous metadolerite sills
	Brockman Iron Formation [1]		BIF, chert and pelite
	Mount McRae Shale [1]		Pelite, chert and BIF
	Wittenoom Dolomite		Thin to medium bodied metadolomite
	Marra Mamba Iron Formation	Mount Newman Member	BIF with thin shale intervals
		MacLeod Member	Shales, chert and BIF
		Nammuldi Member	Chert and iron-formation ORE
Fortescue Group	Jeerinah Formation	Roy Hill Shale Member	Bleached white shale
Pilbara Craton			Granitic Rocks

[1] Only occurs south of the Fortescue River
[2] Banded Iron Formation

The Hamersley Basin is underlain throughout by granitoid rocks, approximately 2800 to 3500 million years old, which form the Pilbara Craton. These rocks are mostly concealed by Proterozoic sedimentary rocks of the Fortescue and Hamersley Groups, however they do outcrop to the east and north of the Project area.

The Fortescue Group, which is the lower of two sedimentary sequences, rests on weathered granite and metasedimentary rocks of the Pilbara Craton. The Jeerinah Formation is the youngest formation within the Fortescue Group, and is relevant to this project because its surface marks the base of the main ore body. The Jeerinah has been sub-divided into a number of members, of which the Roy Hill Shale is the uppermost; it is composed of bleached and silicified white to grey shale, and was intercepted in several of the mineral bores drilled for the project.

The Hamersley Group conformably overlies the Fortescue Group. The basal Marra Mamba Iron Formation consists of inter-bedded iron-stained chert and shale. Outcrops occur in several areas, including the Cloud Break mine sites. The Nammuldi Member is the lowest unit of the Marra Mamba, and is typically 60 m thick.



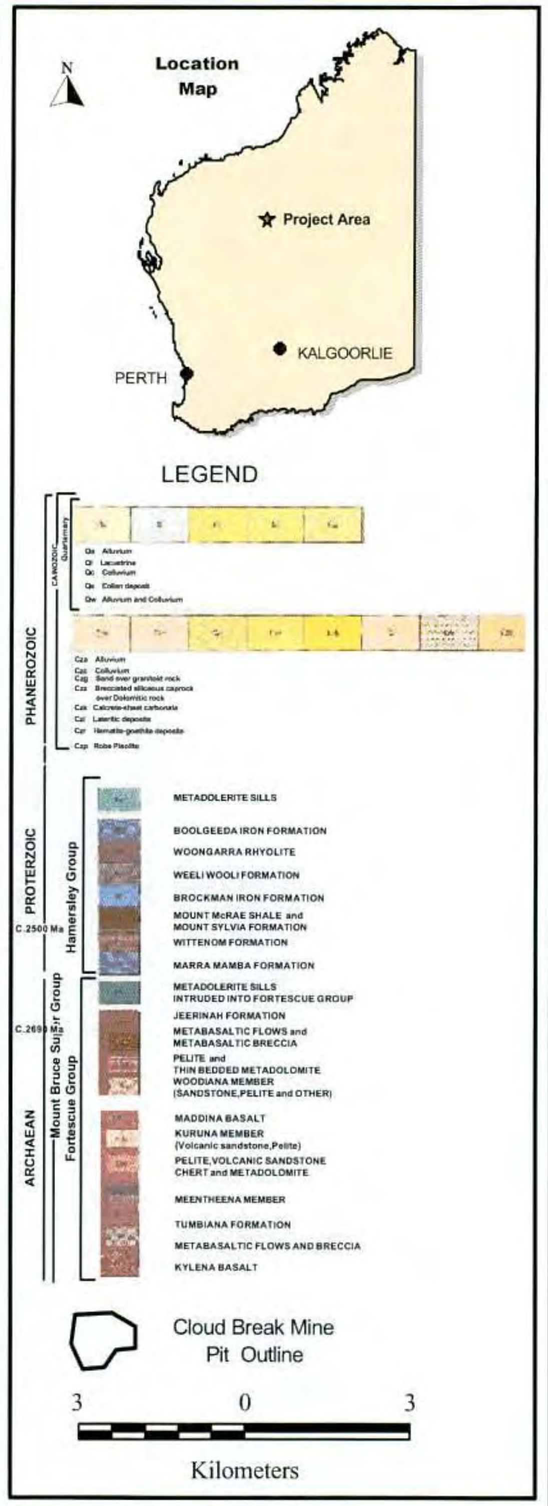


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FIGURE 2.1.
Geology of the Project Area

Author: AB	Date: 14 June 2005
Drawn: KA	Revised:
Job No: 477	Report No.: 477 4023
Projection: MGA 94 Zone 50	Scale: 1:125,000

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In the project area, it consists of yellow-brown chert and brown to black iron-formation bands. The Nammuldi Member contains the ore body at Cloud Break. The overlying MacLeod Member comprises thin shales, chert and Banded Iron Formation (BIF). Wittenoom Dolomite, which generally overlies the Marra Mamba, has been eroded in the proposed pits, however it was intercepted south of Cloud Break, in bore CB068a. To the south of the Fortescue River, the Wittenoom Dolomite is concealed by the Mount McRae Shale, the Brockman Iron Formation, and the Weeli Wolli Formation.

The axis of the Hamersley Basin is marked by the presence of the Fortescue Marsh and Fortescue River systems. The relatively flat Fortescue Plain extends either side of the river. This is underlain by a flat-lying but complex sequence of Quaternary and Tertiary alluvial, colluvial and lacustrine sediments. The sequence has been deposited in a valley incised in the Hamersley Group, which forms the bedrock beneath the Fortescue Plain. The alluvial deposits increase in thickness down gradient towards the Marsh, where a maximum thickness of approximately 70 m has been recorded. Along the ephemeral creeks and riverbeds the alluvial sequence typically comprises of unconsolidated silt, sand and gravel, whereas finer-grained sediments including clays predominate across the adjacent flood plains.

2.1.2 Geology of Cloud Break

The geology underlying Cloud Break has been determined from the mineral exploration drilling, plus the installation of 10 groundwater exploration bores. Appendix A includes bore logs from the groundwater investigation.

The data indicate that the geological sequences dip in an approximate southerly direction. There appears to be a structural fault running northeast to southwest approximately equidistant between Minga Well and Moojari Well.

The available data suggest that the geology at Cloud Break is very similar to that at Christmas Creek, which was investigated for the Stage B PER.

The main ore bodies at Cloud Break are generally concealed below overlying deposits, though at some sites, especially in the north, the Marra Mamba is at the surface. Figures 2.2 to 2.8 show a series of cross sections through the pits, and indicate that the ore is generally around 20m thick.

On the lower slopes at Cloud Break, the Marra Mamba is partially concealed by Cainozoic Deposits of hematite and goethite. Further south still the Marra Mamba is overlain by a sequence of Quaternary and Tertiary deposits, generally referred to as "alluvial deposits". This sequence includes silts, clays, and sands and, at two sties (CB068 and CB068B) a calcrete layer was intercepted. This calcrete has been identified in other bores south of the proposed pits at both Christmas Creek and Mount Lewin, and is believed to represent a paleo water level in the Fortescue Marsh.

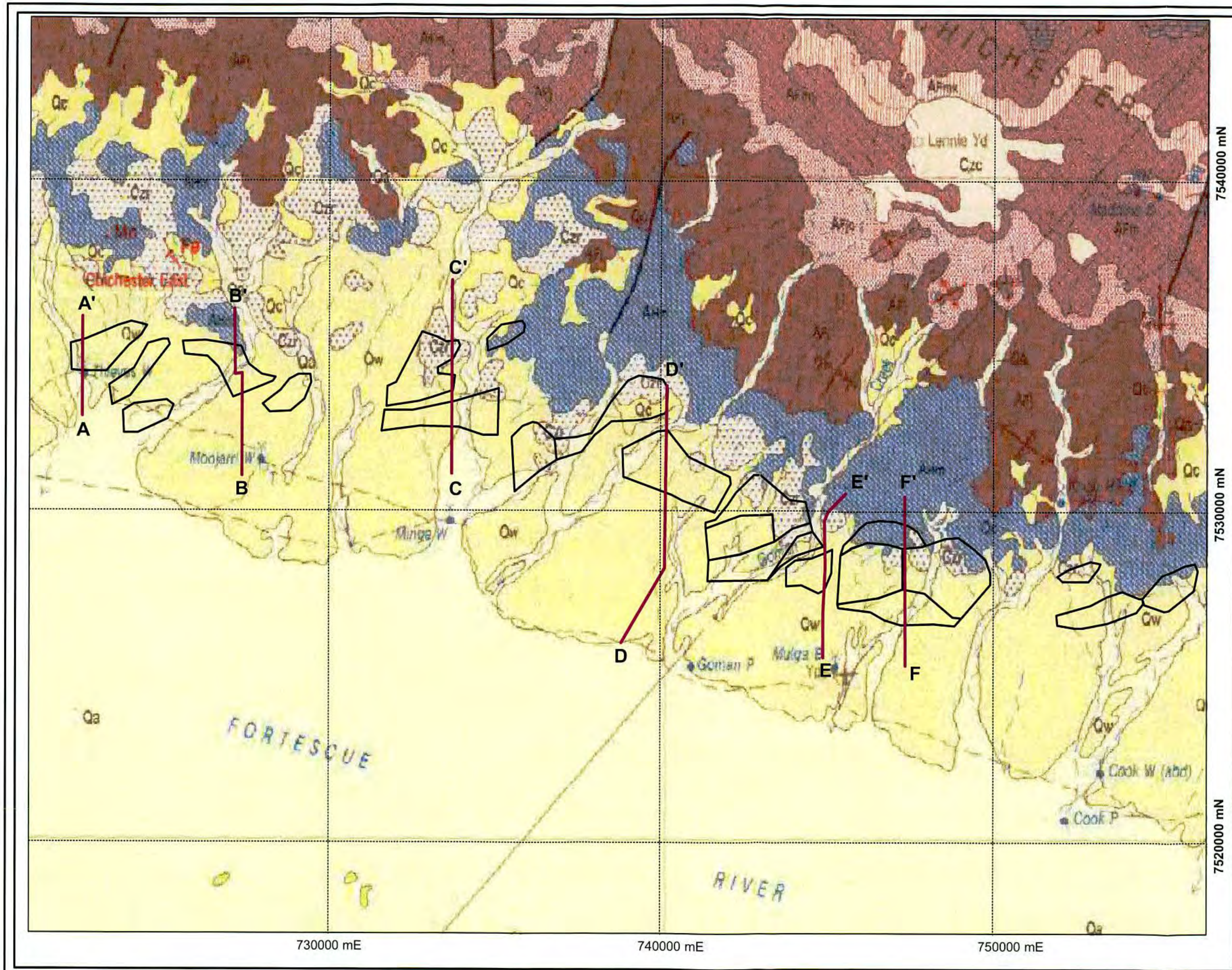

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Figure 2.2. Plan showing the Location of Cross-Sections (Figures 2.3 to 2.8)

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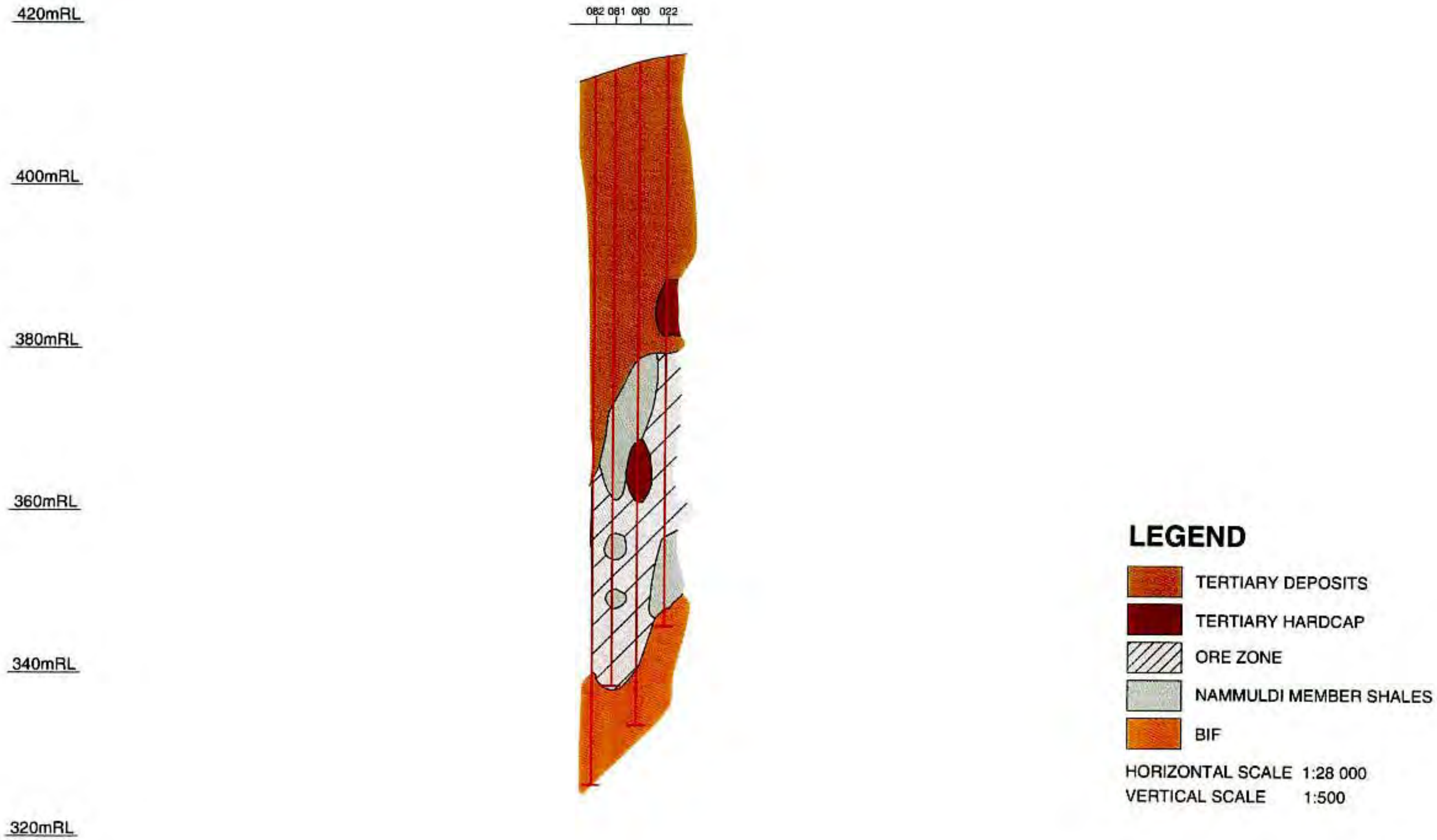
Drawn: KA	Revised:
Job No: 477	Report No.: 477 4023
Projection: MGA94 Zone 50	Scale: 1:125,000

F:\jobs\477\D1_Cloud Break\3000\3100 Maps and Plans\Figure 2.2 Locations of geological cross sections.WOR

Section A - A'



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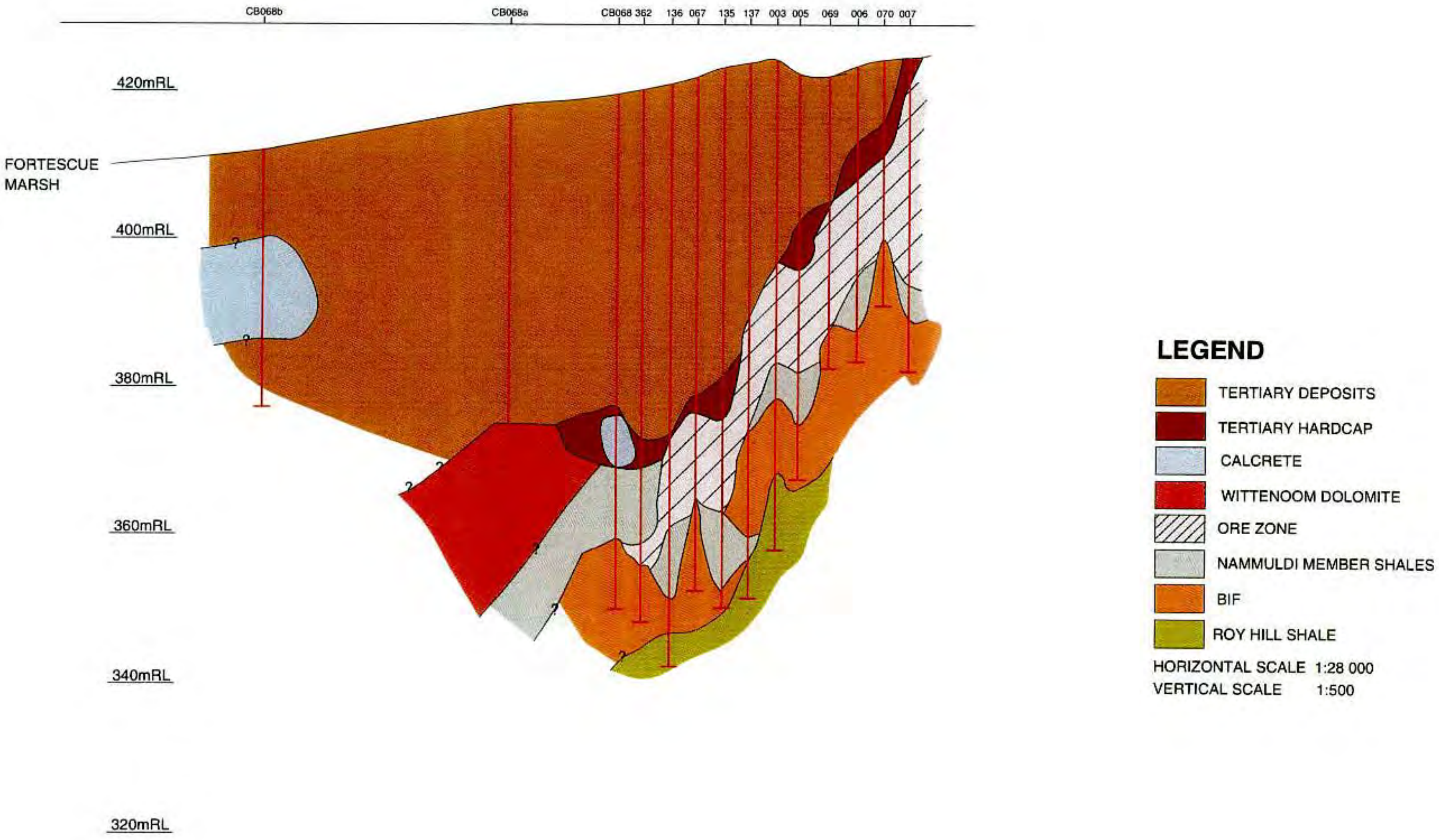
Section A-A'

FIGURE 2.3

Section B - B'



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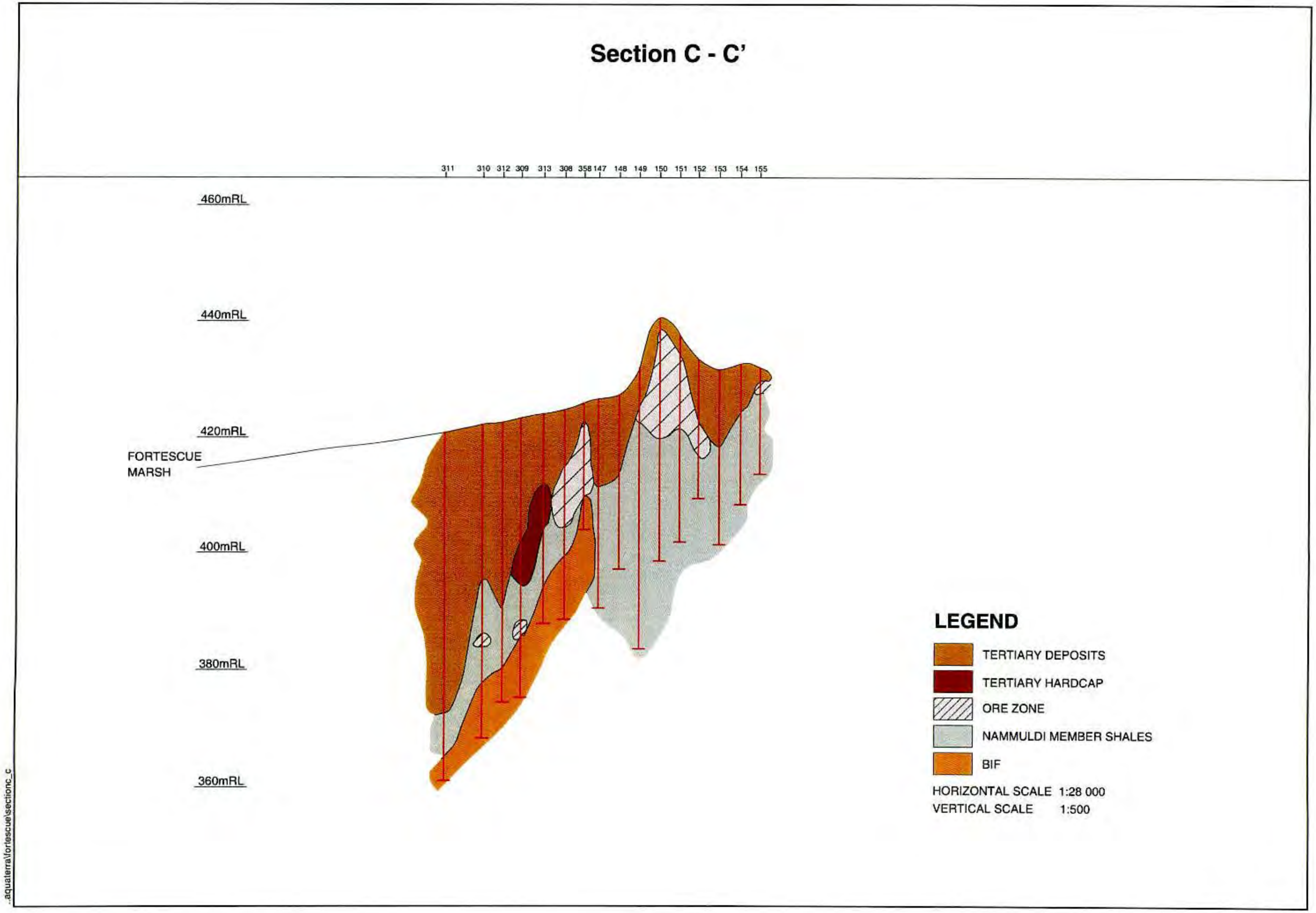
Section B-B'

FIGURE 2.4



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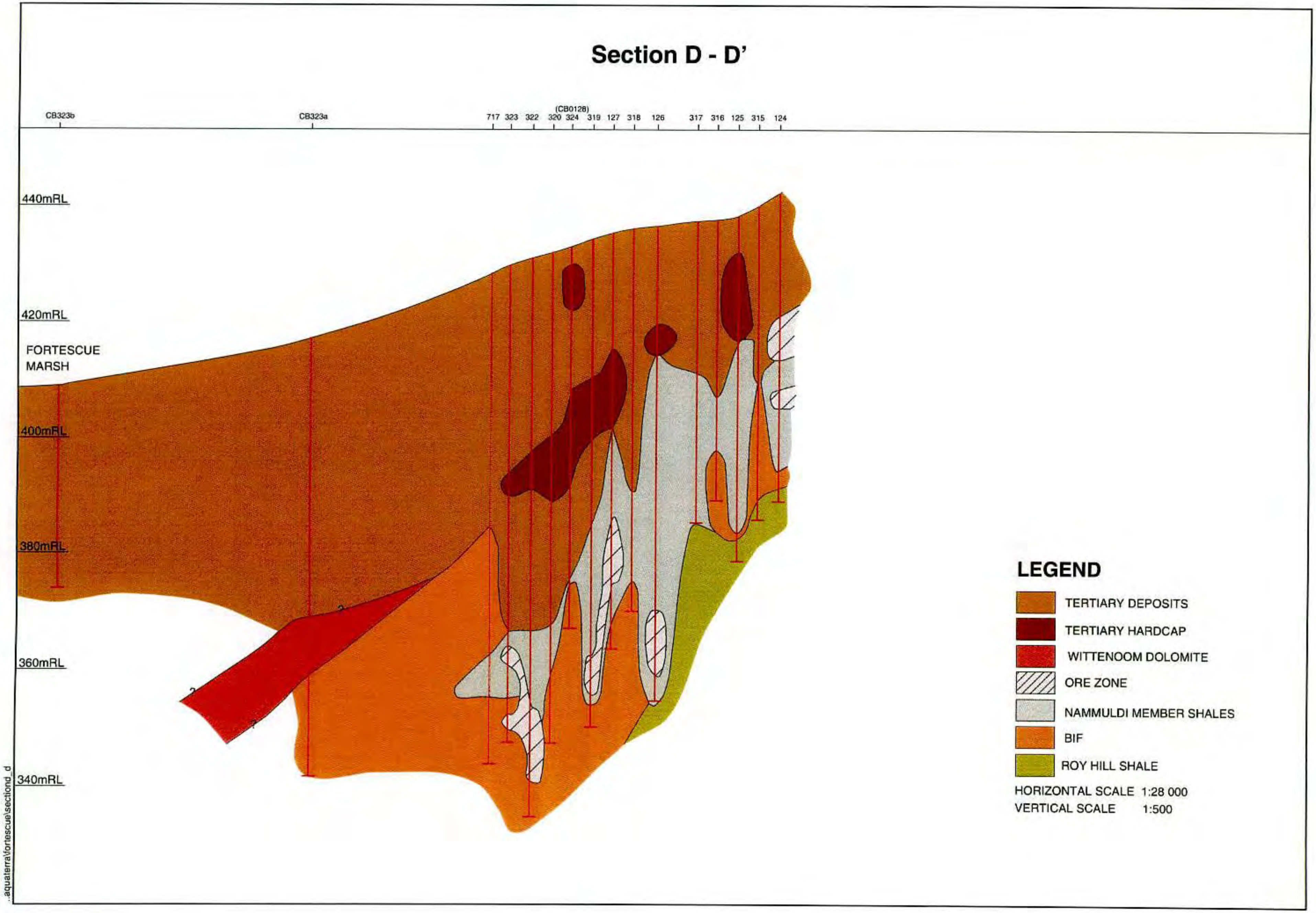
Section C-C'

FIGURE 2.5



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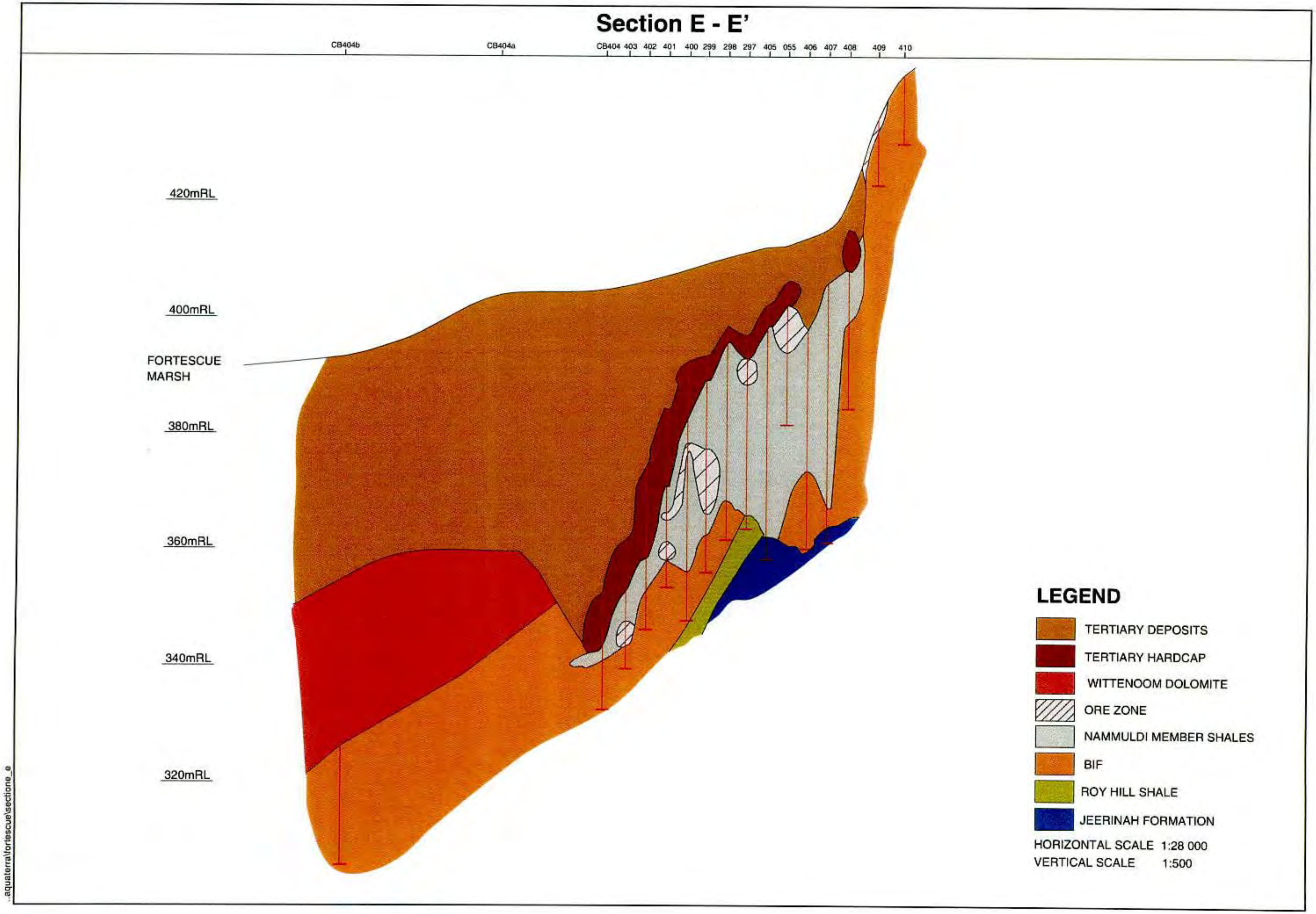
Section D-D'

FIGURE 2.6



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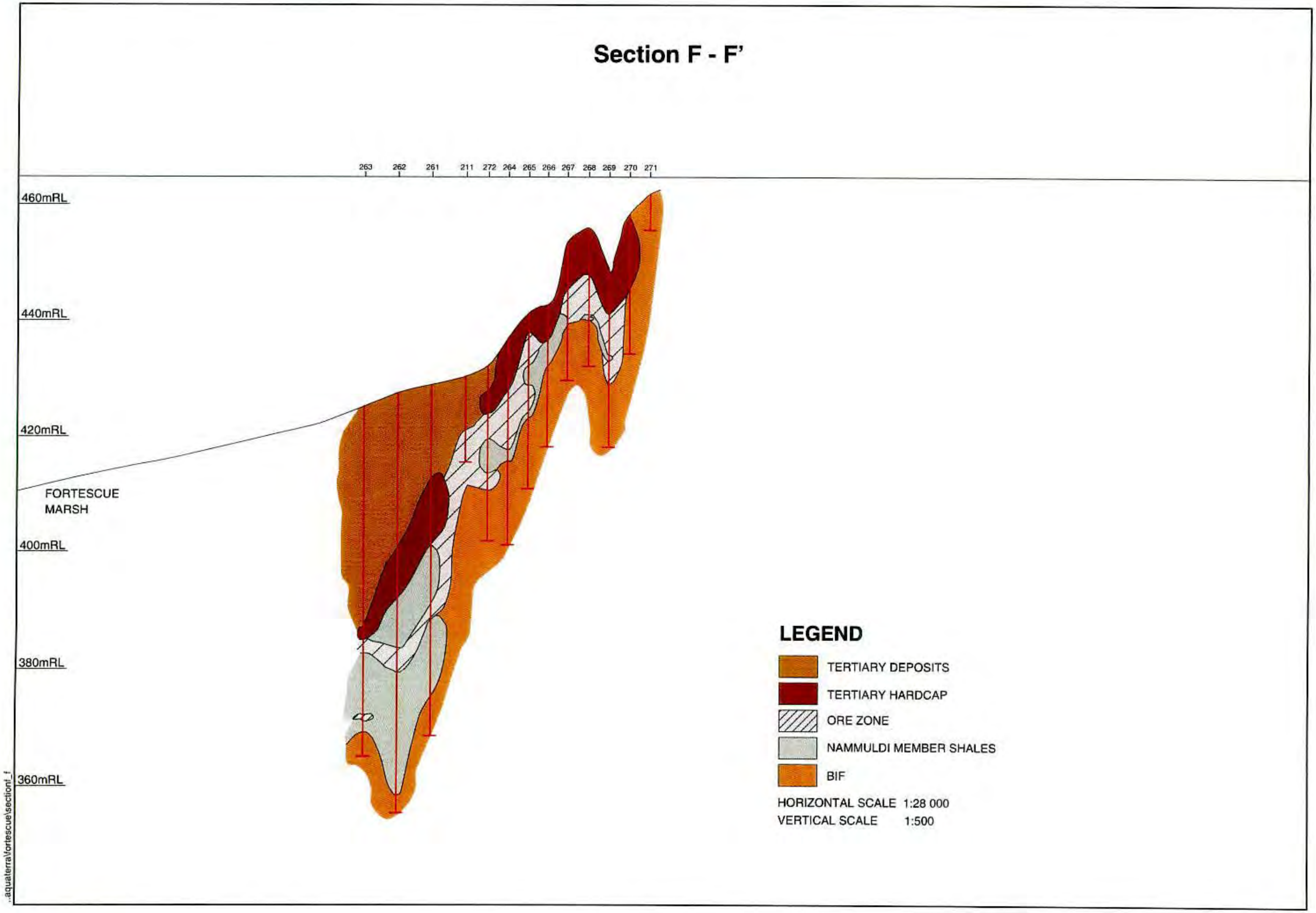
Section E-E'

FIGURE 2.7



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Section F-F'

FIGURE 2.8

SECTION 3 - CLIMATE & HYDROLOGY OF THE PROJECT AREA

3.1 THE CLIMATE OF THE PROJECT AREA

The climate of the Pilbara is classified as arid-tropical, with two distinct seasons, a hot summer from October to April and a mild winter from May to September. There are two main rainfall systems; the northern rainfall system of tropical origin and the southern winter rainfall system. This results in a bi-modal rainfall distribution with a peak occurring between January and March as a result of moist tropical systems followed by significant rainfall occurring between May and June, resulting from cold fronts moving from the south, occasionally extending into the Pilbara. Table 3.1 shows climatic data for Newman, situated approximately 100 km south of the project area, and the nearest station with a long-term record.

Table 3.1
Summary of Climate Data for Newman

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Daily Max Temp	38.8	37.2	35.8	31.6	26.2	22.4	22.2	24.8	29.4	33.6	36.5	38.5	31.3
Mean Daily Min. Temp (°C)	25.3	24.4	22.5	18.5	13.3	9.6	8.0	10.2	23.7	18.0	21.5	24.1	17.3
Mean 9am Rel. Hum. (%)	35.0	41.0	37.0	41.0	49.0	56.0	50.0	43.0	30.0	25.0	24.0	30.0	39.0
Mean 3pm Rel. Hum. (%)	22.0	26.0	23.0	26.0	32.0	34.0	29.0	24.0	17.0	14.0	24.0	19.0	24.0
Mean monthly rainfall (mm)	51.0	80.0	39.0	25.0	23.0	25.0	13.0	11.0	4.0	4.0	10.0	27.0	312.0
Highest monthly rainfall (mm)	226.0	286.0	199.0	212.0	119.0	156.0	64.0	96.0	43.0	23.0	63.0	140.0	286.0
Highest recorded daily rainfall (mm)	142.0	151.0	108.0	72.0	47.0	101.0	29.0	36.0	31.0	17.0	57.0	63.0	151.0
Mean 3pm wind speed (km/hr)	10.1	10.7	8.8	7.7	7.9	8.3	9.3	92.0	20.2	11.0	10.2	9.6	9.4

Record 1965 - 2003

3.2 REGIONAL HYDROLOGY

The hydrology of the region is discussed in more detail in a separate report for the Stage B PER (Aquaterra, November 2004) but is briefly summarised below.

The proposed FMG mining areas are located in the vicinity of the Fortescue Marsh in the Upper Fortescue River Catchment. In common with other areas in the Pilbara Region, the Fortescue Valley is subjected to localised thunderstorm and cyclonic rainfall events. Due to the low rainfall and brief wet season, most watercourses flow, if it all, for only brief periods. However surface water does remain available all year in some river pools, waterholes and springs.

On the southern and northern flanks of the Fortescue Valley, numerous creeks discharge to the marshes. On the lower less steep valley flanks, rainfall runoff tends to flow overland rather than along defined creek courses. These water courses and sheetflow areas frequently support mulga woodlands and other shrubs, particularly in the lower lying areas. The Fortescue River and other main channels entering the marshes typically support eucalypt woodland in their floodplains.

The Goodiadarrie Hills, located on the valley floor around 20 km west from the Cloud Break pit, effectively cuts the Fortescue River into two separate river systems. West from the Goodiadarrie Hills, the Lower Fortescue River Catchment drains to the coast, whereas east from the hills the Fortescue Marshes receives drainage from the Upper Fortescue River Catchment. The alluvial outwash fan from the Weeli Wolli Creek system abutting the Goodiadarrie Hills is believed to be partially responsible for this obstruction to the Fortescue River and forming the Fortescue Marsh.

3.2.1 Hydrology of the Fortescue Marsh

The Fortescue Marshes is an extensive intermittent wetland occupying an area around 100 km long by typically 10 km wide located on the floor of the Fortescue Valley. The marsh has an elevation around 400 mRL. To the north, the Chichester Plateau rises to over 500 mRL, whereas to the south the Hamersley Range rises to over 1000 mRL. Following significant rainfall events, runoff from the approx 31,000 km^2 upper Fortescue River Catchment drains to the marshes. For the smaller runoff events, isolated pools form on the marshes opposite the main drainage inlets, whereas for the larger events the whole marsh area floods.

Published topographical mapping indicates that bed levels in the Fortescue Marshes predominantly lie between 400 mRL and 405 mRL and that a flood level in the Marsh would need to be around 415 mRL to overspill westwards past the Goodiadarrie Hills. Limited flood level data is available for the marsh. Enquires with BHPBIO indicate that flood levels have never overtopped their marsh railway crossing, although large floods in the early 1970's are reported to have caused inundation up to the existing railway track level (pers. com. Geoff Liddell, BHPBIO).

On the upstream edge of the marsh, downstream from the Roy Hill Homestead, the Roy Hill streamflow gauging station (S708008) was operating from September 1973 to September 1986. This station was established to monitor streamflows entering the marsh from the upper Fortescue River. At the gauging station, the main flow channel bed level was around 405.5 mRL and during the 13 years of record, the maximum recorded streamflow level was 408.75 mRL (Feb. 1980). The corresponding flood storage level in the downstream marsh would have been less than this gauge level.

Surface water runoff to the marsh is of low salinity and turbidity, though the runoff turbidity increases after periods of flooding. Following a significant flood event that flooded the whole marsh area, the ponded water could be over 5 m deep in the lower elevation marsh areas. Water stored on the marsh slowly dissipates through the processes of seepage and evaporation, and the aerial extent of the marsh decreases, becoming a series of pools, until the surface water completely dries up. During the evaporation process, the water salinity levels increase and as the ponded area recedes, traces of surface salt can be seen.

SECTION 4 - EXISTING HYDROGEOLOGY OF THE PROJECT AREA

4.1 METHODS USED

Following a desk study and literature review the existing hydrogeology of the area has been investigated using a variety of techniques, including:

1. The drilling of 10 exploratory bores to determine the presence of aquifers and groundwater levels. These bores were drilled in potential dewatering zones at Cloud Break and south of Cloud Break to gain understanding of the hydrogeology of the region closer to the Fortescue Marsh.
2. Geophysical techniques (including a TEM aeromagnetic survey and down-hole geophysical analysis) to locate hydrogeological features, in particular the extent of saline water throughout the Cloud Break area.
3. Test pumping of two trial bores to determine aquifer parameters of the relevant geological formations.
4. Groundwater sampling and analysis to provide information on the chemistry of the groundwater between Cloud Break and the Fortescue Marsh.
5. Numerical groundwater modelling techniques to simulate existing groundwater systems and enable assessment of the impacts of proposed dewatering and abstraction for the water supply.

4.2 REGIONAL HYDROGEOLOGY

Regional groundwater levels were initially obtained from the Department of the Environment's AQWABASE system. In addition FMG has commenced a programme of regular groundwater level monitoring, as part of its ongoing groundwater monitoring programme. This programme has involved the construction of 34 monitoring bores throughout the Fortescue Valley and surveying of a further 25 bores (mainly station bores) to determine accurate reference levels at each site. Monthly monitoring of these bores has commenced and these data were combined with groundwater measurements from the bores drilled for the project and used to construct a groundwater contour plot. Figure 4.1 shows these contours as meters above reduced level (mRL).

In low-lying areas, particularly along the Fortescue Marsh, Fortescue River and major creek systems, depth to groundwater is typically less than 10 m. At sites on the flanks of the Fortescue Valley groundwater levels are typically at depths of 20 m or more.

Throughout the region groundwater levels are a subdued reflection of topography. Maximum groundwater levels (approximately 430 mRL) were observed along the topographic highs associated with rocks of the Hamersley and Fortescue Groups, whilst groundwater levels were lowest in low-lying areas associated with creeks and the Fortescue Marsh and Fortescue River system. It is important to note that groundwater levels in the vicinity of the Fortescue Marsh have been reported as being below 400 mRL, which, as discussed in Section 3, represents the bed of the marsh. During the recent groundwater monitoring programme water levels in these bores were above 400 mRL, and this is believed to be due to surface recharge in 2004 when the Marsh was seen as being a large expanse of water.

At Cloud Break there are two extensive aquifers; an alluvial aquifer within the Quaternary and Tertiary sequence discussed in Section 2, and the upper portion of the Marra Mamba formation where it is either mineralised or weathered. In addition, south of the pit, close to the Fortescue Marsh, there is evidence of Wittenoom Dolomite which is an important aquifer regionally, especially in the proposed water supply borefield at Mount Lewin, where the surface of this horizon was found to be weathered and occasionally karstic and yielded large quantities of water. In comparison the unmineralised Marra Mamba generally consists of low-permeability shales.

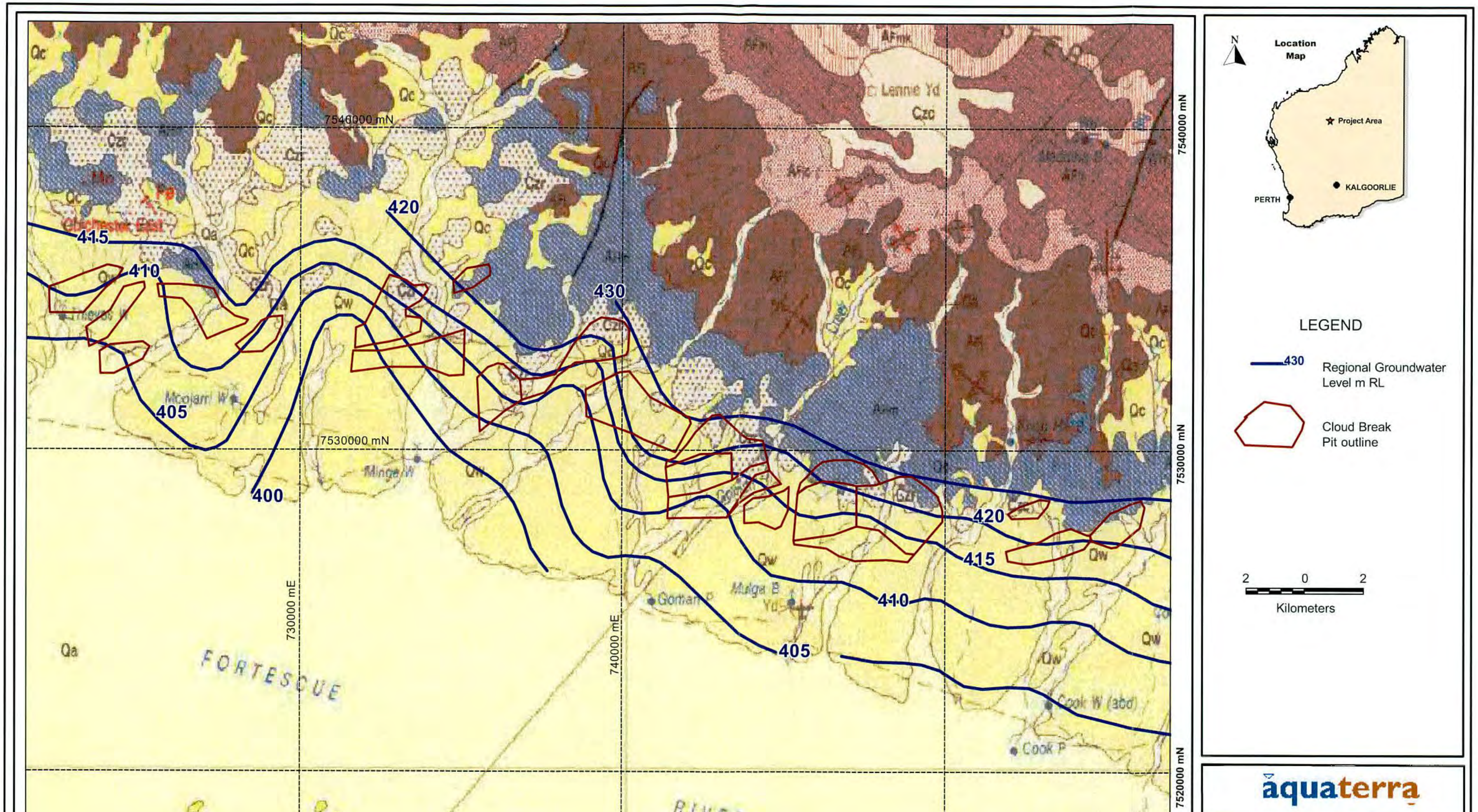


Figure 4.1. Regional Groundwater Contour Plan

Author: AB	Date: 16 JUNE 2005
Drawn: KA	Revised:
Job No: 477	Report No.:477 4023
Projection: MGA 94 Zone 50	Scale: 1:125,000

The saturated thickness of the alluvial deposits is in excess of 60 m in the south, with the alluvium becoming unsaturated in the north. The mineralised Marra Mamba aquifer is typically 20 m thick and is generally saturated, except at higher elevations. The unmineralised Marra Mamba is up to 100m thick.

4.2.1 Hydrogeology of the Fortescue Marsh

Insight into the hydrogeology of the Fortescue Marsh has been obtained from:

Was 2004 a typical rainfall year?

- Water samples from the marsh: These showed that it contained sub-potable water (Total Dissolved Solids (TDS) 7,500 mg/L) in spring 2004, but that the water becomes more saline towards summer (TDS 10,000 mg/L in October 2004) as water levels in the marsh decline. More recently in May 2005 a sample was taken from one of the few pools still present in the marsh and the conductivity value was 71,000 mg/L.
- Bores installed in the area between Cloud Break and the marsh: These indicate that, in this area, groundwater levels in both the alluvium and underlying basement material are currently 2 mbgl. However, previous data has shown regional water levels recorded in stock bores suggest groundwater levels along the Fortescue Valley are typically 5 m or more below ground level (see the Stage B PER report).
- Groundwater samples, taken from bores between Cloud Break and the marsh: These indicate that the alluvium intercepted contains water with a similar water quality to that in the marsh.
- Anecdotal evidence suggesting that the marsh completely dries out during sustained dry periods, and salt crystals form on the surface of the bed (Gary Clark, pers coms., October 2004). In support of this, during September 2004, occasional, salt deposits were observed on the flanks of the marsh. The marsh has been dry since October 2004, except for a few small isolated pools.
- Groundwater levels in the vicinity of the marsh, in the area close to Cloud Break, have been reported is being approximately 397 mRL. Unpublished data suggests that groundwater levels along the Mount Newman Railroad, approximately 40 km west of Cloud Break, are approximately 410 mRL to 415 mRL. These groundwater level data indicate a groundwater catchment divide downstream of Cloud Break, with the Fortescue Valley acting as a groundwater discharge point.

The available data set indicate that water levels in the alluvium on the plain are generally below the bed of the marsh, except after recharge of the alluvium via the bed of the marsh, as has occurred since August 2004 when the marsh was observed as a large expanse of water, several meters deep. This confirms the surface water in the marsh forms as a result of rainfall rather than as a result of groundwater discharging. During flooding events salts deposited during previous drying episodes are redissolved, and the freshwater entering the marsh becomes moderately saline over time.

Following a flood event, a portion of the ponded surface water will infiltrate causing water levels to rise beneath the marsh, ultimately to ground (marsh bed) level. Continual evaporation will remove ponded surface water, after which the watertable in the marsh bed sediments will decline to its former position under the combined processed of direct evaporation and radial groundwater flow to the Fortescue valley. It is considered likely that the depth to water beneath the marsh is, or closely approximates, the extinction depth for direct evaporation.

With the above concept, any change in groundwater level beneath the marsh will have no impact on the occurrence of surface water ponding, or on the rate of seepage from the marsh bed into the water table. It is conceivable however that where the groundwater level is lowered significantly, an increased amount of water would be required to fully saturate the profile, and this could reduce the duration of surface water ponding.

The alluvium and, to a lesser extent, Marra Mamba aquifers on the flanks of the valley are recharged with fresh water during rainfall events. Given there is a hydraulic gradient; this water will drain towards the marsh. Groundwater both below and close to the marsh is saline, whilst that further away is fresh. A schematic diagram representing the process is given in Figure 4.2.

Approximately 30 km west of the proposed Cloud Break mine lie the Goodiadarrie Hills, which consist of siliceous chert, which formed as a result of chemical precipitation within the Fortescue Valley. The hills form a narrow restriction across the Marsh, which prevents any western migration of groundwater away from the Marsh area.

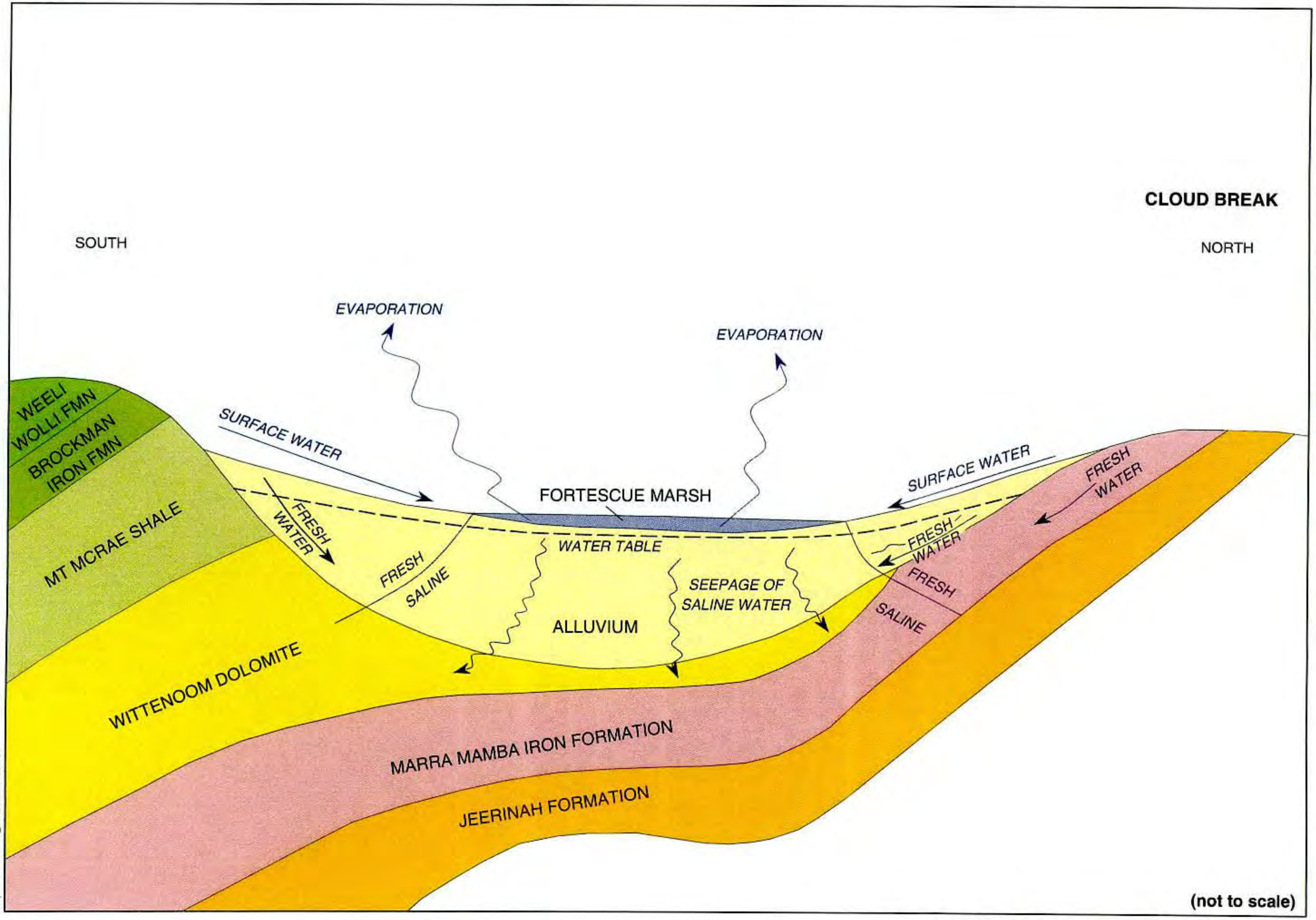
4.3 TEST PUMPING

As part of the investigation test pumping of two trial bores was undertaken to determine the hydraulic properties of the alluvium and Marra Mamba. The two trial bores were constructed close to the hanging wall of the proposed pits to provide estimates of the hydraulic properties of the hanging wall material. In bore CB068T slotted casing was installed through the clays and silty aggregate of the alluvium, whilst in bore CB471T slotted casing was installed through the Marra Mamba Summary details of the test and observation bores are given in Table 4.1 and details of the tests are provided in Table 4.2. Copies of the test pumping data are provided in Appendix B.

Table 4.1
Summary of Well Details

Well	Easting	Northing	Distance from Test Well (m)	Total Depth (m)	Slotted Interval (mbgl)	Unit
CB068T	727212	7532001	-	39.5	9.5-39.5	Alluvium & Lacustrine Clay
CB068_shallow	*727200*	*7532000*	11.8	36	Open hole	Alluvium & Lacustrine Clay
CB068_deep	*727202*	*7532000*	9.7	60	54-60	BIF
CB471T	746000	7528200	-	45	12-45	Shales, Ore Zone & BIF
CB471_Obs	*746000*	*7528215*	15.2	32	20-32	Ore Zone

Italics = inferred values based on distance from test bore



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Schematic Section Across the Fortescue Marsh

FIGURE 4.2

Table 4.2
Summary of Pumping Test Schedules

Test Well	Test Date	Test Duration (mins)		Discharge Rate (m^3/d)	Observation Well	SWL (mbgl) *1	Maximum Drawdown (m)*2
		Constant rate	Recovery				
CB068T	13/05/05	2,880	2,940	346	CB068T	8.63	14.36
					CB068_Shallow	7.61	0.16
					CB068_Deep	8.985	0.015
CB471	16/05/05	2,880	2,940	1,296	CB471T	17.23	1.17
					CB471_Obs	16.88	0.44

*1 Static water level at start of constant rate test
*2 Maximum drawdown during constant rate test

4.3.1 Test Pumping of Bore CB068T

Overview of CB068T Constant Rate Test Pumping

The test well was slotted in the alluvium and lacustrine clay unit (9.5 to 39.5 metres below ground level (mbgl)). Water levels were monitored in two observation wells: CB068_Shallow, which was left open hole across the alluvium and lacustrine clay (0 to 36 m) and CB068_Deep, which was slotted in chert beds of the underlying Marra Mamba (54 to 60 mbgl).

The initial water level was similar in all three bores at approximately 8 mbgl. A maximum drawdown of approximately 14.36 m was recorded in the test well. Water levels were within the alluvial sediments for the duration of the test in all three bores.

Analysis of Data for CB068T

Water levels in the test well dropped steadily throughout the test, reaching a maximum drawdown of approximately 14.36 m after 48 hours. A couple of irregularities in the water levels recorded are evident which appear to be associated with pumping rate changes, but which may represent leakage from the overlying formations. A transmissivity of approximately 20 m^2/d was derived from analysis of the drawdown data (Theis and Cooper-Jacob), without any correction for well efficiency.

Analysis of data for CB068_Shallow

This bore is situated 11.8m from test well and intercepts the same aquifer units. Water levels in the shallow well dropped steadily throughout the test, reaching a maximum drawdown of 0.16 m after 48 hours. A transmissivity of approximately 920 m^2/d was be derived from analysis of the drawdown data (Theis and Cooper-Jacob) and a storativity estimate of 3.3×10^{-3} was derived.

Analysis of data from CB068_Deep

This bore is located 9.7 m from test well and penetrates the Nammuldi Formation, consisting mostly of chert. Water levels fluctuated during the pumping test, reaching a maximum drawdown of 0.065 m after 15 hours pumping, and then recovering and stabilising at 0.015 m drawdown. There is no slotted interval overlap between the test well and this observation well. Calcrete (8 m) and BIF (4 m) separate the alluvium/lacustrine clay units and the chert beds of the Nammuldi Formation. The water level monitoring results from this well have implications with regards to the hydraulic characteristics of the chert beds of the Nammuldi Formation, the intermediate calcrete and BIF and the hydraulic continuity between the alluvium/lacustrine clay and the underlying formations.

Analysis of CB068T Recovery Test

Recovery water levels were recorded in the test well only. Water levels recovered to within 2 m of initial water levels within 7 minutes then recovered steadily to within 0.85 m of initial levels at the end of the test. A transmissivity of approximately 20 m^2/d was derived from analysis of the early recovery test data, with a transmissivity value of 65 m^2/d derived from the late recovery test data.

CB068T Summary

A transmissivity value of approximately 20 m^2/d was derived for the alluvium and lacustrine clay from the drawdown and recovery data obtained from the test well. This provides a mean value of hydraulic conductivity of 0.66 m/d, based on the screened interval. However, the shallow observation well recorded a drawdown of 0.16 m and provided transmissivity and storativity values of 920 m^2/d and 3.3×10^{-3}, respectively. This provides a k value of 25.55 m/d, based on the screened interval. The response in bore CB068_Shallow is unusually small, and may have been affected by the clays blinding the walls of the bore. It is considered that the results obtained for this bore are unreliable.

The deep observation well (screened within the chert beds of the underlying Nammuldi Member) was impacted by 0.015 m suggesting that pumping the alluvium and lacustrine clay at this location has limited impact on the water levels in the underlying chert beds.

4.3.2 Test Pumping of Bore CB471T

Overview of CB471T Constant Rate Test Pumping

The test well was drilled to a depth of 45 m with slotted casing installed through the hard cap, shale, ore, and BIF of the Nammuldi Member (12 m to 45 m). Water levels were monitored in one observation well CB471_Obs, slotted in the ore zone of the Nammuldi Member (from 20 m to 32 m).

The initial water level was similar in both bores at approximately 17 m below ground level. A maximum drawdown of approximately 1.17 m was recorded in the test well. Water levels in the test well went from within the hard cap to just into the shale over the duration of the test. Water levels in the observation well remained within the hard cap for the duration of the test.

Analysis of Data for CB471T

Water levels in the test well declined at a steady rate until approximately 550 minutes (0.965 m drawdown), when a slight increase in the rate of drawdown was recorded until the end of the test (1.17m total drawdown). A transmissivity value of approximately 4,090 m^2/d can be derived from the first 550 minutes of drawdown data (Cooper-Jacob), which could possibly be indicative of transmissivity of the hard cap. A transmissivity of approximately 1,240 m^2/d can be derived from the late time drawdown data (Cooper-Jacob).

Analysis of Data for CB471_Obs

This bore is situated 15.2 m from test well. The water level declined by 0.44 m during the 48 hour test. As observed in the test well, the water level declined steadily for approximately the first 550 minutes, after which a slight increase in the rate of drawdown was observed. A transmissivity of approximately 4,000 m^2/d can be derived from analysis of the early drawdown data and a transmissivity of 1,150 m^2/d for the late time drawdown data (Theis and Cooper-Jacob Methods of analysis). A storativity estimate of approximately 6.1 x 10^{-4} was derived for the early time data and 1.8 x 10-1 for the late time data.

Analysis of CB471T Recovery Test

Recovery water levels were recorded in the test well only. A relatively steady water level recovery was evident. A transmissivity of 5,450 m^2/d was derived from analysis of the recovery data.

CB471T Summary

Transmissivity values of approximately 4,000 m^2/d (early) and 1,200m^2/d (late) were derived from the constant rate test for the formations of the Nammuldi Member (for both the test well and the observation well). This provides a k value of 124 m/d (early time) and 38 m/d (late time), based on the screened interval of the test well. While recovery data from the test well provided a transmissivity value of approximately 5,450 m^2/d (k=165m/d). The observation well returned storativity values of approximately 6.1 x 10^{-4} (early time data) and 1.8 x 10^{-1} (late time data).

The increase in rate of drawdown after approximately 550 minutes suggests a boundary impact. Examination of the drill log for the adjacent mineral bore hole (CB471) indicates that the water level in the test bore may be reaching the boundary between the hard cap (vuggy ore) and the underlying goethitic and haematitic shales at this time (approximately 1 m drawdown in the test well). Therefore, the early time data may represent the hydraulic properties of the full aquifer sequence, while the late time data may represent the hydraulic properties of the underlying shales. Alternatively the data may indicate a vertical boundary condition, such as the thinning of mineralised Marra Mamba.

4.3.3 Summary of Test Pumping Results

Table 4.3 summarises the results of the test pumping analysis. It can be seen from the test data the values of transmissivity (and therefore permeability) are, generally high. Values of K from the test pumping range from 0.66 m/d to greater than 120 m/d. Test pumping undertaken elsewhere in the Pilbara has suggested that typically values of k for the alluvium and mineralised Marra Mamba are in the order of 0.3m/d.

Table 4.3
Summary Pumping Test Results

Test Well	Observation Well	Constant Rate Test Transmissivity (m^2/d)	Recovery Test Transmissivity (m^2/d)	Storativity Estimate
CB068T	CB068T	20	20 (early); 65 (late)	-
	CB068_Shallow	920 (considered unreliable)	-	3.3 x 10^{-3} (considered unreliable)
	CB068_Deep	-[a]	-[a]	-[a]
CB471T	CB471T	4,090 (early); 1,240 (late)	5,450	-
	CB471_Obs	4,020 (early); 1,190 (late) *Theis* 3,910 (early) 1,130 (late) *Cooper-Jacob*	-	6.06 x 10^{-4} (early); 1.79 x 10^{-1} (late) *Theis* 6.14 x 10^{-4}(early); 1.95 x 10^{-1} (late) *Cooper-Jacob*

Note: a. Insufficient drawdown induced in observation well to enable analysis

The test pumping analysis confirms the heterogeneity of both the alluvium and mineralised Marra Mamba, but does not provide reasonable estimates of regional hydraulic properties. Actual values used in the numerical modelling are described in Section 6.

4.4 GROUNDWATER QUALITY

Groundwater quality throughout the project area has been determined from three separate investigations.

1. Firstly, samples were taken from bores in the vicinity of Cloud Break and analysed both in a laboratory and in the field using portable monitoring equipment.
2. Secondly, down-hole geophysics studies were undertaken on the exploration bores and station bores to determine changes of conductivity with depth.
3. Finally, a TEM survey was undertaken by Quartz Water on behalf of FMG, which has been used to delineate areas of saline water throughout the project area.

Within this report water of salinity between 10,000 mg/L and 35,000 mg/L is referred to as "saline" and concentrations greater than 35,000 mg/L (the approximate salinity of seawater) are referred to as "hyper-saline".

4.4.1 Water Quality Sampling

Water quality samples were taken at 7 bores. Figure 4.3 shows the location of the bores and the results are presented in Table 4.4. It can be seen from the table that there is a large range of results, especially for conductivity (EC) and Total Dissolved Solids (TDS). In particular the deeper bores, and especially those closer to the Marsh (e.g. Cook's Bore intercepted brackish water and CB068 intercepted hyper-saline water). (Note: samples were taken from bore CB068 from its initial depth of approximately 70m prior to the bore being redrilled as a trial bore at a shallower depth of 39.5 m and less saline water was encountered at this shallower depth).

4.4.2 Down Hole Geophysics

In addition to the groundwater samples taken from the bores described in the previous section, FMG commissioned WestLog Wireline Services (WestLog) to undertake down-hole geophysical surveys of 22 wells and bores in the vicinity of Cloud Break. The aim of the surveys was to identify at what depths the saline water occurred and measure approximate conductivity values for the water.

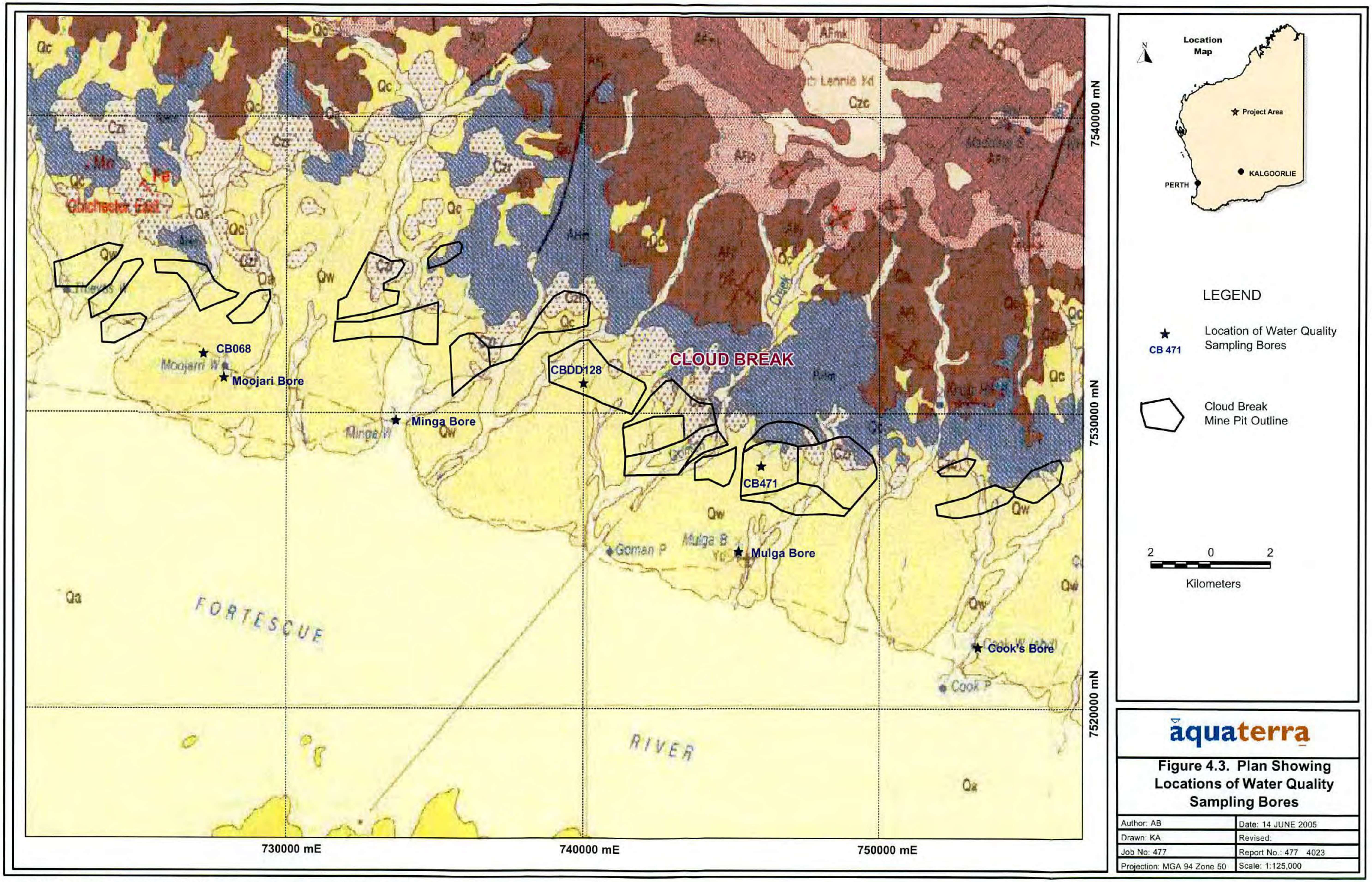

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Figure 4.3. Plan Showing Locations of Water Quality Sampling Bores

Author: AB	Date: 14 JUNE 2005
Drawn: KA	Revised:
Job No: 477	Report No.: 477 4023
Projection: MGA 94 Zone 50	Scale: 1:125,000

F:\jobs\477\D1_Cloud Break\3000\3100 Maps and Plans\Figure- 4.3_Plan showing_loc_water qua_sampling sites.WOR

Figure 4.4 shows the locations of the bores that were logged. The results of the investigation are described in Appendix C where copies of the geophysical logs supplied by WestLog are also given. A brief summary of the results is presented below.

Down-hole access to the original drilled depth of the mineral bores was difficult as many had partially collapsed. As a result it was not possible to log to the entire depth of some of the bores. In each case the bores were logged using three separate tools: induction, temperature and gamma.

The data from the induction tool indicate salinity of the water column in the bore. However, it should be noted that because saline water is denser than freshwater, saline water will tend to sink through the water column, and there may be differences between the salinity recorded in each bore, and that occurring in the aquifer. The down-hole geophysics interpretation has categorised water into "fresh" which is water with an induction-log reading of less than 150 mS/m, brackish, with a reading of 150-2000 mS/m and saline at readings greater than 2000 mS/m.

The temperature log indicates the temperature of the fluid column. There is a general trend of increasing water temperature with depth, as a result of the geothermal gradient towards the core of the earth.

The gamma log indicates the clay content in the rock material.

Summary

Analysis of the data confirms the results of the water quality sampling and shows that the groundwater within the alluvial deposits is generally fresh but becomes brackish to saline moving closer to the Fortescue Marsh. The fresh/brackish and brackish/saline interfaces are generally closer to ground surface the closer to Fortescue Marsh. There are brackish water occurrences within alluvium.

There is a fresh water inflow associated with the top of the ore zone within bore CB128. The data suggests that different units in the aquifer sequence can contain different salinities to units immediately above and below. Changes in water quality are therefore not just a function of depth, but also a function of aquifer parameters. Sections presented in Appendix C show estimates of salinity with depth.

4.4.3 TEM Survey

The water sampling and down-hole geophysics investigations provided useful information on water quality at discrete locations. Additionally, to provide an overview of salinity across the project area, particularly at depth, FMG commissioned Quartz Water to undertake A TEM survey of the Cloud Break area. Analysis of the results provides additional information into the occurrence of saline water within the project area. Appendices from the report by Quartz Water are provided in Appendix D (Quartz Water June 2004).

Figures 4.5 to 4.8 show variations in salinity along three sections. The figures clearly show that groundwater is more saline closer to the Marsh and at depth, however the data is based on interpretation of complex data, and there is a degree of uncertainty in the results, especially below the pits, due to the conductivity of the Marra Mamba and underlying shales.

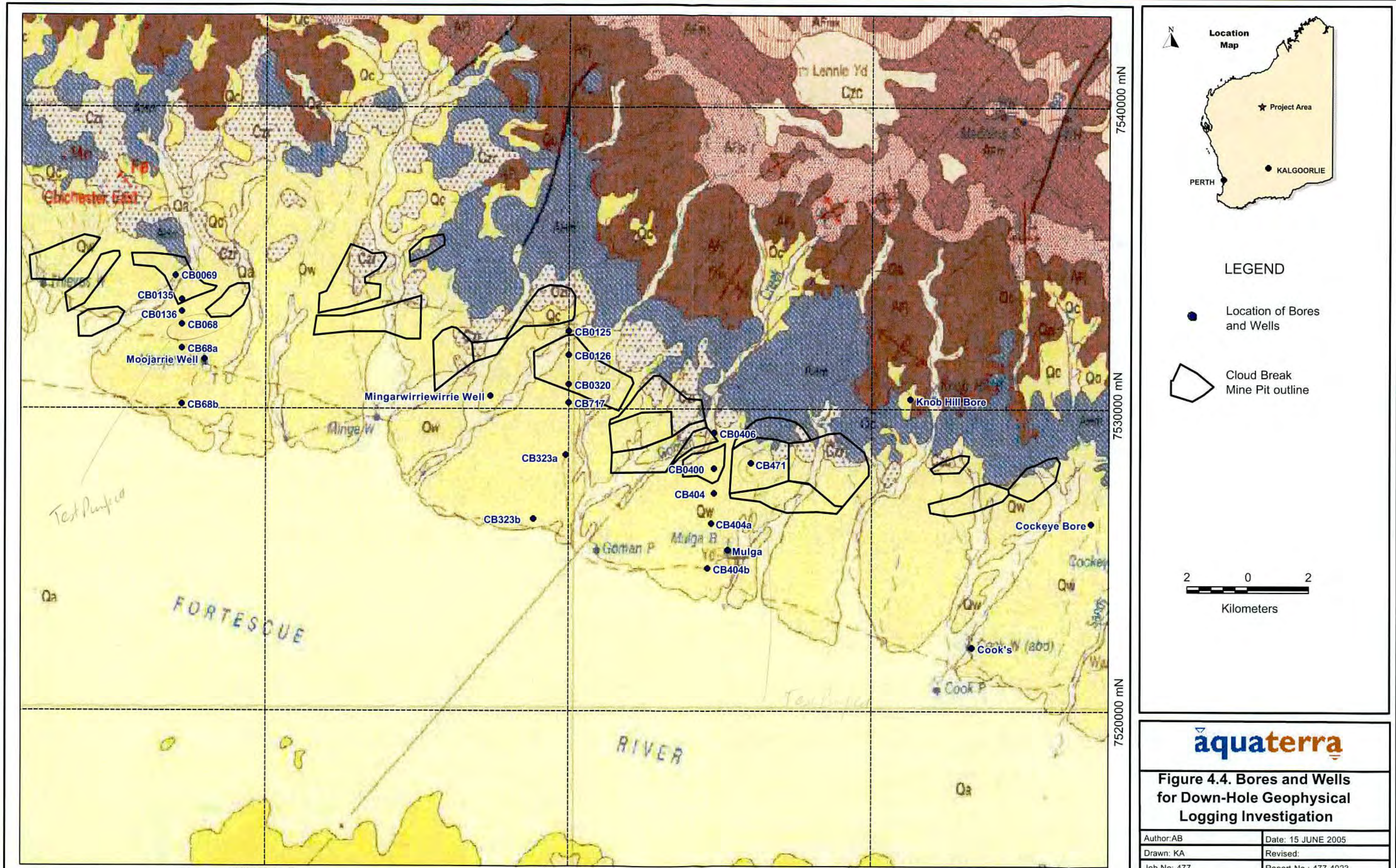

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Figure 4.4. Bores and Wells for Down-Hole Geophysical Logging Investigation

Author: AB	Date: 15 JUNE 2005
Drawn: KA	Revised:
Job No: 477	Report No.: 477 4023
Projection: MGA 94 Zone 50	Scale: 1:125,000

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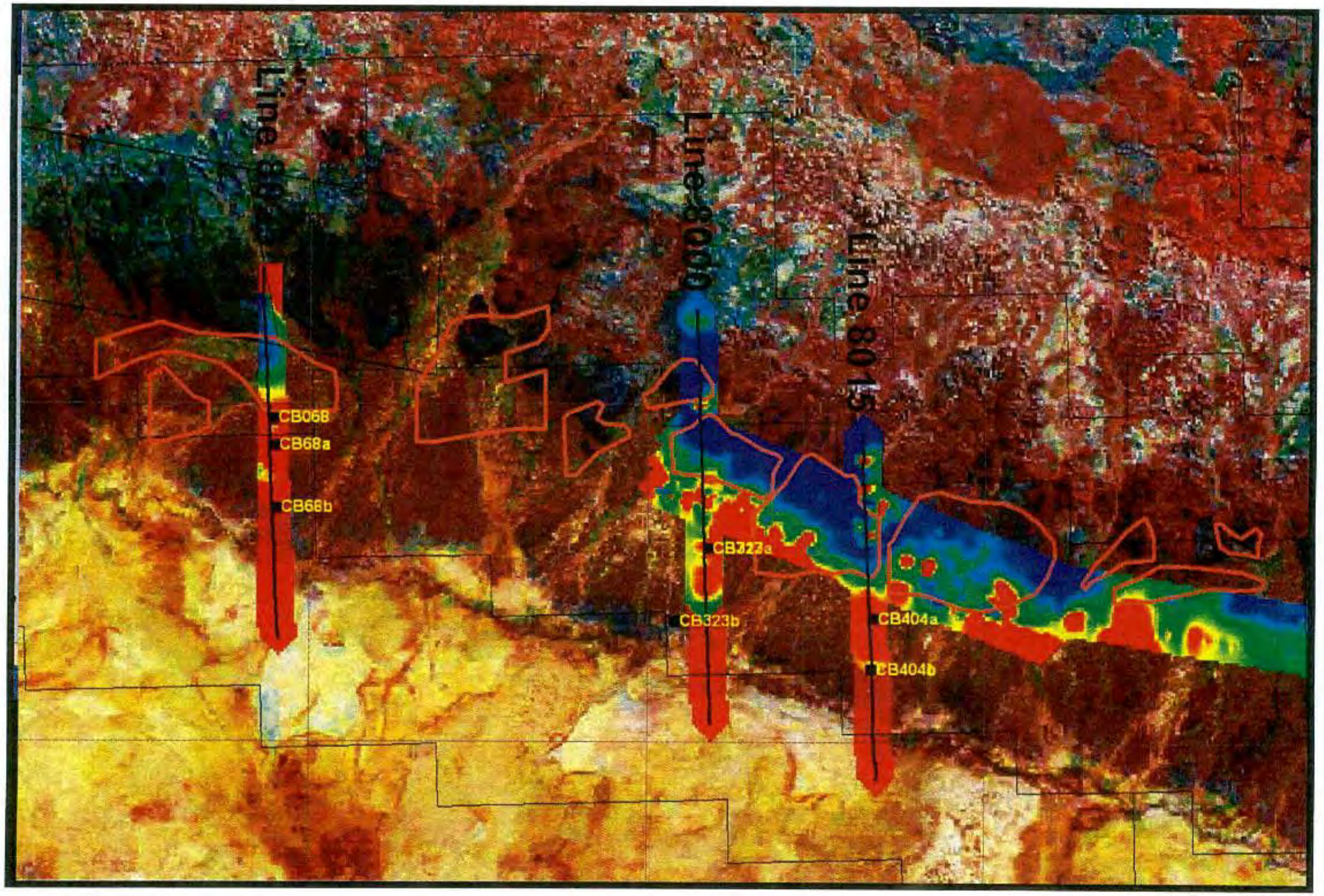
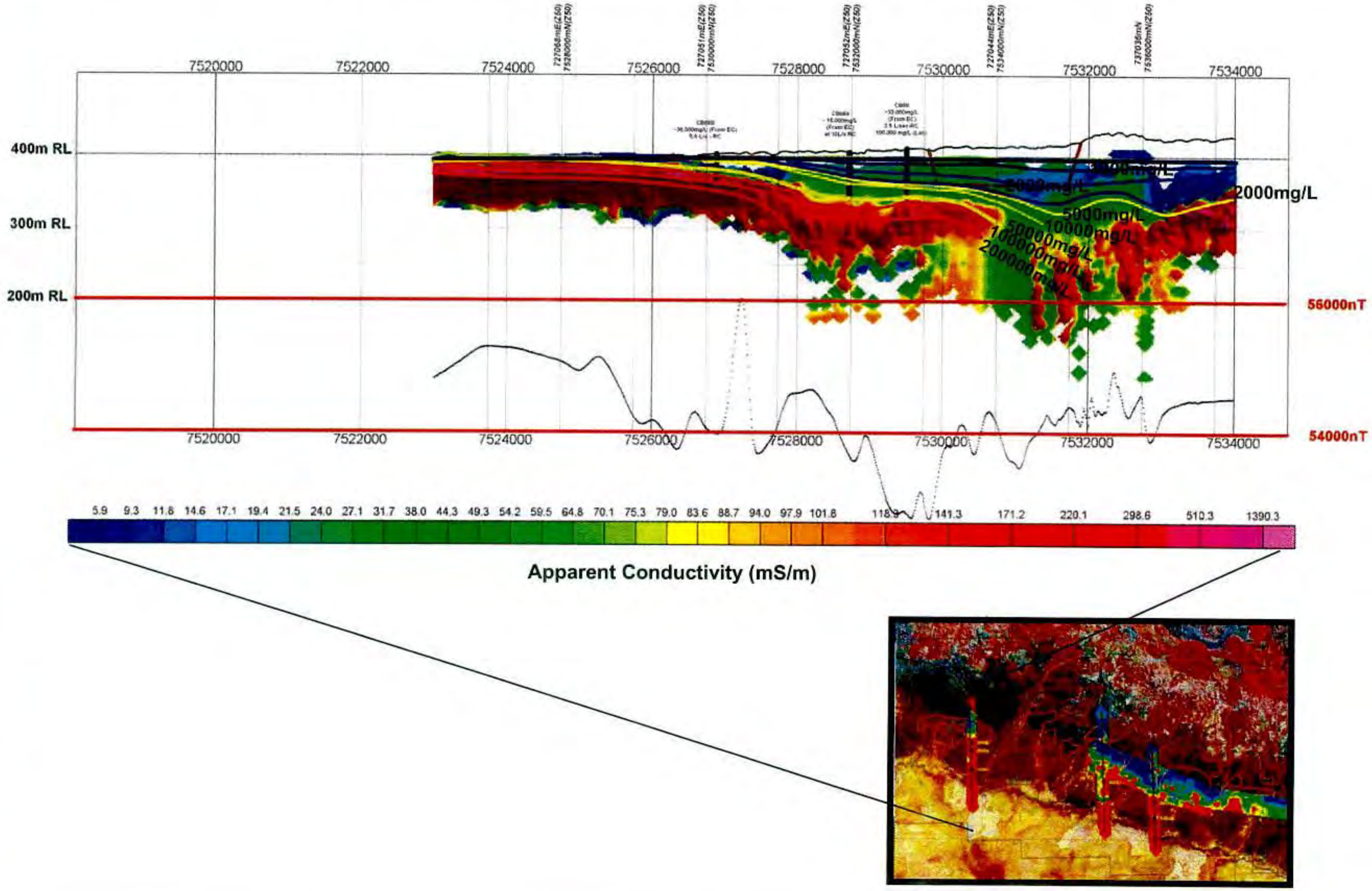


Plan Showing Cloud Break TEM Lines –
(Image is 100m Apparent Conductivity depth slice over landsat)

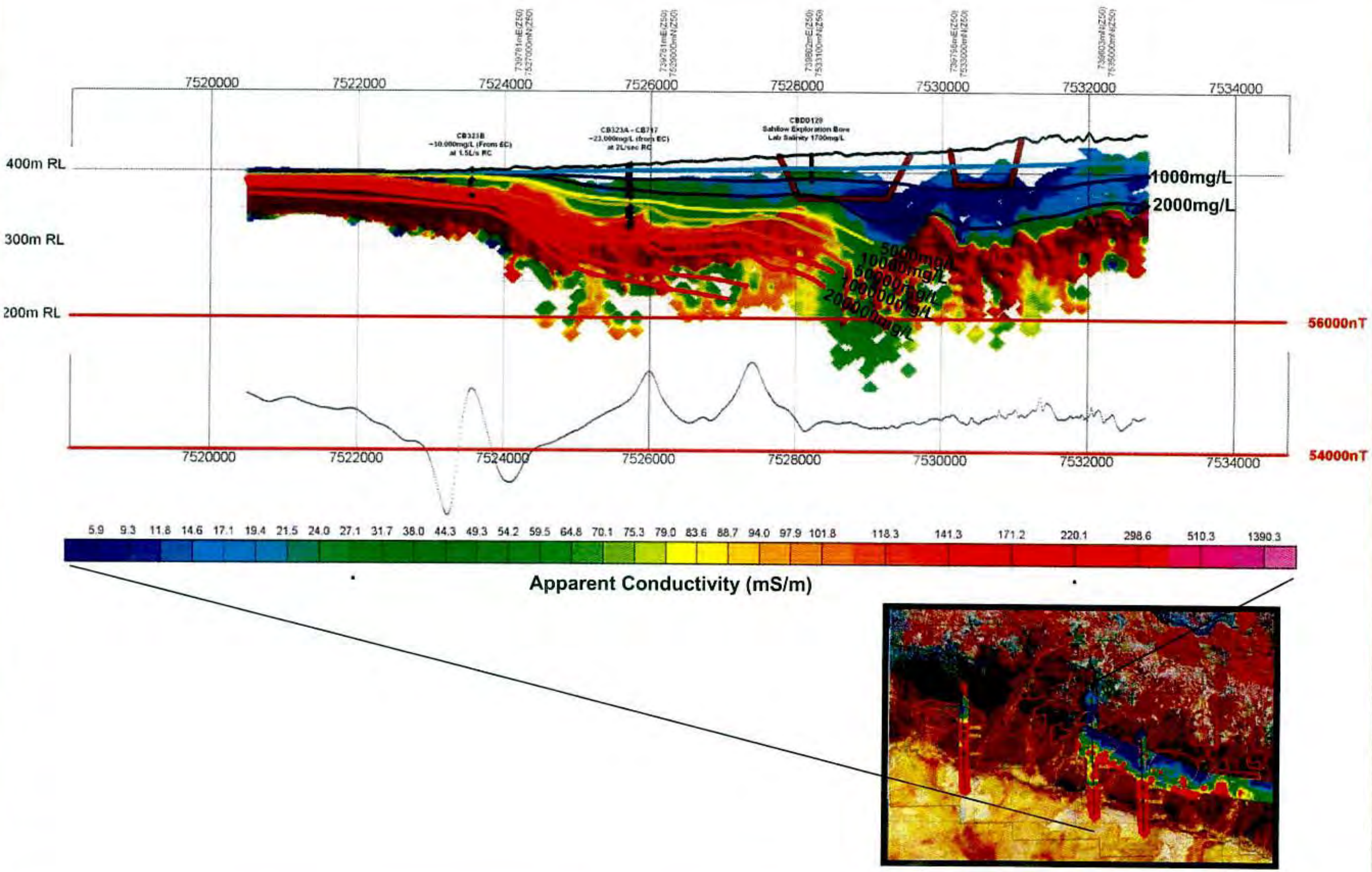
Figure 4.5

Figure created by Quartz Water



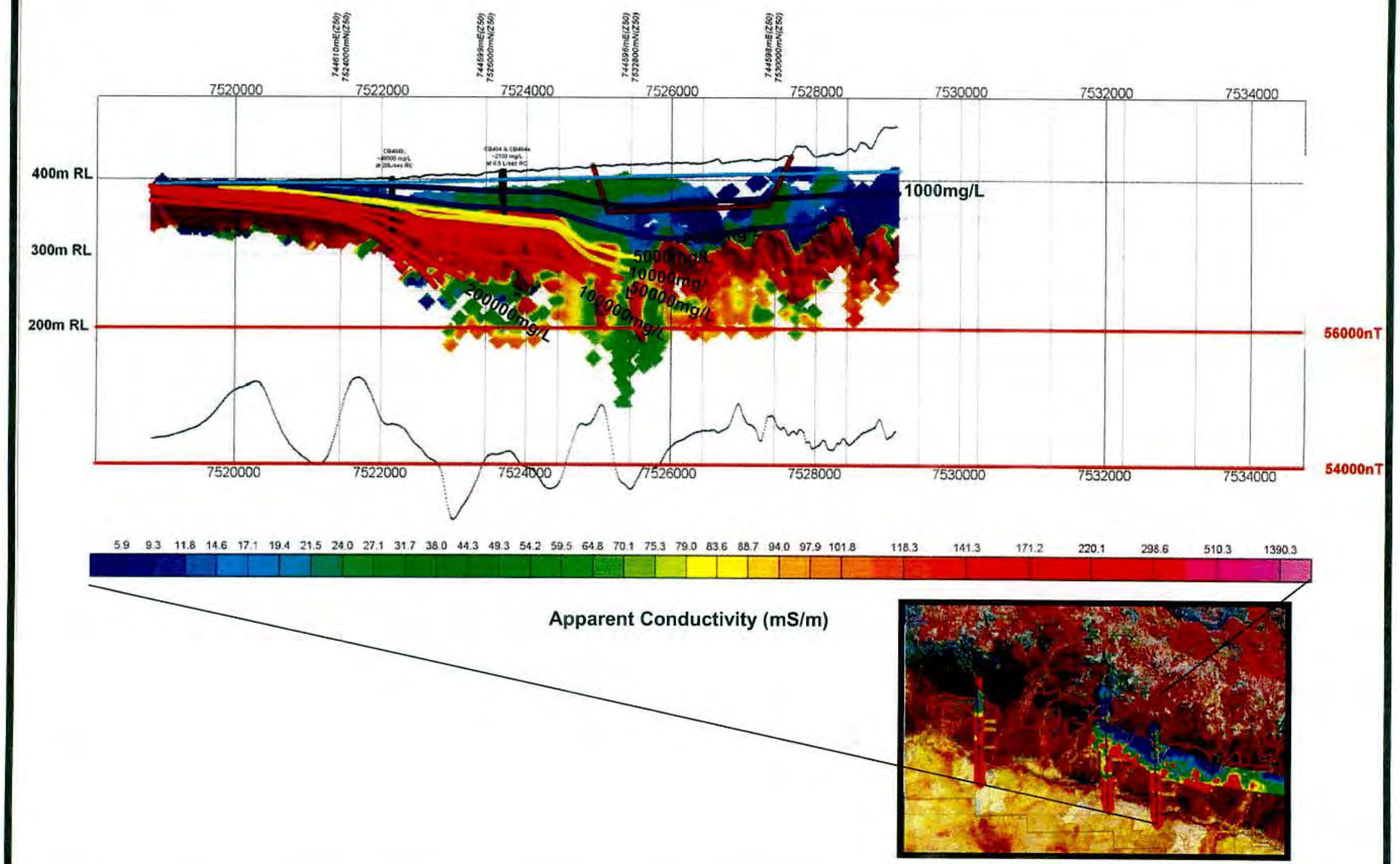
Line 8025 – Solute concentration contours over TEM apparent resistivity image **Figure 4.6**

Figure created by Quartz Water



Line 8080 – Solute concentration contours over TEM apparent resistivity image **Figure 4.7**

Figure created by Quartz Water



Line 8015 – Solute concentration contours over TEM apparent resistivity image **Figure 4.8**

Figure created by Quartz Water

Table 4.4
Water Sample Analysis Results

Bore		Mulga bore			Cook's Bore			Minga Bore			CBDD128			CB471T	CB068		Moojari Bore	
Date	Units	28/02/05	14/05/05	17/05/05	28/02/05	14/05/05	17/05/05	28/02/05	14/05/05	17/05/05	28/02/05	14/05/05	17/05/05	27/04/05	23/04/05	11/04/05	14/05/05	17/05/05
pH	pH	7.45	7.03	7.3	7.45	7.43	7.40	8.11	7.83	7.95	9.55	7.09	8.40	7.8	7.5	7.5	7.1	7
EC	Us/cm	3700	3000	3700	9800	7210	9900	1800	1520	1700	2600	370	2600	1500	140000	130000	2680	1900
TDS	mg/L	2700	1500	2900	5900	3600	6000	1200	760	1100	1700	190	1700		120000	99000	1340	3200
Na	mg/L	340		360	1800		1800	330		350	470		510		33000	31000		520
Ca	mg/L	310		230	69		73	13		18	10		15		580	590		58
Mg	mg/L	140		150	140		150	13		18	8.2		6.8		2400	2000		46
K	mg/L	49		47	110		110	38		46	45		45		2600	2400		47
Mn	mg/L	0.63		0.73	0.009		0.001	0.002		0.003	0.1		0.081		<0.5	0.5		0.007
Al	mg/L	0.033		<0.005	<0.005		<0.005	0.075		0.006	<0.005		<0.005		<1	<1		<0.005
Fe	mg/L	<0.01		<0.01	<0.01		<0.01	<0.01		<0.01	3.2		0.15		<0.5	<0.5		<0.01
Cl	mg/L	630		880	2800		1500	250		280	530		530		49000	46000		780
SO4	mg/L	860		880	840		480	160		150	230		230		17000	14000		310
CO3	mg/L	<1		<1	<1		130	<1		<1	60		9		<1	<1		<1
HCO3	mg/L	380		630	170		130	410		350	210		260		95	140		110
NO3	mg/L	22		54	35		33	33		28	0.1		0.4		3.6	10		26

4.4.4 Water Quality Summary

The results from the water quality analysis, down-hole geophysics and TEM survey show that the groundwater in the Cloud Break area has highly variable conductivity. In particular groundwater close to the marsh; in the alluvium, Marra Mamba and dolomite is hyper-saline. North of the marsh the water gradually becomes less saline, particularly in the alluvium, which contains almost fresh water (TDS < 2000 mg/L) in the vicinity of the pits.

The Marra Mamba has been shown to be saline close to the marsh. In areas south west of the Project there are also occurrences of saline water, and ore samples from the Reverse Circulation (RC) drilling programme have been reported by FMG staff to contain saline water. The TEM survey indicates that there is saline water below the pits, but this has not been confirmed with sample data.

The TEM survey suggests that there is saline water underlying the pits, but it is important to recognise that this has been inferred from interpretation of complex data, and no water quality data is available to confirm either the depth of saline water below the pits or its maximum salinity.

Bore CB068, immediately to the south of one of the pits had a salinity (as TDS) of 120,000 mg/L at 70 mbgl.

SECTION 5 - PROJECT OUTLINE

5.1 OVERVIEW

Previous sections of this report have described the existing environment, including the geology, climate, hydrology and hydrogeology. This section briefly describes the project, in particular those aspects that could potentially impact upon the hydrogeology of the region.

The proposed project involves the following key elements that have the potential to impact upon the existing hydrogeology:

- Water supply for dust suppression, moisture control of the iron ore and camp water supplies.
- Excavation of the pits, requiring dewatering.
- Disposal of excess water from the dewatering.
- Closure of the pits.

Abstraction of groundwater will result in the lowering of the groundwater table in the vicinity, which is known as a cone of depression. The shape of this depression is dependent upon the rate of abstraction, the location of the bores, the hydraulic properties of the aquifer(s) and occurrences of any recharge and discharge boundaries. Lowering of the water table has the potential to impact on the ability of phreatophytic vegetation to obtain sufficient water, and can affect the presence of surface water features such as pools and lakes.

During the first six years of mining the ore extracted from Cloud Break will be high-grade ore suitable for direct shipping and, therefore, the water requirement of the Cloud Break Project is considerably less in the first six years. Water will only be required for moisture control in the ore (as it is transported from Cloud Break to Port Hedland) and for dust suppression around the mine and for camp supplies.

In years seven onwards ore mined at Cloud Break will be low-grade and require beneficiation. This process will take place at the proposed ore-beneficiation plant at Christmas Creek. Water demand at the process plant has been estimated by FMG to be 11 GL/a (approximately 30 ML/d), (assessed as part of the Stage B Project). However the water requirements for the beneficiation plant are for a salinity (TDS) of less than 35,000 mg/L

5.2 WATER SUPPLY FOR THE PERMANENT CAMPS AND DUST SUPPRESSION

A personnel camp will be required during the lifetime of the mining operations. The permanent camp will provide accommodation for 170.

Water demand from the permanent camp at Cloud Break is anticipated to be 0.25 ML/d (250 m^3/d), and will be obtained from the dewatering bores. It may be necessary to install a reverse osmosis plant for the camps to ensure a potable supply. A dedicated borefield may also be considered in the future if the water becomes too saline.

Effluent from the camps will be treated in a packaged sewage treatment plant and, once treated, will be used for irrigation by means of sprinklers. Effluent will therefore not impact on the hydrogeology of the project area.

In addition to the water supply for the camps water will also be required for dust suppression. It has been estimated by FMG that that the volume of water required for dust suppression is 0.85 ML/d (850m^3/d), but will largely depend on the area of pit open at any one time. This water will be obtained from the dewatering bores. The total water requirement (both camp and dust suppression) is 400 ML/a (1100 m^3/d).

5.2.1 Water Requirements for Moisture Control

During the first year of ore production all the ore is expected to be mined from above the pre-mining water table and will therefore have a low moisture content. It will be necessary to add water to the dry ore for transportation to Port Hedland, a process referred to as "moisture control". The volume of water required is 1.4 GL in the first year only.

In years 2 to 6 the ore mined will be from below the pre-mining water table, and will have greater residual moisture content. FMG anticipates that no additional wetting of this ore will be required prior to transport to Port Hedland.

In subsequent years the ore mined at Cloud Break will require beneficiation (a wet process) and no moisture control will be required.

Table 5.1 summarises the total water requirements for Cloud Break. This table excludes the water requirements from the ore-beneficiation process at Christmas Creek, as water there will be obtained from a purpose built borefield (see Stage B PER report).

Table 5.1
Water Supply Requirements at Cloud Break

Year	Quarter 1 (ML/d)	Quarter 2 (ML/d)	Quarter 3 (ML/d)	Quarter 4 (ML/d)
1	1.5 (moisture control) 1.1 (dust suppression & camp supply) Total = 2.6	3.1 (moisture control) 1.1 (dust suppression & camp supply) Total = 4.2	4.6 (moisture control) 1.1 (dust suppression & camp supply) Total =5.7	6.2 (moisture control) 1.1 (dust suppression & camp supply) Total =7.3
2 to 12	1.1 (dust suppression & camp supply)	1.1 (dust suppression & camp supply)	1.1 (dust suppression & camp supply)	1.1 (dust suppression & camp supply)

5.3 MINE DEWATERING REQUIREMENTS

The proposed schedule of mining in each year it set out below. The tonnes of ore given are those shipped from the mine as high-grade ore, however, in some areas the high-grade ore is covered with layers of low-grade ore which will have to be mined and stockpiled to allow access to the high grade material:

- Year 1 20MT
- Year 2 30MT
- Year 3 25MT
- Year 4 20MT
- Year 5 10MT
- Year 6 14 MT

After the high-grade ore is removed mining will continue on the low-grade ore. The total mine life is forecast to be approximately 12 years.

Figure 5.1 shows the mine schedule proposed by FMG, in particular it shows the direction of mining and mining periods (Note; each period on the map represents 2 years, therefore areas of the pit labelled "1" will be mined in the period year 1 to year 2).

In the first year of mining most of the ore will be mined from above the water table, and little dewatering will be required, however, in subsequent years the mined ore lies below the pre-mining water table, and more dewatering will be needed. A numerical groundwater model has been developed to simulate the rate of dewatering so that sufficient ore is dewatered in time to meet the mine schedule. The model has also used to determine potential environmental impacts from dewatering. Details of the model are described in Section 6. The model results indicate that dewatering at the following rates will need to be achieved to meet the mine schedule requirements.

Table 5.2
Dewatering Requirements at Cloud Break

Year	Quarter 1 (ML/d)	Quarter 2 (ML/d)	Quarter 3 (ML/d)	Quarter 4 (ML/d)	Total (ML/a)
1	0.0	3.8	3.3	5.7	1200
2	5.7	4.6	4.1	3.9	1700
3	3.9	9.1	6.8	9.5	2700
4	9.5	3.9	3.1	1.8	1700
5	1.8	11.3	9.2	12.2	3100
6	12.2	15.3	11.4	13.9	4800
7	13.9	6.8	5.5	6.2	3000
8	6.2	21.5	15.8	15.7	5400
9	15.7	11.6	8.8	8.2	4000
10	8.2	2.1	1.9	2.2	1300
11	2.2	10.8	9.0	10.9	3000
12	10.9	3.8	3.3	4.0	2000
13	4.0	1.8	1.3	0	600

5.4 DISPOSAL OF EXCESS WATER FROM THE DEWATERING

Table 5.3 shows the overall balance between the dewatering requirements at the Cloud Break pits and the water demands for moisture control, camp water supplies and dust suppression.

Table 5.3
Water Balance at Cloud Break

Year	Quarter 1 (ML/d)	Quarter 2 (ML/d)	Quarter 3 (ML/d)	Quarter 4 (ML/d)	Total (ML/a)
1	-2.6	-0.4	-2.4	-1.6	-600
2	4.6	3.5	3.0	2.8	1300
3	2.8	8.0	5.7	8.4	2300
4	8.4	2.8	2.0	0.7	1300
5	0.7	10.2	8.1	11.1	2700
6	11.1	14.2	10.3	12.8	4400
7	12.8	5.7	4.4	5.1	2600
8	5.1	20.4	14.7	14.6	5000
9	14.6	10.5	7.7	7.1	3600

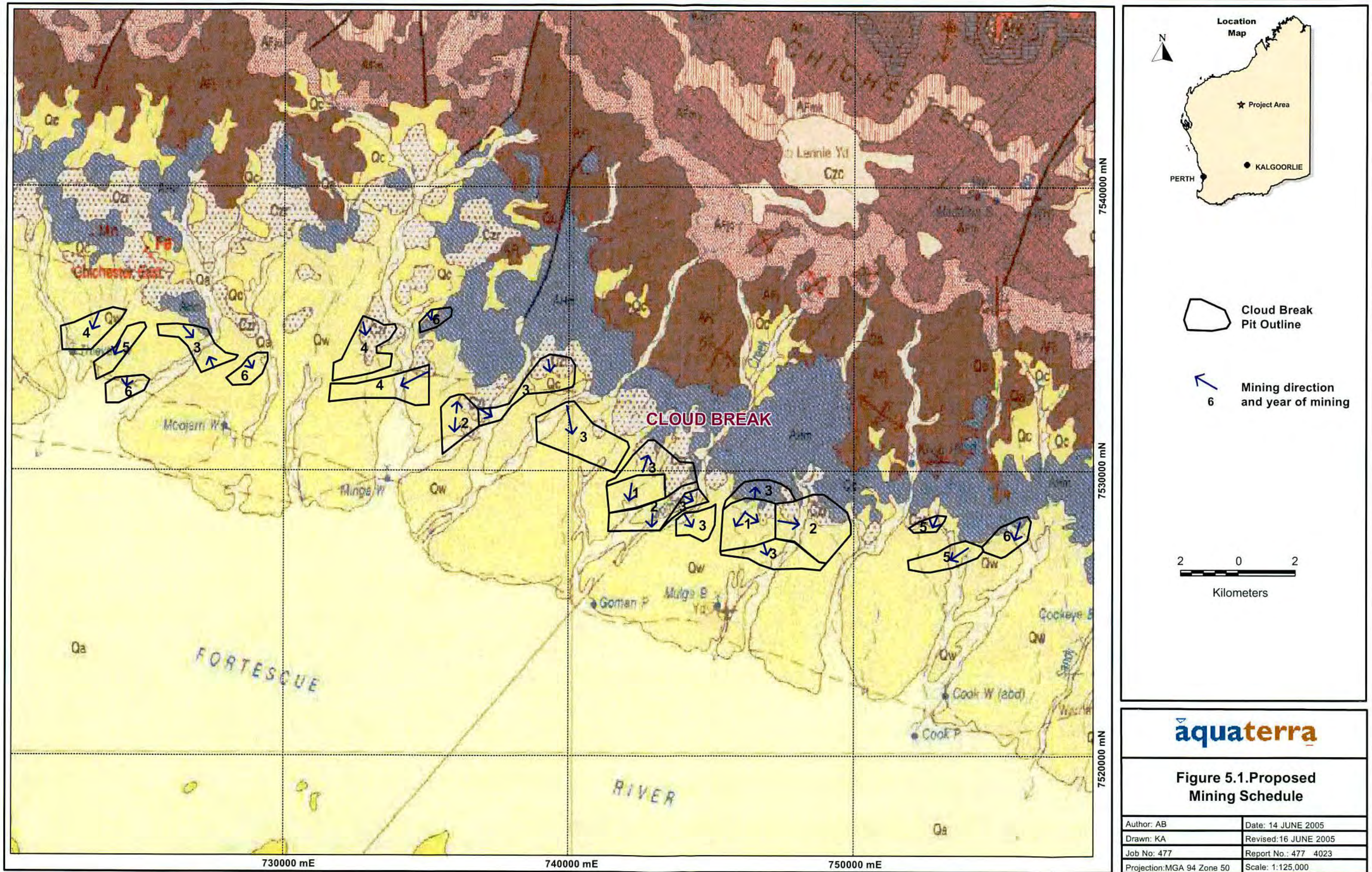


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Figure 5.1.Proposed Mining Schedule

Author: AB	Date: 14 JUNE 2005
Drawn: KA	Revised:16 JUNE 2005
Job No: 477	Report No.: 477 4023
Projection:MGA 94 Zone 50	Scale: 1:125,000

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Year	Quarter 1 (ML/d)	Quarter 2 (ML/d)	Quarter 3 (ML/d)	Quarter 4 (ML/d)	Total (ML/a)
10	7.1	1.0	0.8	1.1	900
11	1.1	9.7	7.9	9.8	2600
12	9.8	2.7	2.2	2.9	1600
13	4.0	1.8	1.3	0.0	600

It can be seen that in the first four quarters there is insufficient water available from the required dewatering programme to meet the demands of the project. It is thus proposed that the dewatering of the pits will commence ahead of schedule to provide the necessary water. After the first four quarters the dewatering of the pits results in a surplus of water. This water will need to be disposed of in an appropriate manner. This issue is discussed in Section 7.

5.5 MINE CLOSURE PLAN

In semi-arid areas, such as the Pilbara, where pits are excavated below the water table, mine closure plans are required to prevent saline water forming in abandoned pits and potentially contaminating otherwise fresh aquifers.

During mining, waste material, including overburden, will be progressively placed into worked parts of each of the pits. Thus, on completion of mining, all pits will have been backfilled with waste material to a level above the original groundwater table.

6.1 APPROACH TO IMPACT ASSESSMENT

As stated in Section 5, the dewatering of the pits will result in a cone of depression. The extent of the cone of depression has been estimated using a numerical model. This first simulates the existing hydrogeology, and is then used to determine the dewatering requirements of the pits and then potential impacts on phreatophytic vegetation and the Fortescue Marsh.

Mitigation measures to reduce the potential impacts are discussed in Section 7.

6.2 IMPACTS FROM THE DEWATERING - MODELLING APPROACH

6.2.1 Assumptions Made

In the course of any groundwater modelling it is necessary to make a series of assumptions based on local and regional data. These assumptions include:

- Estimates of recharge to each of the different aquifers
- The groundwater recharge mechanisms
- The permeability and storage coefficients of the different aquifers

For this particular project Aquaterra has used results from the groundwater investigations undertaken for both the Cloud Break study and the studies undertaken for the Stage B PER, including test pumping of bores in the alluvial, calcrete and dolomite aquifers at Christmas Creek and the proposed borefield.

As described in Sections 2 and 3, the hydrogeology of the Cloud Break project area is a very similar setting to that at Christmas Creek, and the work done at both Cloud Break and Christmas Creek has provided sufficient information for development of the numerical groundwater model and estimates of environmental impacts from dewatering of the pits to be made.

In addition, knowledge obtained from other work undertaken in the Pilbara and published data for the area has also been used. Aquaterra has extensive experience in the Pilbara on which to base these assumptions as outlined Section 1.1.

6.3 THE CLOUD BREAK MODEL

Appendix E includes details of the Cloud Break Model; however a summary of the approach is included below.

6.3.1 Conceptual Model

The conceptual hydrogeology of the project area has been developed from the field investigations at Cloud Break and previous work for Stage B at Christmas Creek. In the model, sedimentary rocks of the Hamersley Group and Fortescue Group outcrop along the northeast and southwest boundaries of the model where they form the Chichester Range and Hamersley Range. These rocks typically have a low permeability, which is enhanced where they are mineralised, fractured or weathered. The two Ranges are groundwater watersheds and represent no-flow boundaries in the model.

Incised within these rocks is the Fortescue Valley, in-filled with a sequence of Quaternary and Tertiary deposits, which is up to 100 m thick. This extensive sequence includes an alluvial aquifer, which is generally fine-grained but, along creeks, contains sands and gravel deposits. The hydraulic heads in both the alluvium and underlying basement rocks are equal.

The bed of the Fortescue Marsh is at an elevation of approximately 400 mRL. The marsh is a surface water feature along the base of the valley, where flood waters pond after run-off from significant rainfall events. Evaporation and downward seepage result in the marsh drying out and elevation of the groundwater table to surface. Evaporation from the shallow water table then occurs, with capillary action limiting this depth to 5 mbgl. Groundwater flow is towards the Fortescue Valley, but groundwater does not appear at the surface as a surface water discharge.

Groundwater contours across the region are a subdued reflection of topography, ranging from more than 500 mRL along the Chichester Range and Hamersley Range, to less than 395 mRL along the floor of the valley.

There is limited groundwater flow from the southeast, which is represented in the model as a fixed head boundary, but with a very shallow hydraulic gradient. The northwest of the model is bounded by the Goodiadarrie Hills, represented as a no-flow boundary across the alluvial plain downstream of the marsh area of interest.

Aquifers are recharged directly after extreme rainfall events of more than 150 mm per month. Direct recharge of rainfall in arid environments is minimal, indirect recharge, however, may locally be significant with infiltration of run-off (streamflow) along drainage courses and the marsh. Recharge occurs preferentially along creeks and from the Fortescue Marsh.

The study area is arid with high summer temperatures, high mean evaporative demand (2480 mm/yr), and low mean annual rainfall (310 mm/yr). The literature suggests that in the Northern Territory, for example, this hydrogeological situation is likely to experience a mean groundwater recharge of 0.1 to 2 mm/yr (Harrington, Cook, and Herczeg, 2002). In the model therefore recharge along the creeks is 2 mm/year, elsewhere, along the alluvial plain, recharge is 0.2 mm/year (0.06% of mean annual rainfall (MAR)) and, across the Marra Mamba outcrop, is 0.1 mm/year (0.03 % of MAR).

Seepage from the marsh results in recharge estimated to be 250 mm/a, however this is then balanced by evaporation from the shallow water table.

The main aquifer consists of an alluvial sequence, underlain in part by weathered Marra Mamba in the pits. This alluvial aquifer typically has a bulk horizontal permeability of 0.3 m/d along the valley floor, with a lower figure on the valley sides of 0.15, storage coefficient of $5*10^{-4}$ and specific yield of 5%. It attains a maximum saturated thickness of 55 m close to the marsh. The mineralised Marra Mamba has a bulk permeability of 0.5 m/d and unmineralised basement material has a low K of 0.01 m/d.

The horizontal permeability value quoted for the alluvium is lower than that obtained from the pump test of bore CB068T described in Section 4. However the results are similar to values obtained from test pumping of the alluvium elsewhere in the Pilbara. Values of storage coefficient and specific yield used in the conceptual model are consistent with those expected for a generally fine-grained material. The saturated thickness of the alluvium matches the results of the drilling programme undertaken.

The aquifer parameters used for the Marra Mamba are also lower than those obtained from the test pumping of Bore CB471T described in Section 4. However the parameters used are consistent with results obtained elsewhere in the Pilbara and work undertaken by Aquaterra in similar hydrogeological settings in the Pilbara (including several studies undertaken on the permeability of the Marra Mamba in proposed iron ore mines south of the Fortescue River).

At Cloud Break the basement rocks are mainly unmineralised Marra Mamba. In addition one exploration bore proved the presence of Wittenoom Dolomite. In the conceptual model the basement rocks within the model have been assigned a lower horizontal permeability of 0.01 m/d, a vertical permeability of 0.001 m/d and a nominal thickness of 100 m. The storage coefficient is $4x10^{-4}$.

Dewatering is required to lower groundwater levels below the base of each of the proposed pits (alluvium and Marra Mamba) to meet the proposed mining schedule.

6.3.2 Model Geometry

Figure 6.1 shows the area represented by the Cloud Break Model, which includes the following features:

1. The Chichester Range which forms a northeastern boundary of the model.
2. The Hamersley Range which forms the southwest boundary of the model.
3. The Cloud Break pits.
4. The Goodiadarrie Hills, which represent the northwest boundary of the model.
5. A no-flow boundary to the south east of the model.

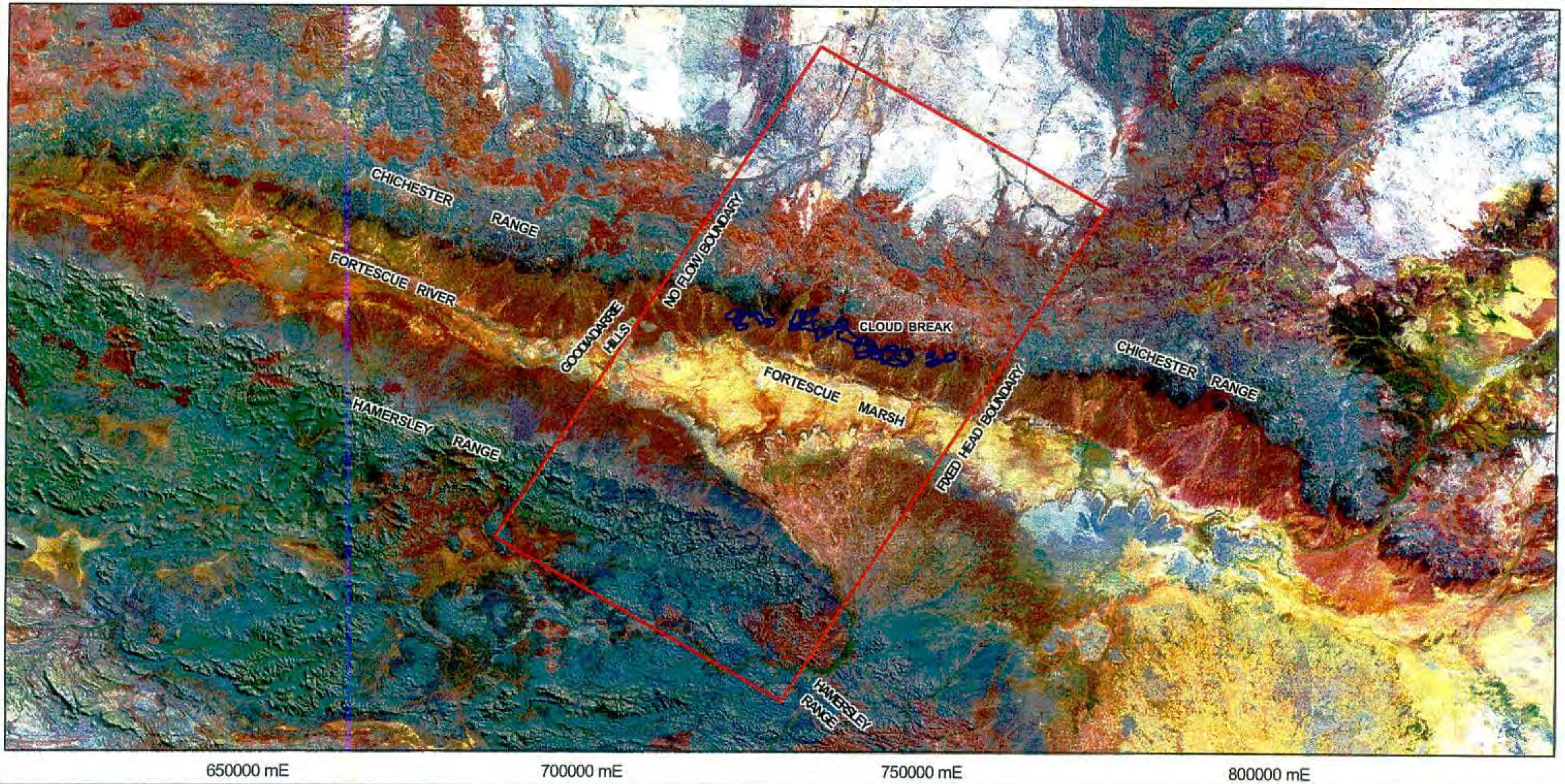
There are three layers within the model:

- Layer 1: Alluvium.
- Layer 2: Mineralised Marra Mamba.
- Layer 3: Bedrock.

6.3.3 Potential Impacts from Dewatering of the Cloud Break

Dewatering requirements and groundwater levels have been modelled for twenty years. This includes six years of mining of high-grade ore and 6 years of mining low-grade ore. During both these periods dewatering is required in advance of mining. On completion of mining the model predicts that dewatering is required to prevent the pits from flooding during backfilling with waste material (which is assumed to take a year). After 13 years the modelling assumes that all dewatering will be turned off, and there will be a gradual recovery of water levels.

Maps showing predicted groundwater drawdowns during the life of the project are presented in Figures 6.2 (five years), 6.3 (twelve years) and 6.4 (twenty years, i.e. 7 years after cessation of dewatering). Key features of the maps are:



20 0 20

Kilometers

LEGEND

Clound Break Pit Outline

Cloud Break Model Outline

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Figure 6.1. Area Represented by the Cloud Break Model

Author: AB	Date: 16 JUNE 2005
Drawn By: KA	Revised:
Job No.: 477	Report No.: 477 4023
Projection: MGA 94 Zone 50	Scale: 1: 900,000

- On each map there is a cone of depression resulting from the dewatering.
- After five years the cone of depression has a maximum depth of approximately 50 m and extends to within approximately 2 km of the boundary of the Marsh.
- After 12 years (the end of mining) the cone of depression extends to a depth of 70 m and the 0.5 m drawdown contour extends towards the Marsh, but not below it.
- After 20 years the deeper parts of the cone of depression have begun to backfill to a maximum of 30 m. The cone of depression extends towards the Marsh, but not below it.

6.3.4 Potential Impacts on Vegetation

FMG has commissioned Libby Mattiske to undertake an impact assessment on vegetation. The results are included in a separate report (Mattiske, June 2005).

6.3.5 Potential Impacts on Stygofauna

Any saturated gravel deposits, calcrete, mineralised Marra Mamba and dolomite along the Fortescue River and other creeks have the potential to support stygofauna (groundwater-dwelling fauna). Some of these deposits will be dewatered by abstraction from the dewatering bores. There is therefore potential for stygofauna communities to be affected by the borefield abstraction.

Stygofauna communities have been identified in the vicinity of most of the iron ore mines of the Pilbara (Johnson & Wright, 2001). The stygofauna sampling programme developed for the Stage B project has been expanded to include four additional sampling bores in the Cloud Break Project area.

FMG has undertaken a round of sampling for stygofauna in bores located within the Cloud Break area. The bores sampled were Mulga Bore, Cook Bore, Mingawirriawirrie Well, and observation bore CBDD128. Additional bores have recently been drilled and will be sampled in the next round of sampling (approximately June 2005) and will be repeated biannually for a period of two years. This will allow water in the newly constructed bores to settle and enable stygofauna (if present) to colonise the waters and also to determine the effects of seasonal variations on stygofauna populations.

A summary of the results in the first round of sampling of bores in the Cloud Break undertaken in March 2005 are provided in Table 6.1.

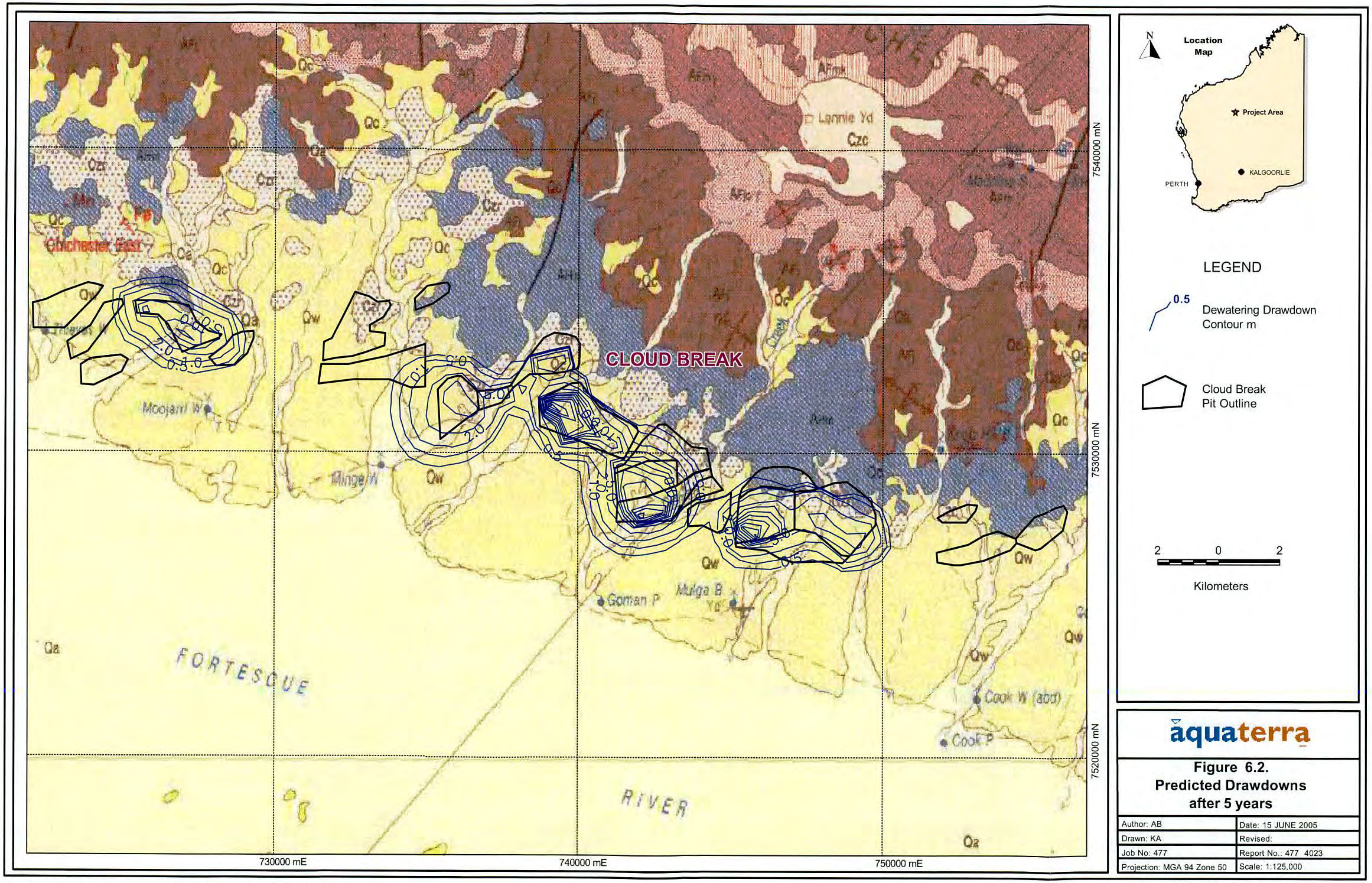

Figure 6.2. Predicted Drawdowns after 5 years

Author: AB	Date: 15 JUNE 2005
Drawn: KA	Revised:
Job No: 477	Report No.: 477 4023
Projection: MGA 94 Zone 50	Scale: 1:125,000

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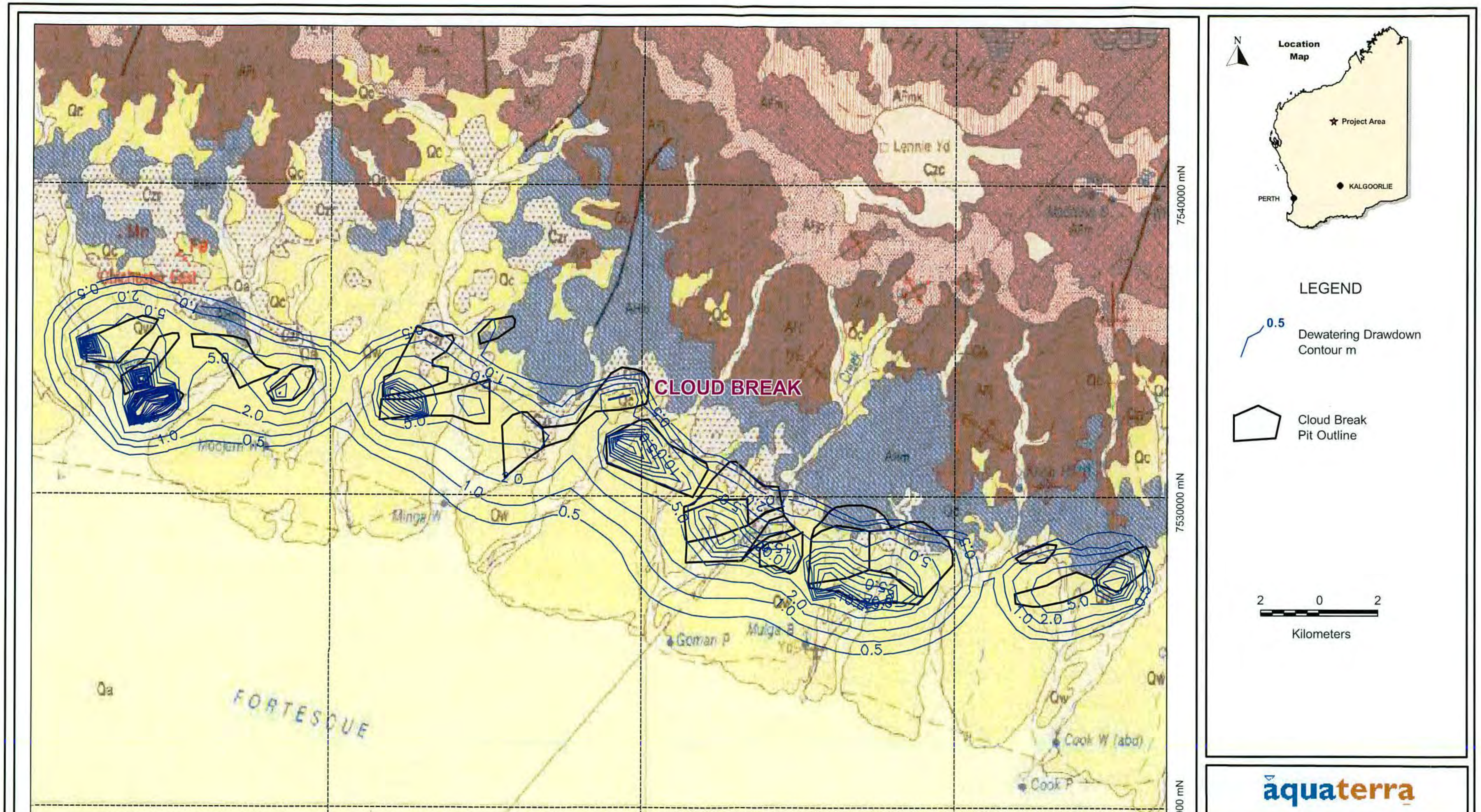

Figure 6.3. Predicted Drawdowns after 12 years

Author: AB	Date: 15 JUNE 2005
Drawn: KA	Revised:
Job No: 477	Report No.: 477 4023
Projection: MGA 94 Zone 50	Scale: 1:125,000

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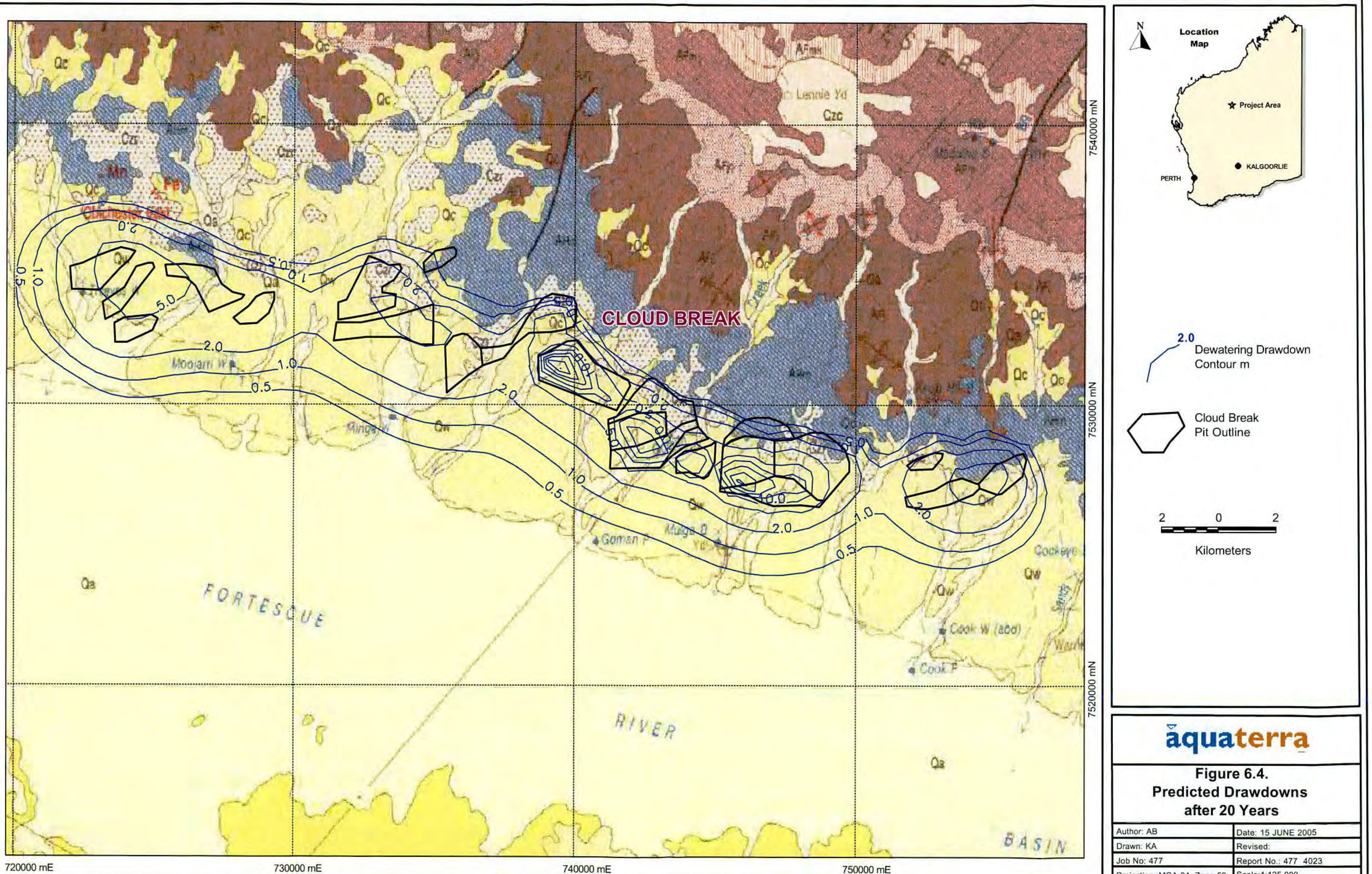

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Figure 6.4. Predicted Drawdowns after 20 Years

Author: AB	Date: 15 JUNE 2005
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Job No: 477	Report No.: 477 4023
Projection: MGA 94 Zone 50	Scale: 1:125,000

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Table 6.1
Stygofauna Sampling Results to Date

Bore Name	Stygofauna Recorded	Notes
Mulga Bore	No invertebrates	Abandoned mill. Requires casing and capping.
Cook Bore	*Diacyclops humphreysi humphreysi (29)* *Pilbarus millsi (43)* *Parapseudoleptomesochra 'tureei' (39)*	Abandoned mill. Requires capping otherwise in good condition.
CBDD128	No invertebrates	Requires casing. Water very turbid otherwise in good condition.
Minga' Well	*Microcyclops varicans (18)* *Cypretta seurati (4)* *Strandesia sp. 1 (20)* *Stenocypris bolieki (4)* *Phreodrilus peniculus (3)*	Mill with adjacent tank. Well in good condition.

Parapseudoleptomesochra 'tureei' has only been recorded at one other site in the Pilbara and *Strandesia* sp. 1 at two other sites in the Pilbara. None of the stygofauna species recorded were considered of significance. The high levels of turbidity in Mulga Bore and CBDD128 possibly due to lack of casing is likely to have resulted in no fauna being recorded at these bores. These bores will be cased if they continue to be used for ongoing monitoring.

The results show that stygofauna are present in two shallow bores. It is likely that stygofauna occur at other sites too, especially in the calcrete aquifer, close to the marsh. Stygofauna are less likely to occur in the alluvium to the north of these bores, where the calcrete is absent, but may exist where mineralized Marra Mamba occurs below the water table.

Figures 6.2 to 6.4 show that the cones of depression from dewatering extend as far as Minga Well, where a drawdown of 0.5 m is predicted. It is considered unlikely that such a small change in groundwater levels will impact on stygofauna populations, as this is less that the seasonal change in water levels. However larger drawdowns in the vicinity of the pits may impact on any stygofauna populations present in the Marra Mamba.

6.3.6 Potential for Saline Water to be Abstracted During Dewatering

As discussed in Section 4 saline water underlies the Fortescue Marsh and extends towards the Cloud Break pits. This saline water dips below a layer of fresh water, of increasing thickness, towards the pits. There is also a general trend of more saline water in the west of the project area than in the east. Thus the quality of the water abstracted during dewatering will vary from pit to pit. In addition, during dewatering, there will a tendency for upconing of deeper saline water, resulting in an increase in salinity with time.

In order to calculate the salinity of abstracted water at the start of dewatering, the pits have been split into four zones as shown in Figure 6.5. From the down-hole geophysics and water quality sampling the salinity has been determined in each of the three aquifers (alluvium, mineralised Marra Mamba and unmineralised Marra Mamba). The results are showing in Table 6.2.

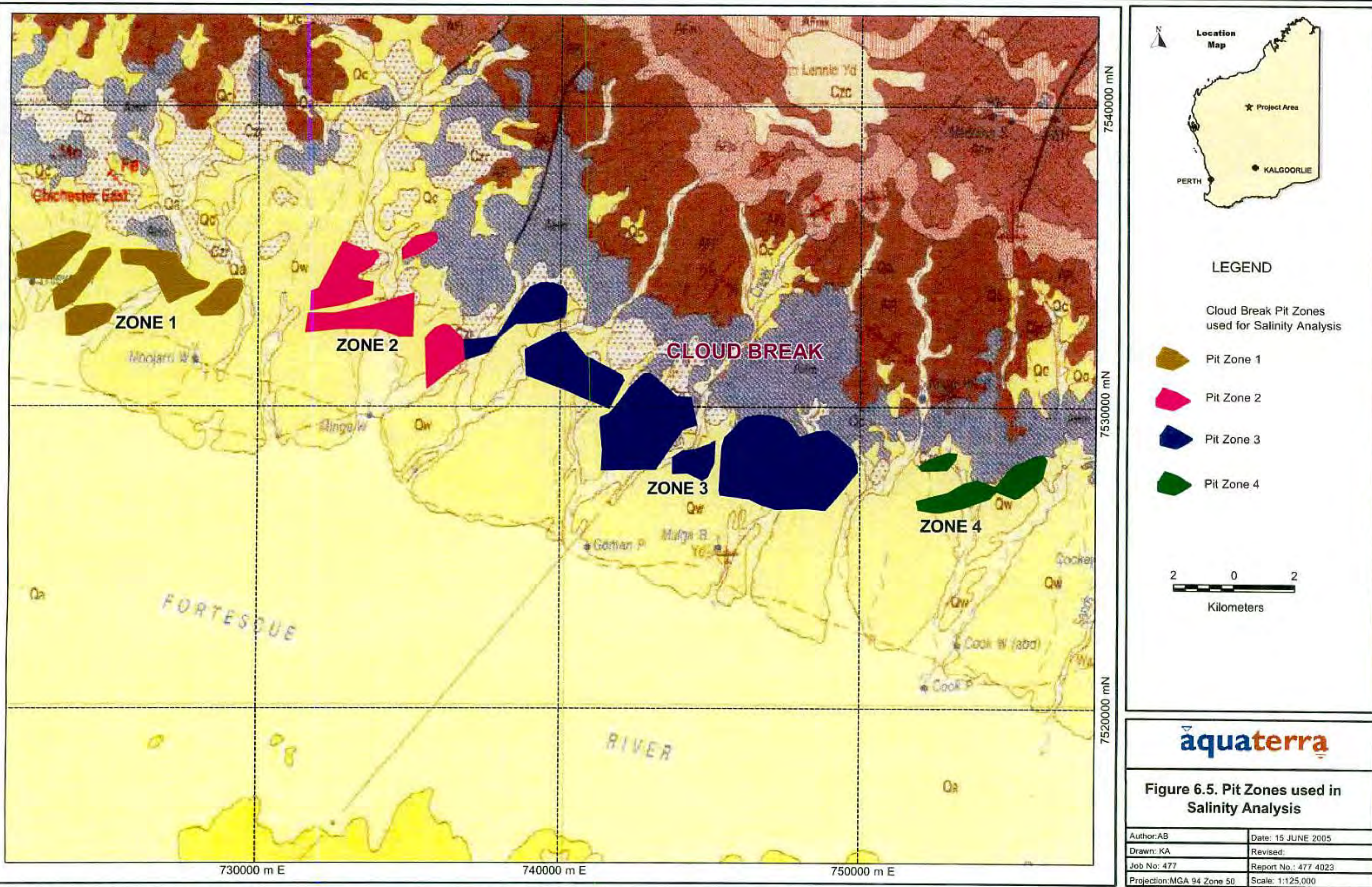

Figure 6.5. Pit Zones used in Salinity Analysis

Author:AB	Date: 15 JUNE 2005
Drawn: KA	Revised:
Job No: 477	Report No.: 477 4023
Projection:MGA 94 Zone 50	Scale: 1:125,000

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Table 6.2
Water Quality in each Zone Prior to Dewatering

Hole No	Estimated TDS (mg/L)
Zone 1	
Alluvium	<1000
Ore Zone	2000
Unmineralised Marra Mamba	4000
Zone 2	
Alluvium	<1000
Ore Zone	<1000
Unmineralised Marra Mamba	2000
Zone 3	
Alluvium	<1000
Ore Zone	2000 (east)-12000 (west)
Unmineralised Marra Mamba	4000 (east)-20000 (west)
Zone 4	
Alluvium	<1000
Ore Zone	<1000
Unmineralised Marra Mamba	2000

Once dewatering commences varying volumes of water will be abstracted from different aquifers (e.g. in a particular bore, 10% of the dewatering water may report from the alluvium, 70% from the mineralised Marra Mamba and the remainder from the basement material). The numerical model described in Section 6.3 has been used to calculate the volume of water reporting from each layer. Thus, in the first year of dewatering, it is possible to estimate the salinity of water abstracted from each of the four zones. The results are presented below in Table 6.3, which shows there is no dewatering in three of the four zones in the first year.

Table 6.3
Volumes of Water Abstracted during first year of Dewatering and Predicted Salinity

	Proportion of Water Reporting from each Formation			Salinity
	Alluvium	Mineralised Marra Mamba	Unmineralised Marra Mamba	
Zone 1	No de-watering in year 1	No de-watering in year 1	No de-watering in year 1	No de-watering in year 1
Zone 2	No de-watering in year 1	No de-watering in year 1	No de-watering in year 1	No de-watering in year 1
Zone 3	9%	63%	28%	7000 mg/L
Zone 4	No de-watering in year 1	No de-watering in year 1	No de-watering in year 1	No de-watering in year 1

The table shows that the calculated water salinity of the abstracted water in year 1 will be 7000mg/L.

In subsequent years it is likely that the salinity will increase, as the alluvium and Marra Mamba, containing fresher water, are dewatered and saline water in the basement material below the pits upcones. In addition saline water to the south may flows laterally towards the cone of depression caused by the dewatering.

Calculating the change in salinity with time is complex, and there would be considerable uncertainty as to the accuracy of the results. Rather than undertake this analysis, it has been assumed that water will become saline, so that by the end of the dewatering (year 13) all of the abstracted water will come from the basement material. It has also been assumed that the salinity of the groundwater from the basement material will be 160,000 mg/L, or the same as the maximum salinity (TDS) observed in any bore during the investigations from either Cloud Break or the Stage B PER at Christmas Creek.

By taking this approach the worst-case scenario is developed, with the water eventually becoming very saline. In reality this may not occur and water quality is likely to be less saline than this.

Methods for disposal of the excess water from the dewatering operation are discussed in Section 7.

6.3.7 Potential Impacts on the Fortescue Marsh

The potential impacts on the marsh from the dewatering have been assessed based on the conceptual model for the marsh discussed in Section 4 and presented in Figure 4.2.

There are two potential impacts that need to be considered. They are:

1. Will surface water in the marsh form less frequently than it does at present? and
2. Will the marsh dry out more quickly than at present?

As stated in Sections 3 and 4 the available data indicates that surface water in the marsh is a result of run-off after rainfall. Evaporation from the water table acts as a control, and results in groundwater levels being maintained 5 m below the base of the marsh (except during periods when surface water in the marsh is draining into the underlying aquifer). Therefore, changes in the hydrogeological regime will not result in the marsh being filled less frequently than at present.

Figure 4.2 shows the water table as being below the marsh (i.e. there is an unsaturated layer below the bed of the marsh). The volume of water draining from the marsh into this unsaturated layer is limited by the available storage within that unsaturated zone. If drawdowns from the dewatering and/or water supply borefield were to extend below the marsh, then the available storage would increase. This would result in an extended period (and volume) of seepage from the marsh, and the marsh becoming drier more quickly than at present.

The groundwater modelling indicates that the cone of depression from the dewatering of Cloud Break will extend towards the Fortescue Marsh, but not beneath it, and therefore that, irrespective of whether the alluvium below the marsh becomes saturated or not, the marsh is unlikely to be affected by drawdowns from the dewatering.

Given the limited available data and importance of the marsh, a risk assessment was undertaken for the Stage B PER, which considered the potential impacts on the marsh from changes in groundwater levels. The results are included in a separate report (minRISK, October 2004). However a summary of the potential risks is provided below. It is important to recognize that although the risk assessment undertaken for he Stage B PER was specifically used to assess the risk to the marsh form the dewatering at Christmas Creek and from the proposed borefield, the results are equally relevant to this Cloud Break assessment.

6.3.8 Fortescue Marsh Risk Assessment

The potential impacts on to the marsh from pit dewatering and saline water were listed and the risks assessed using a model based on AS/NZS 4360: 1999 "Risk Management" and utilising risk criteria specifically developed from the guidelines within HB 203: 2000 "Environmental Risk Management".

Potential Impacts

For the purposes of the risk assessment the marsh was defined as the area within the Australian Nature Conservation Agency (ANCA) boundary. A list of potential impacts on the marsh was developed and impacts and likelihoods estimated; the results are summarised below. Except where the consequences were considered to be insignificant, mitigation measures were developed. These are discussed in Section 8.

Table 6.4
Inherent Risks to the Fortescue Marsh (minRISK, October 2004)

Activity	Issue	Impact	Consequence	Likelihood	Inherent Risk Rating	Inherent Risk Score
Mine Dewatering	Groundwater	Drawdown affecting water levels in the marsh and therefore vegetation.	Minor (2)	Unlikely (D)	L	21
Mine Dewatering	Groundwater	Drawdown affecting Stygofauna.	Insignificant (1)	Rare (E)	L	25
Mine Dewatering	Groundwater	Drawdown affecting yields from stock bores within marsh boundary.	Insignificant (1)	Rare (E)	L	25
Mine Dewatering	Groundwater	Aquifer drawdown impacting drying cycle of the Fortescue Marsh.	Minor (2)	Possible (C)	M	18
Mine Dewatering	Groundwater discharge	Effect of disposal of saline water produced during pit dewatering#	Insignificant (1)	Rare (E)	L	25
Mine Dewatering	Groundwater discharge	Flora loss from pipeline failure releasing saline water	Insignificant (1)	Rare (E)	L	25

The effect of disposal of saline water at Cloud Break has been considered separately and is described in Section 7.

6.3.9 Impacts on Station Bores

Where the cones of depression from the water supply borefield and dewatering extend to station bores, there is the potential that yields from those bores will be reduced. Furthermore, there is likelihood of saline water upconing in the proposed Cloud Break pits. If this occurred and was not effectively managed, it could then contaminate station bores nearby. However, FMG will put measures in place to manage this risk (Section 8).

6.4 MINE CLOSURE PLAN

As stated in Section 5, the mine closure plan involves the backfilling of waste material into the pits. At Cloud Break this material will consist of overburden and waste rock. Once the material is replaced into the pit it is likely to have a permeability similar to the surrounding pit wall materials, and the original ore body, and therefore, in the long-term, groundwater levels will return to approximately their pre-mining level. FMG has committed that all pits will be back-filled to the original ground level; therefore there will not be any pit voids.

It is considered that the mine closure plan proposed by FMG will mean that there will be no long-term impact on the hydrogeology of the pit areas.

SECTION 7 - MECHANISMS FOR DISPOSAL OF DEWATERING WATER

7.1 INTRODUCTION

As discussed in Section 6, it is calculated that there will be an excess of water from the dewatering operation that it will not always be possible to use for water supply. This will mean that some water will need to be disposed of in an appropriate manner.

As described in the introduction of this report, the mining schedule proposed by FMG is that in the first six years of mining at Cloud Break all the ore will be high-grade and therefore will not require beneficiation. As a result there will be little demand for water, other than for dust suppression, moisture control and camp supplies. During this period the dewatering water is likely to be fresh or brackish. In subsequent years low-grade ore will be mined and this will require beneficiation. As a result the demand for water at Christmas Creek will increase and it may be possible to use some of the excess dewatering water to meet the needs of the ore-beneficiation plant. However during this period water quality is also expected to become more saline and the process plant cannot use water with a salinity of more than 35,000 mg/L. Given the uncertainty regarding the quality of the abstracted water, a worst-case scenario has been adopted which assumes that none of the dewatering water will be used in the process plant, and it will all have to be appropriately disposed of.

Therefore, in terms of discharge of the water there are two phases, an initial phase of six years, consisting of relatively large volumes of generally fresh water, followed by a period of discharge of more saline water. The best method of disposal of water may change, with one solution being best practice for the first period, and a different approach being the best solution for the second period.

The volume of water to be discharged is given in Table 7.1.

Table 7.1
Volumes of Water Discharged

Year	Overall Water Balance (ML/d)			
	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1	0	0	0	0
2	4.6	3.5	3.0	2.8
3	2.8	8.0	5.7	8.4
4	8.4	2.8	2.0	0.7
5	0.7	10.2	8.1	11.1
6	11.1	14.2	10.3	12.8
7	12.8	5.7	4.4	5.1
8	5.1	20.4	14.7	14.6
9	14.6	10.5	7.7	7.1
10	7.1	1.0	0.8	1.1
11	1.1	9.7	7.9	9.8
12	9.8	2.7	2.2	2.9
13	4.0	1.8	1.3	0.0

7.2 HIERARCHY OF DISPOSAL OPTIONS

The DoE is responsible for licensing discharge of water into the environment so, before considering possible discharge mechanisms, it is important to understand the guidance from the Regulator. This guidance comes in the form of a hierarchy of disposal mechanisms. This hierarchy is described briefly below:

- The preference is that water should be discharged into the aquifer from where it was abstracted (this could be for instance via bores or potentially via discharging water into a mined pit from where it will seep away).
- If this is not feasible then water should be discharged to another aquifer system (such as via slotted pipes buried into a shallow aquifer).
- If this is not possible the water could be discharged in a controlled manner, to a suitable receiving body.
- If none of these is possible then, as a last resort, consideration will be given to uncontrolled discharge of the water.

7.3 OVERVIEW OF DISPOSAL OPTIONS CONSIDERED

A number of options for disposal of the excess water have been considered. These are discussed briefly in the following sub-sections and then ranked according to a range of criteria in Table 7.1.

It is important to note that FMG will, whenever possible, use excess water from the dewatering for dust suppression, camp water supplies and the ore beneficiation process, thus minimising the discharge back to the environment. However, for the purposes of this analysis a worse case scenario has been adopted, and it is assumed that none of the excess water will be suitable for any of these purposes and all will have to be discharged.

7.3.1 Re-Injection of Groundwater

This option involves the using specially constructed boreholes to re-inject excess dewatering water. Three possible receiving aquifers have been considered. They are the Alluvium, Wittenoom Dolomite and the Marra Mamba. Each of these options is consistent with the preferred method of disposal in the DoE's hierarchy.

Alluvium

The alluvium extends in a broad east-west outcrop between the Chichester Ranges and the Fortescue Marsh. In Section 2 the alluvium is described as silty clay, with occasional sands and gravels. At some locations a calcrete horizon was also intercepted. In general the alluvium is of low or moderate permeability and it is likely that it would not make a good receiving aquifer. Furthermore, because the water table is relatively close to the surface, storage within the aquifer is limited.

The environmental consequences of disposal to the alluvium have been considered. The water table in the alluvium is currently shallow, but the groundwater table would rise as a result of the injection of water. A mound of fresh water rising above the rooting zone of phreatophytes will tend to encourage the spread of fringing phreatophytic vegetation, which will then become stressed once the re-injection ceases and water levels return to current levels. Injection of saline water into the alluvium at later stages in the Project will also result in increased groundwater levels, and the increase in salinity may stress existing phreatophytes. The injection of saline water may also cause increased salinity at station bores.

If excess water were re-injected it could report to the surface as temporary springs or ponds. This water may attract fauna, which would then be affected when the ponds dried up on cessation of re-injection.

Wittenoom Dolomite

In some locations in the Pilbara the dolomite has a relatively high permeability, especially where it dips steeply, however in the Fortescue Valley the dolomite dips gently and most of the secondary permeability within it has been backfilled with clays and silts from the overlying alluvium. Drill logs show that the dolomite is confined below a layer of alluvium, consisting mainly of fine-grained lake sediments.

Water in the dolomite is likely to be saline throughout the area south of Cloud Break and is fully saturated. Therefore water would have to be injected under pressure.

The dolomite sub-crops in a narrow strip along the northern edge of the marsh and dips below the marsh and then below the Hamersley Range. As a result of this, re-injection bores would be drilled in or very close to the marsh, and associated pipe-work and electrics would need to be laid across the marsh. The bores, pipework etc. would be susceptible to flooding during surface water flow, and would therefore have to be constructed at elevated levels having a visual impact on the marsh.

Re-injection of water would result in pressurisation of the water in the dolomite and alluvium. If the system were to become over-pressurised then re-injected water would appear at the marsh surface as artificial springs.

Marra Mamba

The mineralised Marra Mamba is of moderate permeability and, where only partially saturated, has a reasonable storage capacity. One possible disposal mechanism for the excess water therefore is to discharge it into the Marra Mamba via a series of bores in the area between Cloud Break and Christmas Creek where the Marra Mamba consists of a strip approximately 30 km long, with an outcrop approximately 4 km wide. Based on data from Christmas Creek and Cloud Break the formation is partially saturated with fresh water in the north becoming brackish/saline in the south.

Re-injection of fresh or saline water into the Marra Mamba will result in an increase in groundwater levels, but by restricting re-injection to areas with groundwater levels 20 m or more below ground level (beyond the rooting zone of phreatophytic vegetation), there would be unlikely to be any impact on vegetation.

Water injected into the Marra Mamba will tend to flow in a southerly direction towards the Fortescue Marsh. It is likely that discharge of saline water into the Marra Mamba will therefore result in increased salinity in station bores intercepting the Marra Mamba. In the event of the salinity increasing to an unacceptable level alternative supplies of water would need to be provided.

7.3.2 In-Pit Disposal of the Water

In this method water is discharged into a previously worked pit. Slotted tubes are placed horizontally at the base of the pit and are connected to vertical tubes, which are also slotted. Water is discharged into the vertical tubes and then discharges into the ground through the slots. The horizontal tube is placed on a bed of permeable material (gravel etc.) to facilitate draining of the discharged water. Waste material is then back-filled around the tubes during re-instatement of the mine.

Possible materials for the pipe include slotted PVC, concrete sections or possibly steel. PVC has the advantage of being light and flexible so could be installed in one length, using the wall of the pit for support. Concrete and steel tubes would have to be installed in sections, as waste material was backfilled around them.

As with the re-injection option, this method meets the preferred method of disposal in the DoE's disposal hierarchy. A mound of groundwater will occur around the pit, and if this water were to come close to ground level (less than 10 m) then, this may affect phreatophytic vegetation.

7.3.3 Evaporation Ponds

For this method an evaporation pond is constructed and the excess dewatering water discharged into it. The water then evaporates during dry periods, and salts are concentrated in the pond. On completion the ponds are backfilled and the salt buried or removed to a licensed disposal site.

Calculations show that the dimensions of the pond would have to be approximately 500 m by 500 m with a depth of 2.5m for a discharge of 1 ML/d. Excavation of the ponds would result in ground disturbance.

There are several possible locations for the evaporation ponds, including on the valley floor (the ponds would have to be higher than 415 mRL to ensure they were not inundated during flooding events), or at higher elevations where it may be possible to put a dam across a creek to provide the requisite storage.

This method of disposal does not match any of the criteria in the DoE's hierarchy of disposal, but providing appropriate design, maintenance and monitoring of the pond, this method of disposal is considered to be low risk to the environment.

7.3.4 Shallow Infiltration

This method involves the installation of shallow french drains in areas where high permeability occurs at shallow depth; typically along creeks where gravel deposits occur.

The drains, consisting of slotted pipe, are buried at a depth of approximately 2 m in the permeable material. Water discharged into the drains then soaks away into the surrounding aquifers.

There are a number of limitations on this option. Firstly, in the vicinity of Cloud Break, the creaks are associated with vegetation, which would be damaged during the installation of the drains. Secondly, much of the alluvium in the area is known to consist of silts and clays, rather than high permeability material. Gravels are most likely to occur along the Fortescue Valley sides (where groundwater is currently fresh). Finally, the drains can be washed out during severe rainfall events.

This method of disposal is more closely aligned to the second or third level in the DoE's hierarchy.

7.3.5 Discharge to Surface Water

This option would involve discharging excess water to a creek draining into the Fortescue Marsh, or directly into the Fortescue Marsh. As a result a temporary pool of water would form, which would most likely be fresh initially during phase one of dewatering, becoming saline during phase 2.

As described in Section 3, the marsh is a surface water feature, which forms after surface run-off. Water in the marsh is typically therefore fresh, becoming more saline as water within it evaporates. Discharge of the dewatering water may be acceptable initially, whilst the dewatering water is fresh, but long-term discharge of saline water is not considered an option.

This method of disposal would be categorised as 3 or 4 on the DoE's hierarchy.

7.3.6 Sale and Transport

This disposal mechanism involves the transport of the water and sale to a third party. Neither FMG nor Aquaterra is aware of any demand for water in this part of the Pilbara, especially if the water were saline.

However, FMG is committed to this option if a suitable market can be found.

7.3.7 Summary of Options

Table 7.2 summarises the options for disposal of saline water.

Preferred Method of Disposal

It can be seen from the table that the preferred method of disposal is by evaporation. This method has several advantages over alternatives:

- As described in Section 6 groundwater abstracted during the dewatering is likely to become saline, and possibly hyper-saline during the life of the project. Evaporation ponds provide an effective way to dispose of water, and the effectiveness is not adversely affected by changes in salinity.
- Evaporation ponds can be engineered to a high standard, using appropriate geo-textile membranes. In addition collector drains can be installed to contain escaped water and monitoring systems can be installed to quickly identify leaks.
- The gently sloping topography of the Fortescue Valley lends itself to a series of smaller ponds rather than a single larger construction, making maintenance and management easier.
- All the salt from the dewatering operation is contained in a relatively small area and can be removed on completion.

Outline design for an evaporation scheme is provided in the following section.

7.4 OUTLINE DESIGN OF EVAPORATION PONDS

Figure 7.1 shows, in section, the outline design for a series of evaporation ponds. The bed of each pond would be levelled and lined with a layer of sand to protect the overlying geo-textile liner. Collector/monitoring drains would be installed in the sand to collect any leakage. These drains discharge into sumps, which will be monitored to detect any leaks of saline water.

The dewatering water will be discharged into the top pond. In the event of that pond becoming full, an over flow will allow the water to discharge into the pond below.

Based on evaporation of 2480 mm/a and rainfall of 320 mm/a, it has been calculated that a pond 500 m by 500 m could be used to evaporate approximately 1 ML/d. It is calculated that 6 ponds will be needed in the first two years of mining, increasing to 8 ponds in year 4 and ultimately 14 ponds.

Initially it is proposed that the ponds will be located on alluvial deposits south of the pits. The general dip in topography in this area is 0.5%, so a pit 500m long would have a fall of approximately 2.5m. In subsequent years, as individual pits are mined and re-instated, the additional ponds will be constructed on the re-instated surface, thus minimising the volume of land disturbed.

If a worst case is assumed, and after the first year of mining all the abstracted water is hyper-saline, then the average thickness of salt deposited is 1.3 m over the 13 year dewatering programme.

Alternative Methods of Disposal

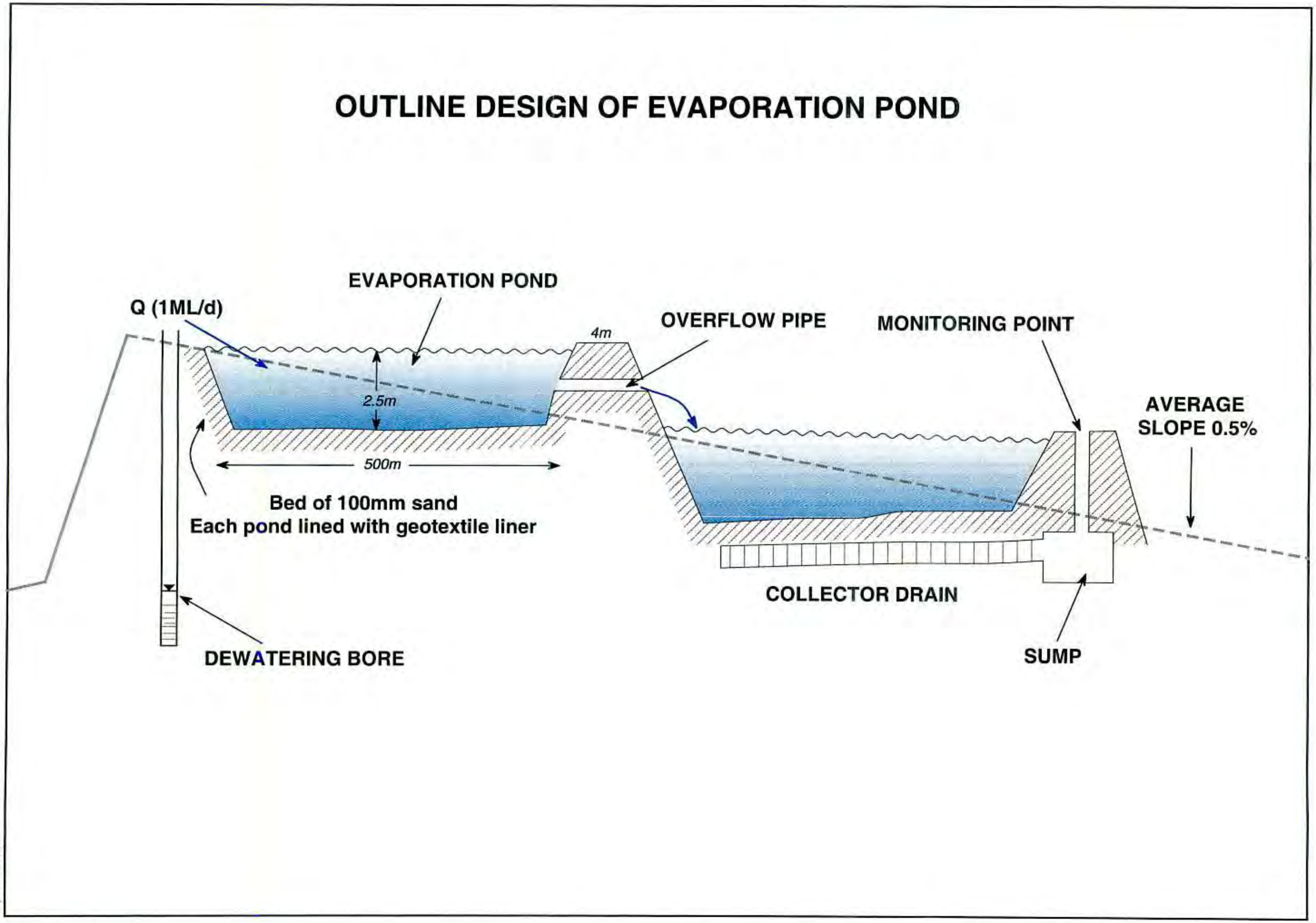
Table 7.2 also indicates that in-pit disposal and re-injection of excess water into the Marra Mamba rank highly.

Two potential sites for re-injection into the Marra Mamba are the areas immediately east and west of Cloud Break, where the Marra Mamba is mineralised, and water quality is likely to be similar to that at Cloud Break.

In-pit disposal of water requires a pit, remote from the other pits, to be mined out initially. With FMG's current mining schedule dewatering is required in year one and there will be no pit void into which to dispose of the saline water. Therefore, although in-pit disposal may be suitable in subsequent years, initially it would not be possible, and an alternative method of disposal would be needed.

Whilst the use of evaporation ponds is the preferred method of disposal, FMG proposes to undertake further field investigations and modelling to determine the most environmentally acceptable method of disposal of the excess water.

This is discussed in the dewatering plan in Appendix F.



aquaterra

FIGURE 7.1

Table 7.2
Summary of Disposal Options

Option	Reliability (High/Medium/Low)	Cost		Investigation Costs (High / Medium / Low)	Environmental Consequences (High/Medium/Low)	Compatibility with DoE Hierarchy (Preferred / Neutral / Least Preferred)	Manageability (Easy / Medium / Difficult)	Overall Rank
		Capital (High / Medium / Low)	Operating (High / Medium / Low)					
Re-injection of groundwater into the alluvium	Medium It will be difficult to recharge aquifer because of the shallow groundwater table. Changes in water quality may impact on station bores. Water quality from the re-injection may be different to the water in the receiving aquifer, resulting in encrustation of the bore linings.	Medium Requires construction of bores, pipeline and associated infrastructure. Re-injection system will not need to be pressurised.	Medium Power costs will depend upon distance between dewatering bores and re-injection bores. Maintenance of bores will be significant on-going expense.	Medium	Medium: Impacts on station bores and phreatophytic vegetation caused by temporary mounding of fresh water and then mounding of saline water. Moderate greenhouse gas emissions.	Preferred Lies between 1 and 2 on the DoE hierarchy.	Medium Changes in salinity of discharge water likely to affect effectiveness of injection system.	Medium
Re-injection of Groundwater into the Dolomite	Low It will be difficult to re-inject into dolomite because it is already saturated The dolomite is an extensive aquifer, but it only occurs close to or below the marsh. Water quality from the re-injection may be different to the water in the receiving aquifer, resulting in encrustation of the bore linings	High Requires construction of bores, pipeline and associated infrastructure in the Fortescue Marsh. Re-injection system will need to be pressurised.	High Injection will need to be pressured, adding to power costs. Infrastructure may be damaged during flood events. Maintenance of bores will be significant on-going expense.	High	High Bores, pipes etc will have to be completed above ground resulting in visual impact on the marsh. Moderate/High greenhouse gas emissions.	Preferred Lies between 1 and 2 on the DoE hierarchy.	Difficult Infrastructure may be damaged during flood events. Changes in salinity of discharge water likely to affect effectiveness of injection system.	Low
Re-injection of Groundwater into the Marra mamba	High Marra Mamba is only partially saturated, therefore there is significant available storage Changes in water quality may impact on station bores. Water quality from the re-injection may be different to the water in the receiving aquifer, resulting in encrustation of the bore linings	Medium Requires construction of bores, pipeline and associated infrastructure Re-injection system will not need to be pressurised.	Medium Power costs likely to be similar to Re-injection into alluvium Maintenance of bores will be significant on-going expense.	Medium	Low/Medium Potential for saline water to be injected into Marra Mamba, which is likely to contain fresh water at present. Possible increase in salinity in station bores. Moderate greenhouse gas emissions.	Preferred Lies between 1 and 2 on the DoE hierarchy.	Medium Changes in salinity of discharge water likely to affect effectiveness of injection system.	Medium/High
In-pit disposal	Medium Requires a pit to be fully mined before this option can be used. Subject to the capacity of the selected pit. Could not be used in the first few years of mining, as no mined pit would be available.	Low/Medium No bores required. Method of discharge consists of a large diameter slotted pipe laid in a bed of permeable material (gravel).	Low/medium Power and maintenance costs likely to be low.	Medium	Low Water is being injected back to original aquifers. Possible effect on phreatophytic vegetation near the pit if groundwater mound approaches ground level Moderate greenhouse gas emissions.	Preferred Number 1 on DoE hierarchy	Easy But only feasible once an initial pit void has been created.	Medium/High Subject to suitable pit void being available.

Option	Reliability (High/Medium/Low)	Cost		Investigation Costs (High / Medium / Low)	Environmental Consequences (High/Medium/Low)	Compatibility with DoE Hierarchy (Preferred / Neutral / Least Preferred)	Manageability (Easy / Medium / Difficult)	Overall Rank
		Capital (High / Medium / Low)	Operating (High / Medium / Low)					
Evaporation Pond	High Effectiveness of this option is not affected by changes in water quality. Needs suitable site located away from possible inundation from creeks and the Fortescue Marsh.	Medium/High Careful engineering design and construction required preventing land control leakage of saline water.	Low Low power and maintenance costs. Geotextile membrane should be suitable for life of mine. Costs of rehabilitation will be significant.	Low	Low Initial void would be created which could be backfilled on completion. Low/Moderate greenhouse gas emissions. Careful design of monitoring and containment required to prevent escape of saline water to the environment. Large excavation required.	Neutral Does not score on DoE hierarchy, but generally not preferred by regulators. Difficult to licence. Likely to have low environmental impact.	Medium Assuming suitable site can be found. Would require careful ongoing management to ensure containment of saline water.	High
Shallow infiltration	Medium Unclear if there are suitable sites for discharging large volumes of water. Subject to damage during flooding.	Medium Requires installation of buried french drains along creeks Cost dependent upon permeability of host material (and thus length of drains to be installed)	Medium Drains tend to become damaged during cyclones. Power costs likely to be low.	Medium	Medium Impact of installation on vegetation may be extensive. Low/Moderate greenhouse gas emissions.	Neutral Scores 3 on DoE hierarchy.	Medium	Medium Suitable locations for sites not yet determined.
Surface water outflow	High Fortescue Marsh has dimensions large enough to store likely water volume	Low Requires only discharge pipe work and baffles to prevent erosion.	Low Power costs low	Low	High Semi permanent body of fresh water initially formed, followed by body of saline water. May impact on vegetation and fauna. Low greenhouse gas emissions.	Least Preferred Scores 4 on DoE hierarchy (discharge of freshwater may score 3) DoE likely to licence only as a last resort.	Easy Uncontrolled discharge means little management required.	Low Environmental issues likely to be too great.
Sale and Transport	Low Requires a market. Which may be only temporary, if at all.	Not Known Depends on method of transport and distance.	Not known Depends on method of transport and distance	Low	Not Known Depends on method of transport and distance.	Preferred Does not score on DoE hierarchy, but likely to be preferred.	Low Depends on market, which may be short-term and unreliable.	Low No market at present

SECTION 8 - MITIGATION MEASURES

8.1 INTRODUCTION

The previous section discussed the potential environmental impacts from the project. This section of the report discusses possible mitigation measures to reduce those impacts.

8.2 IMPACTS TO THE FORTESCUE MARSH

The potential impacts to the Fortescue Marsh were discussed in Section 6.4. A series of management and mitigation measures were developed as part of the Risk Assessment. The results are presented in Table 8.1 below.

Table 8.1
Mitigation Measures to Manage Impacts on the Fortescue Marsh

Potential Impact	Mitigation Measure	Residual Risk	Residual Risk Number
Drawdown from dewatering affecting water levels in the marsh and therefore vegetation.	Installation of groundwater monitoring bores between the pits and the marsh. Monitoring & measurement of those bores Development of and annual calibration of a groundwater impact model. Third party hydrological reports. Timely development of contingency plans for an alternative abstraction borefield if the model and/or monitoring data predict an impact.	L	23
Drawdown from the dewatering affecting Stygofauna.	Not required – initial risk considered insignificant. Stygofauna Management Plan (See Section 8.5).	L	25
Drawdown from the dewatering impacting on the drying cycle of the marsh.	Installation of groundwater monitoring bores between the pits and the marsh. Monitoring & measurement of those bores Development of and annual calibration of a groundwater impact model. Third party hydrological reports.	L	21
Effect of disposal of fresh and saline water produced during pit dewatering	Regular sampling from the dewatering bores. Installation of deeper water quality monitoring bores. Mixing of saline water with fresh water for use in the ore-beneficiation process. Use of evaporation ponds to dispose of excess water. Provide alternative supplies of water for station bores. Development of alternative disposal plans.	L	25
Flora loss from pipeline failure releasing saline water	Bunding, pipeline pressure monitoring and inspections	L	25

8.3 IMPACTS ON PHREATOPHYTIC VEGETATION

FMG have stated that they will develop a Vegetation Monitoring and Management Programme to ensure the vegetation impacts and associated groundwater abstraction are adequately managed. This plan will focus on the vegetation that might be affected by groundwater drawdown (Section 6.4). Possible measures to be included in this plan are as follows:

- The construction of groundwater monitoring bores and monitoring of water levels in the alluvial and basement aquifers along creeks where vegetation might be effected, prior to commencement of abstraction.
- Sampling of groundwater in the vicinity of Cloud Break to monitor changes in salinity in the alluvial aquifer during dewatering.
- Development of improved numerical groundwater models and annual calibration of these models, so that future drawdowns for the life of the project can be identified in a timely manner before potential impacts occur.

- Assessment of vegetation condition, in drawdown areas commencing prior to abstraction.
- If groundwater monitoring and vegetation condition assessments indicate a decline in tree condition due to drawdown, irrigation systems will be considered to support selected communities.

The results of the plan will be reported in the Annual Environmental Report, which is submitted to the Department of Environment (DoE) and the Department of Industry and Resources (DoIR). Results will also be submitted to the Environmental Protection Authority and Department of Conservation and Land Management. FMG has stated that they will also make the results of the sampling programme publicly available if required.

8.4 IMPACTS FROM THE DEWATERING ON STYGOFAUNA

As the study of stygofauna in Western Australia is relatively new, the conservation status of numerous species many of which are yet un-named, is uncertain, and the Project will need to consider the regional distribution of any stygofauna populations encountered.

FMG has undertaken the first round of sampling for stygofauna in bores located within the Cloud Break area. The samples did not indicate the presence of any significant species, or species unique to FMG tenements and additional bores will be sampled prior to commissioning.

8.4.1 Stygofauna Management

FMG has developed a Stygofauna Management Plan in consultation with CALM for its proposed mining operations, which will be expanded to incorporate the Cloud Break Project. The first step in this management plan is understanding the distribution of stygofauna through a sampling programme, which is provided in detail in the management plan. Sampling will be undertaken biannually for two years. Management strategies to minimise disturbance to stygofauna populations and reporting mechanisms will be undertaken in accordance with this plan.

8.5 IMPACTS ON STATION BORES

As described in Section 4.2 information on the location and status of station bores was obtained from the DoE's AQWABASE system. Since then monitoring of a sample of these bores has commenced. This involves water level dipping and water quality sampling each month. The groundwater models will then be used to identify bores currently used, which may be affected by the project.

- Possible mitigation measures include deepening of affected bores or, where this is not possible, provision of an alternative piped supply from the dewatering bores or water supply borefield.
- Water quality samples will continue to be taken from those bores in the vicinity of Cloud Break prior to commencement of the project. In additional down-hole geophysics may be used to accurately determine if movement of the saline interface is occurring. The results will be used to determine if these bores are becoming more saline as a result of the dewatering. If this occurs FMG will make alternative water supplies available to the pastoral leasee.

8.6 IMPACTS FROM MINE CLOSURE

As discussed in Section 6.6, it is concluded that the mine closure programme proposed by FMG of back-filling the pits to the pre-mining level and to only back-fill with waste rock and overburden, means there will be no long-term impacts on the hydrogeology of the project area from the mine closure plan.

8.7 DEWATERING MANAGEMENT PLAN

As described in Section 7, a number of alternatives for disposal of excess dewatering water exist. The preferred scheme is for evaporation of water from a series of ponds. This approach is preferred because its effectiveness is not significantly affected by changes in salinity of the dewatering water.

However, FMG proposes to consider other approaches to disposal of the saline water and these are discussed in the dewatering management plan in Appendix F. This plan includes monitoring strategies, data collection systems, impact modelling and annual reporting proposals.

SECTION 9 - CONCLUSIONS AND PROPOSED FURTHER WORK

9.1 CONCLUSIONS

The key conclusions are:

1. The Fortescue Marsh is a surface water feature, which fills after large rainfall events. The frequency of the marsh filling up is dependent on rainfall and is not affected by the hydrogeology of the project area.
2. After floods, the marsh then dries out as a result of evaporation and seepage into the unsaturated alluvium below. Once the marsh has dried out evaporation from the shallow groundwater occurs, resulting in the water table reducing to 5 mbgl. It is predicted that the cones of depression from the dewatering of Cloud Break will encroach close to, but not under, the Fortescue Marsh.
3. A risk assessment has been undertaken on the marsh for the Stage B PER, however the results are equally applicable to the Cloud Break PER. The risk assessment was conducted by a team of expert consultants and found that changes to the hydrogeology of the project area are unlikely to impact on the marsh. A series of monitoring and mitigation measures have been developed to accommodate potential impacts.
4. There is saline groundwater in the aquifers close to the marsh. Results from geophysical investigations suggest that this saline water also occurs below the base of the proposed pits. It is considered likely that this water will upcone and that the water abstracted during dewatering will become saline over time. However it is not possible to accurately predict long-term changes in water quality with confidence.
5. A number of options for disposal of excess dewatering water have been considered. Three potential solutions have been viewed as being feasible, and outline design for the preferred method – use of evaporation ponds, has been completed. This method of disposal has several advantages over alternatives, however careful design, construction and monitoring of the ponds will be required to ensure there is no escape of water. This method of disposal is particularly suitable for this project, as its effectiveness is not affected by changes in salinity with time.
6. FMG proposes further studies on two alternative options for disposal of the saline water; these are re-injection of the water via a series of bores and in-pit disposal of water using a soakaway system.
7. FMG will implement a Groundwater Monitoring and Management plan which will further consider possible impacts to phreatophytic vegetation and monitor vegetation condition and groundwater levels where appropriate.
8. Stygofauna may be affected by dewatering. A Stygofauna Management Plan has been developed by FMG.
9. There are station bores that will be affected by the drawdowns associated with the dewatering. Mitigation measures include bore deepening and the provision of alternative supplies.
10. It is proposed that rejects from the ore beneficiation process be disposed of above the water table to reduce the likelihood of the blinding of the hanging wall at Christmas Creek with low permeability material.

9.2 PROPOSED FURTHER WORK

Whilst sufficient data has been obtained for this study to be able to undertake a preliminary assessment of the potential impacts of the project, it is recognised there is a need for further work, prior to licensing and borefield development. The following sections outline the work that is proposed.

9.2.1 Dewatering Requirements

Further work is proposed to improve the assessments of dewatering requirements in the pits. This will involve the drilling of trial water bores in the hanging wall material at Cloud Break. Monitoring bores will be drilled to penetrate the hanging wall material.

Each trial bore will be test pumped using a submersible pump. The analysis of the data will provide improved estimates of the hydraulic characteristics of the saturated material. This work is expected to be completed in July 2005.

The results of these investigations will be used to improve the Cloud Break numerical groundwater model, providing more robust estimates of dewatering requirements.

9.2.2 Groundwater Modelling

The modelling studies require additional work as recommended in Groundwater Flow Modelling Guideline (MDBC, 2000), including:

1. Model sensitivity assessment, and
2. Uncertainty analyses.

The current models will be refined as more field data becomes available. Model features that are identified for refinement include:

1. Water table elevations, with data from new bores and surveys for existing regional bores;
2. Evapotranspiration, including aerial zonation and rooting depths of major vegetation types;
3. Recharge, including aerial zonation of major recharge zones; and
4. Stratigraphic elevations, including alluvial and basement thickness.

Other potentially important issues for the model development, calibration, and predictions, are also being considered. These include:

1. Examination and refinement of the whole-of-model water budget to ensure that the water budget is consistent with (a) the catchment water balance, and (b) the estimated regional inflows/outflows connecting the current study area with neighbouring aquifers, and
2. Examination of the historical rainfall for the region and the assessment of impacts of rainfall variability on (a) water supply, and (b) water table drawdown.

9.2.3 Dewatering Plan

FMG will discuss with the DoE on the preferred method of disposal of the saline water. In the meantime FMG will continue to pursue the option of evaporation ponds as the best means of disposal of saline water.

FMG will also commence field investigations to determine possible locations for re-injection of excess water from the dewatering, which will be followed by numerical groundwater modelling to determine the potential impacts on receiving aquifers, station bores and vegetation.

FMG is also proposing to review its mining schedule to determine if in-pit disposal of saline water is a feasible solution.

SECTION 10 - REFERENCES

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APPENDIX A

BORE LOGS FROM THE HYDROGEOLOGICAL INVESTIGATION

aquaterra
Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB068

Client: FMG **Project:** Cloud Break Groundwater Exploration

Commenced: 11/04/05 **Method:** 0-69m AC **Area:** Cloud Break
Completed: 11/04/05 **Fluid:** **East:** 727196
Drilled: Connector **Bit Record:** **North:** 7532795
Logged By: S Collett **Elevation:** 423

Static Water Level: 9.7 mbrp **Date:**

Depth (mbgl)	Lithological Description	Field Notes	Well Completion Notes
0	ALLUVIUM: Silty aggregate	E.C. = 3.14mS/cm	Collar Height = 0.1magl
~24	CLAY: Pisolitic, goethitic clay (Lacustrine)	E.C. = 3.84mS/cm	
~42	CALCRETE	Water yielding E.C. = 12.38mS/cm	
~50	BIF: Ochreous goethite	E.C. = 19.98mS/cm	
~54	CHERT: Broken	Water yielding E.C. = >20mS/cm Yield = 2.5L/s EOH at 69m	

Depth scale: 0, -10, -20, -30, -40, -50, -60, -70, -80, -90, -100

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Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB068a

Client: FMG
Project: Cloud Break Groundwater Exploration

Commenced: 22/04/05	**Method:** 0-63m DC	**Area:** Cloud Break
Completed: 22/04/05	**Fluid:**	**East:** 727200
Drilled: Connector	**Bit Record:**	**North:** 7532001
Logged By: S Collett		**Elevation:**418

Static Water Level: 7.6 mbrp
Date:

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion Notes
0			ALLUVIUM: Brown silty aggregate	Yield = 1L/s	Collar Height = 0.15magl
-20			ALLUVIUM: Brown silty clay	E.C. = 2.4mS/cm Yield = 2.5L/s	
-30			ALLUVIUM: Brown silty aggregate	Water yielding E.C. = 2.94mS/cm Yield = 3.4L/s	
-40			CLAY: Red brown, stiff, puggy (Lacustrine)	E.C = 2.87mS/cm Yield = 8.5L/s Water yielding	
			DOLOMITE: White amorphous weathered dolomite with micro vugs	E.C. = 18.08mS/cm Yield = 10L/s EOH at 63m	

Depth scale: 0, -10, -20, -30, -40, -50, -60, -70, -80, -90, -100

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Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB068b

Client: FMG
Project: Cloud Break Groundwater Exploration

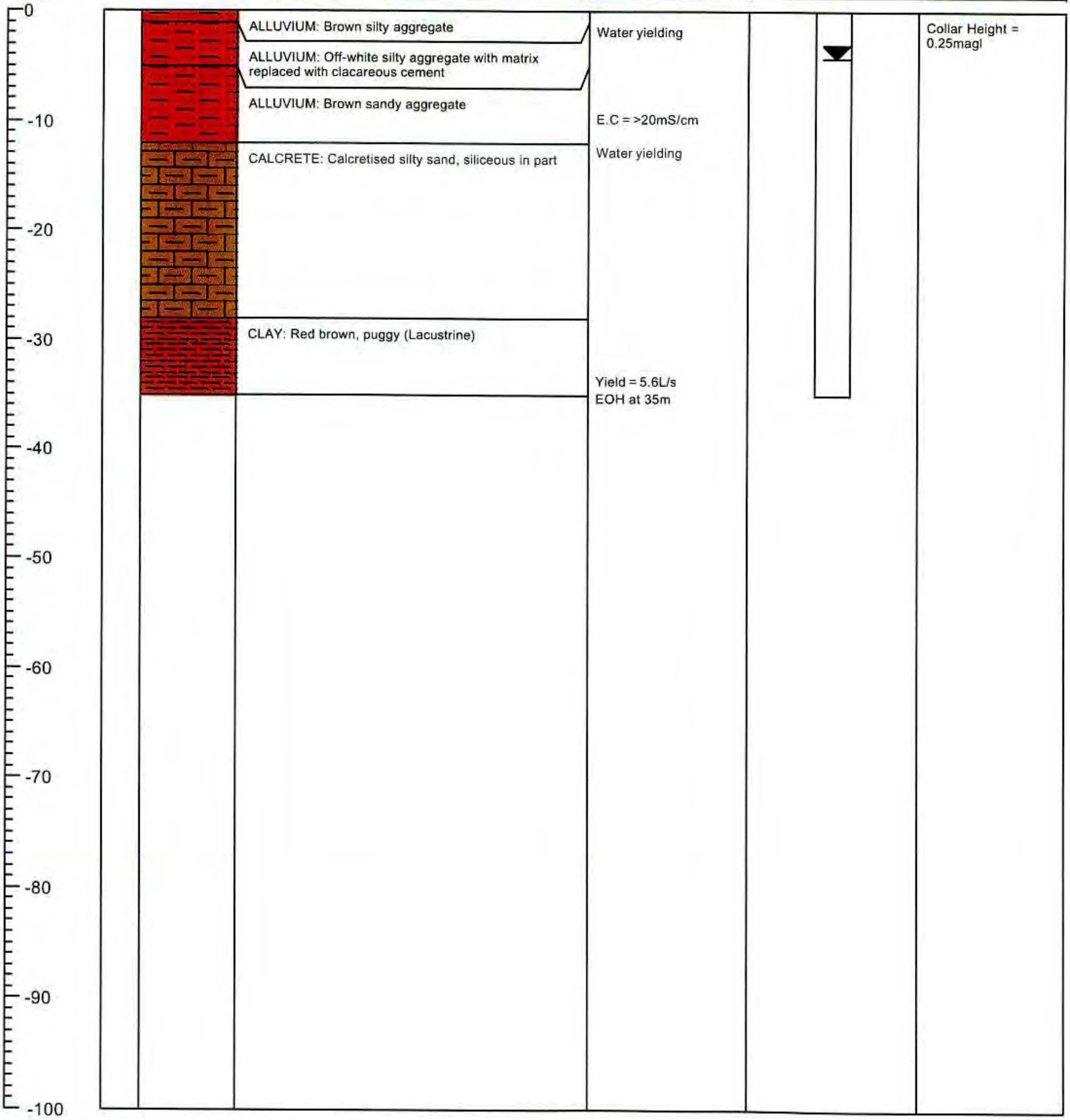
Commenced: 22/04/05
Completed: 23/04/05
Drilled: Connector
Logged By: S Collett

Method: 0-35m DC
Fluid:
Bit Record:

Area: Cloud Break
East: 727194
North: 7530145
Elevation: 412

Static Water Level: 4.28 mbrp
Date:

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0			ALLUVIUM: Brown silty aggregate	Water yielding		Collar Height = 0.25magl
			ALLUVIUM: Off-white silty aggregate with matrix replaced with clacareous cement			
-10			ALLUVIUM: Brown sandy aggregate	E.C = >20mS/cm		
			CALCRETE: Calcretised silty sand, siliceous in part	Water yielding		
-30			CLAY: Red brown, puggy (Lacustrine)	Yield = 5.6L/s EOH at 35m		



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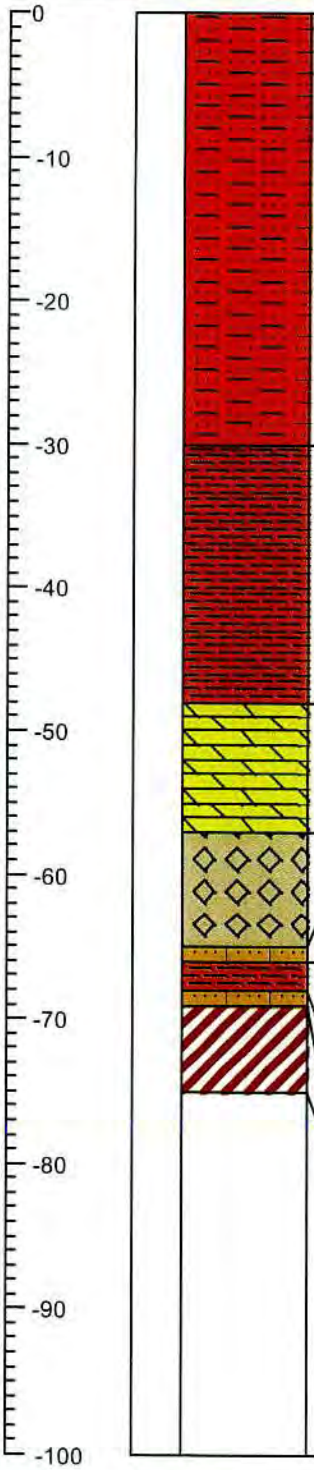
Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB323a

Client: FMG		**Project:** Cloud Break Groundwater Exploration	
Commenced: 09/04/05	**Method:** 0-75m RC		**Area:** Cloud Break
Completed: 10/04/05	**Fluid:**		**East:** 739898
Drilled: Connector	**Bit Record:**		**North:** 7528474
Logged By: S Collett			**Elevation:** 417
Static Water Level: 8.4 mbrp		**Date:**	

Depth (mbgl)	Lithological Description	Field Notes	Well Completion Notes
0 – 30	ALLUVIUM: Brown, interbedded sequence of silty aggregates and fine-grained sands. 27-30: Water-bearing aggregate	E.C. = 2.25mS/cm Water yielding (27-30m) Yields salty water	Collar Height = 0.2magl
30 – 48	CLAY: Red brown stiff, puggy clay interbedded with thin pisolitic gravel beds (Lacustrine).		
48 – 57	DOLOMITE: Light brown to white marl (weathered dolomite). 56-57: Hard calcrete	E.C. = 18.23mS/cm Water yielding (56-57m)	
57 – 65	CHALCEDONY: Grey. Open voids clay infilled.		
65 – 66	SILCRETE: Grey infilled	E.C. = >20mS/cm	
66 – 69	CLAY: Yellow limonitic with trace of goethite and quartz pebbles		
69 – 71	SILCRETE		
71 – 75	BIF: Yellow silty clay with minor amounts of concretionary goethite pebbles and welded pisolite	Yield = 2L/s pH = 7.48 EOH at 75m	



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Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB323b

Client: FMG | **Project:** Cloud Break Groundwater Exploration

Commenced: 23/04/05	**Method:** 0-35m DC		**Area:** Cloud Break
Completed: 23/04/05	**Fluid:**		**East:** 738827
Drilled: Connector	**Bit Record:**		**North:** 7526340
Logged By: S Collett			**Elevation:**409

Static Water Level: 4.04 mbrp **Date:**

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0			ALLUVIUM: Brown silty aggregate			Collar Height = 0.3magl
			CLAY: Off-white, calcrete-marl clay replacement (Lacustrine)	Water yielding E.C. = 25mS/cm		
-10						
			CLAY: Red, hard, (Lacustrine). Minor nodular calcrete			
-20						
-30				Yield = 1.5L/s E.C. = 50mS/cm EOH at 35m		
-40						
-50						
-60						
-70						
-80						
-90						
-100						

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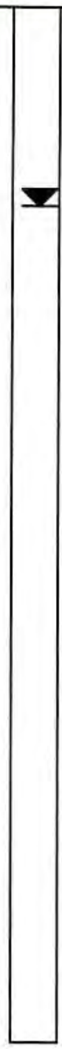
Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB404

Client: FMG		**Project:** Cloud Break Groundwater Exploration	
Commenced: 09/04/05	**Method:** 0-72m RC		**Area:** Cloud Break
Completed: 09/04/05	**Fluid:**		**East:** 744797
Drilled: Connector	**Bit Record:**		**North:** 7527202
Logged By: S Collett			**Elevation:**
Static Water Level: 13.74 mbrp	**Date:**		

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0			ALLUVIUM: Red brown silty aggregate.			Collar Height = 0.1magl
			ALLUVIUM: Red brown silty clay	Minor water yields from alluvium		
-20			ALLUVIUM: Red brown silty aggregate	pH = 7.8 E.C. = 1.7mS/cm		
			ALLUVIUM: Red brown pisolitic clay			
			CLAY: Kaolin clay, weathered shale?			
			BIF: Earthy goethite banded iron formation	pH = 7.4 E.C. = 3.4mS/cm		
			CHERT	Minor water yields from top of chert pH = 7.4 E.C. = 3.6mS/cm Yield = 0.5L/s EOH at 72m		



Depth scale (mbgl): 0, -10, -20, -30, -40, -50, -60, -70, -80, -90, -100

COMPOSITE WELL LOG

Well No: CB404a

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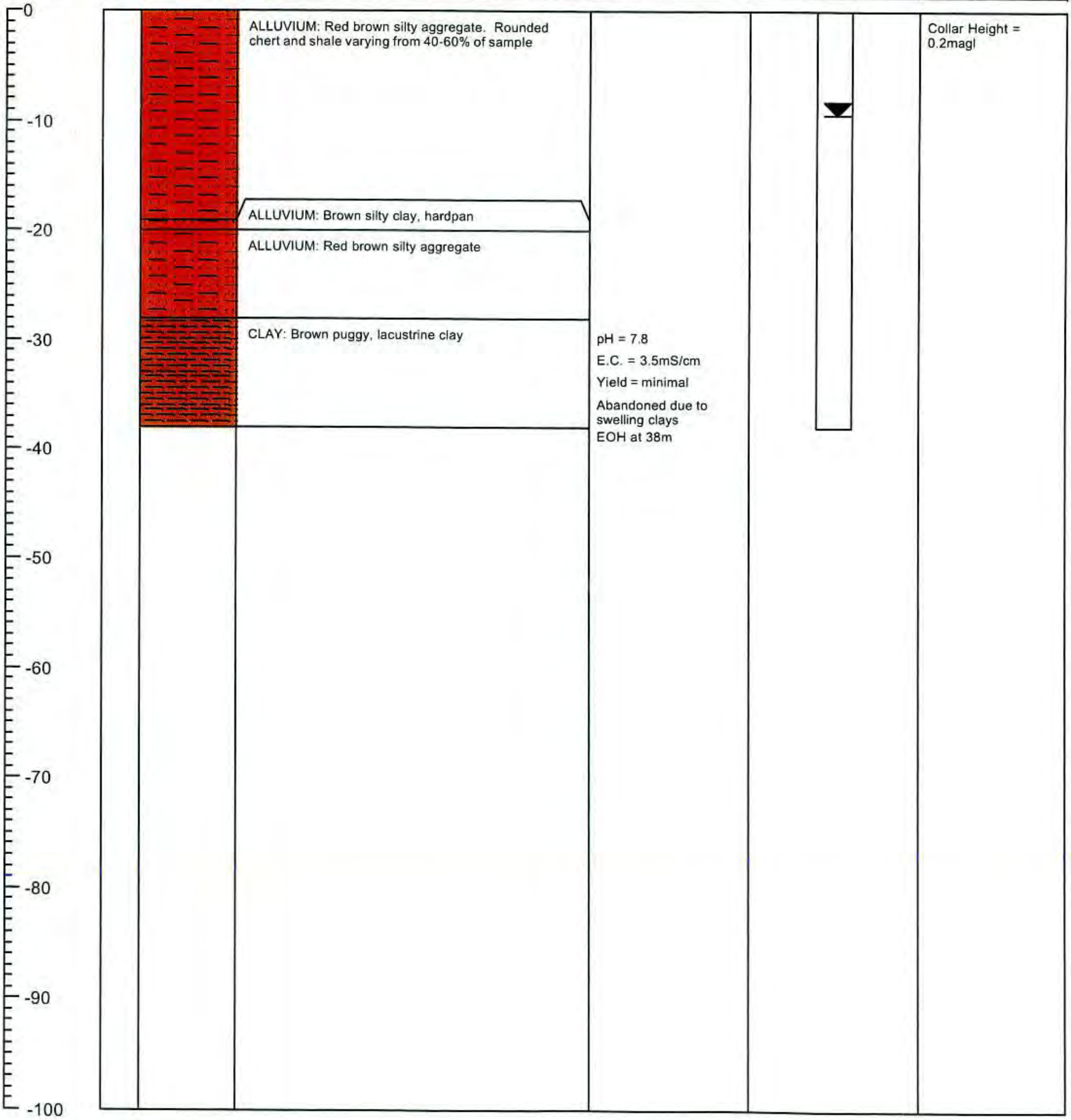
Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

Client: FMG
Project: Cloud Break Groundwater Exploration

Commenced:	07/04/05	**Method:**	0-38m RC	**Area:**	Cloud Break
Completed:	09/04/05	**Fluid:**		**East:**	744700
Drilled:	Connector	**Bit Record:**		**North:**	7526200
Logged By:	S Collett			**Elevation:**	424

Static Water Level: 9.45 mbrp
Date:

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0			ALLUVIUM: Red brown silty aggregate. Rounded chert and shale varying from 40-60% of sample			Collar Height = 0.2magl
			ALLUVIUM: Brown silty clay, hardpan			
			ALLUVIUM: Red brown silty aggregate			
			CLAY: Brown puggy, lacustrine clay	pH = 7.8 E.C. = 3.5mS/cm Yield = minimal Abandoned due to swelling clays EOH at 38m		



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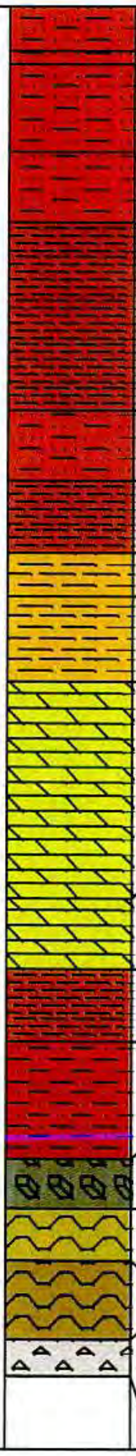
Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB404b

Client: FMG		**Project:** Cloud Break Groundwater Exploration	
Commenced: 06/04/05	**Method:** 0-95m RC		**Area:** Cloud Break
Completed: 07/04/05	**Fluid:**		**East:** 744600
Drilled: Connector	**Bit Record:**		**North:** 7524700
Logged By: S Collett			**Elevation:**423
Static Water Level: 2.7 mbrp	**Date:**		

Graphic Log



Depth (mbgl)	Lithological Description	Field Notes	Well Completion Notes
0	ALLUVIUM: Red brown silty aggregate, chert aggregate (50%)		Collar Height = 0.1m agl
	ALLUVIUM: Off-white silty aggregate, calcrete replacement of silty matrix	Water bearing E.C. = 3.4mS/cm	
-10	ALLUVIUM: Brown sandy aggregate, medium grained sand (60%)		
	ALLUVIUM: Red brown silty aggregate		
	CLAY: Red brown, friable, burrow structure (Lacustrine Clay), with minor chert pebbles.		
-20			
-30	ALLUVIUM: Red brown, hard, with minor matrix supported sand	Water bearing along planar beds	
	CLAY: Off-white, calcareous puggy clay, interbedded with brown puggy clay (Lacustrine Clay).		
-40	MARL: Yellow calcareous clay		
	MARL: White		
-50	DOLOMITE: White amorphous calcareous sediment. Chips interlaced with micro vugs. 47-52: Sicrete formed	High water yields	
-60	DOLOMITE: Weathered, light brown earthy calcareous clay. 67: Manganese-rich		
-70	CLAY: Grey-white kaolin clay		
	LATERITE: Brown ochreous goethite and vuggy concretionary bands (welded pisolite). Concretionary bands grade to vitreous. 73-80: Yellow limonitic bands		
-80	PYROLUSITE: Black, manganese-rich, earthy, broken and vuggy pyrolusite		
	GOETHITE: Dark brown, vuggy, goethitic welded pisolite and concretions		
-90	LIMONITE: Yellow ochreous limonite, concretionary geothite	pH = 7.8 E.C. = >20mS/cm	
	CHERT: Brown banded chert and jaspilite. Limonitic coating on bedding planes, very broken along bedding planes.	Yield = >20L/s EOH at 95m	
-100			

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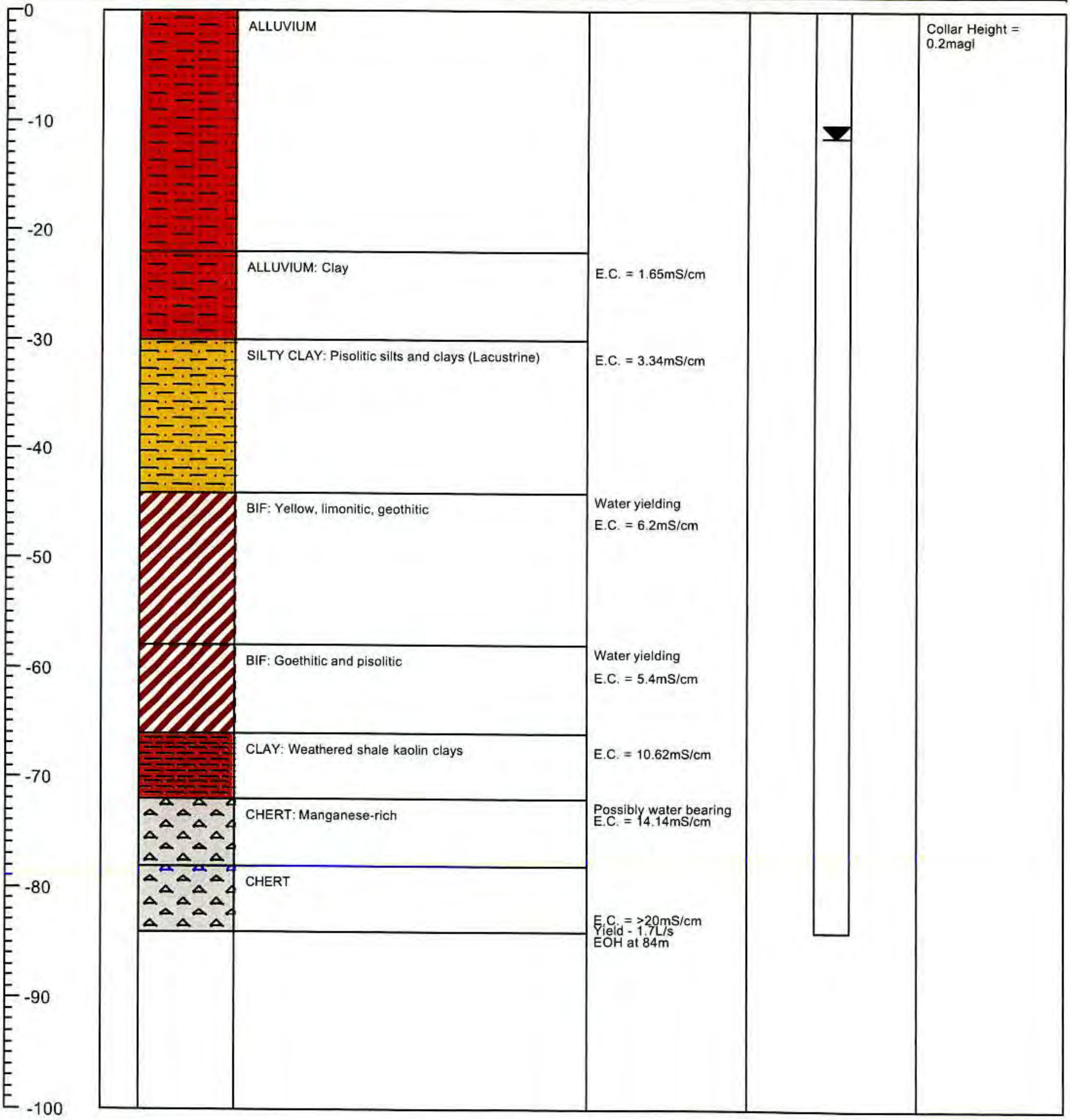
Suite 4, 125 Melville Parade
Como
WA 6152
Australia
Tel: (+61) (08) 9368 4044
Fax: (+61) (08) 9368 4055

COMPOSITE WELL LOG

Well No: CB717

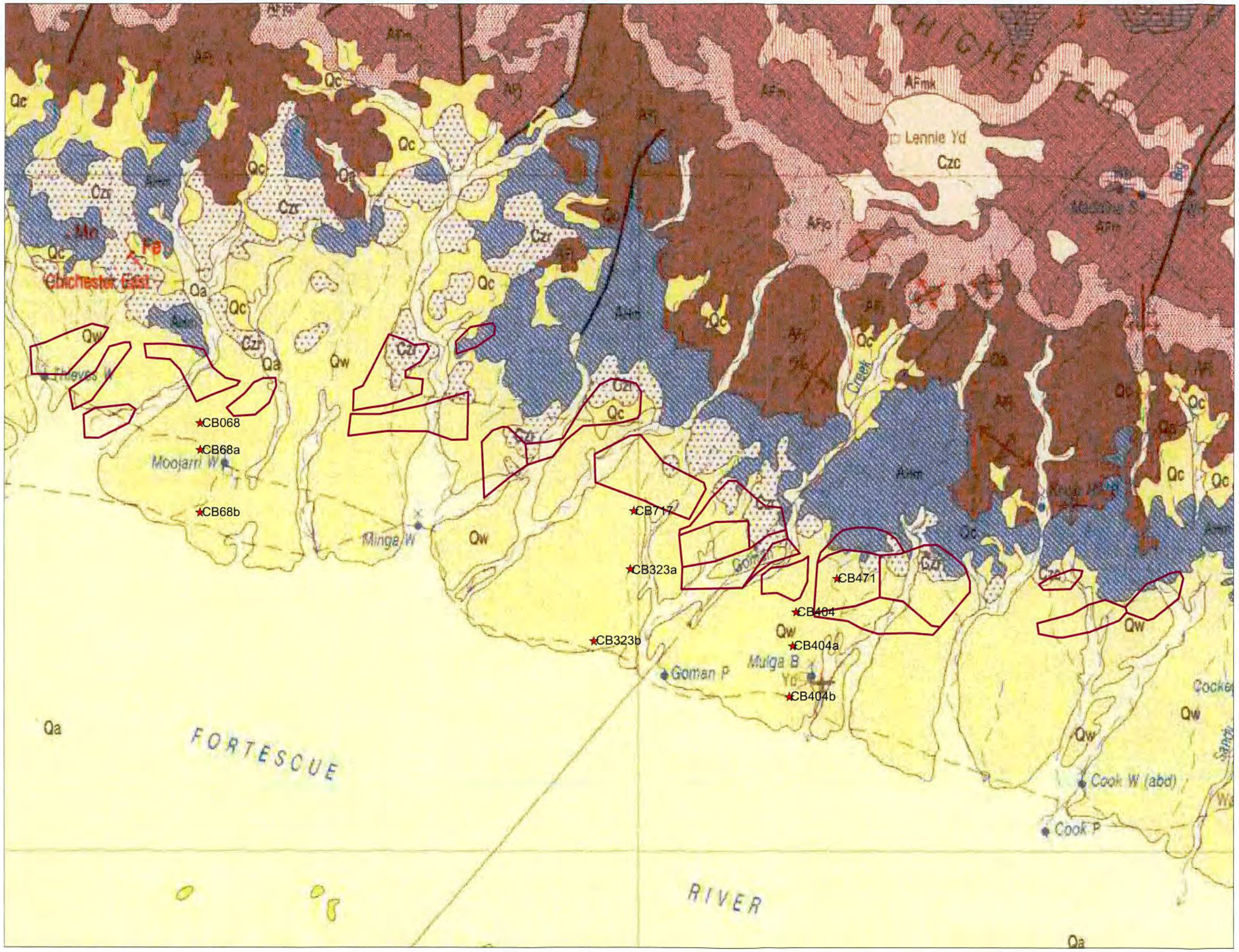
Client: FMG **Project:** Cloud Break Groundwater Exploration

Commenced: 11/04/05	**Method:** 0-84m AC		**Area:** Cloud Break
Completed: 11/04/05	**Fluid:**		**East:** 740000
Drilled: Connector	**Bit Record:**		**North:** 7530200
Logged By: S Collett			**Elevation:**
Static Water Level: 11.55 mbrp	**Date:**		



Depth (mbgl)	Lithological Description	Field Notes	Well Completion Notes
0	ALLUVIUM		Collar Height = 0.2magl
~22	ALLUVIUM: Clay	E.C. = 1.65mS/cm	
~30	SILTY CLAY: Pisolitic silts and clays (Lacustrine)	E.C. = 3.34mS/cm	
~44	BIF: Yellow, limonitic, geothitic	Water yielding E.C. = 6.2mS/cm	
~58	BIF: Goethitic and pisolitic	Water yielding E.C. = 5.4mS/cm	
~66	CLAY: Weathered shale kaolin clays	E.C. = 10.62mS/cm	
~72	CHERT: Manganese-rich	Possibly water bearing E.C. = 14.14mS/cm	
~78	CHERT	E.C. = >20mS/cm Yield - 1.7L/s EOH at 84m	

Figure Showing Location of Hydrogeology Bores



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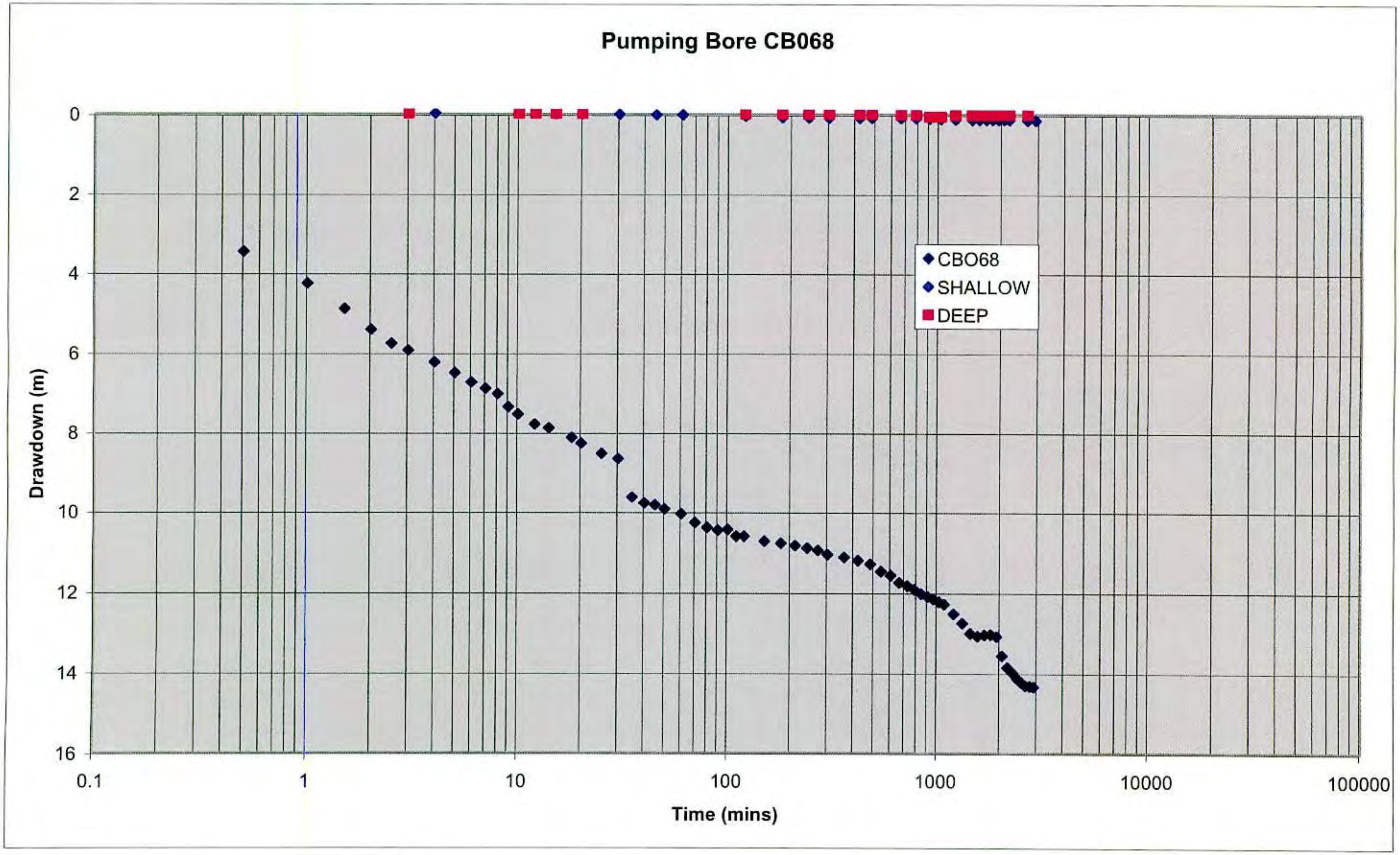
Appendix A
Location of Drill Sites

Author: A Ball	Date: June 05
Drawn: A Ball	Revised:
Job No: 477 D1	Report No.: 477 4023
Projection:	Scale:

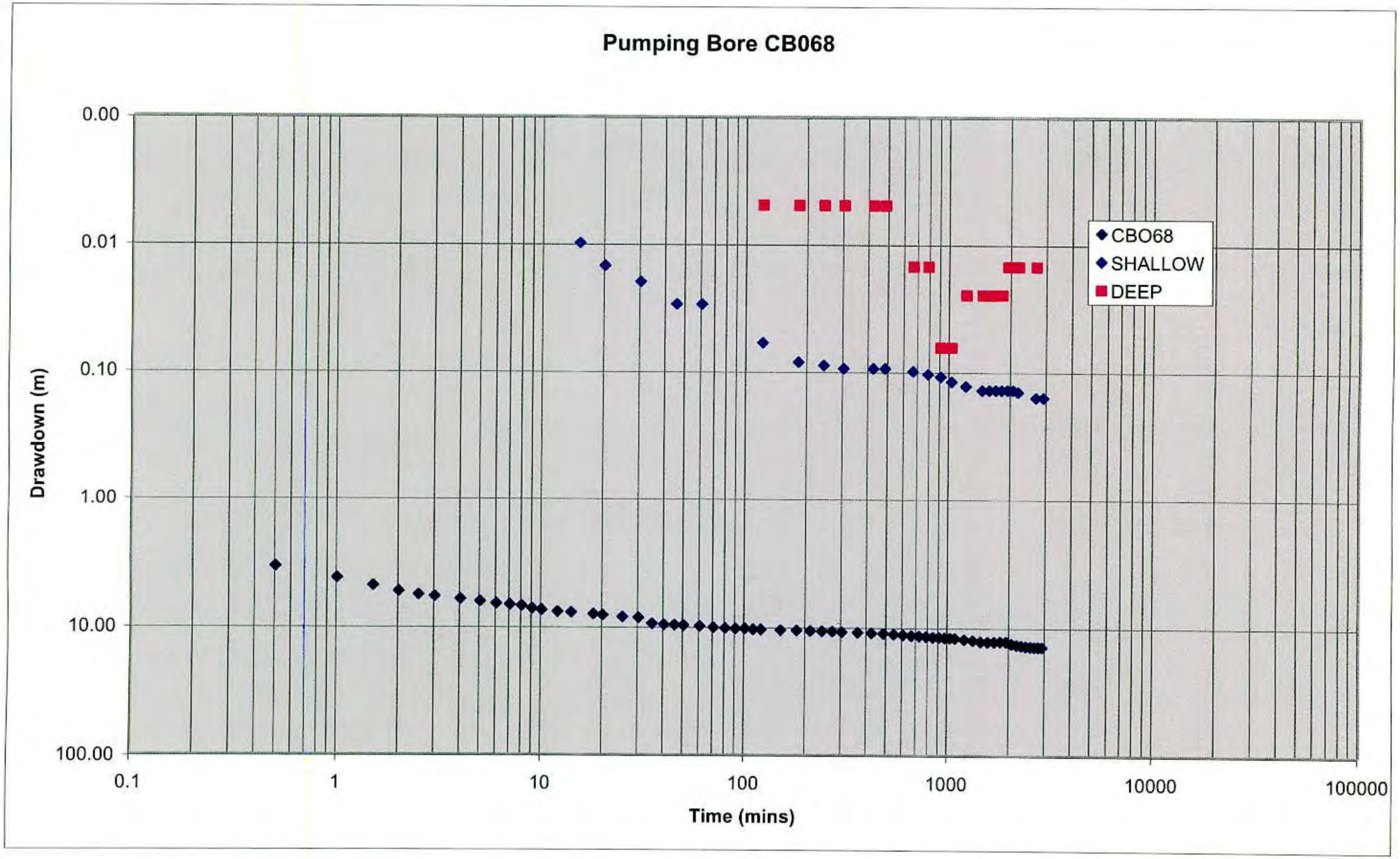
F:\jobs\

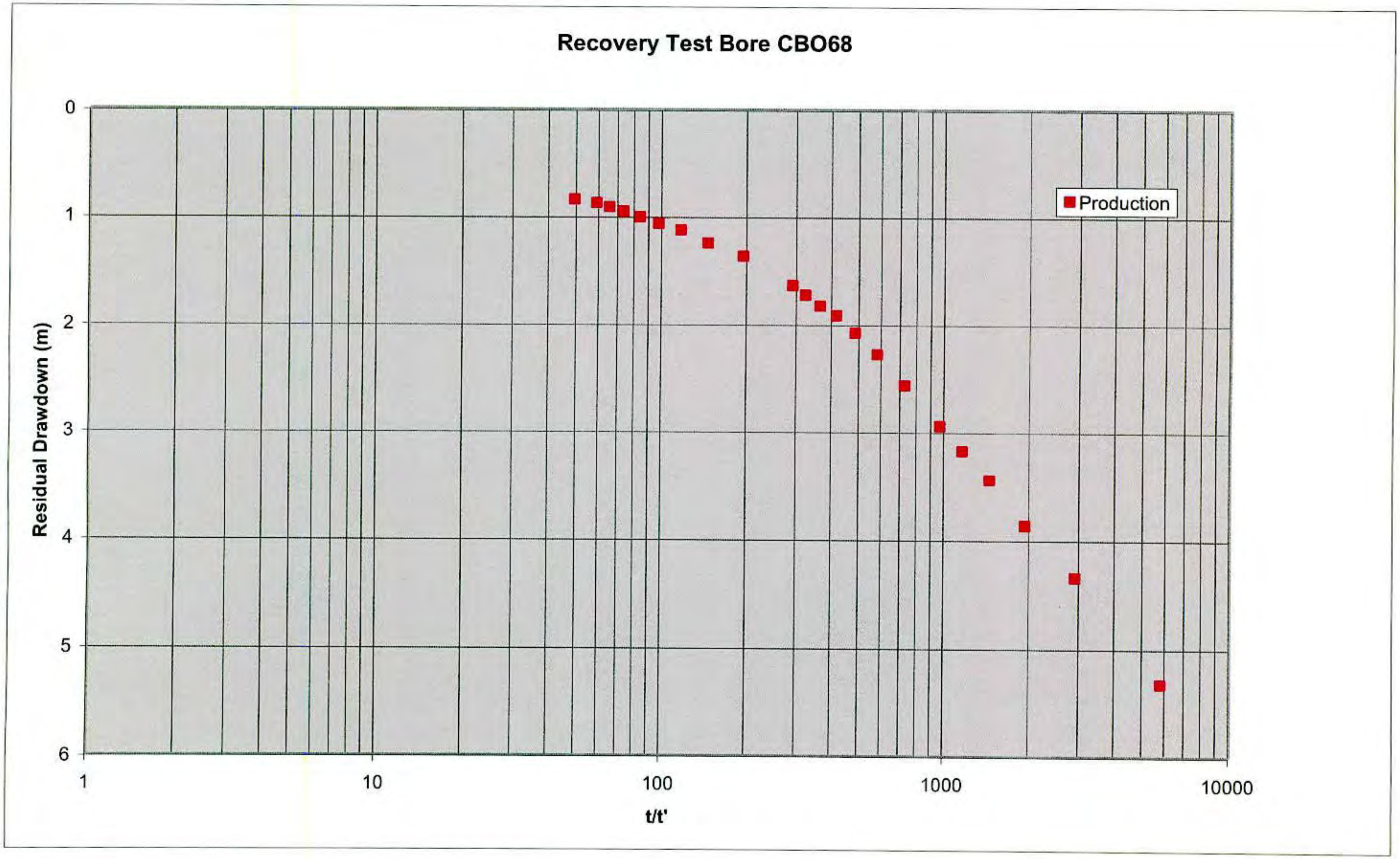
APPENDIX B

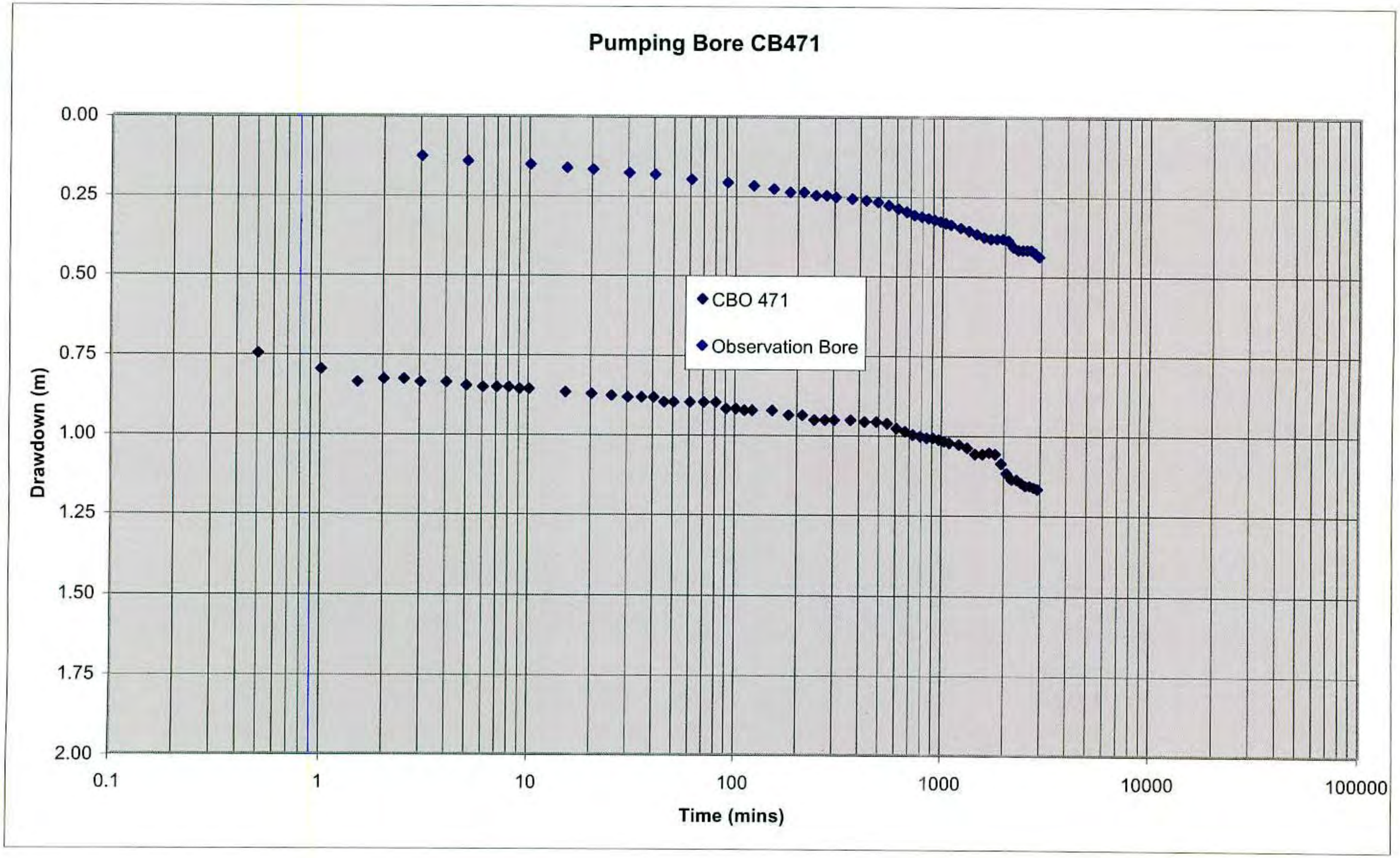
TEST PUMPING DATA



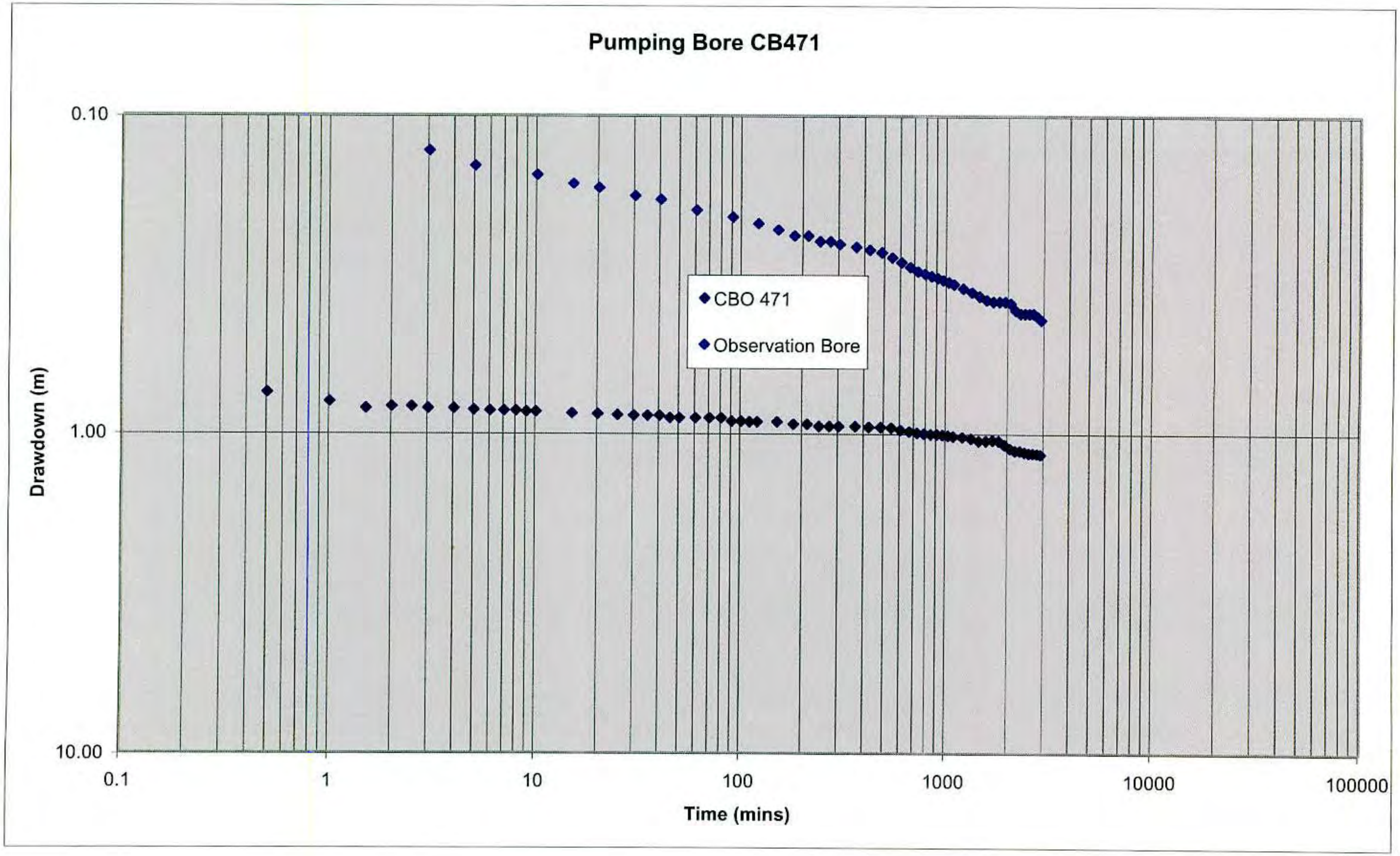
Pumping Bore CB068
Drawdown (m)
0
2
4
6
8
10
12
14
16
0.1
1
10
100
1000
10000
100000
Time (mins)
CBO68
SHALLOW
DEEP


Pumping Bore CB068
Drawdown (m)
0.00
0.01
0.10
1.00
10.00
100.00
0.1
1
10
100
1000
10000
100000
Time (mins)
CBO68
SHALLOW
DEEP

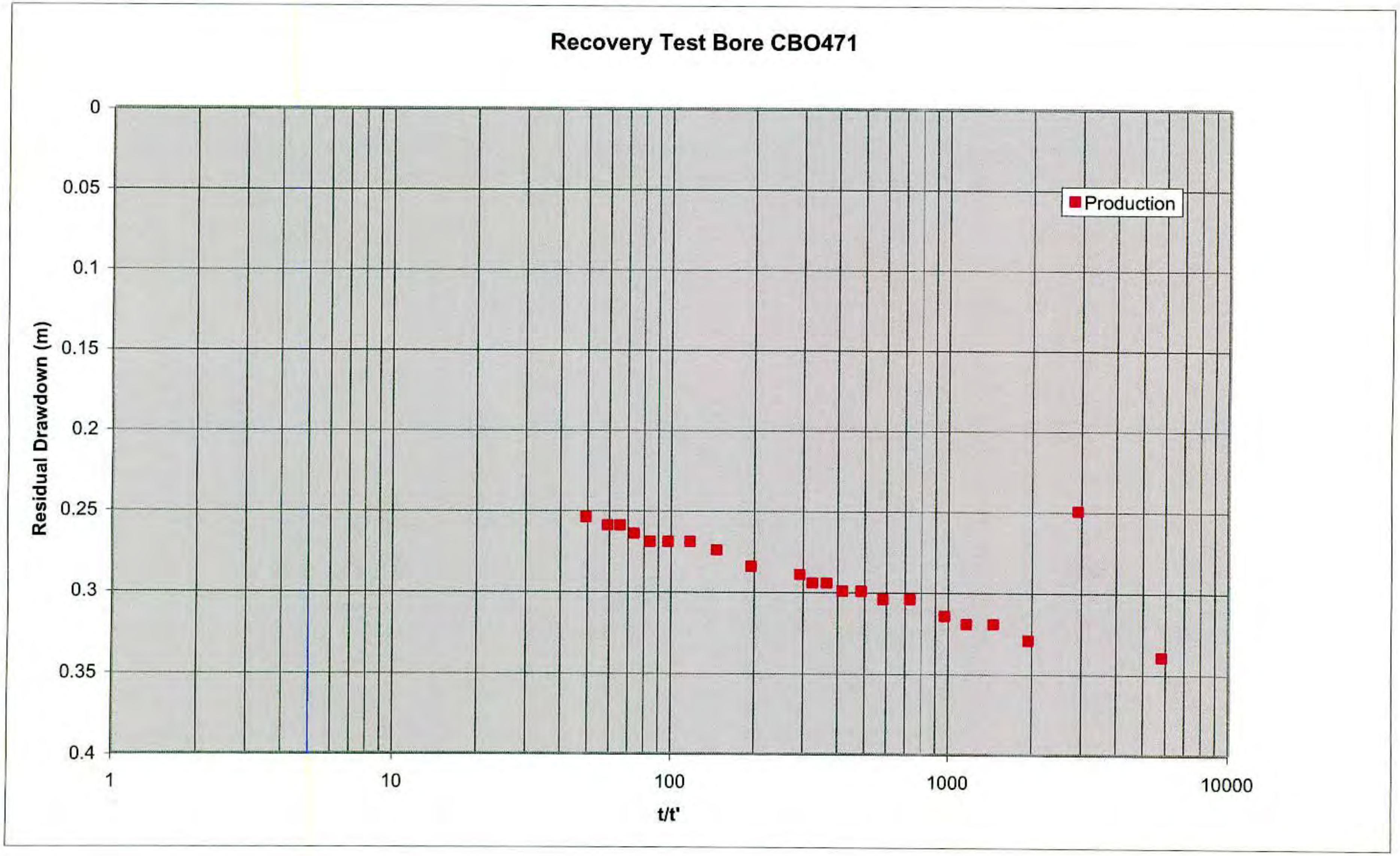

Recovery Test Bore CBO68
Production
Residual Drawdown (m)
0
1
2
3
4
5
6
1
10
100
1000
10000
t/t'



Pumping Bore CB471
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Drawdown (m)
CBO 471
Observation Bore
0.1
1
10
100
1000
10000
100000
Time (mins)



Pumping Bore CB471
0.10
1.00
10.00
0.1
1
10
100
1000
10000
100000
Drawdown (m)
Time (mins)
CBO 471
Observation Bore


Recovery Test Bore CBO471
Production
Residual Drawdown (m)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
1
10
100
1000
10000
t/t'

APPENDIX C

DOWN-HOLE GEOPHYSICAL ANALYSIS

APPENDIX C – DOWNHOLE GEOPHYSICAL ANALYSIS

STATION BORES

There is no information available regarding the construction or geology of the station bores, although they are generally shallow. As expected the groundwater within the station bores is generally fresh to brackish.

Mulga Bore

The static water level (SWL) was approximately 5.8 mbgl. The geothermal response was normal and showed a slight increase in temperature with depth. The gamma log decreased below the water table, indicating lower clay content in the saturated zone. Fresh water was encountered throughout the bore.

Moojarrie Well

The SWL was approximately 7.5 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth, typically between 80-100 API. Fresh water was encountered throughout the bore with a slight increase in conductivity towards the base of the bore.

Mingarwirriewirrie Well

The SWL was approximately 1.5 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. Minor inflections in the temperature log at 2 and 3 mbgl suggest possible groundwater inflow between these levels or near-surface temperature gradients. The gamma log decreased at about 5 mbgl, indicating lower clay content in the surrounding lithology.

Fresh water was encountered from SWL to 5 mbgl. Brackish water was encountered between 5 mbgl and the base of the bore at approximately 7 mbgl, corresponding with the zone of lower gamma readings.

Cook's Bore

The SWL was approximately 5 mbgl. The geothermal response showed a slightly higher temperature at the top of the bore, decreasing with depth, suggesting inflows to the lower levels of the bore. The gamma log showed a slight peak at about 7.5 mbgl, indicating a clay-rich layer at this level.

Fresh water was encountered from SWL to the base of the bore at approximately 11 mbgl with a minor brackish water intersection at approximately 9 mbgl.

EXPLORATION HOLES

CB136

Mineral exploration bore CB136 was found to have collapsed to a depth of approximately 26 mbgl on geophysical logging (initial depth was 78 m). The bore has collapsed to within the Tertiary detritals.

The SWL was approximately 10.5 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth. Fresh water was encountered throughout the bore.

CB135

Mineral exploration bore CB135 was found to have collapsed to a depth of approximately 24 mbgl on geophysical logging (initial depth was 72 m). The bore has collapsed to within the Tertiary detritals.

The SWL was approximately 12 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth. Fresh water was encountered throughout the bore.

CB069

Mineral exploration bore CB069 was found to have collapsed to a depth of approximately 17 mbgl on geophysical logging (initial depth was 39 m). This corresponds approximately to the base of the hard cap and top of the underlying Nammuldi Member.

The SWL was approximately 12.5 mbgl. The geothermal response was normal and showed a slight increase in temperature with depth. The gamma log indicated a slightly more clayey layer between 6 and 11 mbgl. Fresh water was encountered throughout the bore.

CB320

Mineral exploration bore CB320 was found to have collapsed to a depth of approximately 26 mbgl on geophysical logging (initial depth was 84 m). The bore had collapsed to within the alluvium.

The SWL was approximately 16 mbgl. The geothermal response was normal, with a slight inflection at 20 mbgl possibly indicating groundwater inflow at this level. The gamma log was relatively constant with depth. Fresh water was encountered from SWL to approximately 25 mbgl. Brackish water was encountered from 25 mbgl to the base of the bore at approximately 26 mbgl.

CB126

Mineral exploration bore CB0126 was found to have collapsed to a depth of approximately 19 mbgl on geophysical logging (initial depth was 84 m). This corresponds approximately to the base of the Tertiary detritals and top of the underlying hard cap.

CB125

Mineral exploration bore CB0125 was found to have collapsed to a depth of approximately 55 mbgl on geophysical logging (initial depth was 60 m). The collapsed zone corresponds approximately to the base of Nammuldi Member and top of the underlying Jeerinah Formation.

The SWL was approximately 23 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log ranged between 50-120 API, with a spike in the gamma response at approximately 33 mbgl within the ore zone. Fresh water was encountered throughout the bore.

CB400

Mineral exploration bore CB400 was found to have collapsed to a depth of approximately 30 mbgl on geophysical logging (initial depth was 60 m). This corresponds to the top of the ore zone.

The SWL was approximately 17 mbgl (approximately the base of the alluvium). The geothermal response was normal, with temperature gradually increasing with depth. A decrease in the gamma response was observed from approximately 17 mbgl to the base of the bore, corresponding to the base of the alluvium. Fresh water was encountered throughout the bore.

CB406

Mineral exploration bore CB406 was found to have collapsed to a depth of approximately 30 mbgl on geophysical logging (initial depth was 54 m). The bore has collapsed to within the shales of the Nammuldi Member.

The SWL was approximately 21 mbgl (within the shales of the Nammuldi Member). The geothermal response was normal, with temperature gradually increasing with depth. An increase in the gamma response was observed from approximately 18 mbgl to the base of the bore, approximately corresponding to the shales of the Nammuldi Member. Fresh water was encountered throughout the bore.

CB128

Mineral exploration bore CB128 was found to have collapsed to a depth of approximately 70 mbgl on geophysical logging (initial depth was 72 m).

The SWL was approximately 22 mbgl (within the alluvium). Fresh water was encountered from SWL to approximately 45 mbgl, with a brackish water inflow at approximately 37 mbgl (interface between hard cap and underlying shales of the Nammuldi Member). Brackish water was encountered between 45 mbgl and the base of the bore at 70 mbgl, with a fresh water inflow between 53 and 57 mbgl (top of the ore zone).

CB404

Water exploration bore CB404 was found to have collapsed to a depth of approximately 25 mbgl on geophysical logging (initial depth was 72 m). The bore has collapsed to within the alluvium.

The SWL was approximately 13.5 mbgl. The geothermal response showed an initial decrease at SWL. The gamma log was relatively constant with depth. Fresh water was encountered throughout the bore.

CB404a

Water exploration bore CB404a was found to have collapsed to a depth of approximately 12 mbgl on geophysical logging (initial depth was 38 m). The bore has collapsed to within the alluvium.

The SWL was approximately 9 mbgl. The geothermal response decreased with depth. The gamma log was relatively constant with depth. Fresh water was encountered throughout the bore.

CB404b

Water exploration bore CB404b was found to have collapsed to a depth of approximately 9 mbgl on geophysical logging (initial depth was 69 m). The bore has collapsed to within the alluvium.

The SWL was approximately 2.5 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth. Brackish water was encountered throughout the bore with conductivity gradually increasing with depth.

CB717

Water exploration bore CB717 was found to have collapsed to a depth of approximately 35 mbgl on geophysical logging (initial depth was 84 m). The bore has collapsed to within the lacustrine clays.

The SWL was approximately 12 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth. Fresh water was encountered throughout the bore.

CB068

Water exploration bore CB068 was found to have collapsed to a depth of approximately 24 mbgl on geophysical logging (initial depth was 69 m). This corresponds to the base of the alluvium and top of the lacustrine clays.

The SWL was approximately 9 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant between ground level and 17 mbgl, with a slight decrease in the gamma response at about 17 mbgl, suggesting a decrease in clay content in the alluvium.

Fresh water was encountered from SWL to 17 mbgl. Brackish water was encountered between 17 mbgl and the base of the bore at approximately 24 mbgl. The increase in salinity corresponds to the lower levels of the alluvium. The decrease in the gamma log towards the base of the alluvium possibly indicates a zone of higher groundwater yield.

CB068a

Water exploration bore CB068a was found to have collapsed to a depth of approximately 39 mbgl on geophysical logging (initial depth was 63 m). This corresponds to the base of the alluvium and top of the lacustrine clays.

The SWL was approximately 8 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth.

Fresh water was encountered from SWL to approximately 32 mbgl. Brackish water was encountered between 32 mbgl and the base of the bore at approximately 39 mbgl, with two fresh water inflows at 33 mbgl and 37 mbgl. The increase in salinity corresponds to the lower levels of the alluvium and the underlying clay and dolomite.

CB068b

Water exploration bore CB068b was found to have collapsed to a depth of approximately 27 mbgl on geophysical logging (initial depth was 35 m). This corresponds approximately to the base of the calcrete and top of the lacustrine clays.

The SWL was approximately 4 mbgl. After an initial temperature high at the top of the bore, the geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth with a significant decrease between 13 and 22 mbgl, corresponding to the top of a calcrete layer.

Brackish water was encountered from SWL to approximately 16.5 mbgl. Saline water (conductivity >2000 mS/m) was encountered between the 16.5 mbgl and the base of the bore at approximately 27 mbgl. The increase in salinity corresponds to the calcrete horizon.

CB323a

Water exploration bore CB323a was found to have collapsed to a depth of approximately 29 mbgl on geophysical logging (initial depth was 75 m). This corresponds to the base of the alluvium and top of the lacustrine clays.

The SWL was approximately 8 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log was relatively constant with depth, with slight decreases at 24, 26 and 28 mbgl.

Fresh water was encountered from SWL to approximately 23 mbgl. Brackish water was encountered between 23 mbgl and the base of the bore at approximately 29 mbgl, with fresh water inflows at 25 and 28 mbgl. The increase in salinity corresponds to the base of the alluvium and approximately with a zone of higher water yield between 27 and 30 mbgl. The peaks in the conductivity response correspond to the lower gamma responses.

CB323b

Water exploration bore CB323b was found to have collapsed to a depth of approximately 21 mbgl on geophysical logging (initial depth was 35 m). The bore has collapsed to within the lacustrine clays.

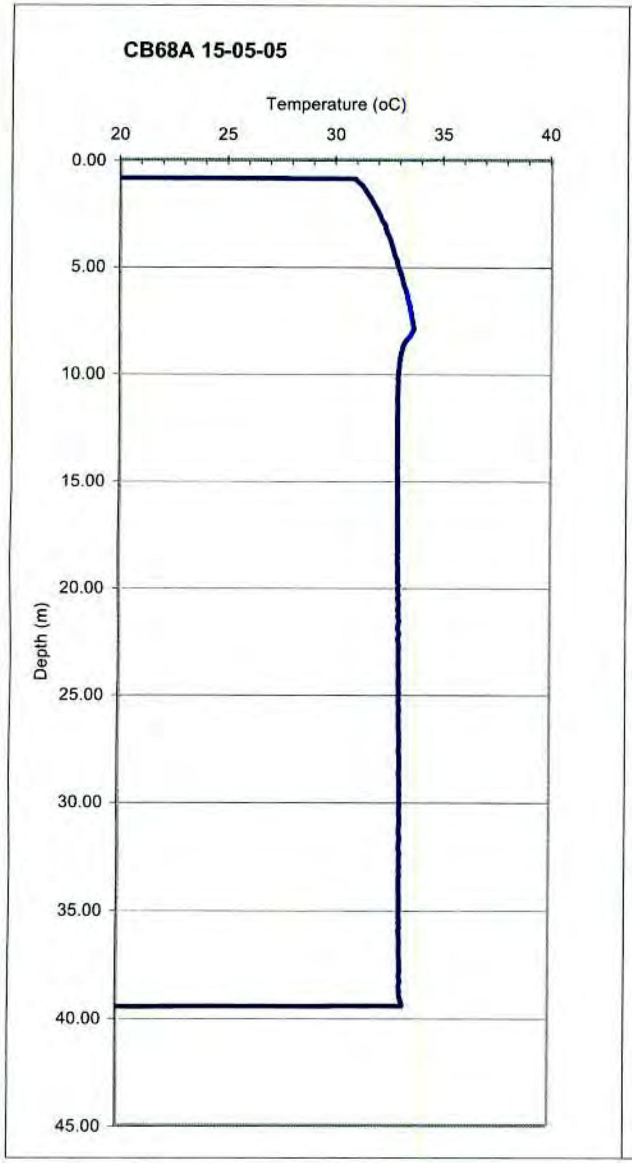
The SWL was approximately 3.5 mbgl. After an initial temperature high at the top of the bore, the geothermal response was normal, with temperature gradually increasing with depth. The gamma log showed a decrease between approximately 3 and 13 mbgl, corresponding to a calcrete/marl clay replacement zone.

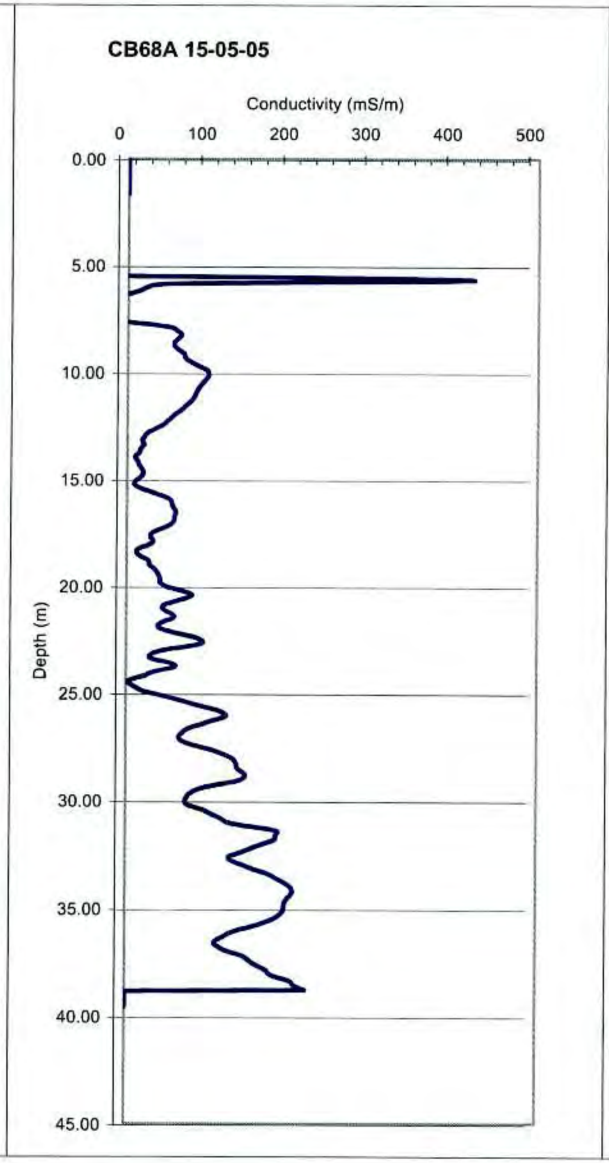
Brackish water was encountered at the top of the bore from SWL to approximately 10.5 mbgl. Saline water was encountered between 10.5 mbgl and the base of the bore at approximately 21 mbgl.

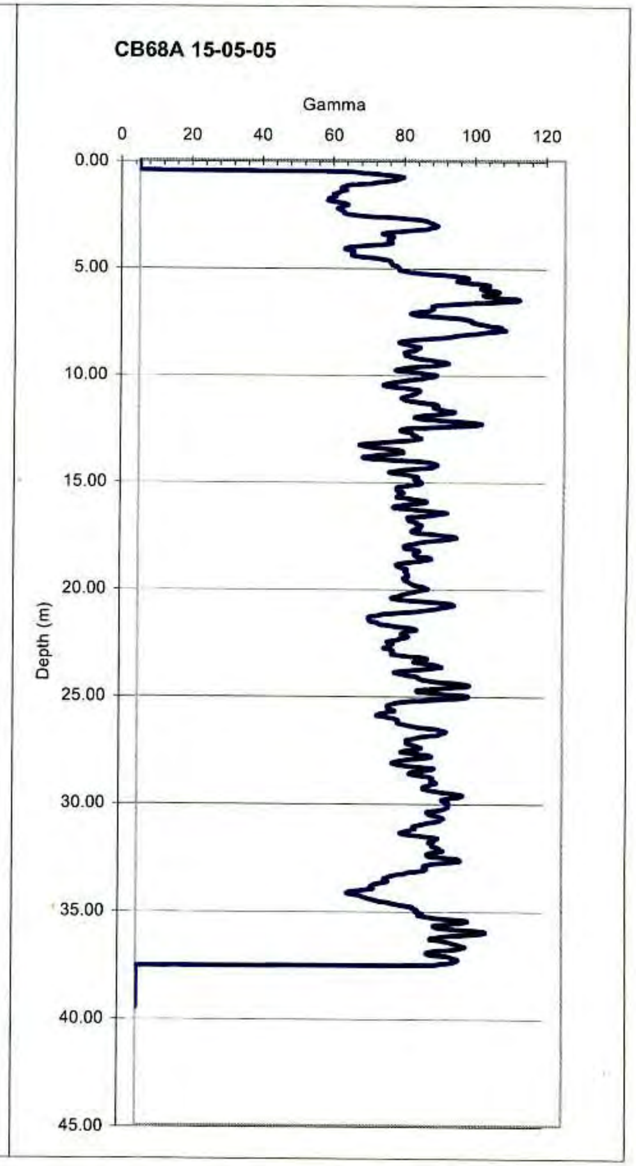
CB471T

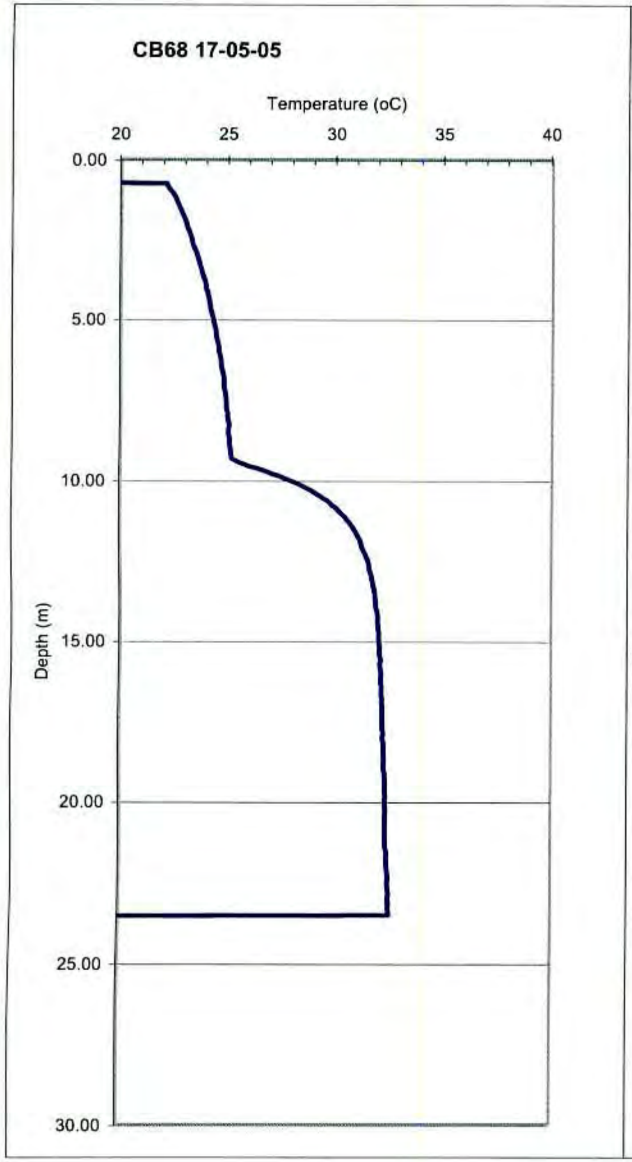
The SWL in trial bore CB471T was approximately 17 mbgl. The geothermal response was normal, with temperature gradually increasing with depth. The gamma log showed a slight decrease from approximately 18 mbgl to the base of the bore, corresponding to the Marra Mamba.

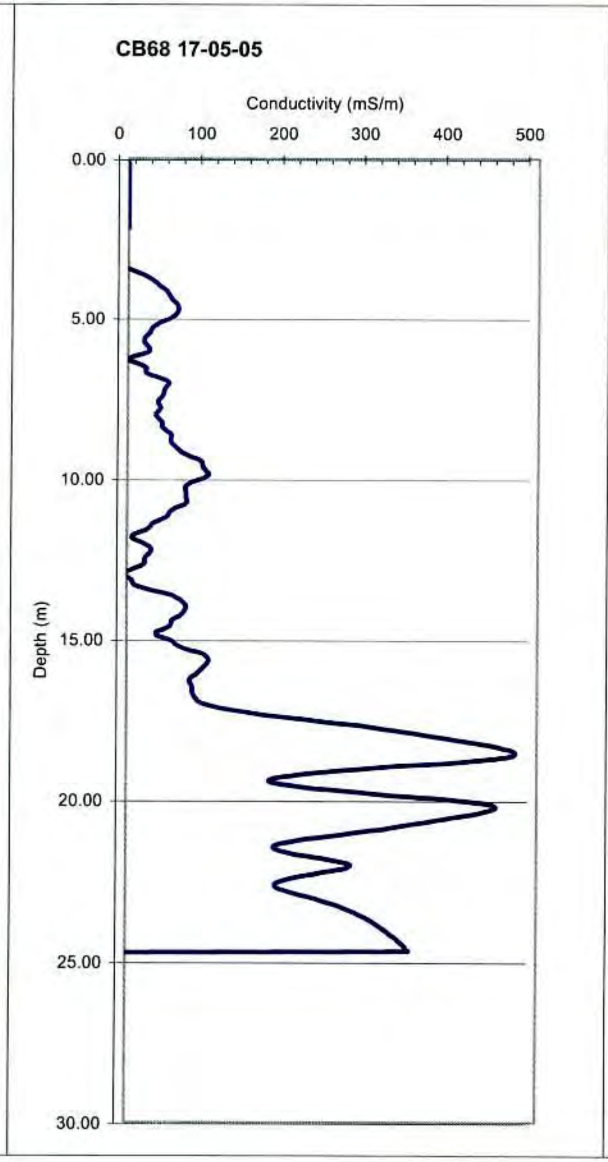
Fresh water was generally encountered within the bore. A peak in the conductivity log was observed between 19 and 25 mbgl. It is likely that this reflects the conductivity probe passing through a band of highly conductive iron ore mineral. The peak in the conductivity log corresponds to the top of the ore zone (ore zone 19 to 35 mbgl).

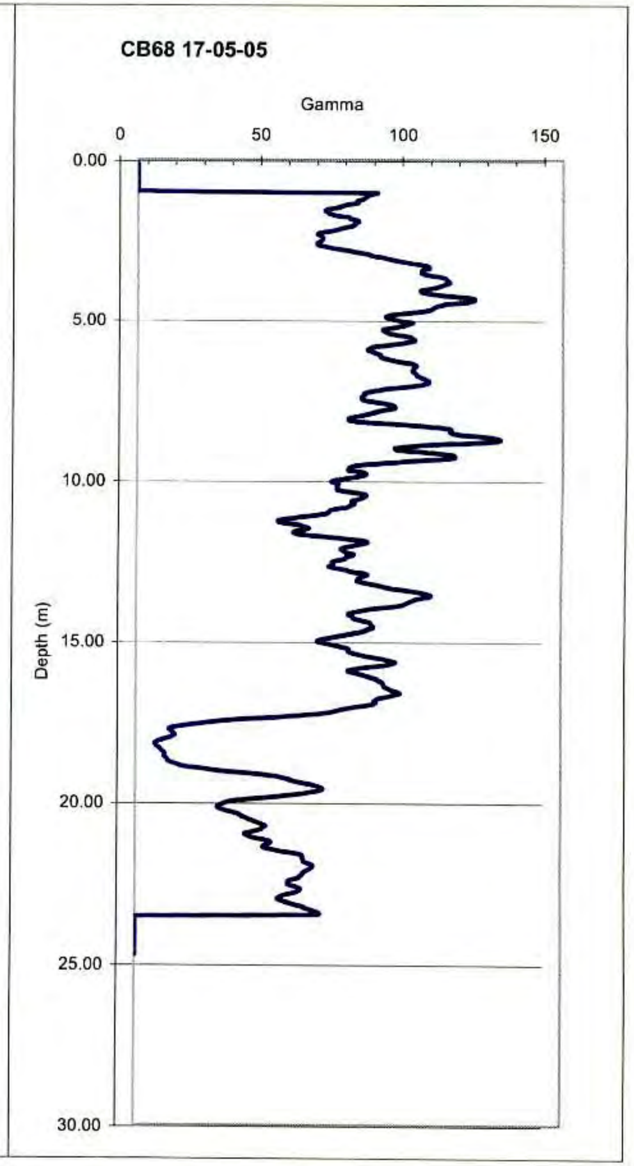

CB68A 15-05-05
Temperature (oC)
20
25
30
35
40
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00

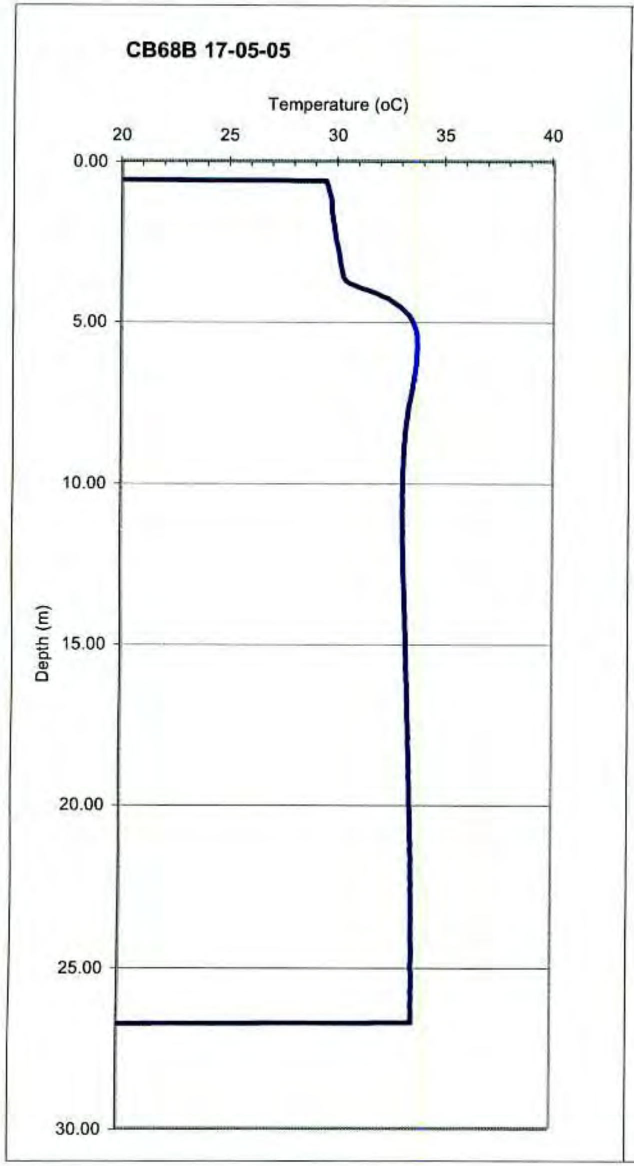

CB68A 15-05-05
Conductivity (mS/m)
0
100
200
300
400
500
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00

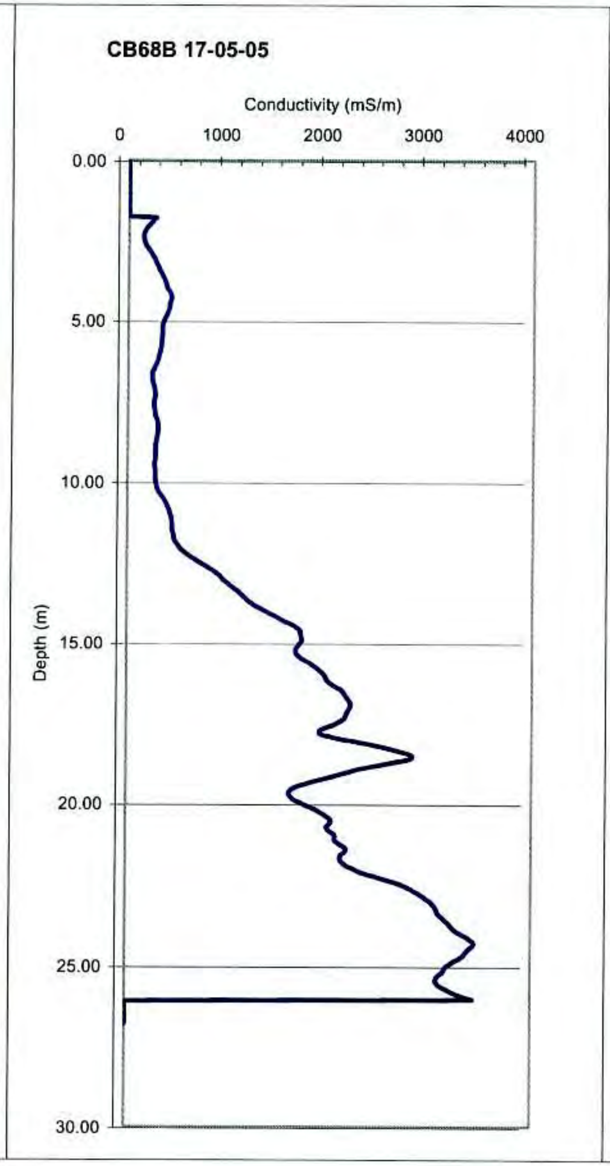

CB68A 15-05-05
Gamma
0
20
40
60
80
100
120
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00

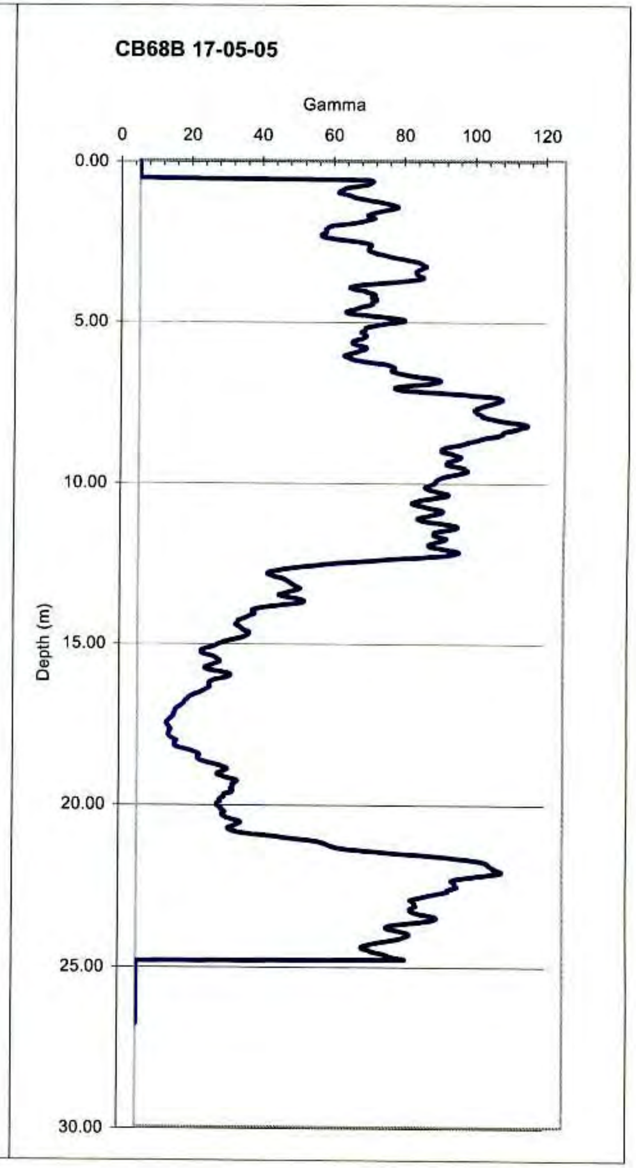

CB68 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

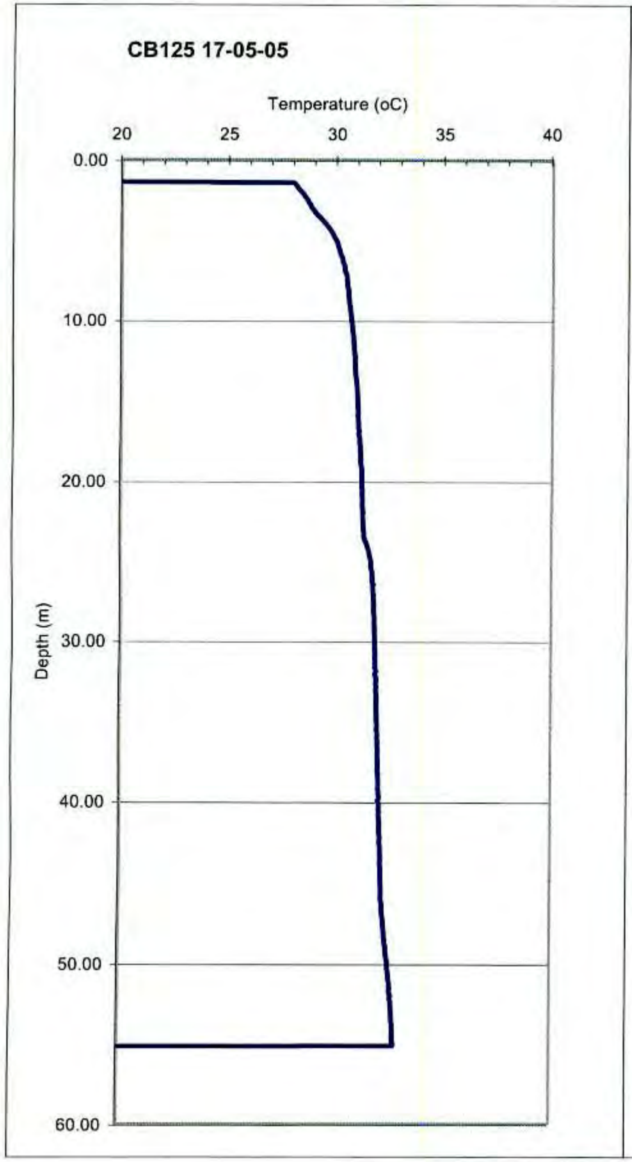

CB68 17-05-05
Conductivity (mS/m)
0
100
200
300
400
500
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

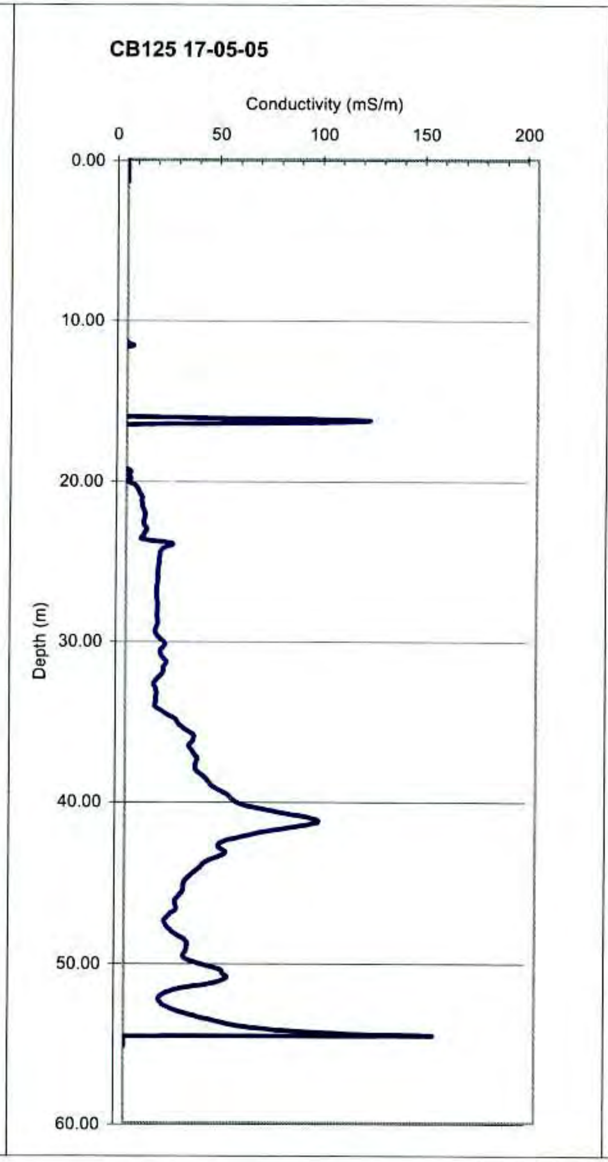

CB68 17-05-05
Gamma
0
50
100
150
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

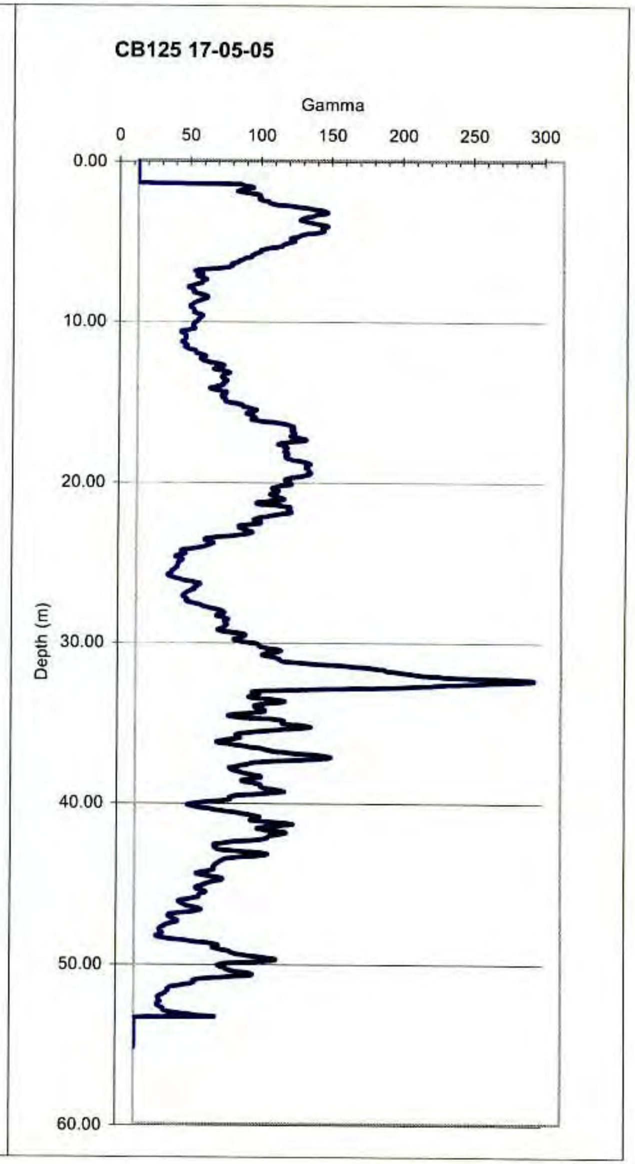

CB68B 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

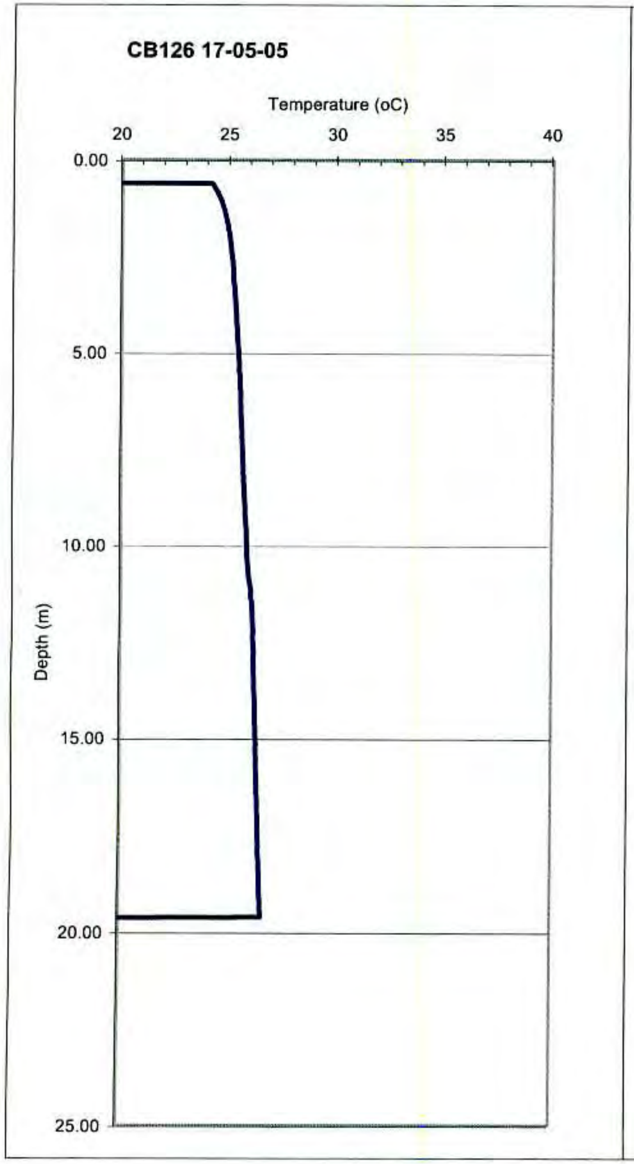

CB68B 17-05-05
Conductivity (mS/m)
0
1000
2000
3000
4000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

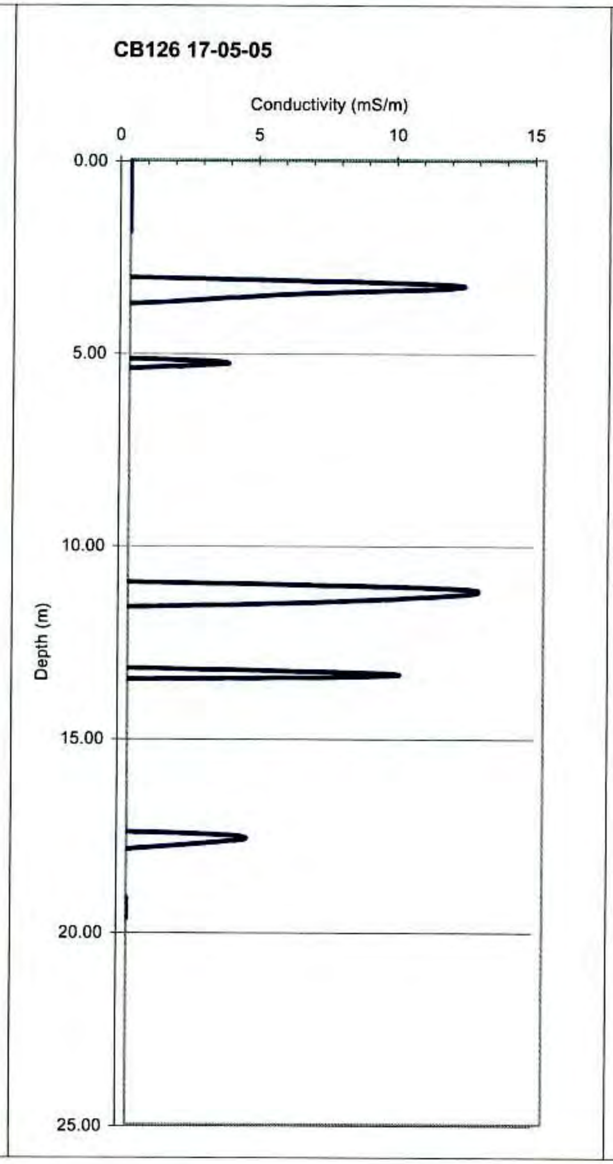

CB68B 17-05-05
Gamma
0
20
40
60
80
100
120
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

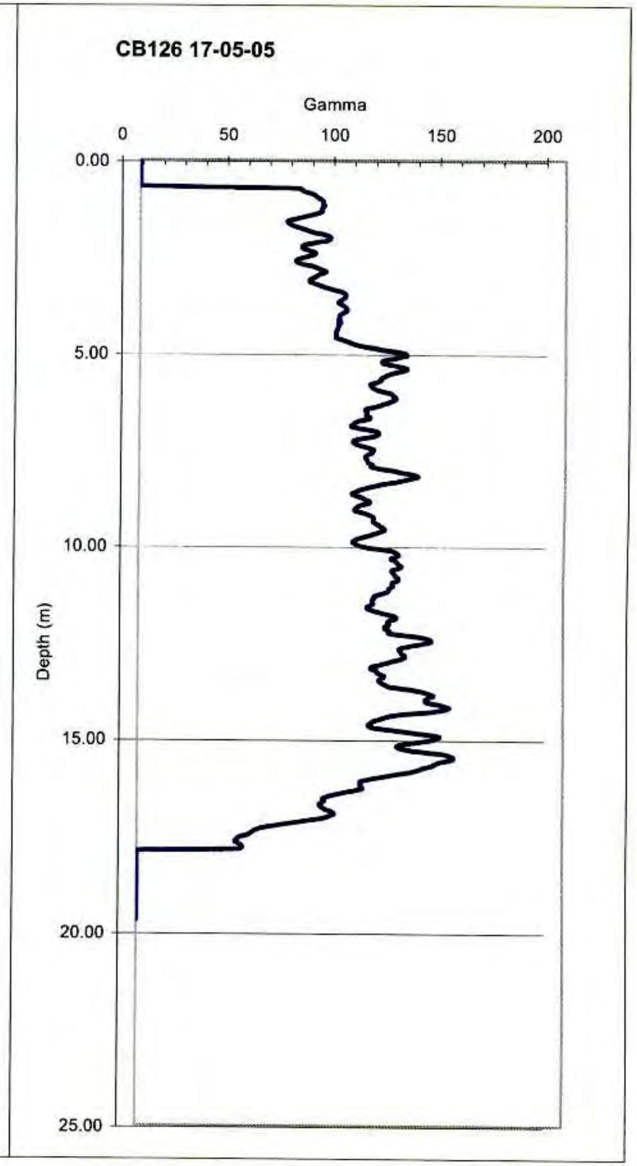

CB125 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Depth (m)

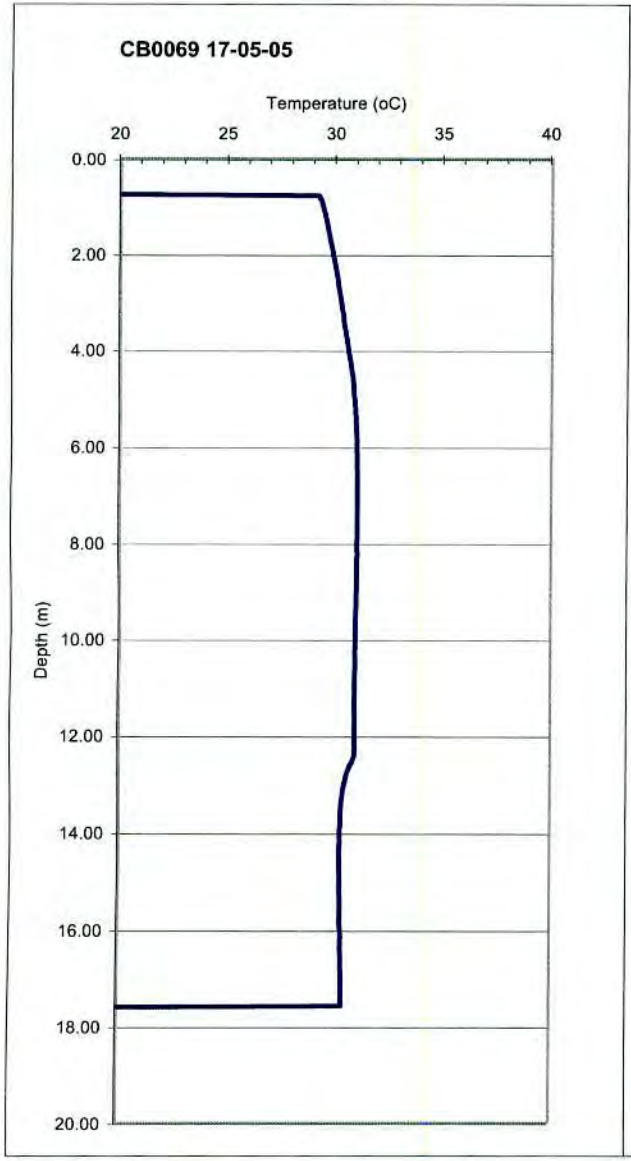

CB125 17-05-05
Conductivity (mS/m)
0
50
100
150
200
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Depth (m)

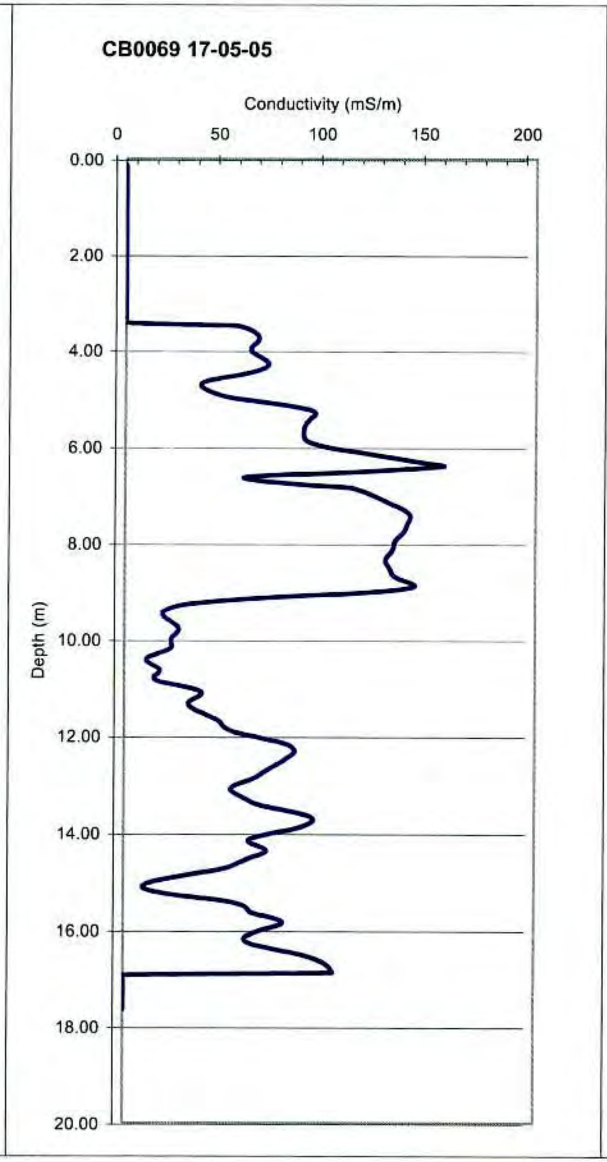

CB125 17-05-05
Gamma
0
50
100
150
200
250
300
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Depth (m)

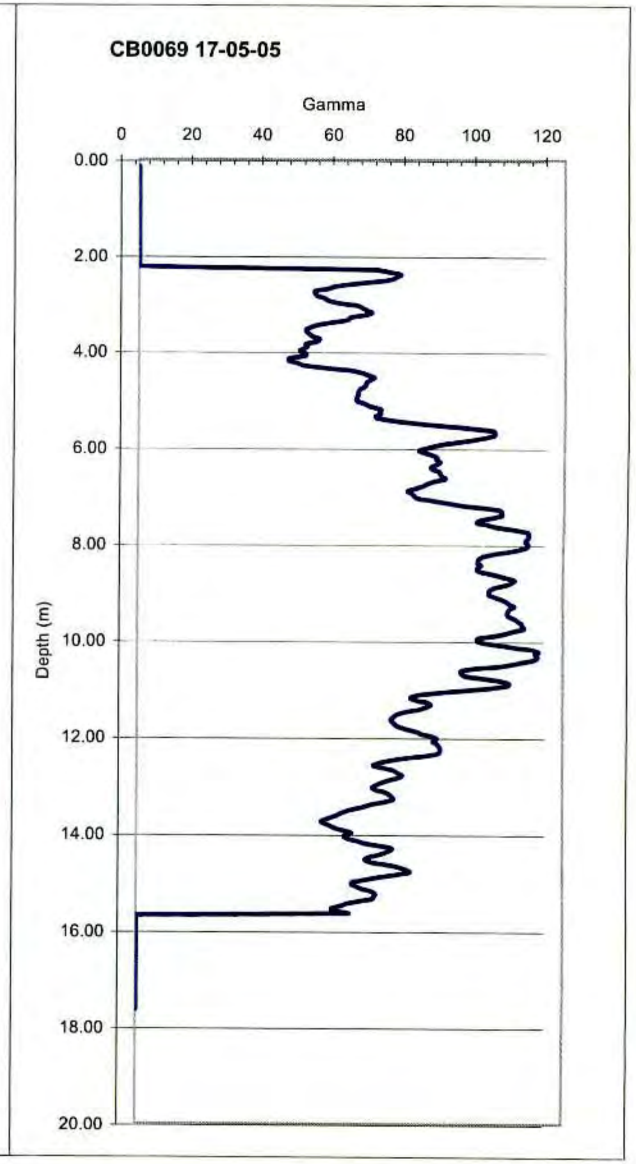

CB126 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
Depth (m)

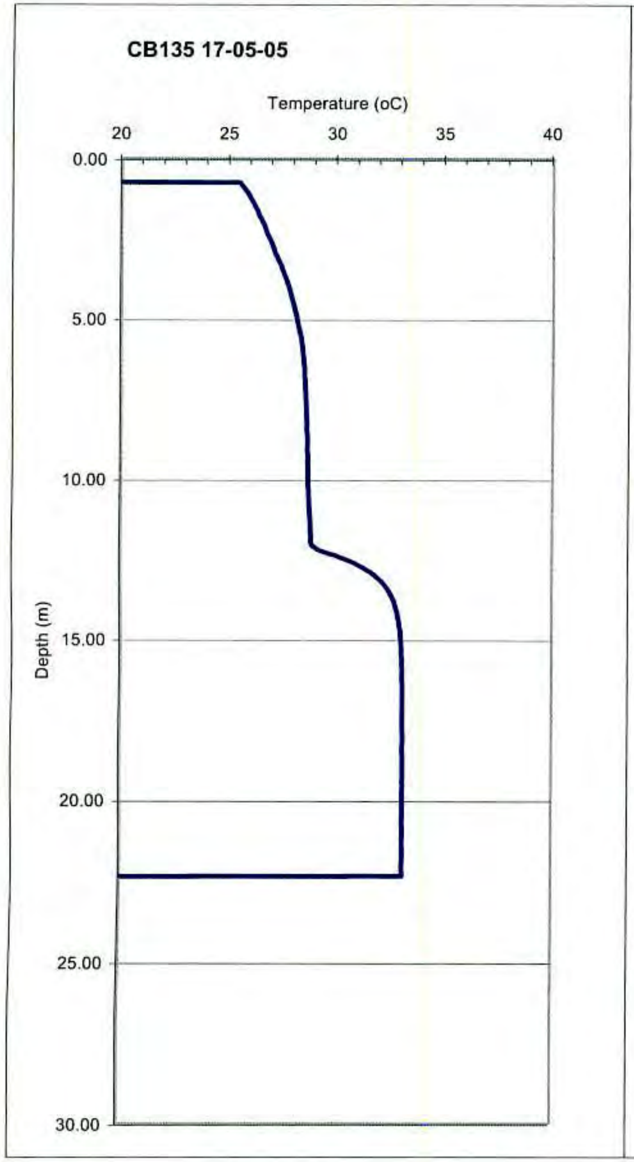

CB126 17-05-05
Conductivity (mS/m)
0
5
10
15
0.00
5.00
10.00
15.00
20.00
25.00
Depth (m)

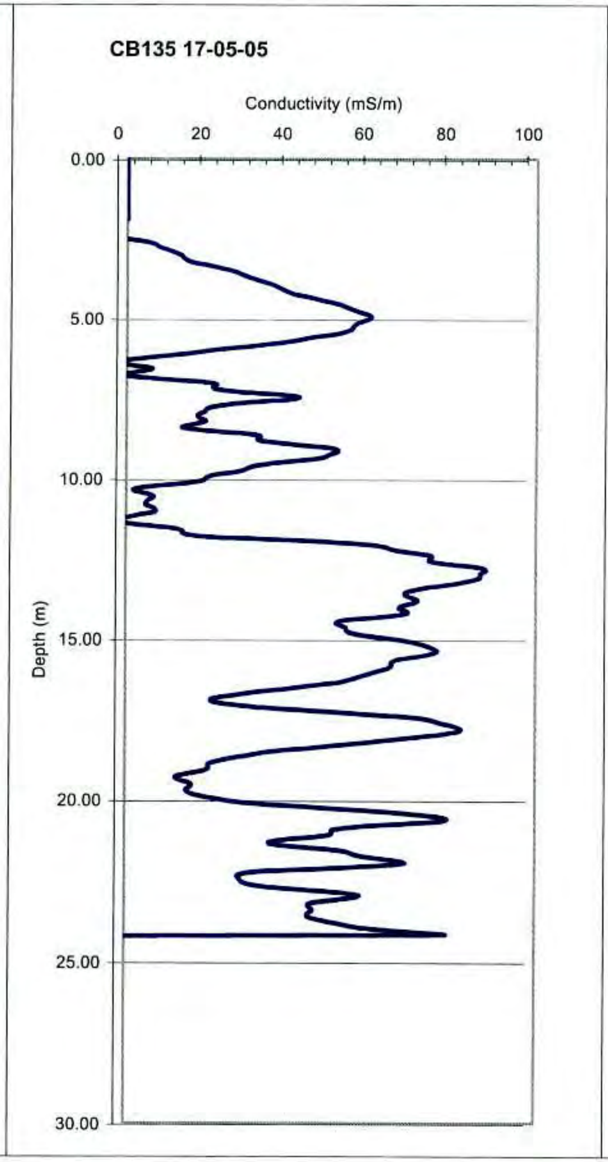

CB126 17-05-05
Gamma
0
50
100
150
200
0.00
5.00
10.00
15.00
20.00
25.00
Depth (m)

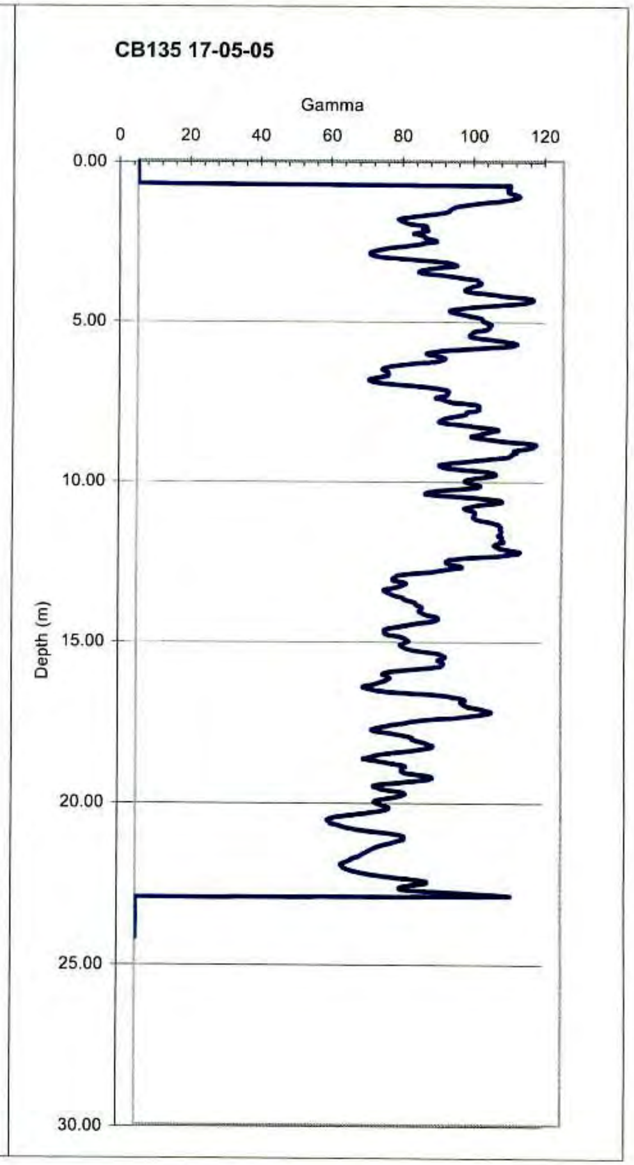

CB0069 17-05-05
Temperature (oC)
20
25
30
35
40
Depth (m)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00

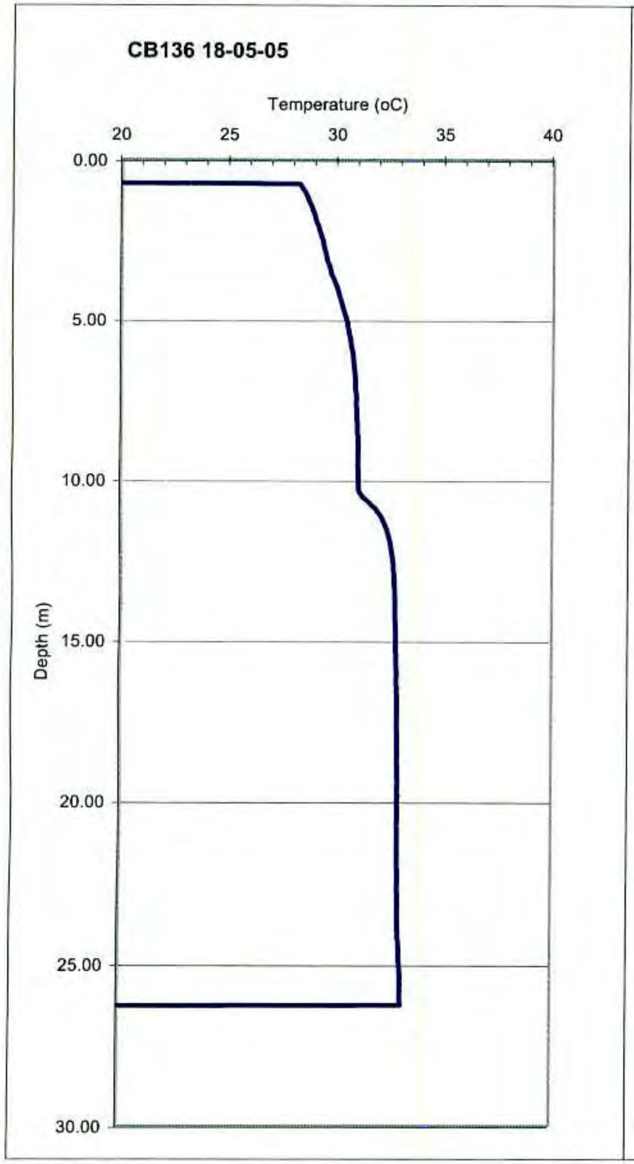

CB0069 17-05-05
Conductivity (mS/m)
0
50
100
150
200
Depth (m)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00

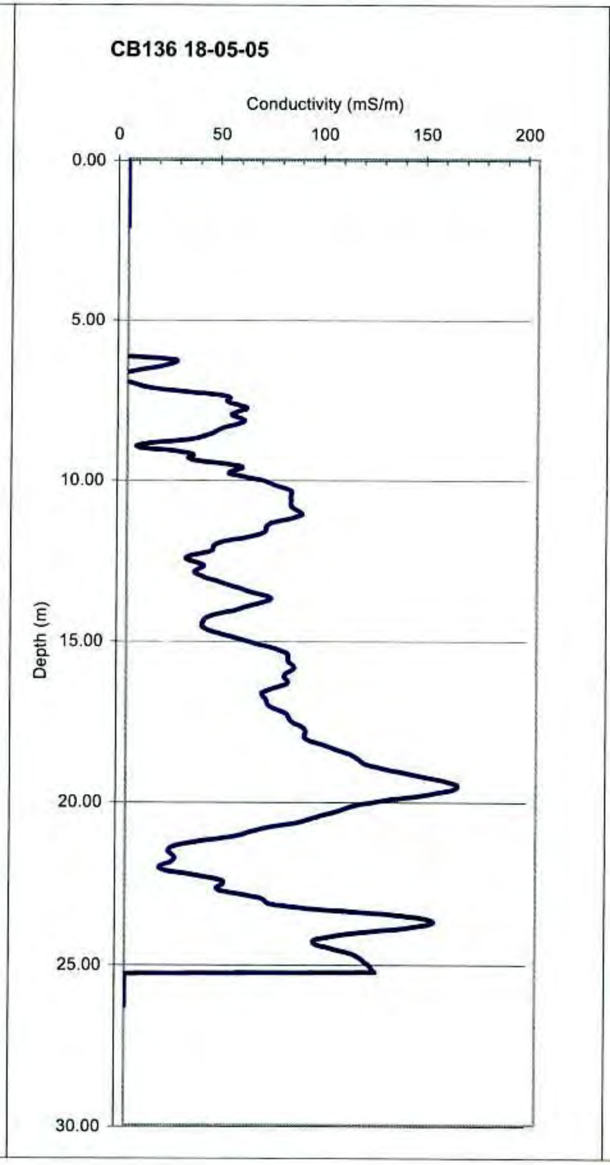

CB0069 17-05-05
Gamma
0
20
40
60
80
100
120
Depth (m)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00

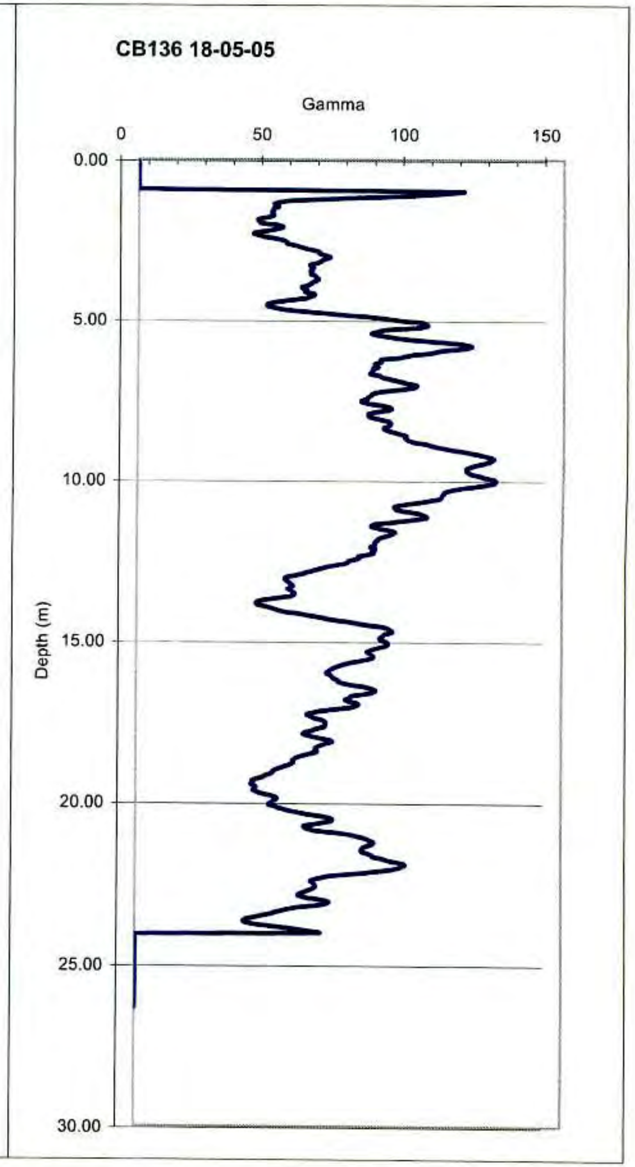

CB135 17-05-05
Temperature (oC)
20
25
30
35
40
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00

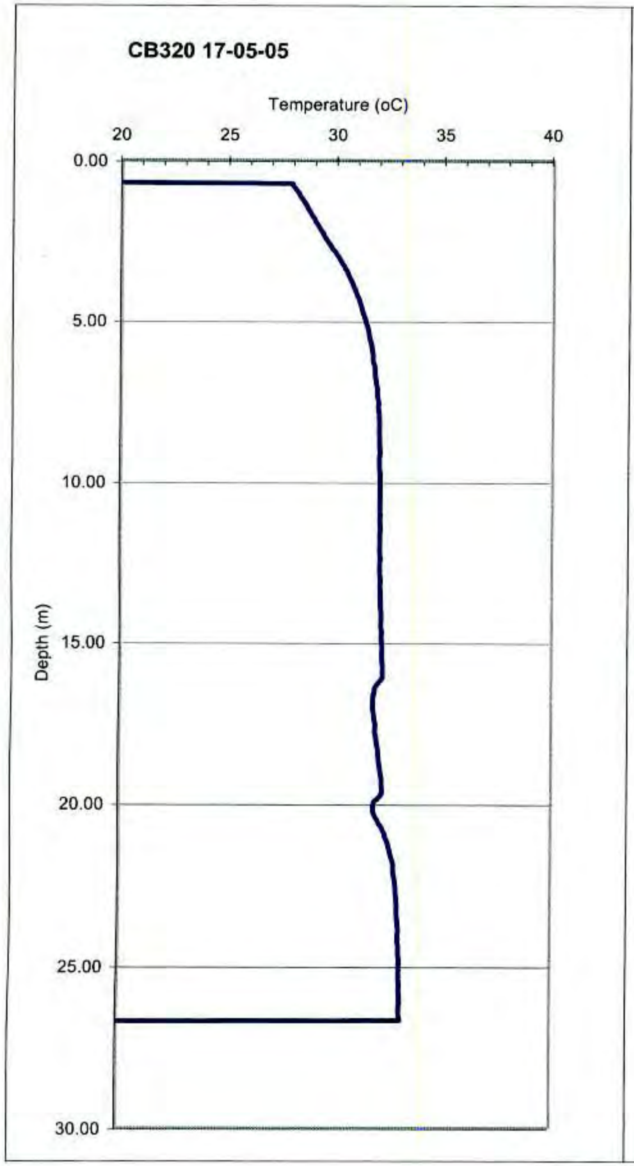

CB135 17-05-05
Conductivity (mS/m)
0
20
40
60
80
100
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00


CB135 17-05-05
Gamma
0
20
40
60
80
100
120
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00

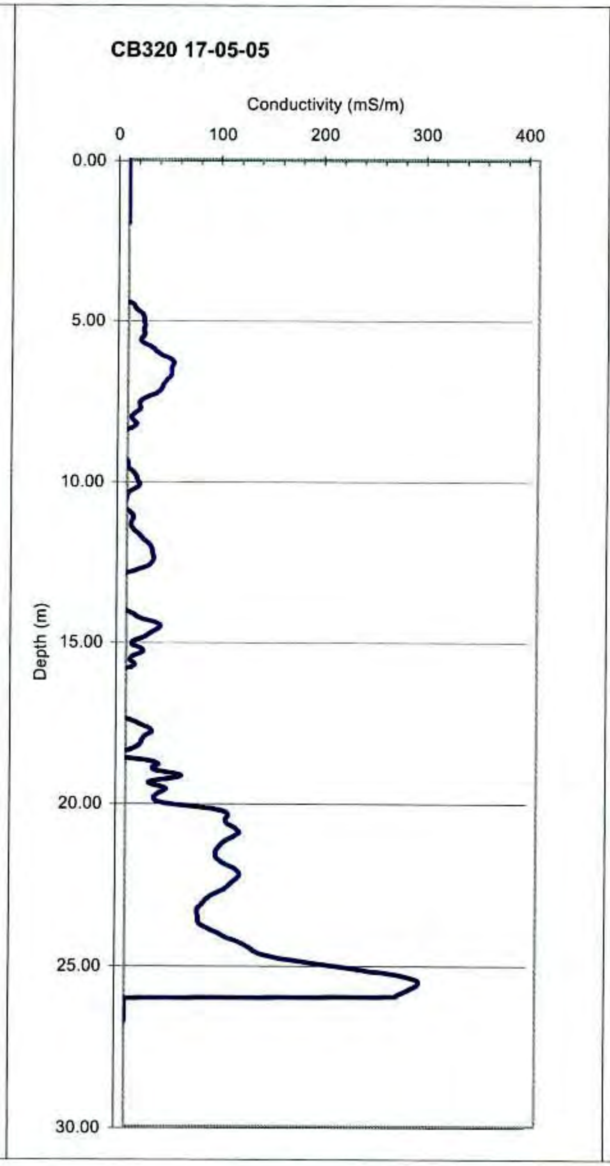

CB136 18-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)


CB136 18-05-05
Conductivity (mS/m)
0
50
100
150
200
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

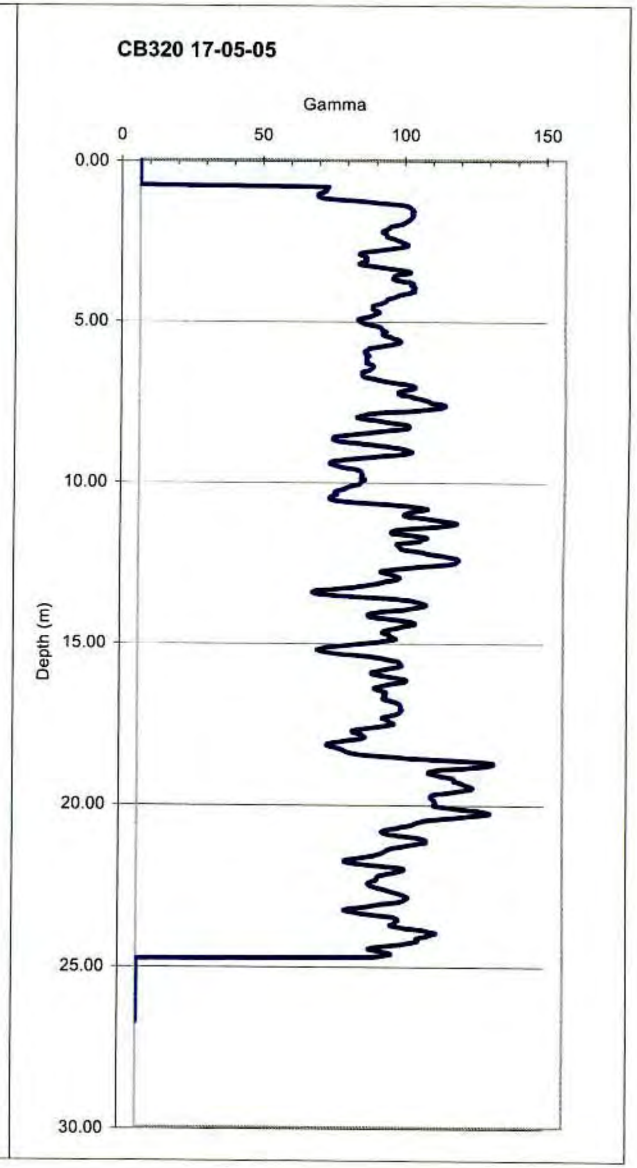

CB136 18-05-05
Gamma
0
50
100
150
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)



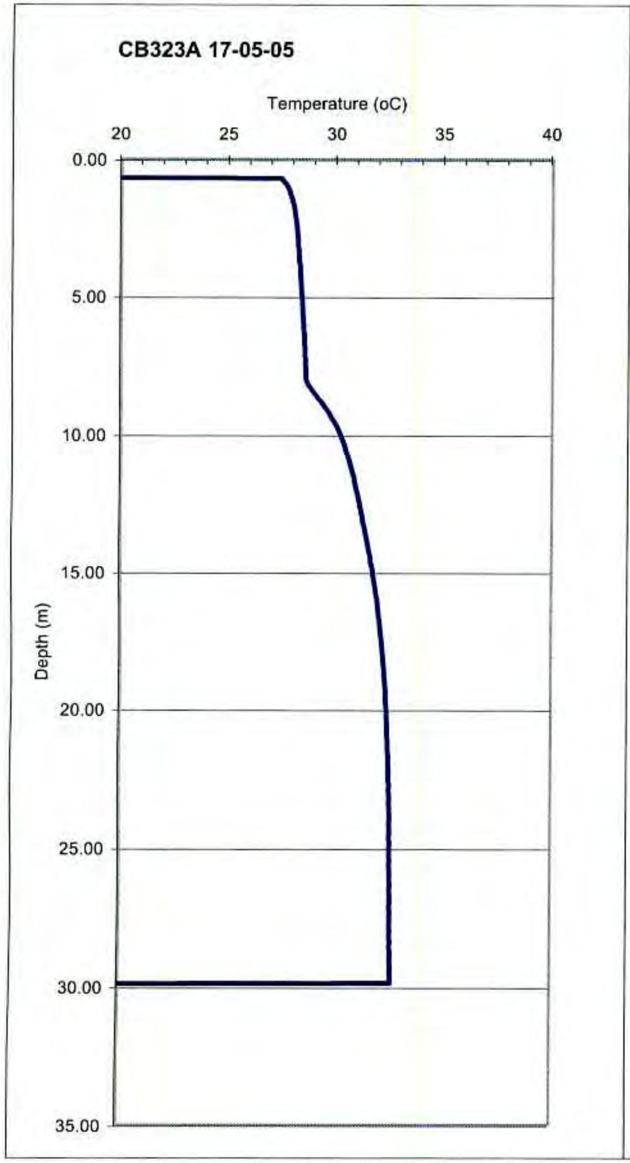
CB320 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

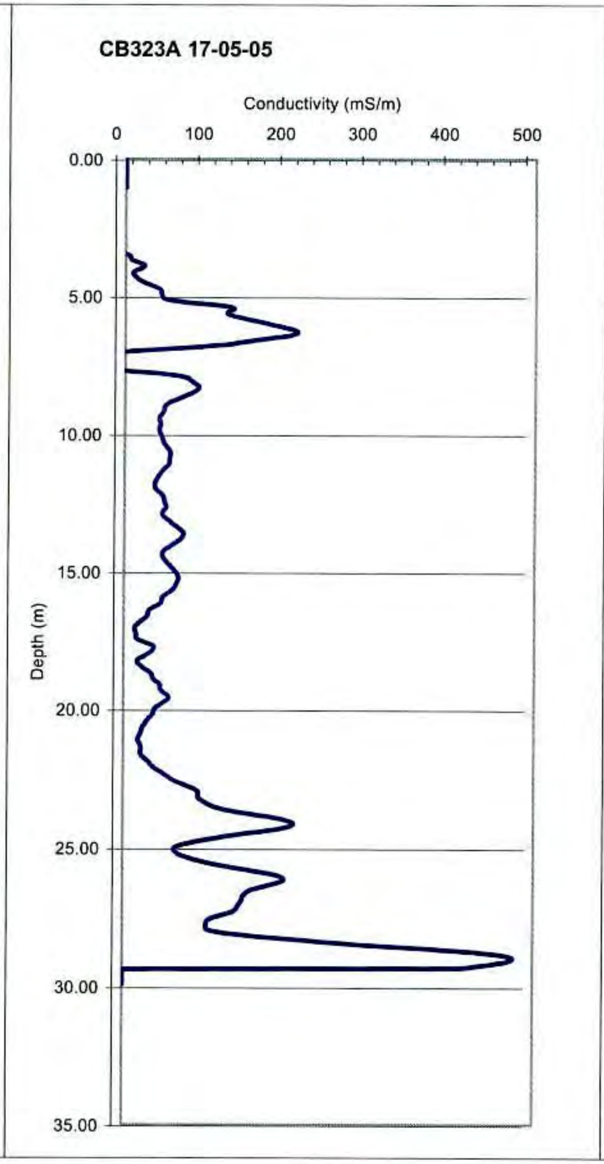


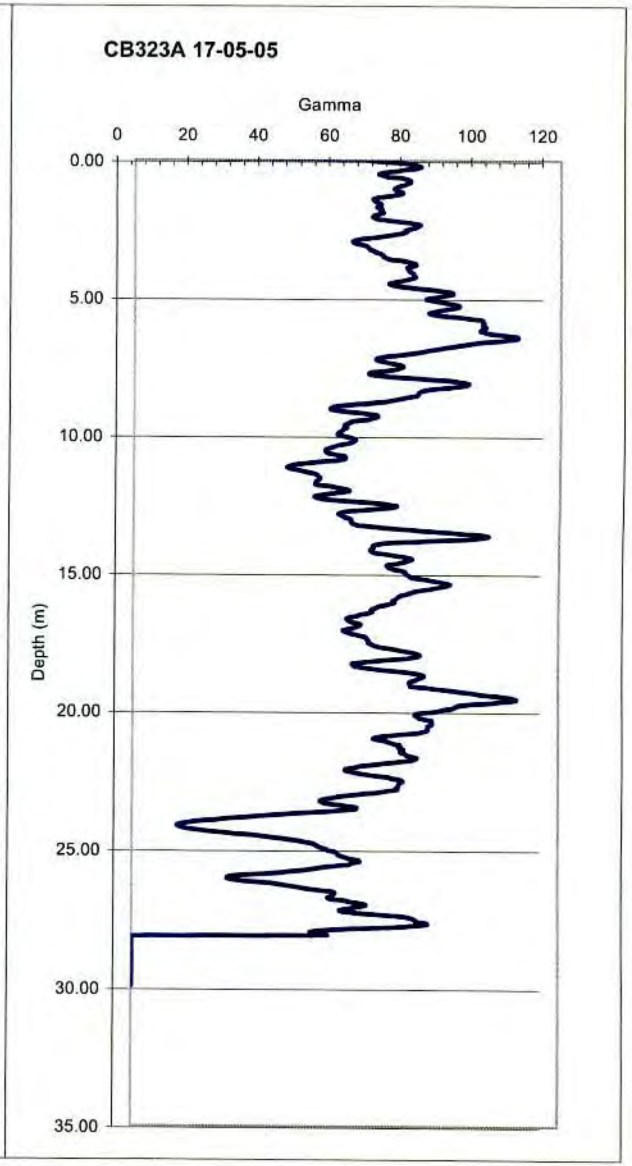
CB320 17-05-05
Conductivity (mS/m)
0
100
200
300
400
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

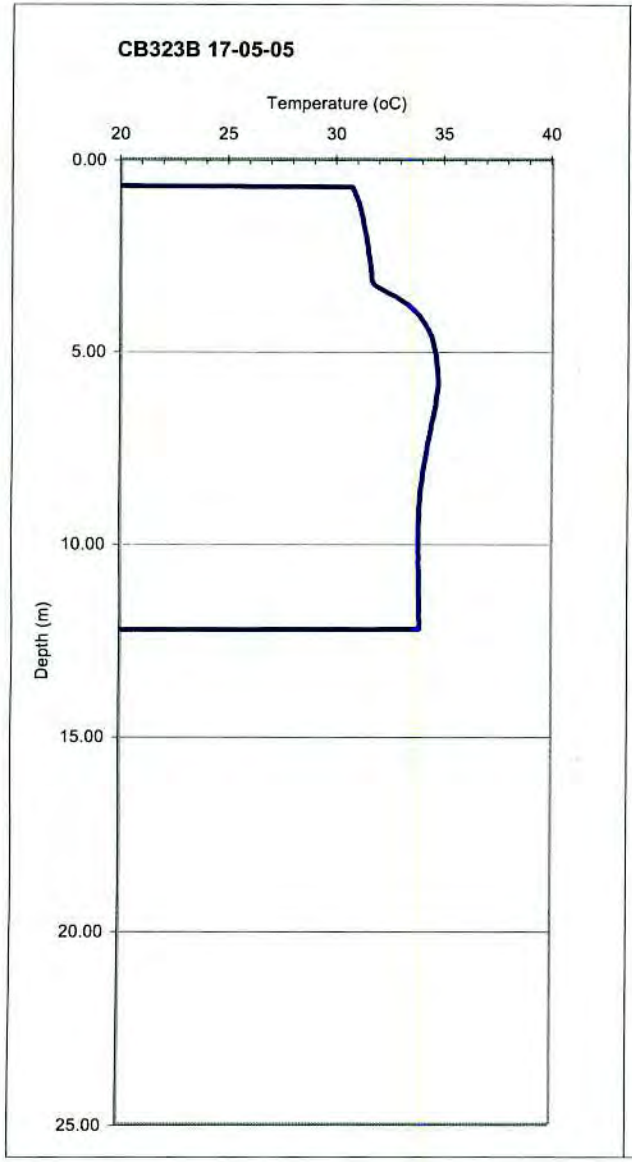


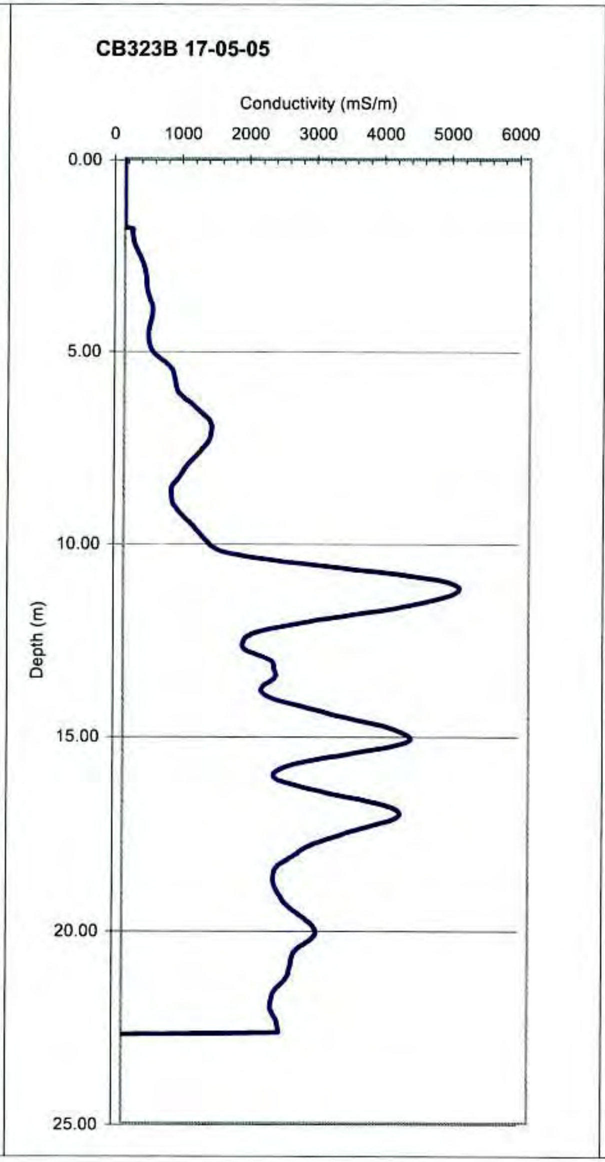
CB320 17-05-05
Gamma
0
50
100
150
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

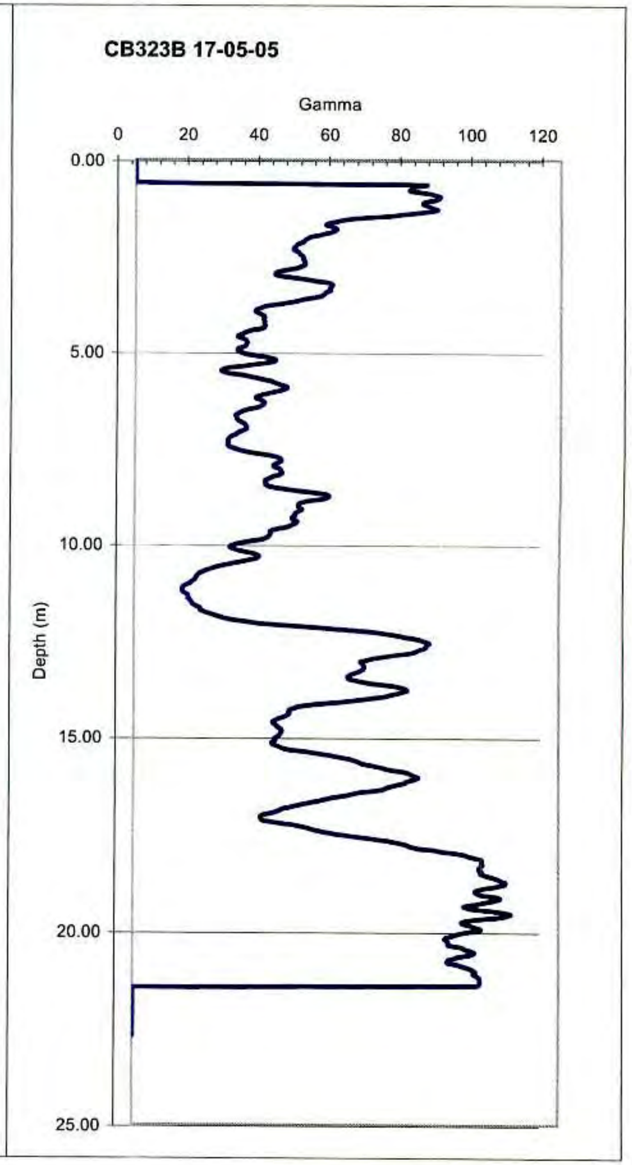

CB323A 17-05-05
Temperature (oC)
20
25
30
35
40
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00

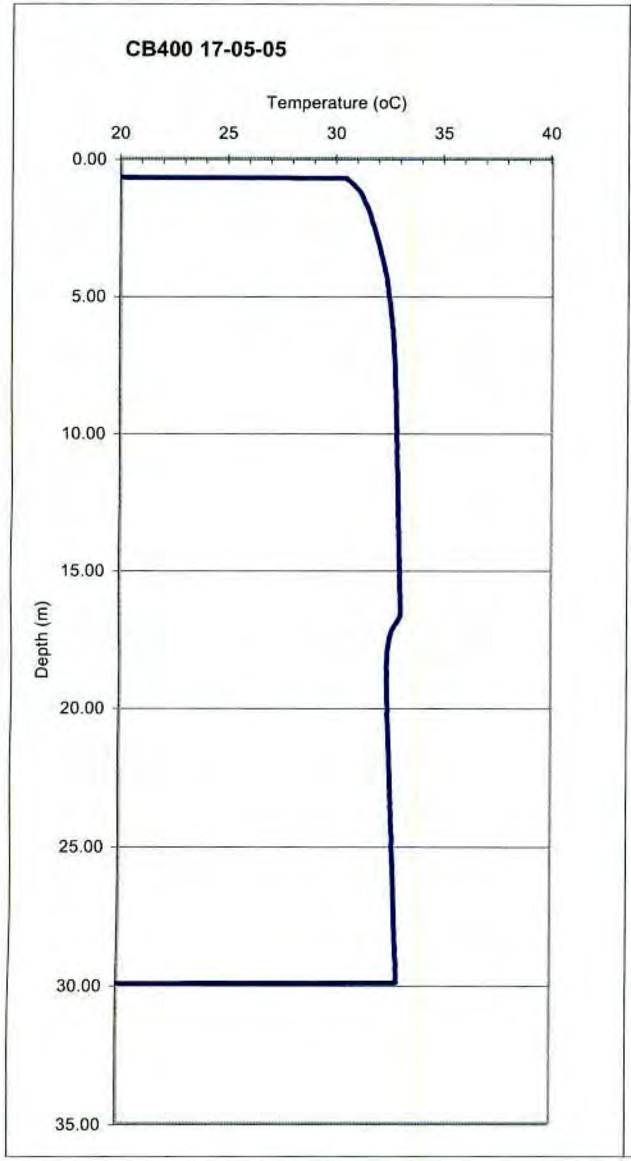

CB323A 17-05-05
Conductivity (mS/m)
0
100
200
300
400
500
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00

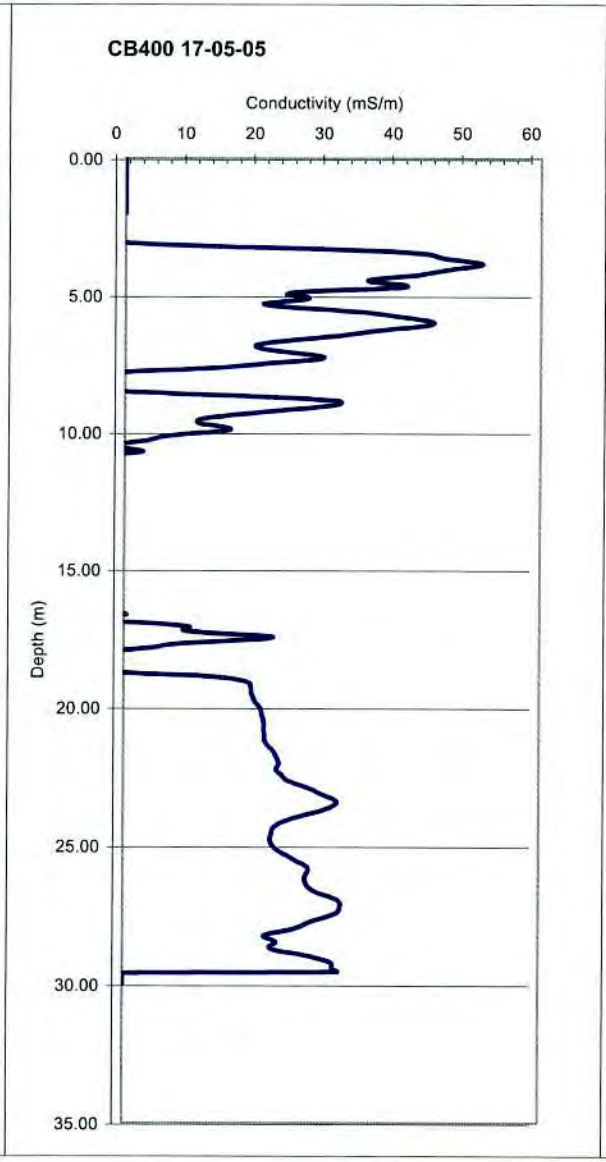

CB323A 17-05-05
Gamma
0
20
40
60
80
100
120
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00

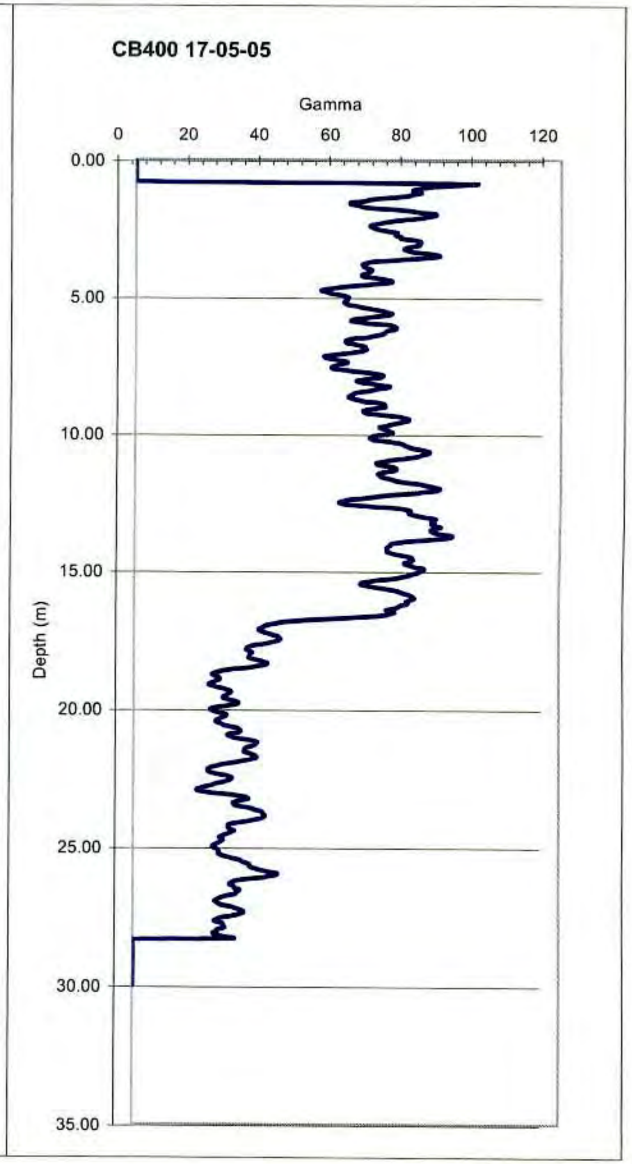

CB323B 17-05-05
Temperature (oC)
20 25 30 35 40
0.00
5.00
10.00
15.00
20.00
25.00
Depth (m)

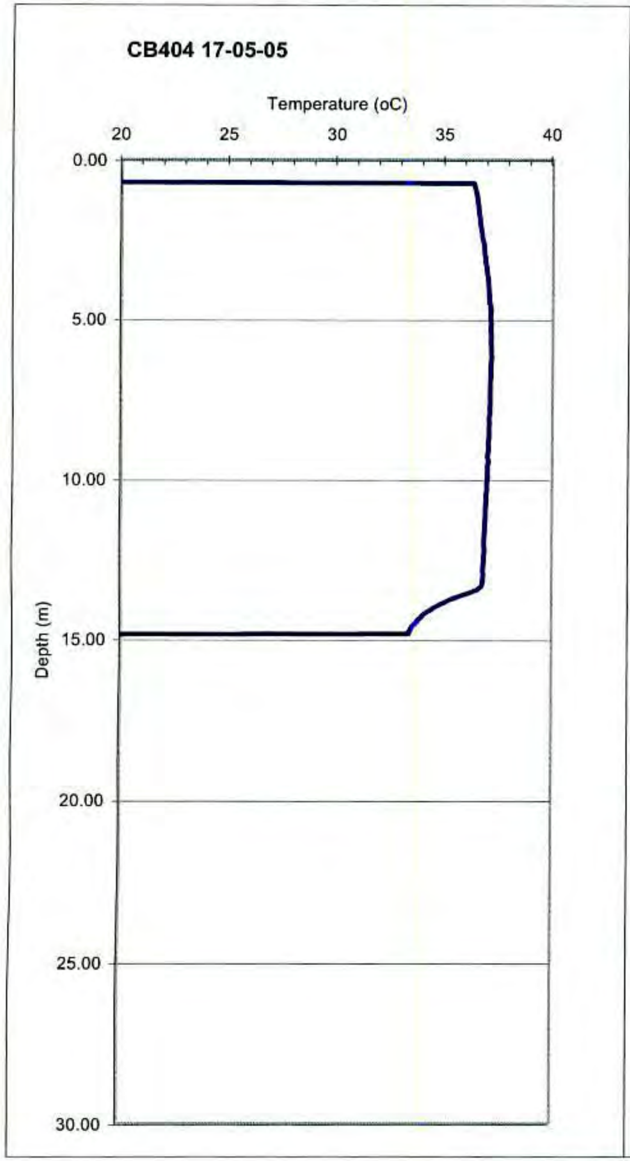

CB323B 17-05-05
Conductivity (mS/m)
0 1000 2000 3000 4000 5000 6000
0.00
5.00
10.00
15.00
20.00
25.00
Depth (m)

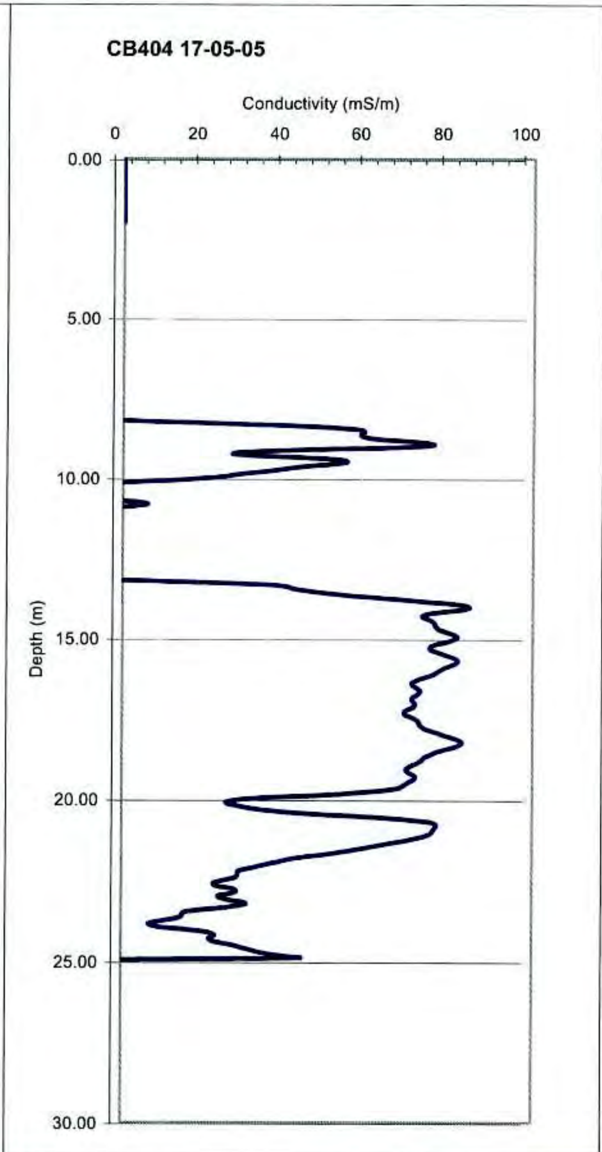

CB323B 17-05-05
Gamma
0 20 40 60 80 100 120
0.00
5.00
10.00
15.00
20.00
25.00
Depth (m)

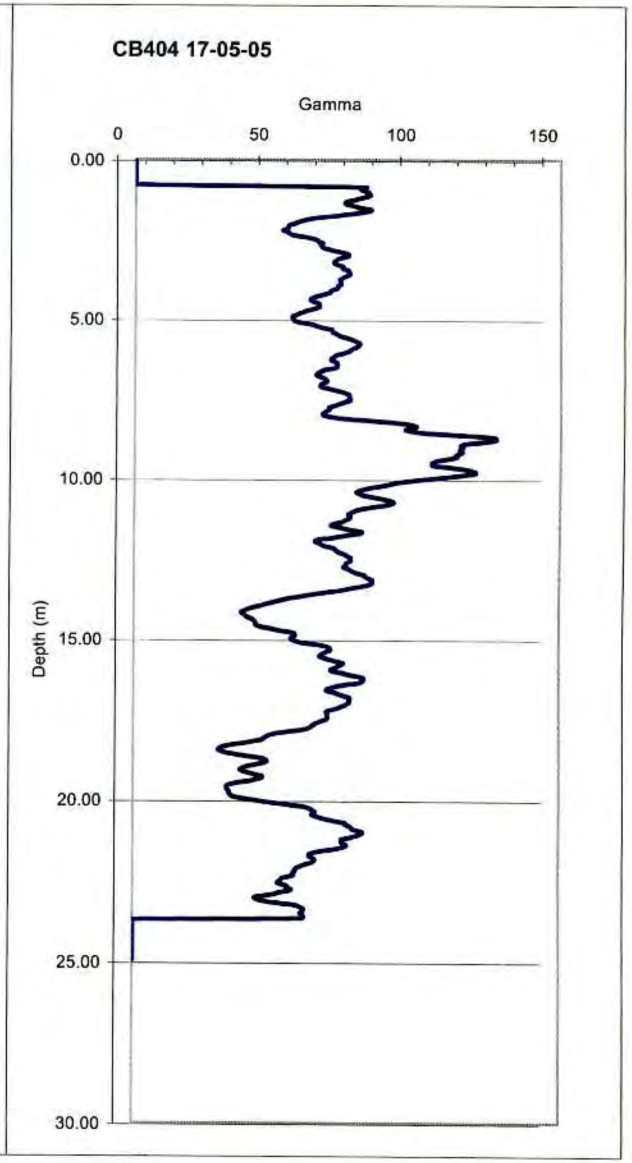

CB400 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Depth (m)

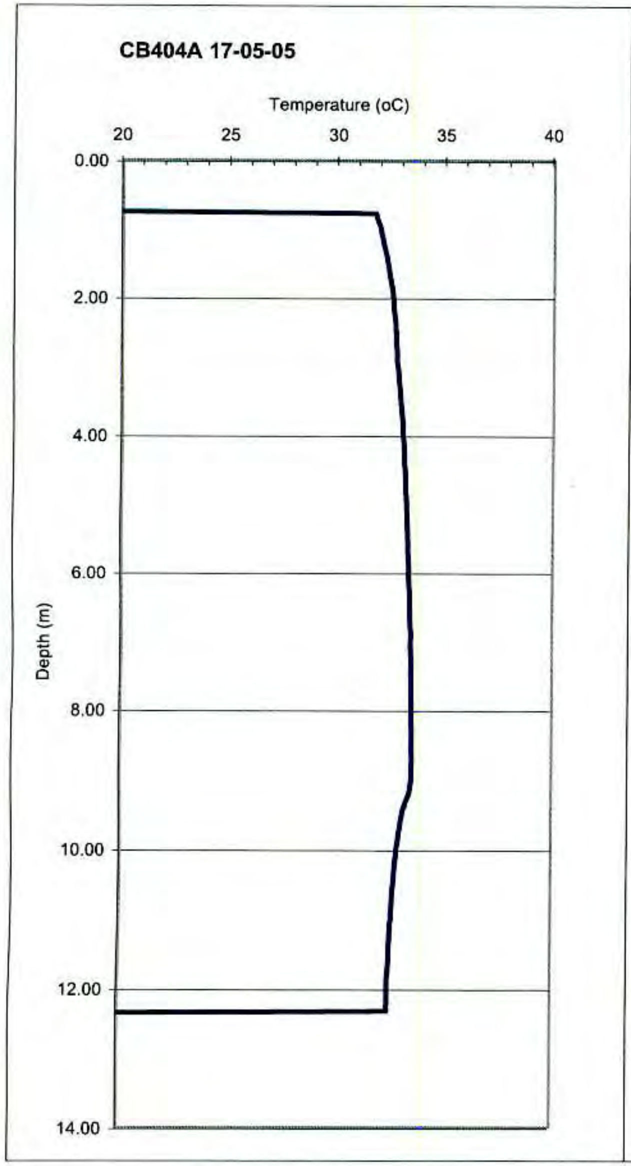

CB400 17-05-05
Conductivity (mS/m)
0
10
20
30
40
50
60
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Depth (m)

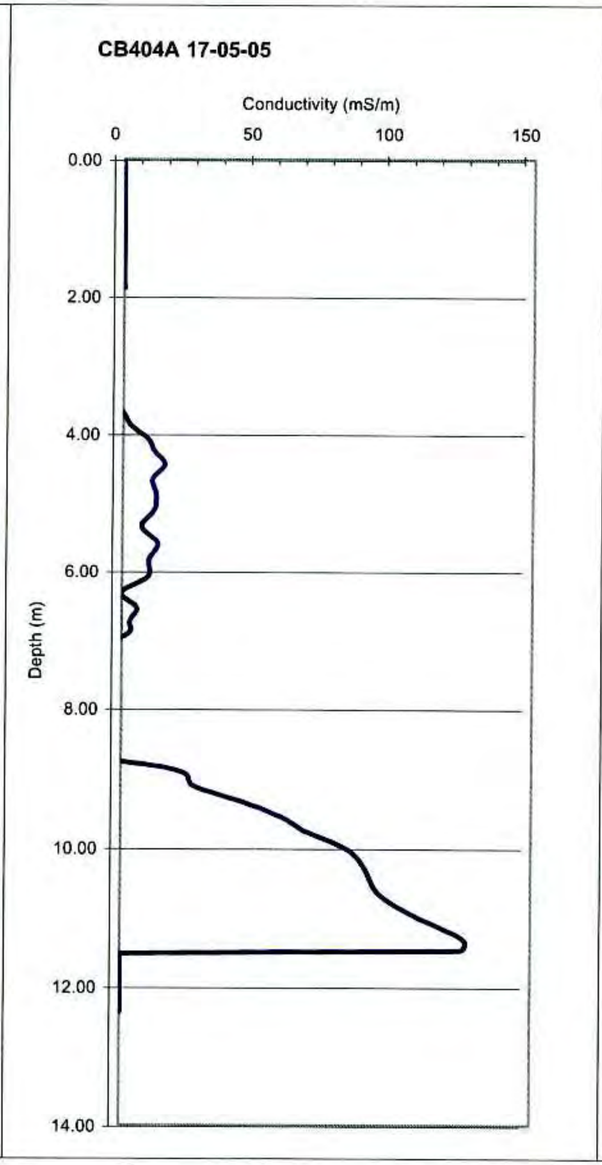

CB400 17-05-05
Gamma
0
20
40
60
80
100
120
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
Depth (m)

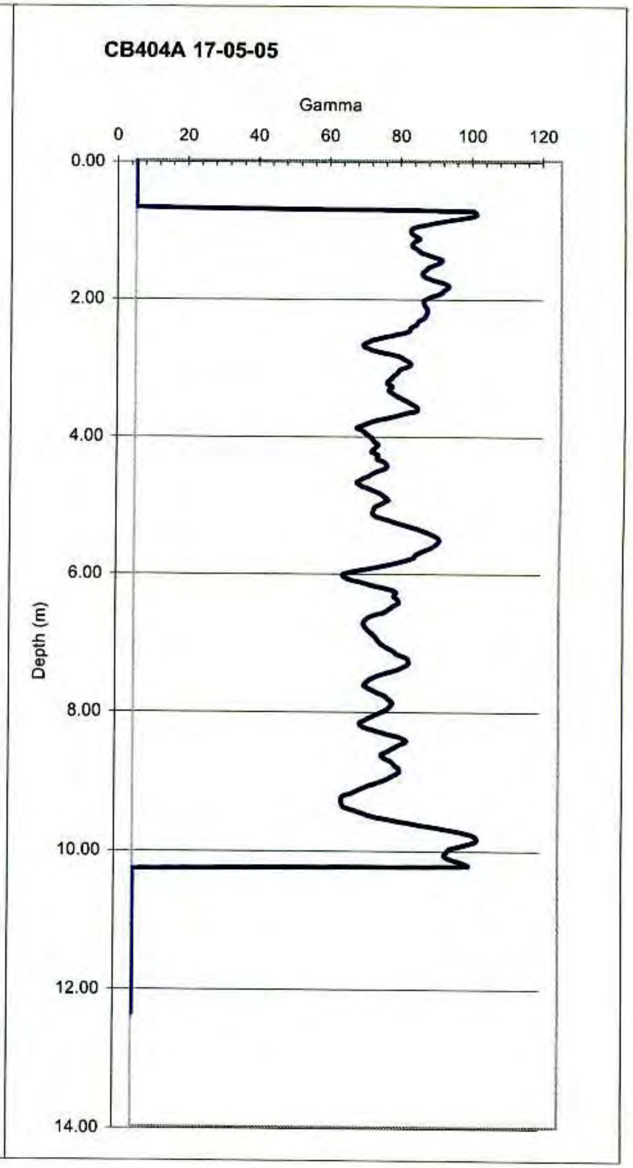

CB404 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

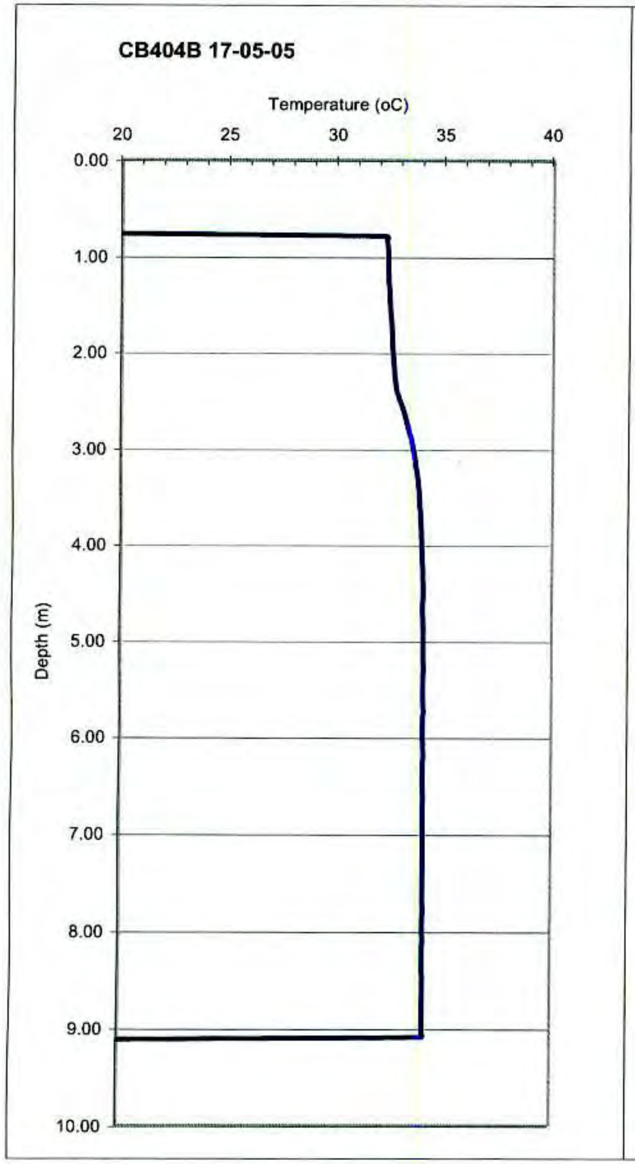

CB404 17-05-05
Conductivity (mS/m)
0
20
40
60
80
100
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

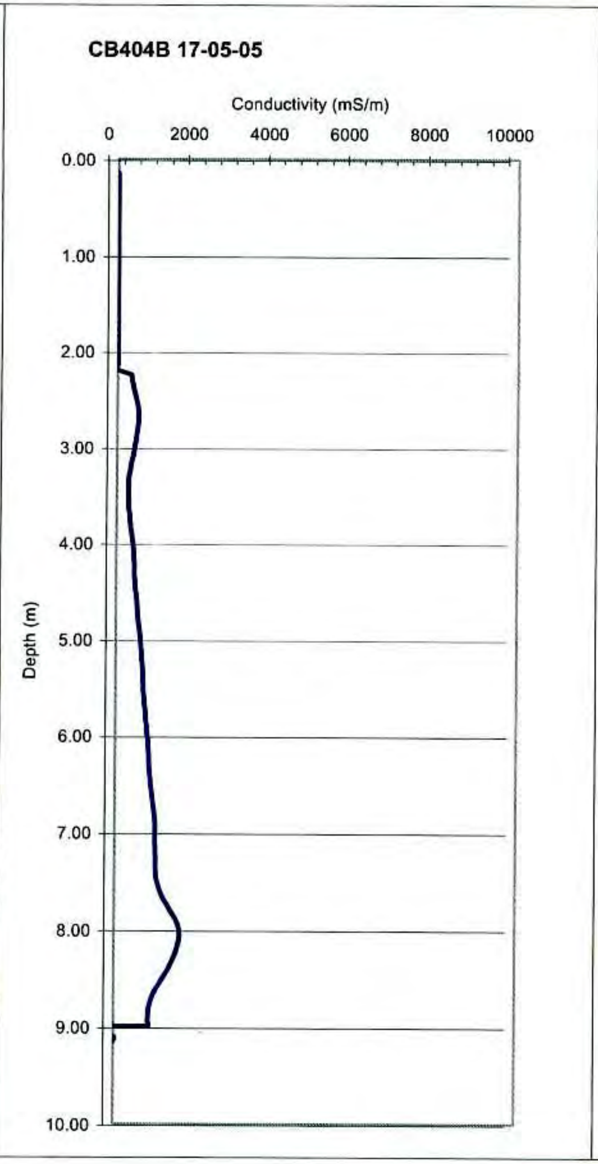

CB404 17-05-05
Gamma
0
50
100
150
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth (m)

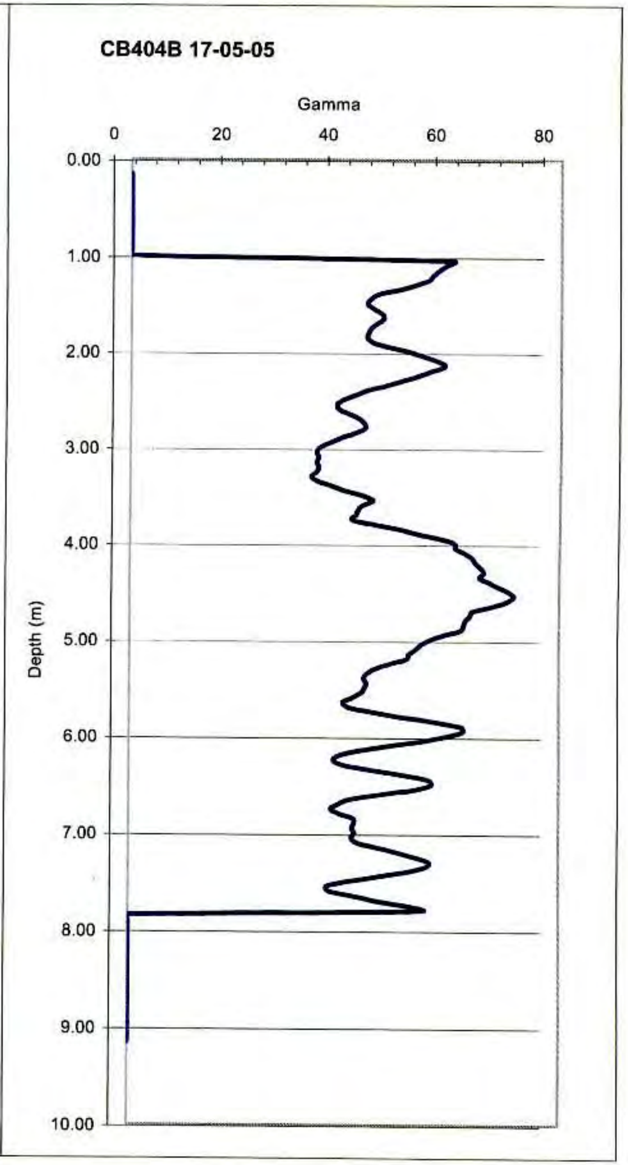

CB404A 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
Depth (m)

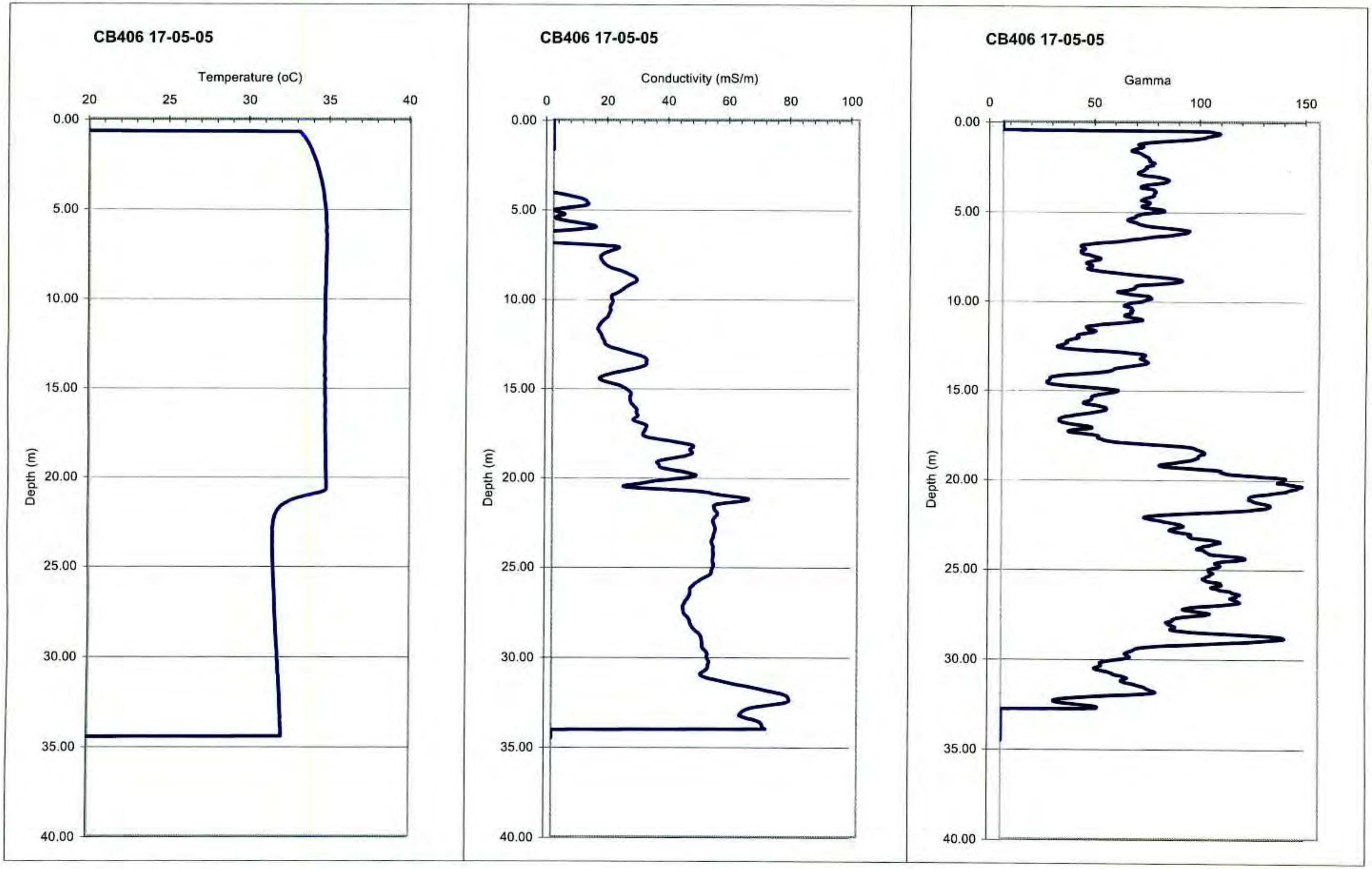

CB404A 17-05-05
Conductivity (mS/m)
0
50
100
150
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
Depth (m)

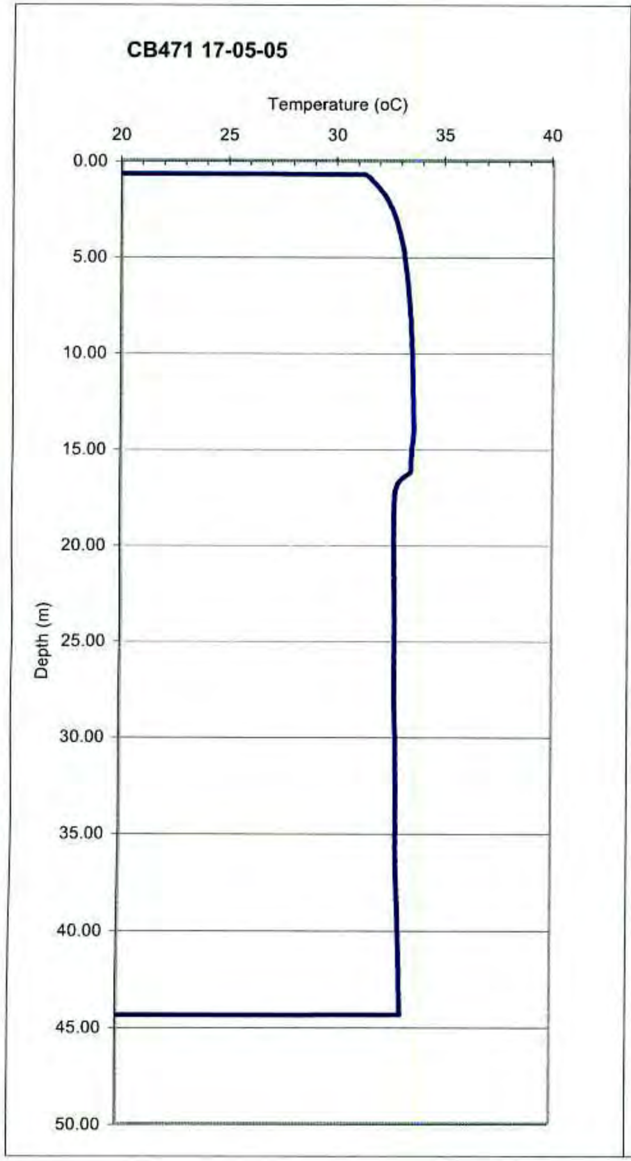

CB404A 17-05-05
Gamma
0
20
40
60
80
100
120
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
Depth (m)

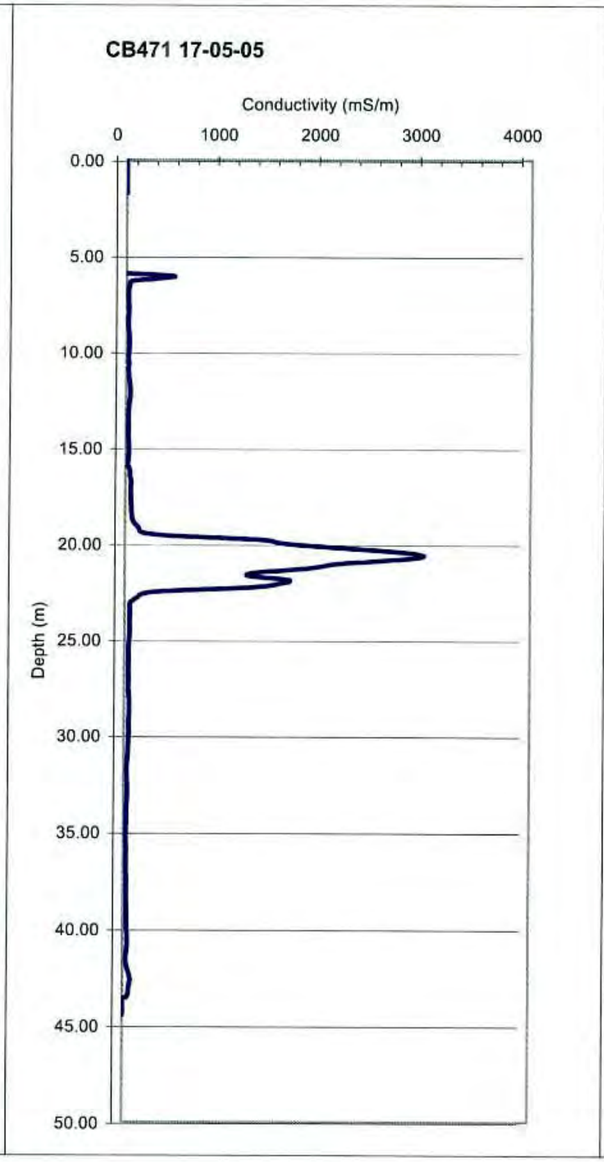

CB404B 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Depth (m)

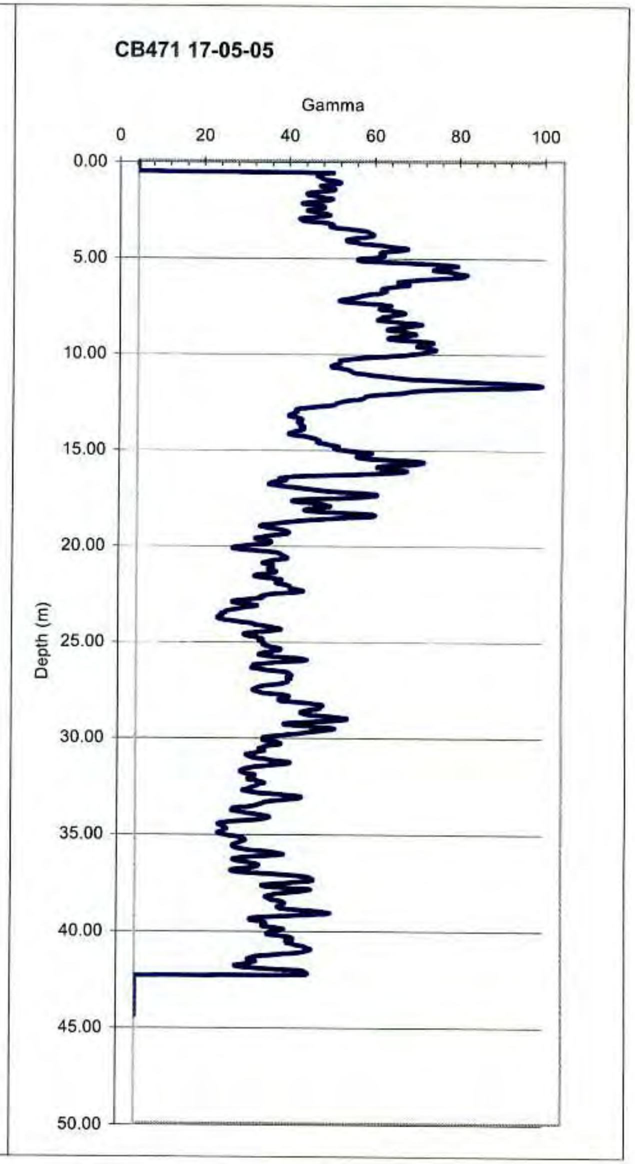

CB404B 17-05-05
Conductivity (mS/m)
0
2000
4000
6000
8000
10000
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Depth (m)

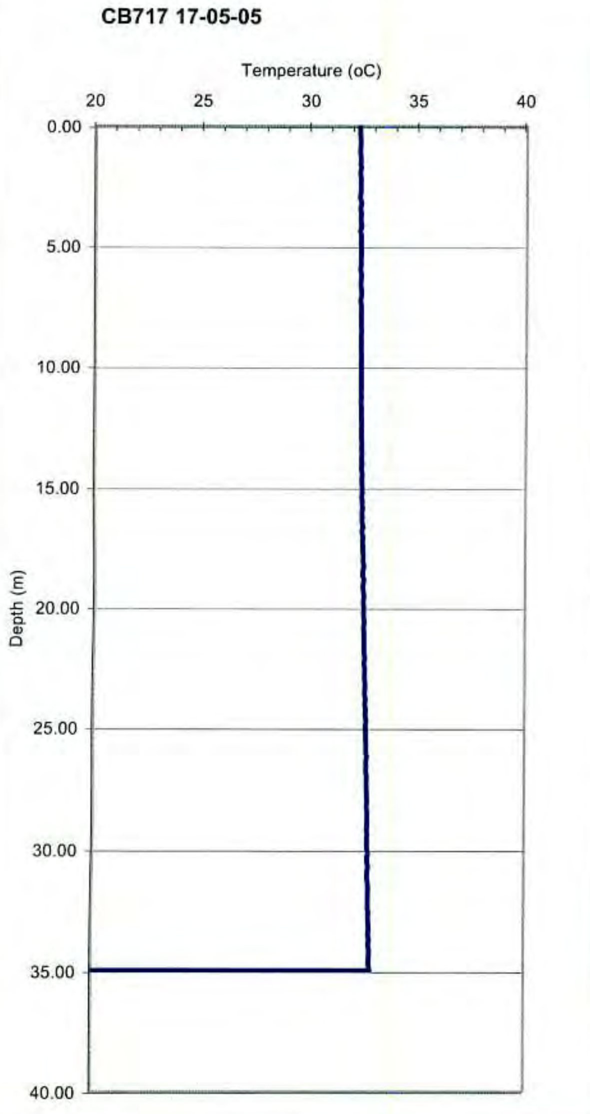

CB404B 17-05-05
Gamma
0
20
40
60
80
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Depth (m)

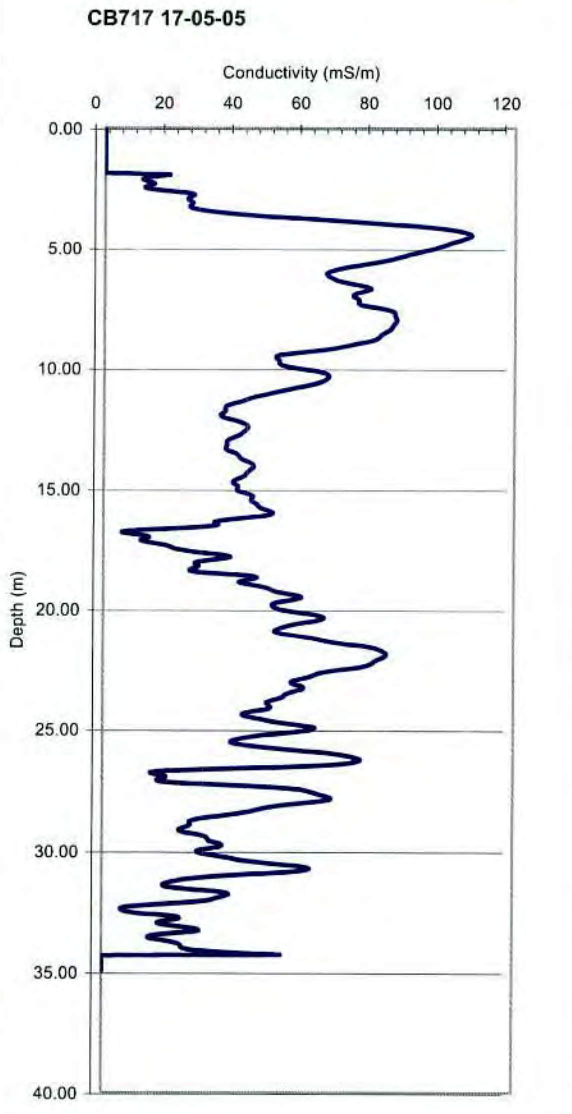

CB406 17-05-05
Temperature (oC)
20
25
30
35
40
Depth (m)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
CB406 17-05-05
Conductivity (mS/m)
0
20
40
60
80
100
Depth (m)
CB406 17-05-05
Gamma
0
50
100
150
Depth (m)

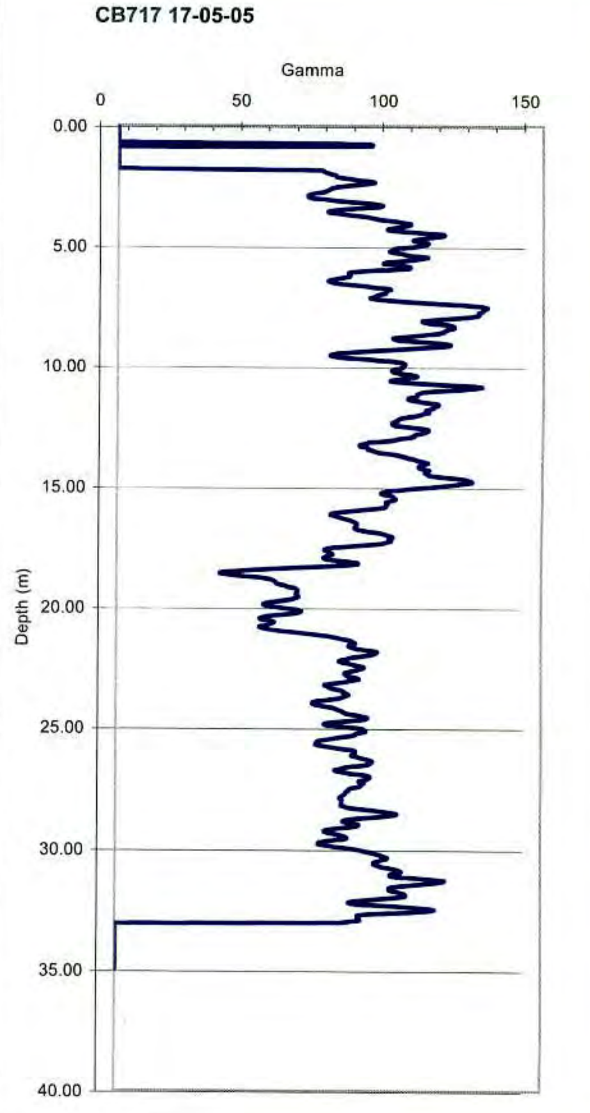

CB471 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Depth (m)

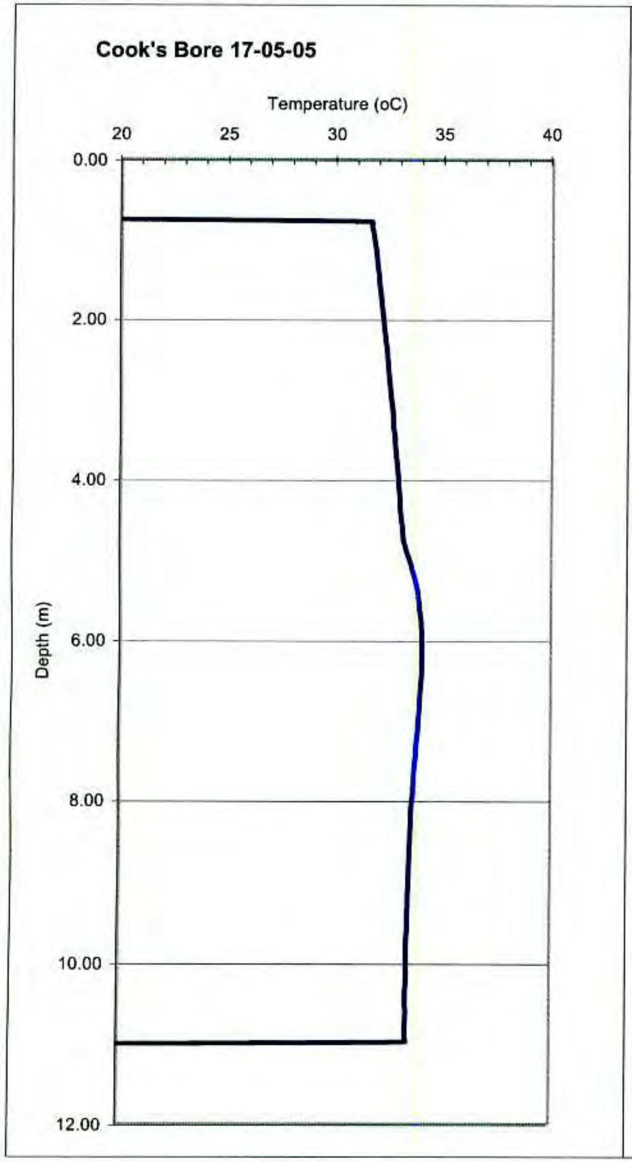

CB471 17-05-05
Conductivity (mS/m)
0
1000
2000
3000
4000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Depth (m)

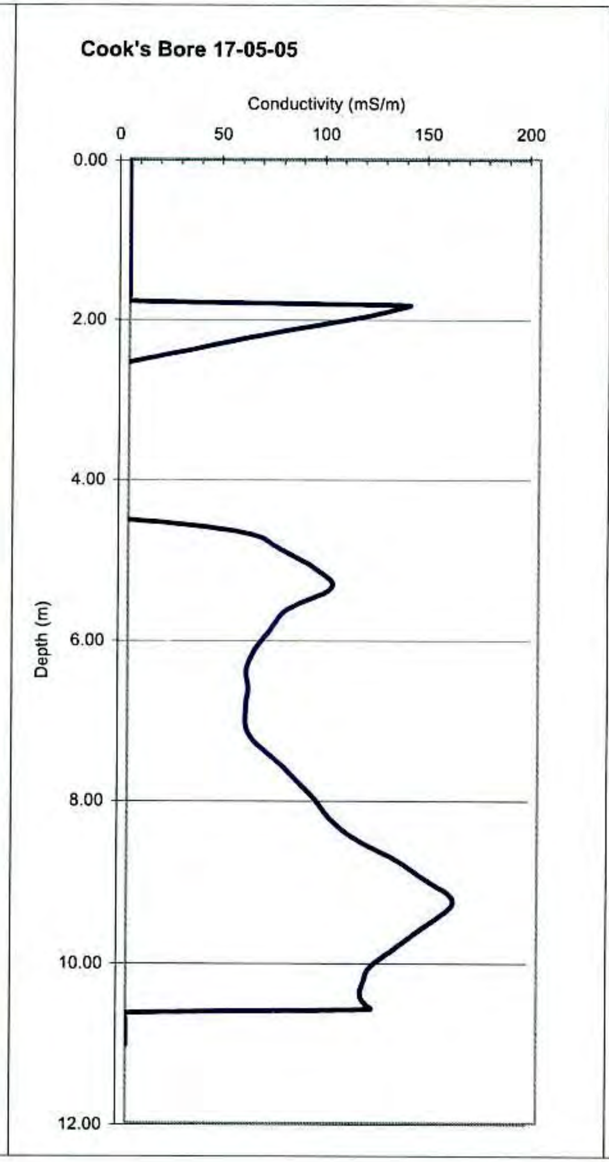

CB471 17-05-05
Gamma
0
20
40
60
80
100
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Depth (m)

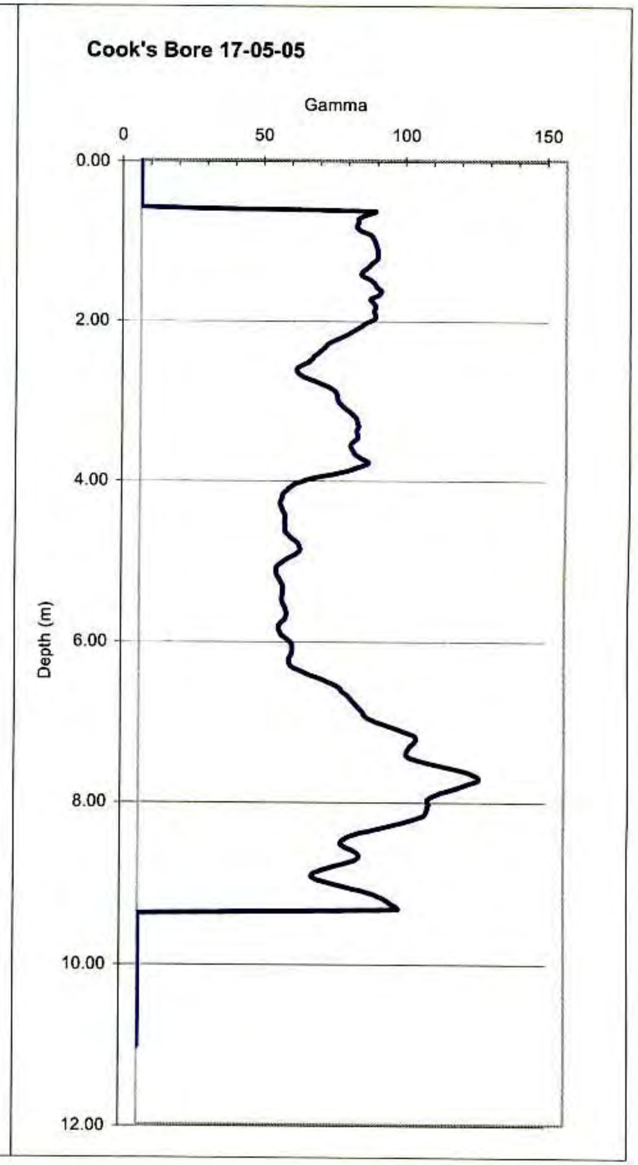

CB717 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Depth (m)


CB717 17-05-05
Conductivity (mS/m)
0
20
40
60
80
100
120
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Depth (m)

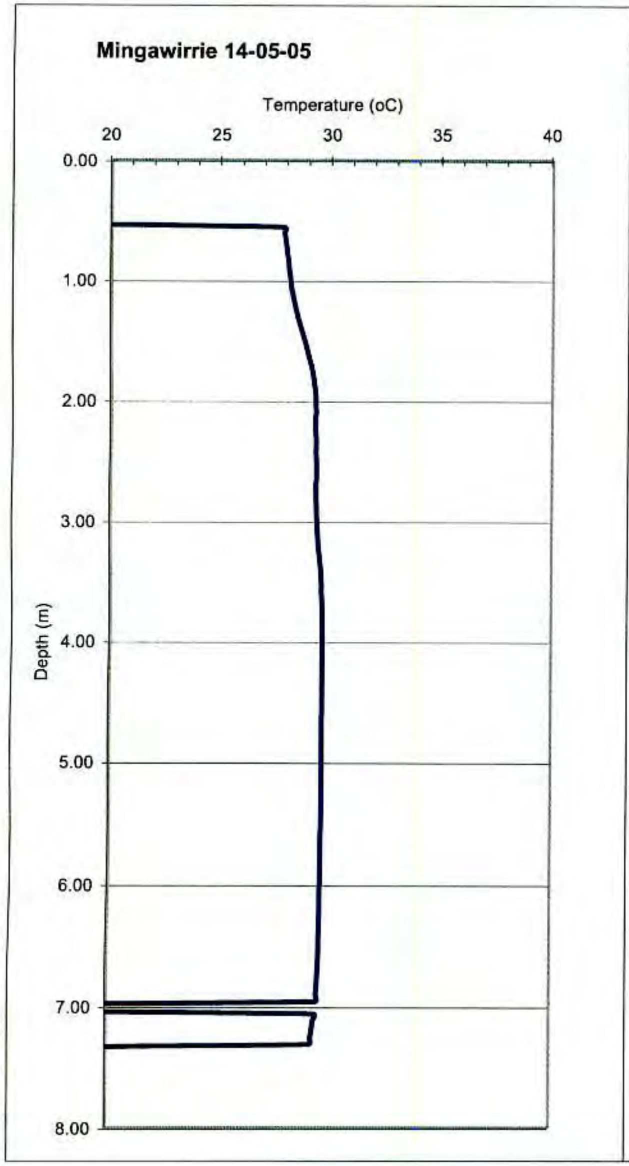

CB717 17-05-05
Gamma
0
50
100
150
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Depth (m)

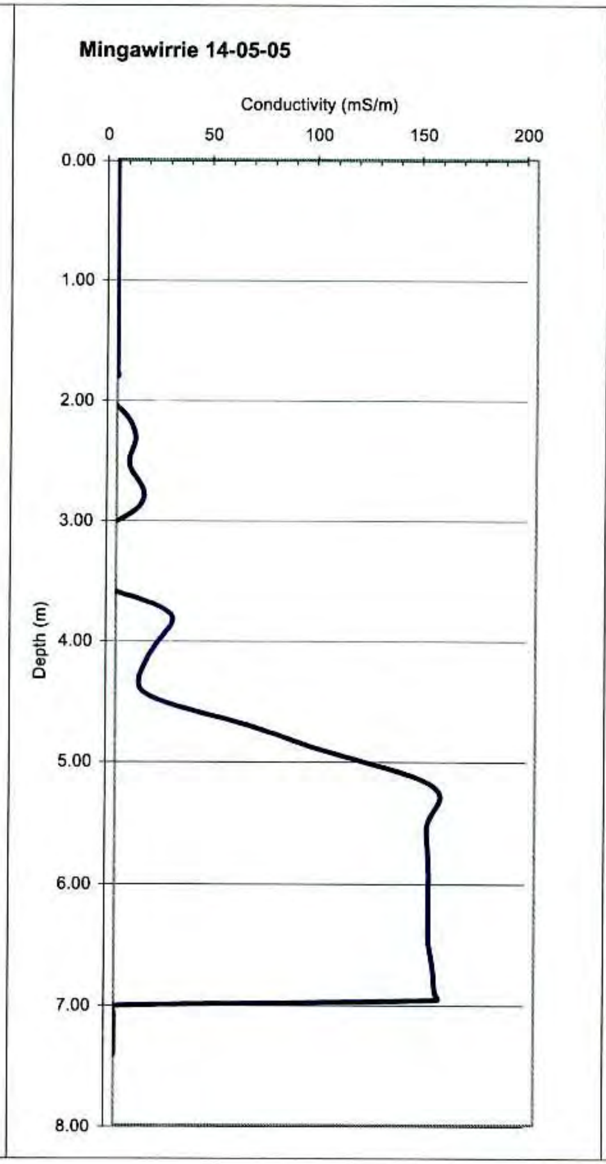

Cook's Bore 17-05-05
Temperature (oC)
20
25
30
35
40
Depth (m)
0.00
2.00
4.00
6.00
8.00
10.00
12.00

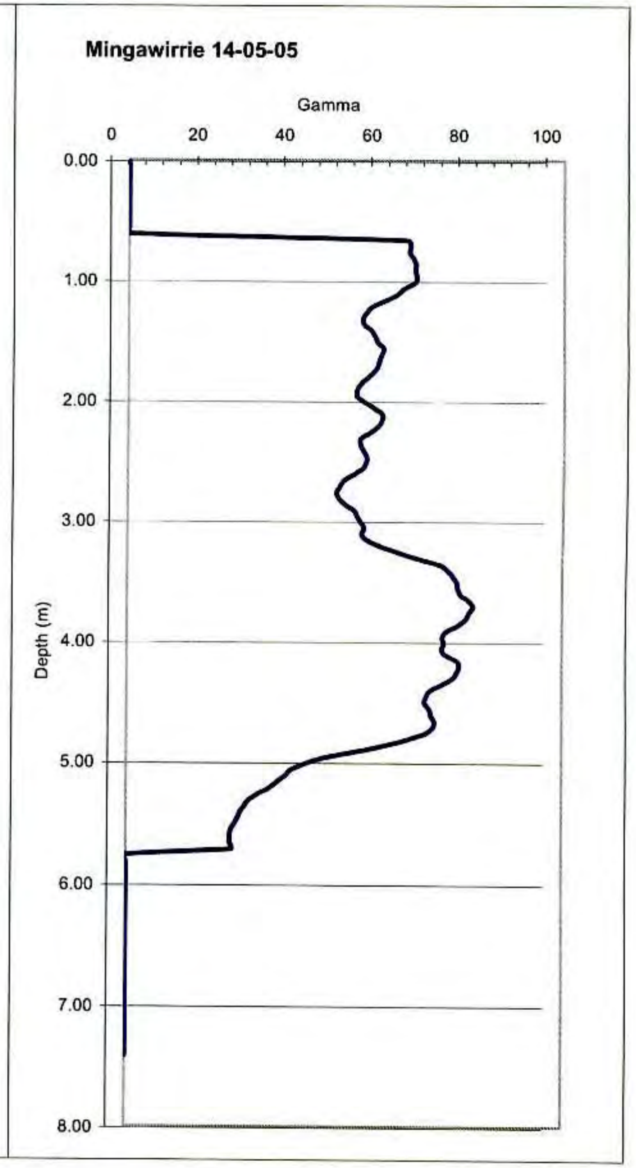

Cook's Bore 17-05-05
Conductivity (mS/m)
0
50
100
150
200
Depth (m)
0.00
2.00
4.00
6.00
8.00
10.00
12.00


Cook's Bore 17-05-05
Gamma
0
50
100
150
Depth (m)
0.00
2.00
4.00
6.00
8.00
10.00
12.00

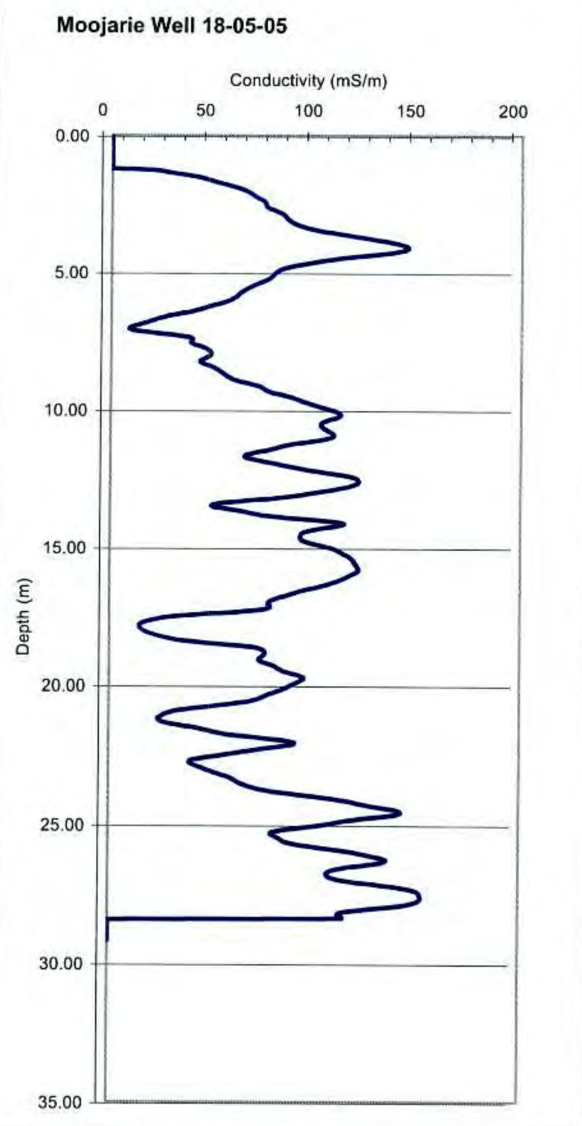
[redacted]

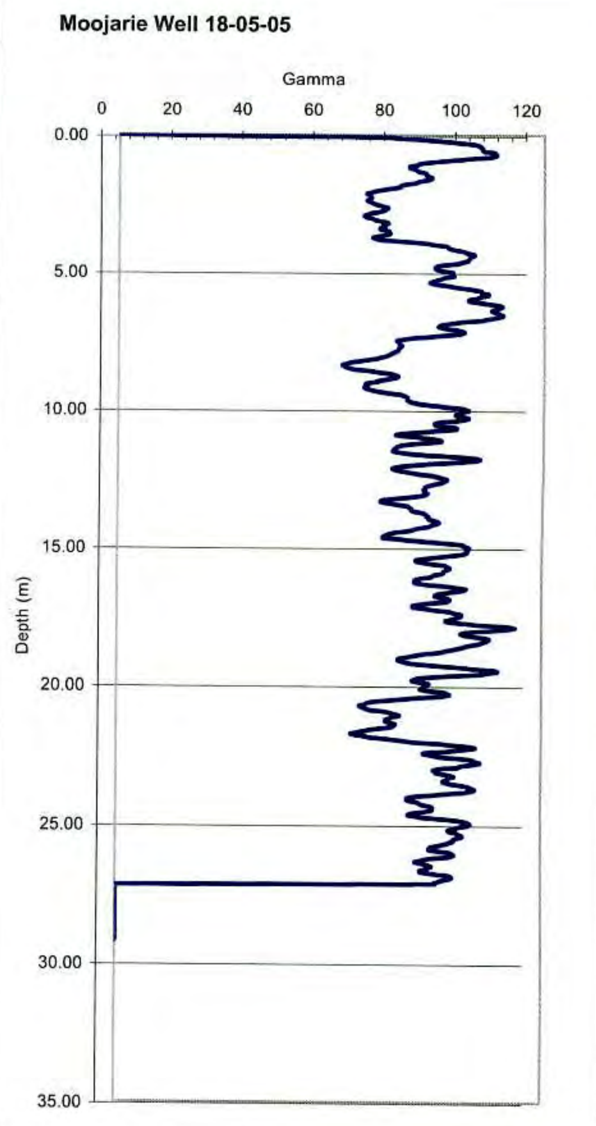

Mingawirrie 14-05-05
Temperature (oC)
20
25
30
35
40
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

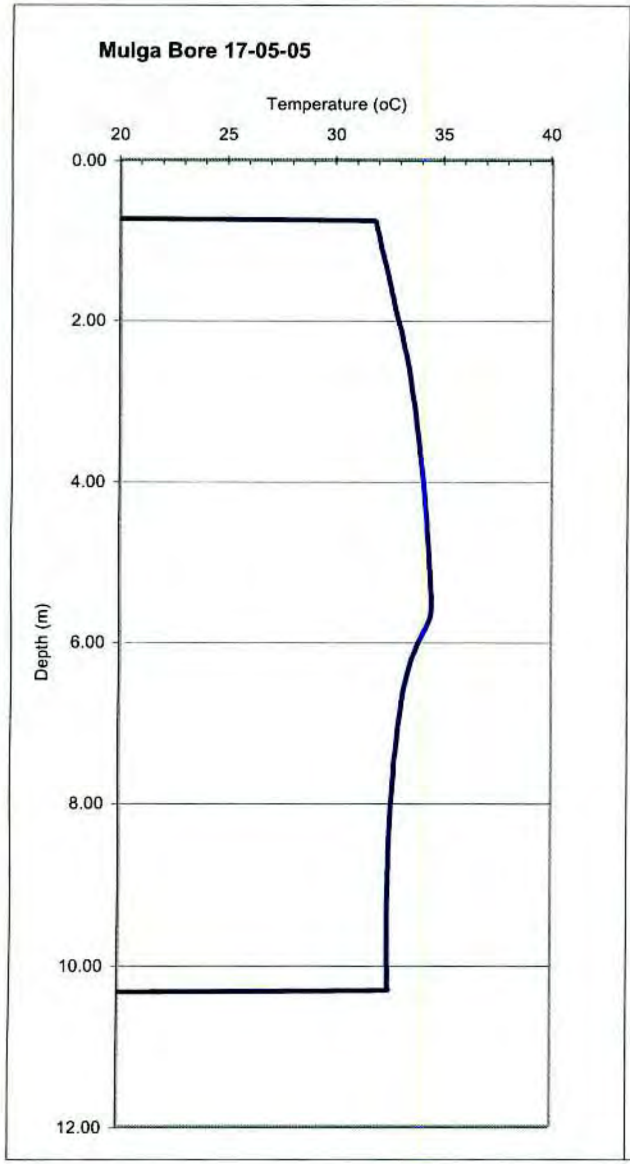

Mingawirrie 14-05-05
Conductivity (mS/m)
0
50
100
150
200
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

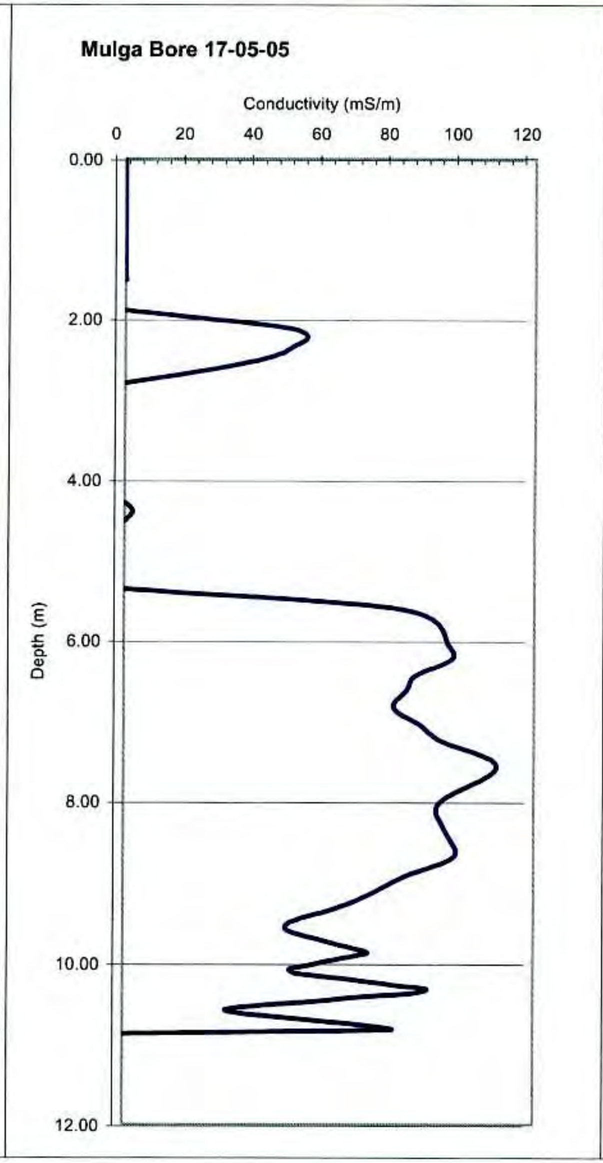

Mingawirrie 14-05-05
Gamma
0
20
40
60
80
100
Depth (m)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

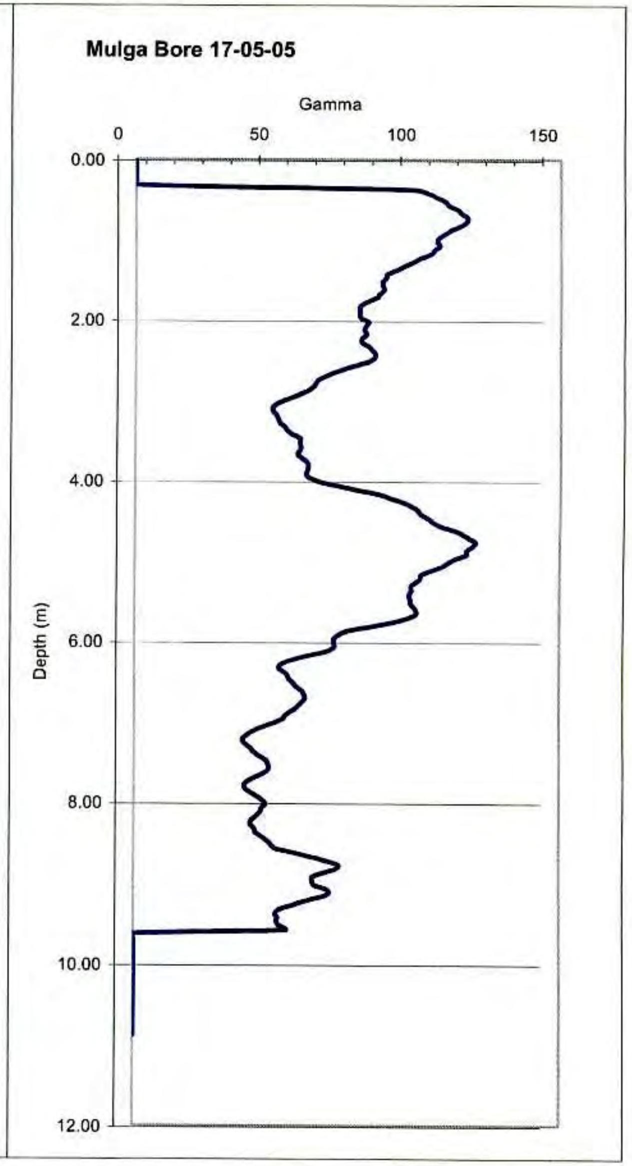

Moojarie Well 18-05-05
Temperature (oC)
20 25 30 35 40
0.00 5.00 10.00 15.00 20.00 25.00 30.00 35.00
Depth (m)


Moojarie Well 18-05-05
Conductivity (mS/m)
0 50 100 150 200
0.00 5.00 10.00 15.00 20.00 25.00 30.00 35.00
Depth (m)

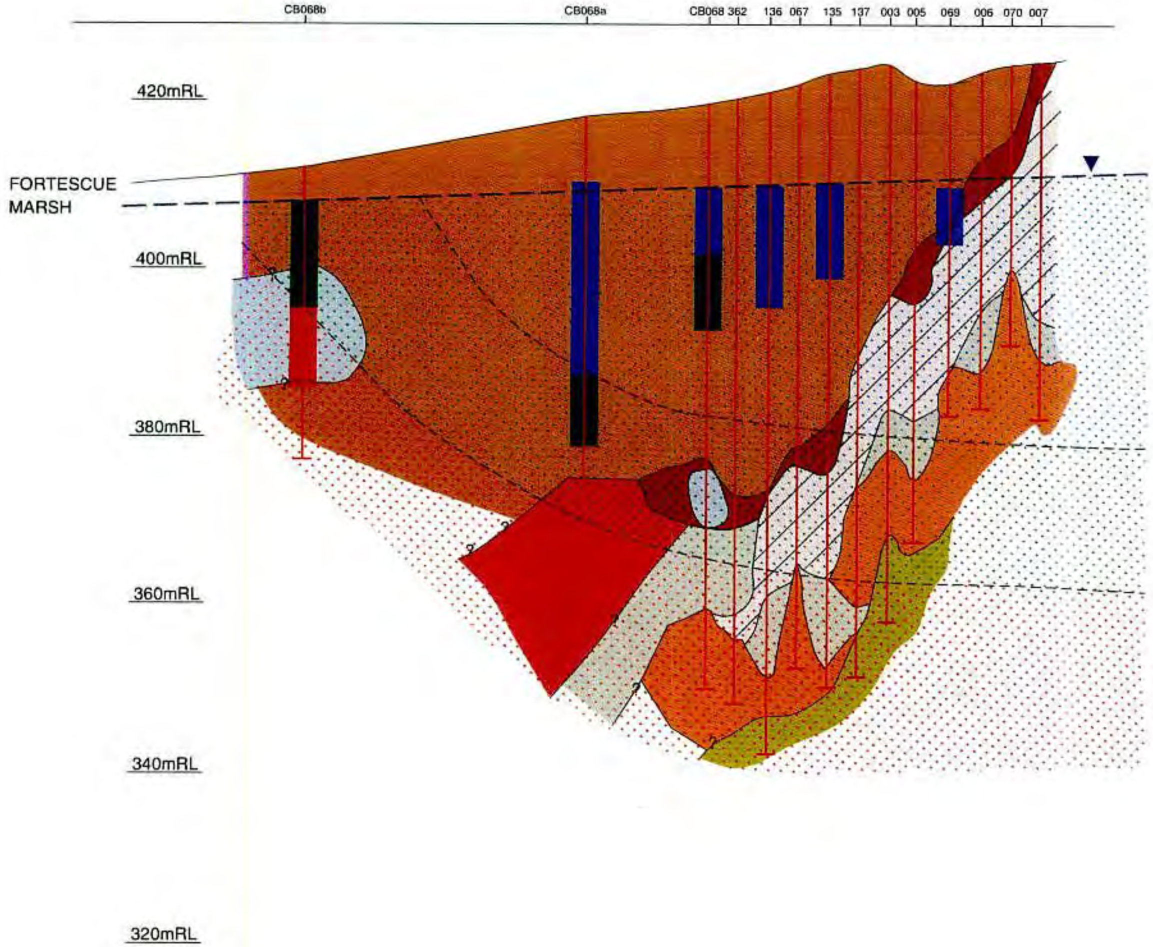

Moojarie Well 18-05-05
Gamma
0 20 40 60 80 100 120
0.00 5.00 10.00 15.00 20.00 25.00 30.00 35.00
Depth (m)


Mulga Bore 17-05-05
Temperature (oC)
20
25
30
35
40
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)


Mulga Bore 17-05-05
Conductivity (mS/m)
0
20
40
60
80
100
120
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)


Mulga Bore 17-05-05
Gamma
0
50
100
150
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)

HYDROGEOLOGICAL SECTION
(Section B - B')



LEGEND
Geology

- TERTIARY DEPOSITS
- TERTIARY HARDCAP
- CALCRETE
- WITTENOOM DOLOMITE
- ORE ZONE
- NAMMULDI MEMBER SHALES
- BIF
- ROY HILL SHALE

Hydrogeology

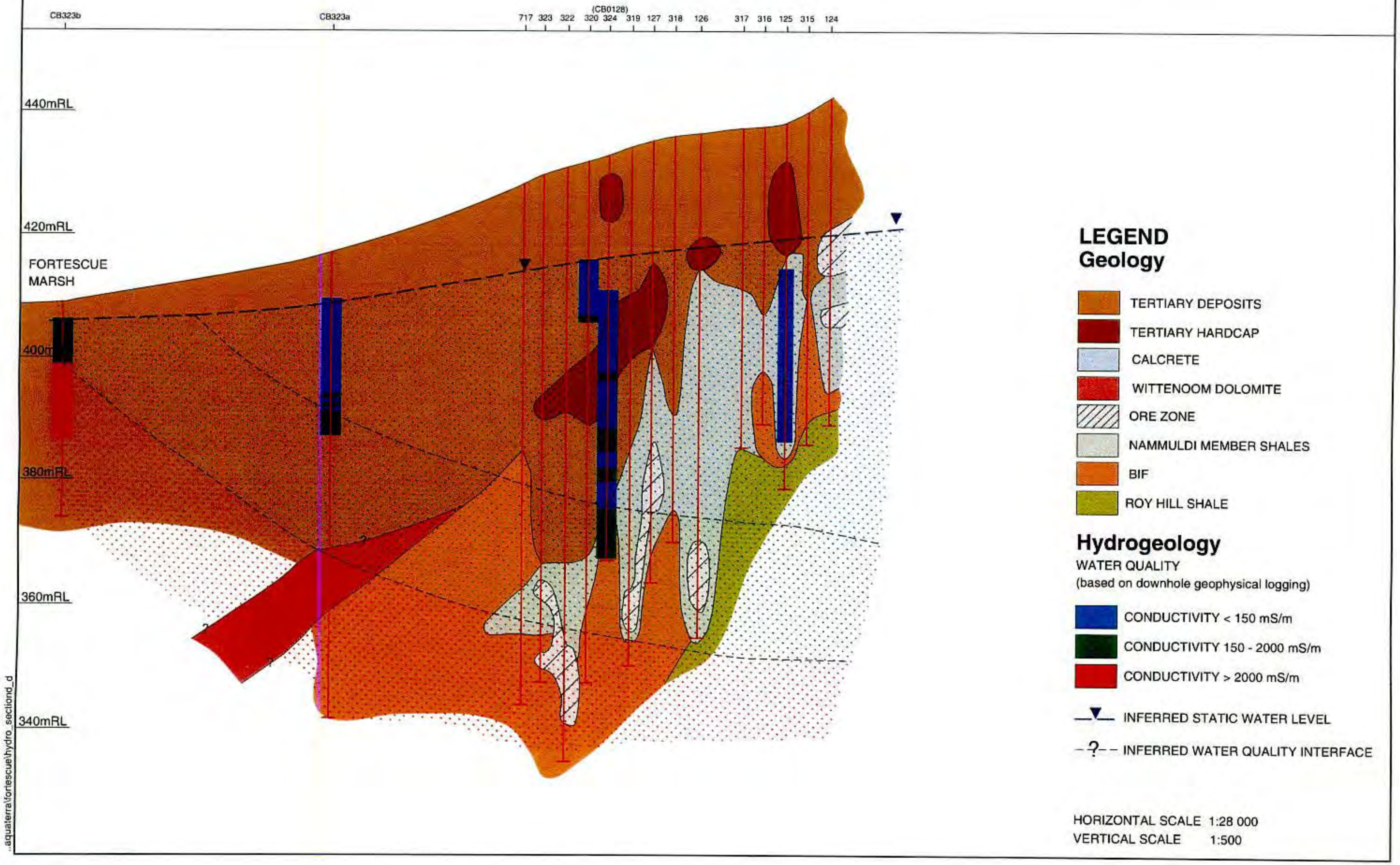
WATER QUALITY
(based on downhole geophysical logging)

- CONDUCTIVITY < 150 mS/m
- CONDUCTIVITY 150 - 2000 mS/m
- CONDUCTIVITY > 2000 mS/m
- INFERRED STATIC WATER LEVEL
- - ? - - INFERRED WATER QUALITY INTERFACE

HORIZONTAL SCALE 1:28 000
VERTICAL SCALE 1:500

..aquaterra\fortescue\hydro_sectionb_b

HYDROGEOLOGICAL SECTION
(Section D - D')

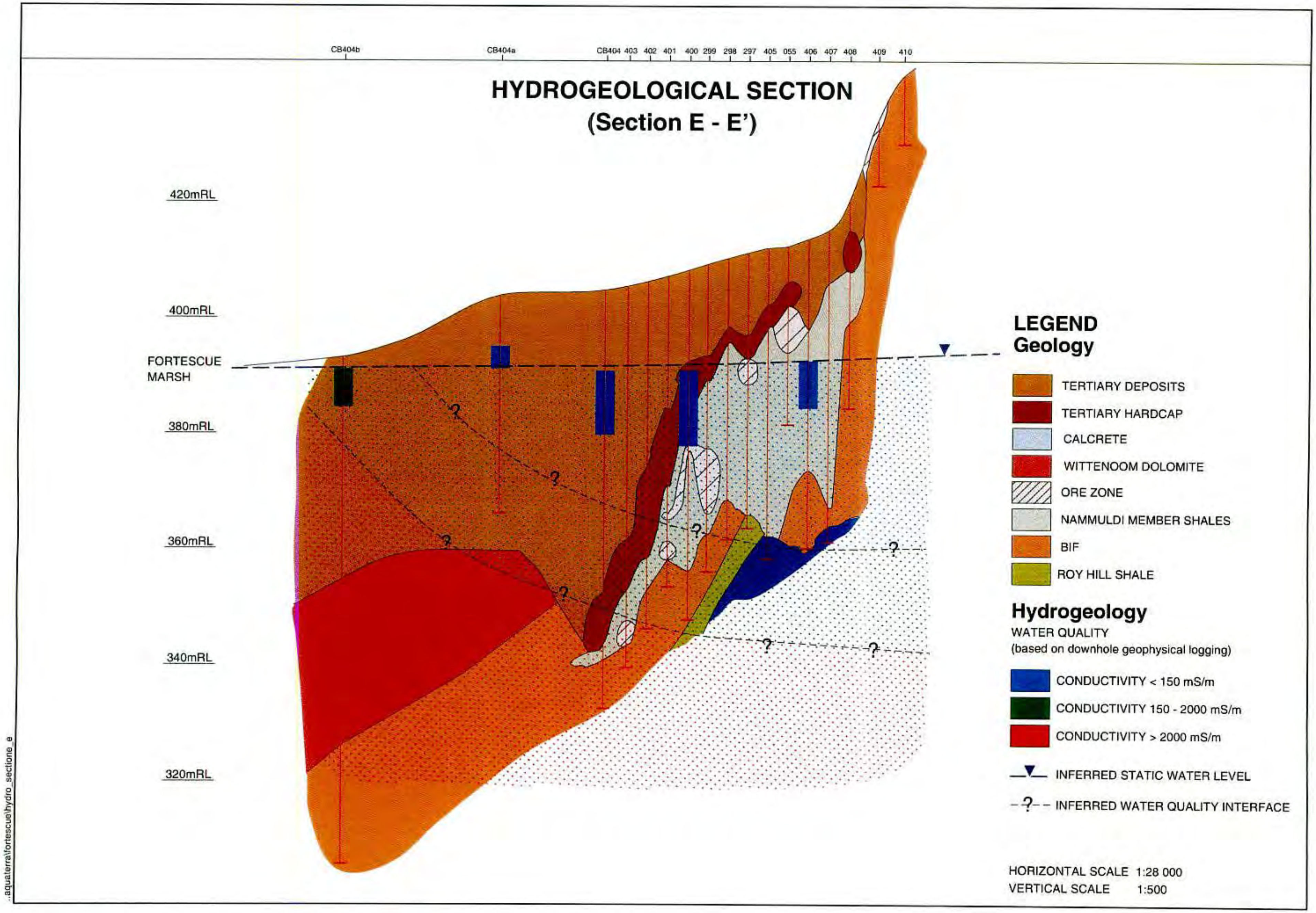


..aquaterra\fortescue\hydro_sectiond_d

aquaterra

Appendix C

FIGURE 2



..aquaterra\fortescue\hydro_sectione_e

aquaterra

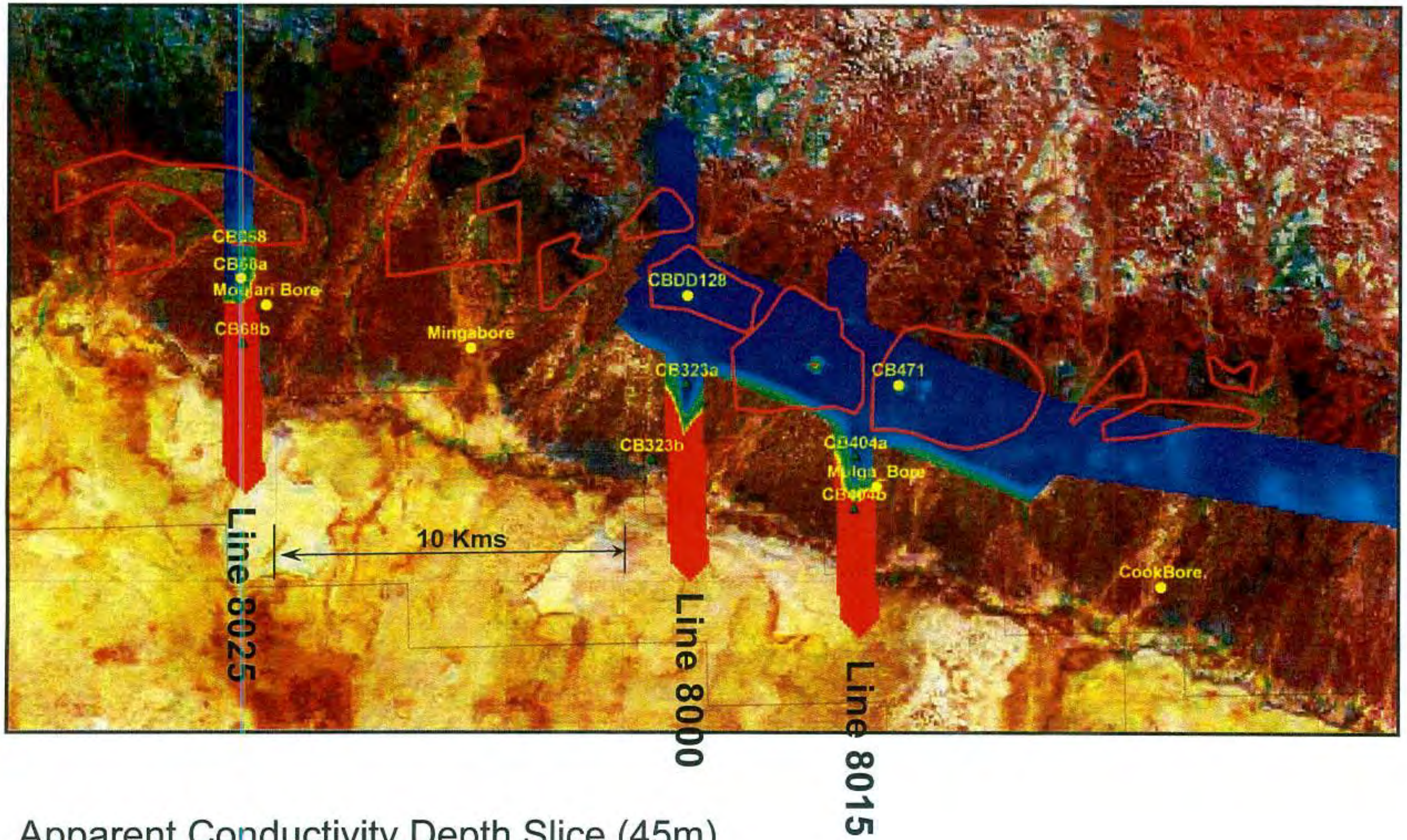
Appendix C

FIGURE 3

APPENDIX D

REPORT BY QUARTZ WATER ON THE TEM SURVEY

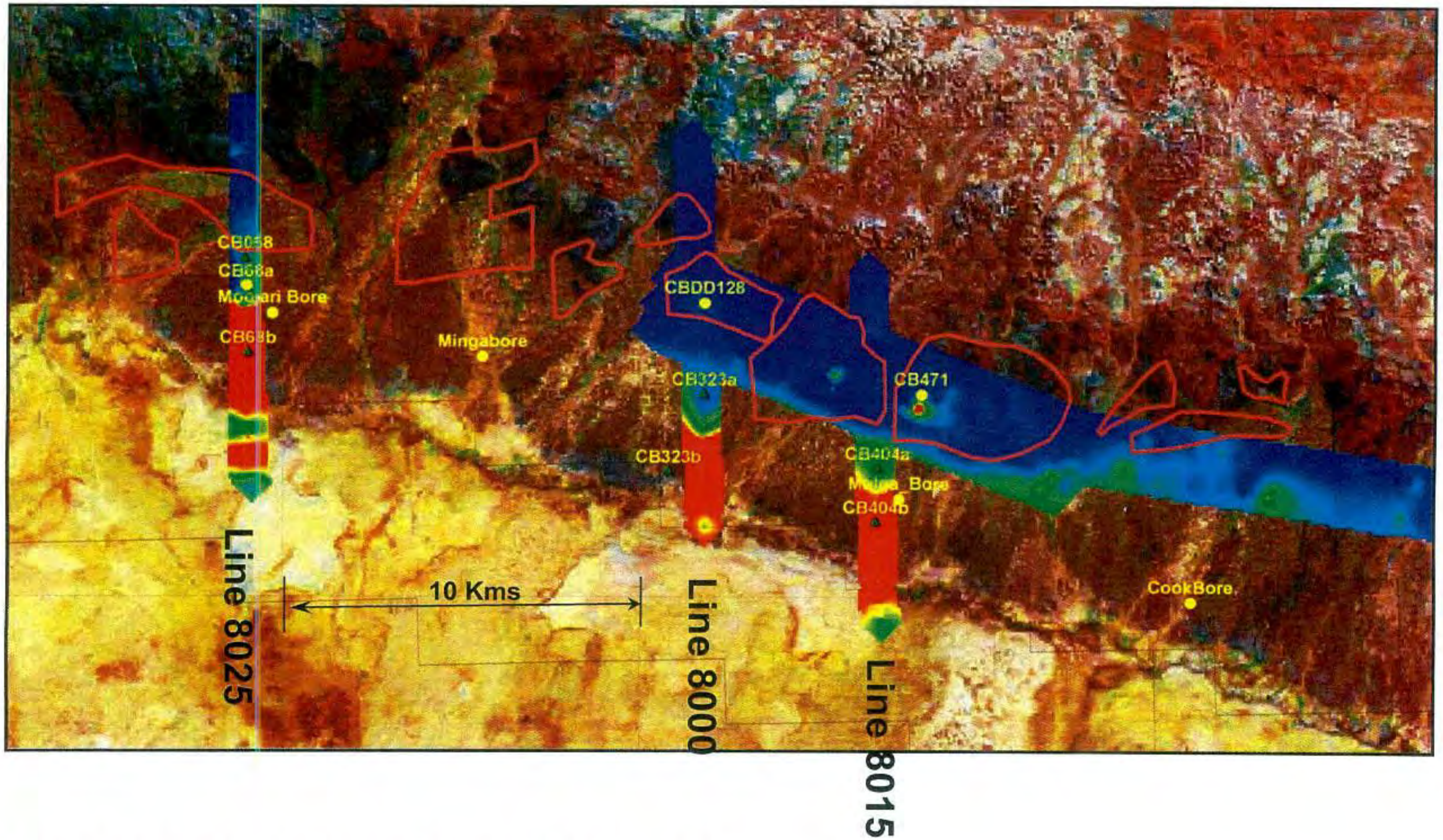
Cloud Break Solute Concentrations (CB-SC)



Apparent Conductivity Depth Slice (45m)

Plan Showing Cloud Break TEM Lines and drill hole locations – (Image is 45 mbgl - Apparent conductivity depth slice over landsat)

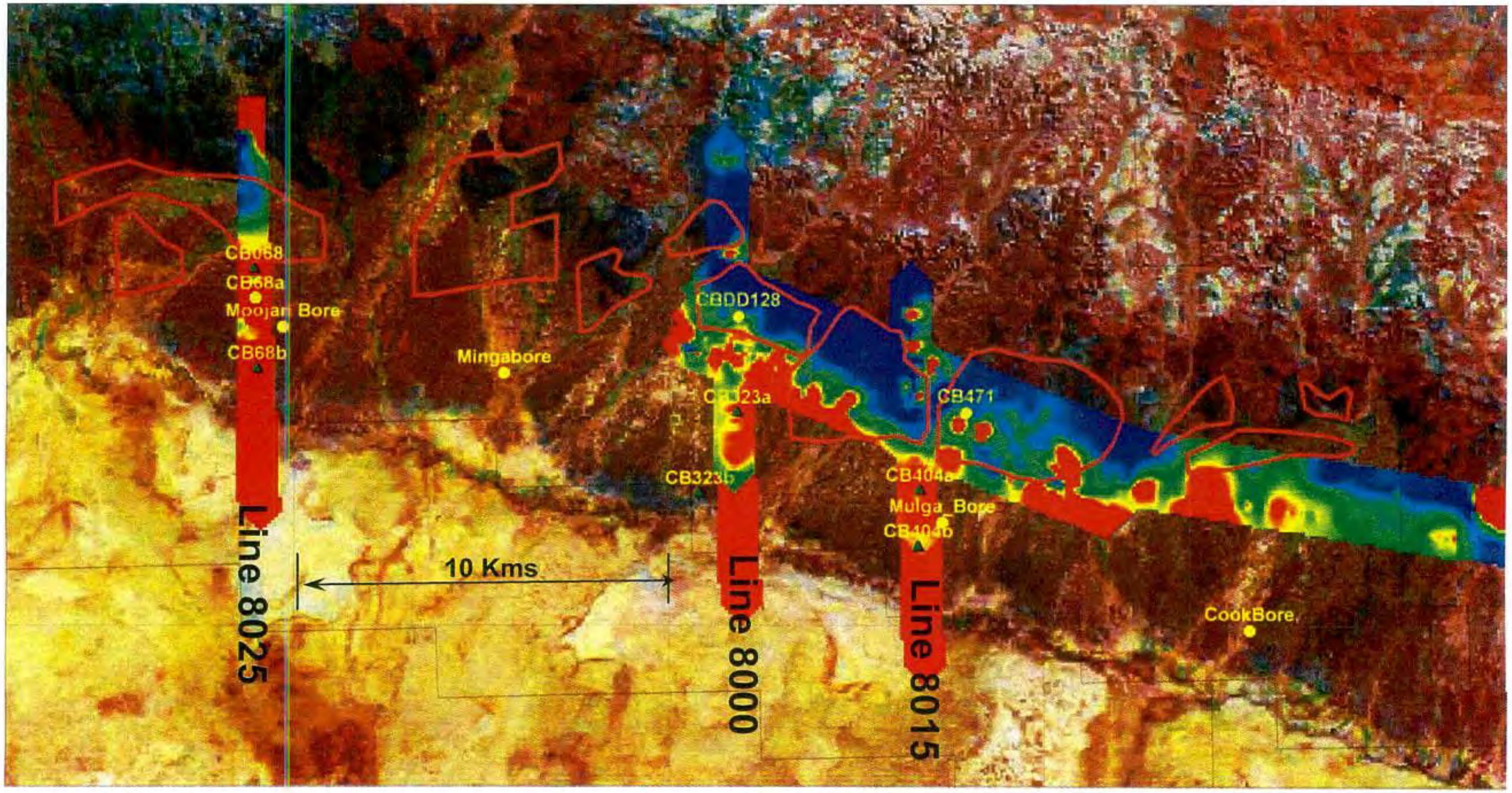
CB-SC-1



Apparent Conductivity Depth Slice (60m)

Plan Showing Cloud Break TEM apparent conductivity and Drill Hole Locations – (Image is 60mbgl - apparent conductivity depth slice over landsat)

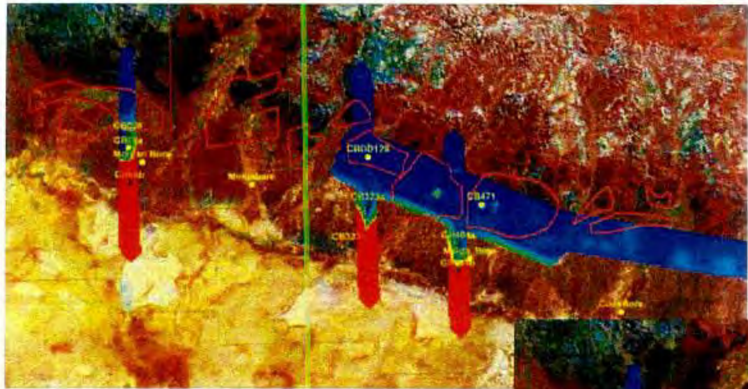
CB-SC-2



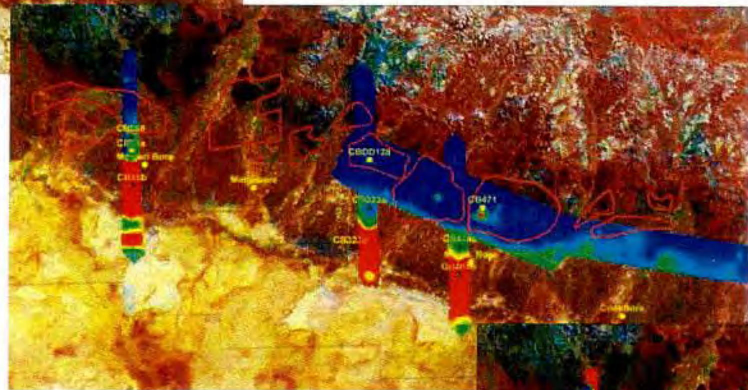
Apparent Conductivity Depth Slice (100m)

Plan Showing Cloud Break TEM apparent conductivity and drill hole locations – (Image is 100mbgl - Apparent conductivity depth slice over landsat)

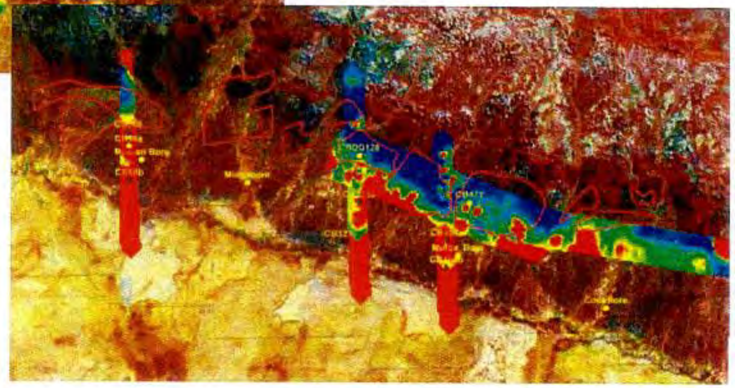
CB-SC-3



45 m



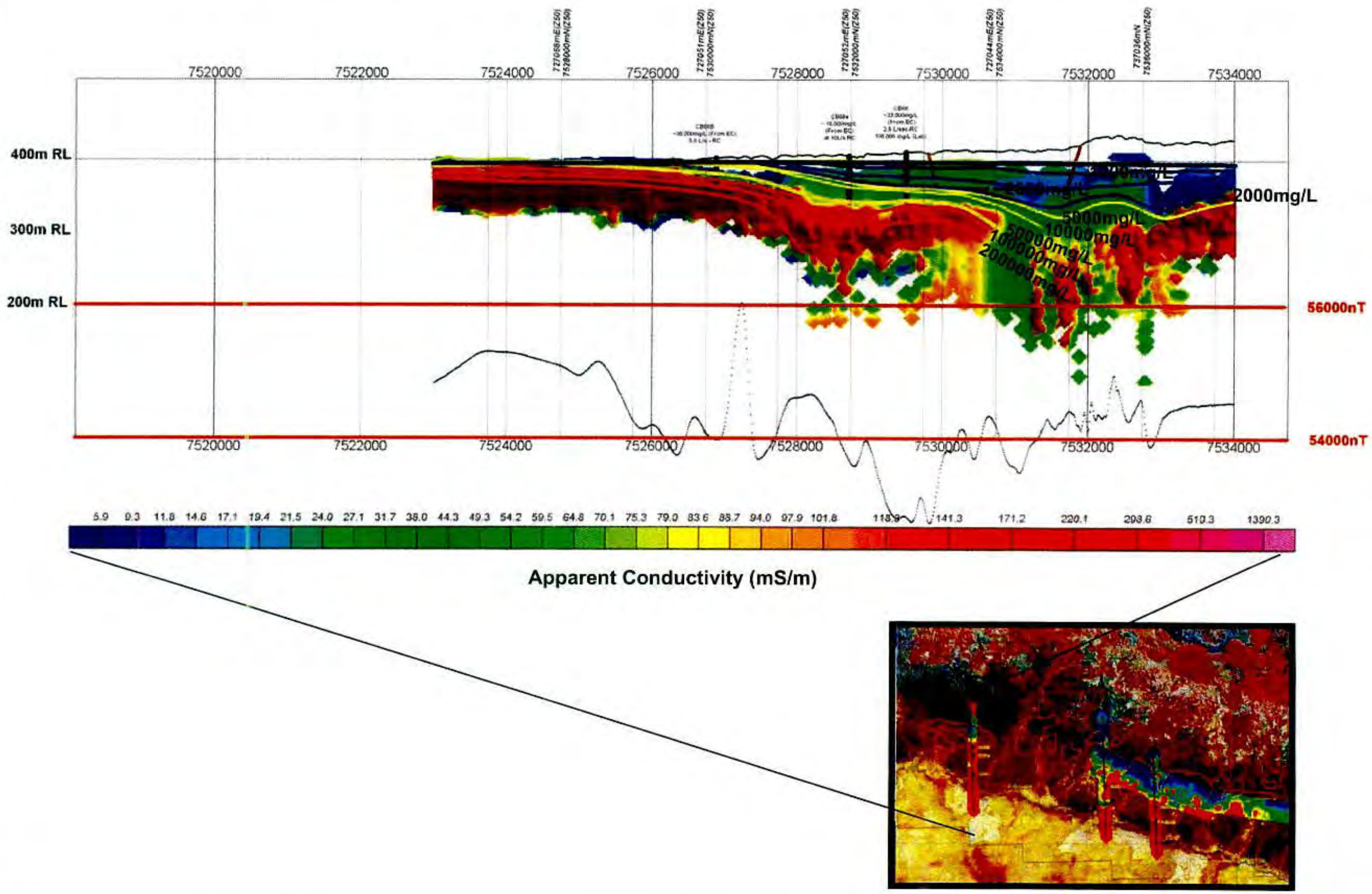
60 m



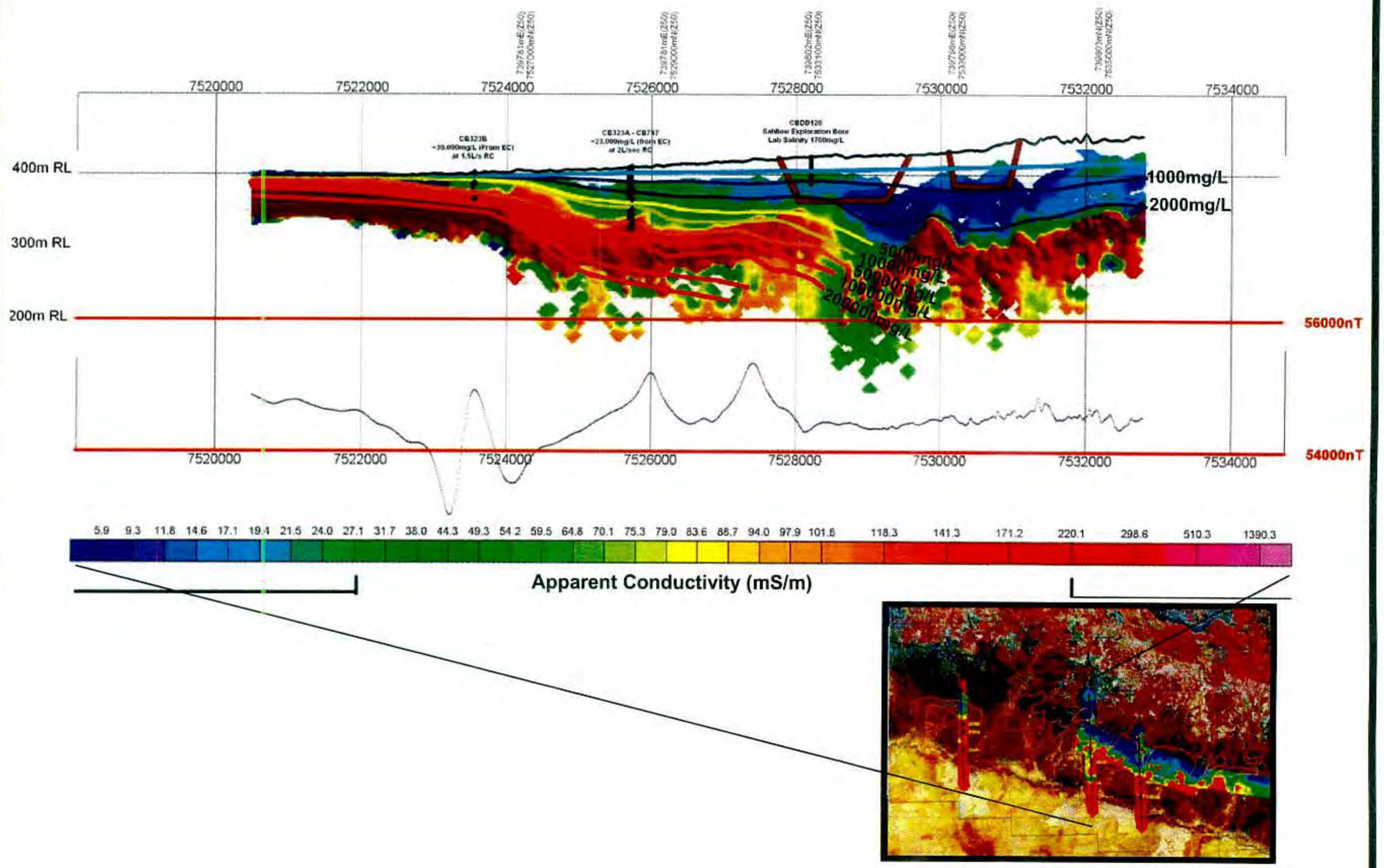
100 m

Plan Showing Cloud Break TEM apparent conductivity and drill hole locations – (Image is 45, 60, and 100mbgl - apparent conductivity depth slice over landsat)

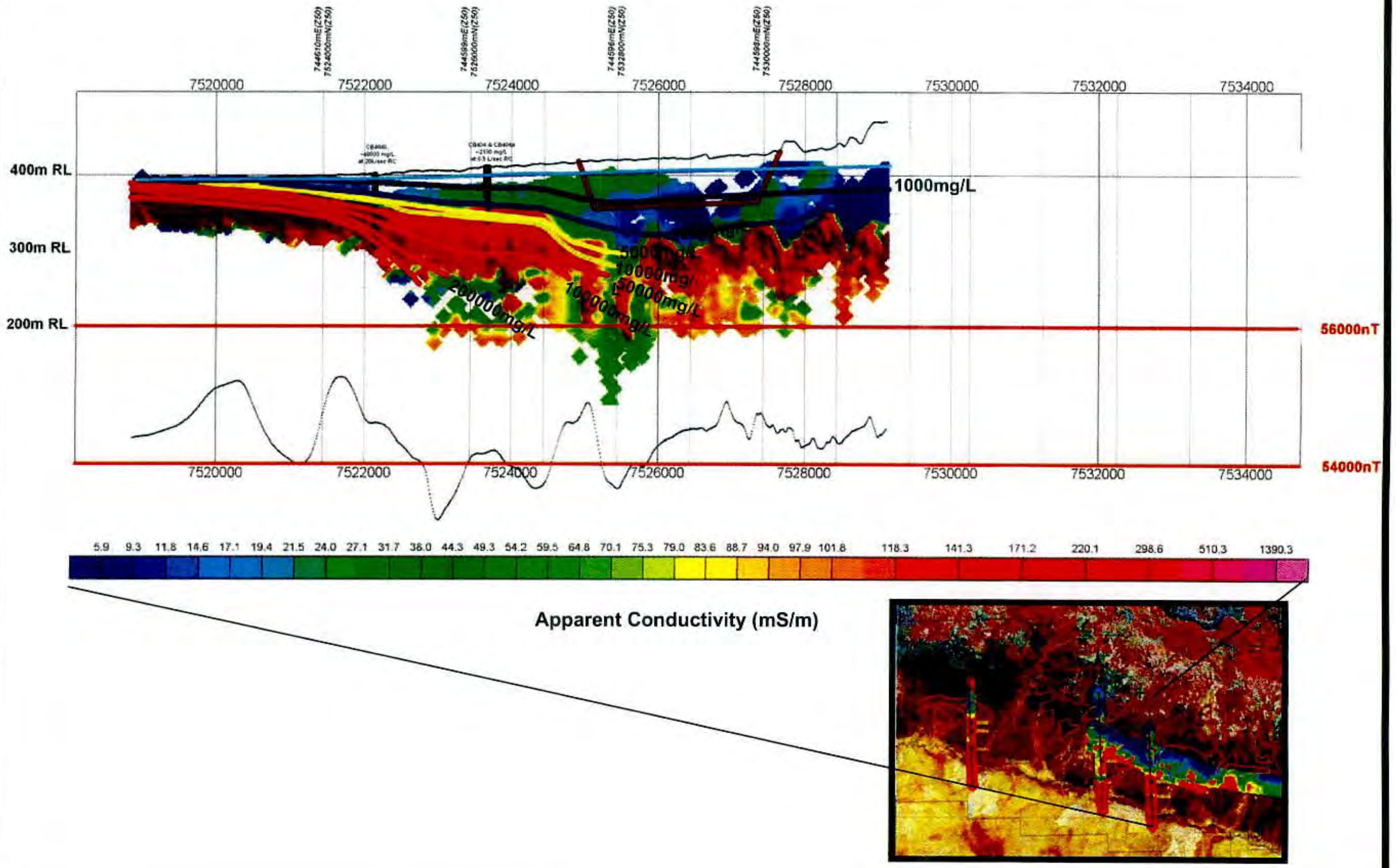
CB-SC-4



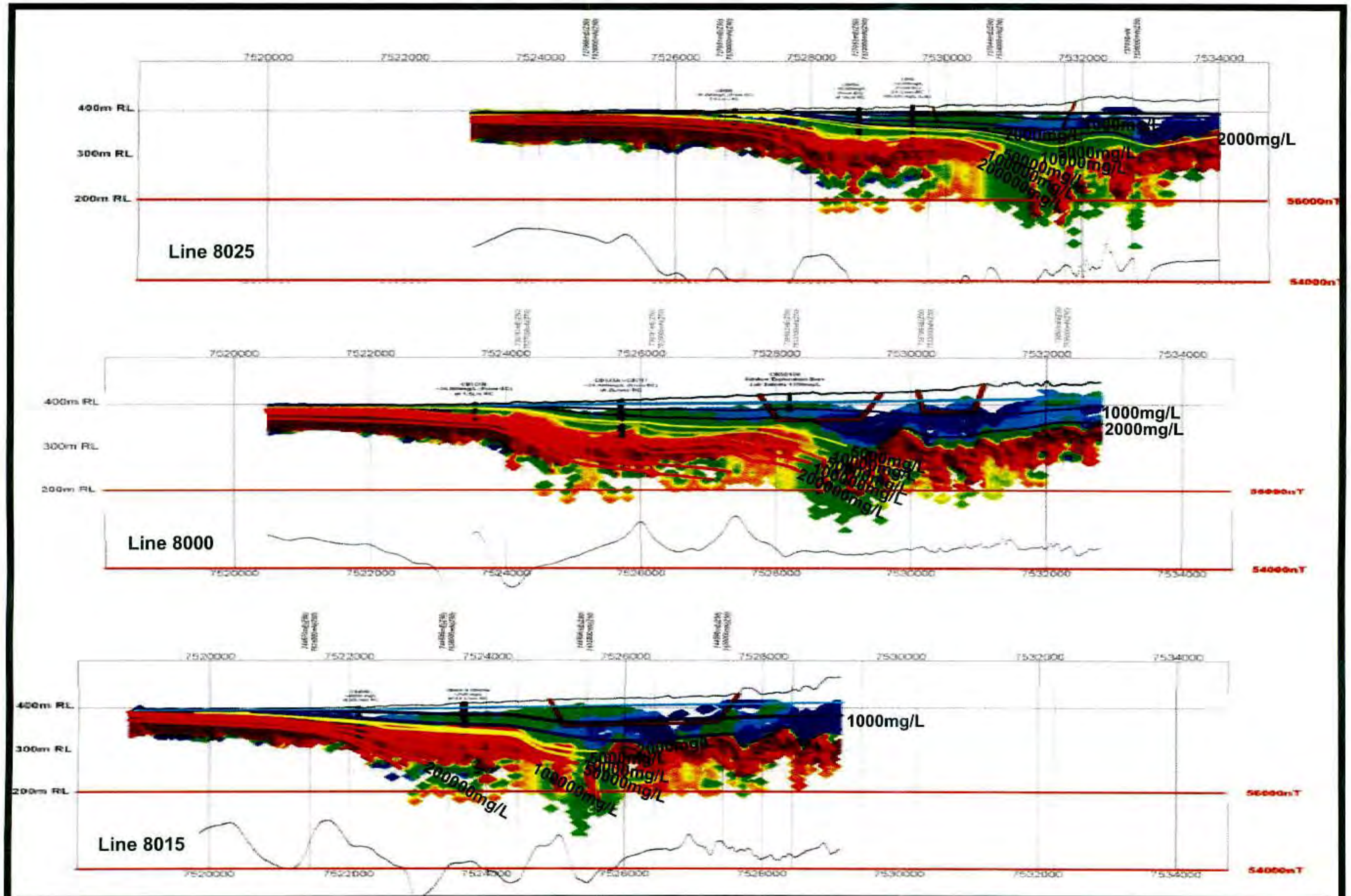
Line 8025 – Solute concentration contours over TEM apparent conductivity section CB-SC-5



Line 8000 – Solute concentration contours over TEM apparent conductivity section CB-SC-6



Line 8015 – Solute concentration contours over TEM apparent conductivity section CB-SC-7



Line 8025, 8000 and 8015 – Solute concentration contour sections

CB-SC-8

HoistEM System Specifications

Transmitter

Waveform –	25% duty cycle square wave
Pulse on Time -	5 ms (inclusive of 1ms cosine ramp on)
Pulse off Time -	15 ms
Pulse Current -	320 Amps
Switch on Ramp -	1 ms
Switch off Ramp -	40 μs
Tx Loop Area -	~375 m^2
Tx NIA –	120,000
Tx Frequency-	25 Hz

Receiver

A-D Circuitry -	20 bit
Sample Time -	0 - 14 ms
Sampling -	124 Linear channels

(12 channels from 54 microsecs after switchoff-25 microsecs wide

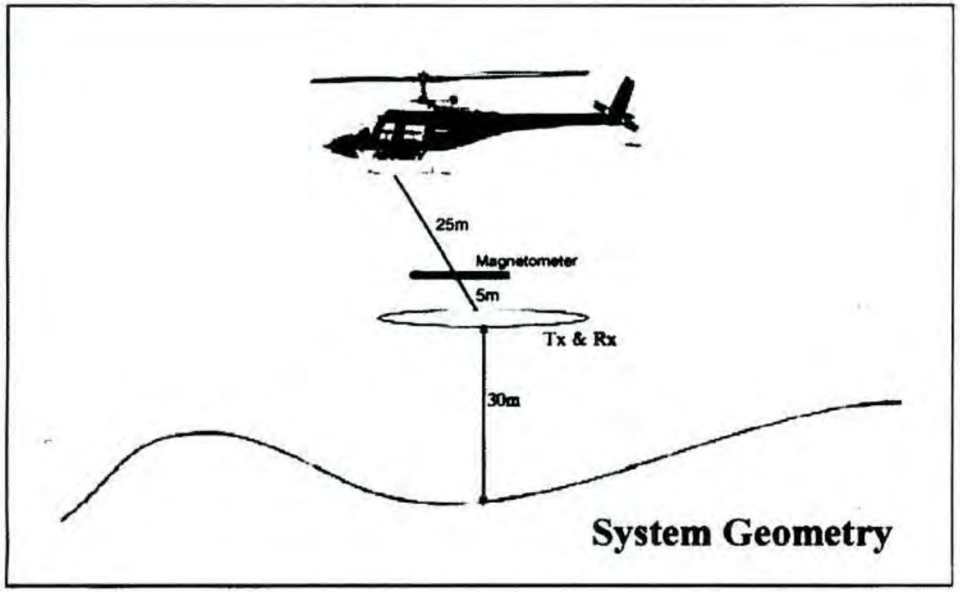
Then -112 channels to 13 millisecs-113 microsecs wide.

Receiver Coil

Effective NA -	3400 Square Metres
Bandwidth –	45,000 Hz

From:
FMGL: HoistEM Airborne Geophysical Survey
Chichester Range / Newman Area,
Western Australia
April 2005,
Survey and Operations Report
Report/Surveyed by:
GPX Airborne Pty. Ltd. Job 2188.

Geometry.



Transmitter loop is towed 35 m below helicopter- Receiver coil is located at centre of Tx loop.

Transmitter / Receiver at nominal 35 m terrain clearance.

Helicopter survey speed is between 35 and 45 knots.

Along line sample interval is between 8 and 10 metres

From:
FMGL: HoistEM Airborne Geophysical Survey
Chichester Range / Newman Area,
Western Australia
April 2005,
Survey and Operations Report
Survey/Report by:
GPX Airborne Pty. Ltd. Job 2188.

HoistEM – TEM Survey parameters 2.

CB-SC-10

APPENDIX E

SUMMARY REPORT ON THE CLOUD BREAK MODEL

APPENDIX E – SUMMARY OF MODEL

A groundwater flow model of a major section of the Fortescue Valley and Fortescue Marsh site was developed using MODFLOW-96 (Harbaugh and McDonald, 1996). The model is used to simulate open pit dewatering at the proposed Cloud Break mine given a preliminary 12-year mine schedule. The eastern boundary of the model is coincident with the western boundary of another model previously developed by Aquaterra for the assessment of the Christmas Creek, Mt Lewin and Mt Nicholas mine sites (Aquaterra, 2005 draft). The two models represent over 150 km of the semi-arid Fortescue Valley, Marsh and River system.

Main Aims

- To simulate/predict of the effects of pit dewatering (at Cloud Break) on groundwater levels for regional environmental impact assessment.
- To simulate/predict the rates and volumes of groundwater that will be dewatered at Cloud Break as a result of a 12 year preliminary mine schedule. This information will be required for mine water management.
- To simulate/predict the flow direction of groundwater to the open pit to assist estimates of groundwater salinity (based on salinity mapping). This information will be required for mine water management.

Model Domain and Grid

The model domain includes a rectangular area 50 km wide and 92.5 km long. The domain is rotated 30 degrees clockwise about its north-west corner which is located at 119.29 degrees Latitude and –21.889 degrees Longitude. The model domain resides in UTM map zone 50, however the neighbouring groundwater model (Aquaterra, 2005 draft) spans two zones (zone 50 and 51) and consequently the coordinates of both models were converted to zone 51 for consistency. In plan the model grid is comprised of 185 rows and 100 columns of uniformly sized cells (each 500m by 500m). The level of detail provided by this grid is sufficient for regional scale simulations and preliminary drawdown predictions (for PER).

Model Layering

The model has 3 layers to represent two major stratigraphic units within which groundwater flow is expected to occur: (Unit 1) a shallow alluvial layer, and (Unit 2) a basement layer of Marra Mamba Iron Formation, Jeerinah Formation, and Wittenoom Dolomite. The upper-most layer (Layer 1) represents the alluvial aquifer which has a thickness that varies from a minimum of about 5 m (along the valley edges and near the mine sites) increasing to 65 m near the middle of the Fortescue Valley and increasing to about 100m along the southern edge of the valley where there are large colluvial fans. Alluvial depths were inferred from available drill logs, geologic maps and satellite images.

Bedrock outcropping is assumed to be an effective barrier to regional groundwater flow. The extent of Layer 1 (and the active model domain) is therefore limited by bedrock to the north and the south of the valley. Geologic maps indicate that elevations above ~485 mRL approx. coincide with bedrock outcropping and the valley sides. These areas are defined either by inactive cells or by low-conductivity cells. Other alluvial aquifers occur to the north of the study area but these were not represented since they are separated from the Fortescue Valley by groundwater divides, bedrock outcropping and water sheds.

The deeper layers, Layers 2 and 3, were assigned a uniform thicknesses of 20m and 80m, respectively. These layers represent basement material (~100m effective thickness assumed) that underlies the alluvium. Layer 2 also represents localised ore (approx. 20 m thick) where ore has been detected along the northern edge of the valley where mining is proposed (ie at Cloud Break).

Boundary Conditions

The model's domain-limiting boundaries include a specified (constant) head boundary along its east side (Layers 1 to 3) and no-flow boundaries along the other three sides. Heads of the specified head boundary were extrapolated from available water level measurements. The no-flow boundaries that occur along the north and south sides of the valley are to approximate the hydraulic barrier and groundwater divide associated with the major bedrock outcrops. Much of the alluvium in the upland areas is dry (on average) and hence a portion of cells in Layers 1 and 2 are "dry cells". The west side of the model is a no-flow boundary based on the assumption that regional groundwater movement is primarily from the valley edge towards the valley centre (ie parallel with the western boundary). There is scant field data in this area from which to develop other possibly more sophisticated boundary conditions.

Hydrologic Balance

The study area is arid with high summer temperatures, high mean evaporative demand (2480 mm/yr potential evaporation), and low mean annual rainfall (310 mm/yr). The literature indicates that in the Northern Territory, for example, a similar hydrogeological environment is likely to experience a mean groundwater recharge of only 0.1 to 2 mm/yr (Harrington, Cook, and Herczeg, 2002). Another example is the Australian Goldfields where an average recharge estimate of 0.6 mm/yr was quoted by the Water & Rivers Commission. These mean recharge values were used as a guide in the development of the current groundwater model and are similar to values used in other Pilbara models.

Evapotranspiration: Two different evapotranspiration zones were assigned: (1) one for the Fortescue Marsh where a shallow water table occurs, and (2) for areas with Coolibah trees. Both zones have a 1520 mm/yr potential evapotranspiration rate (60% of the recorded average potential). The water table in the Fortescue Marsh is shallow at ~5 mbgl (inferred from available water level data at the end of the dry season) and hence significant groundwater losses will occur via evaporation and plant transpiration. A 5 m rooting depth of marsh vegetation was assumed (ie the extinction depth). The area of Coolibah was inferred from vegetation mapping and a rooting of 10 m was assumed.

Groundwater Recharge: Three different recharge regimes were defined in the model, including: (1) 0.1 mm/yr net recharge in the valley floor other than the marshes and streambeds, and (2) 1.4 mm/yr along streambeds (these occur mostly in the foothills), and (3) 250 mm/yr of surface water that collects and ponds in the topographic lows of the Fortescue Marsh. The location of the 'marsh zone' was inferred from aerial photographs and topographic data. It is expected that gross recharge of the order of 250 mm/yr (or more) is possible in the Marsh given that (i) about 5 m of soil ($S_y \approx 0.05$) may be saturated each wet season as a result of rainfall-runoff, and (ii) the catchment analysis. The catchment area for the whole upper Fortescue Valley is ~33800 km^2 and is expected to yield on average ~7 mm of runoff per year based on regional trends (Water Rivers Commission, 2000). Given that the total maximum area of the Fortescue Marsh is roughly 900 km^2, this average runoff volume could produce at least 270 mm depth of water within the Marsh (not including direct rainfall to the Marsh). Hence, whilst the first two recharge zones define a *net* recharge situation (ie accounting for evaporative losses), the third recharge zone is for *gross* infiltration-recharge (ie not accounting for evaporative losses) related to surface water inflows and rainfall. This distinction is important, because it implies that the water table within the Marsh is likely to fluctuate seasonally because of significant wet season inputs (flooding) and subsequent dry season evaporation. The water table is unlikely to remain above the plant root-zone for extended periods because of the high evaporative demand. Conversely, the water table is unlikely to fall significantly below the plant root-zone because (a) this would induce reductions in the transpiration rate, and (b) there is no other major regional sink for groundwater other via evaporation. It is therefore expected that the water table will be seasonally variable but stable within the Fortescue Marsh.

Model Calibration - Preliminary

The model parameterisation was initially based on estimates of aquifer material properties and hydrological variables that were determined during a previous modelling study of the Fortescue Valley immediately to the east of the current study area (Aquaterra, 2005 draft).

The hydraulic conductivities of the base-case model were refined through manual calibration of the model under steady-state conditions. The steady-state approach assumes that the observed groundwater levels are typical of the system if the effects of climate variation are averaged-out. Water level data include readings from five (5) regional bores and forty-eight (48) mineral bores. These bores are mostly located near or within the proposed Cloud Break mine site.

The calibration process involved altering the horizontal hydraulic conductivity of the alluvium, bedrock and ore until the model simulated water-table matched (imperfectly) the interpreted water-table. The important parameters of the calibrated model are listed in Table 1. Note that the hydraulic conductivities adopted are within range of available field test data, and the recharge rates are similar to that estimated for other locations in the Pilbara (eg West Angelas).

The collar elevations of some regional bores were surveyed with GPS, and hence the uncertainty on the regional water table is about +/-3 m at these bores. Most other bores were surveyed accurately. The mineral exploration bores were sampled for water levels shortly after construction and so the standing water levels that were recorded in these bores are not considered 100% reliable. Due to this inherent uncertainty, the current approach was to accept a Scaled-RMS of <10% with a statistical weighting of 50% for the exploration bores and 100% for the regional bores. Moreover, the simulated water table was developed such that it is consistent with (a) the topographic model (so the water-table did not "daylight"), (b) observed water level and extrapolated water level trends, and (c) the conceptual hydrological model for the marsh and river and the hydrogeological model for the valley.

Model Predictions - Preliminary

After the model was calibrated to steady-state conditions, the model was then modified to simulate transient seasonal recharge and evapotranspiration. This involved modifying the recharge and evapotranspiration boundary conditions to include three periods per year: (Period 1) January to March, (Period 2) April to September, and (Period 3) October to December. These periods correspond to the wet season, the cool dry season and the hot dry season, respectively. It was assumed that all of the recharge occurs in the wet season. Sixty percent (60%) of the evaporative potential was distributed in time according to long-term monthly averages. The transient model was then executed over 20 years (quasi steady-state) and the water levels validated against the field records. The pre-mining (existing) water-table surface was approximated by the quasi steady-state values produced by the model at 1st of January.

The transient model was then used predictively to simulate 12 years of scheduled mine pit dewatering followed by 8 years of post-mine recovery. The mine pits at Cloud Break were simulated using the 'drain package' of MODFLOW-96 and a drain conductance of 500 m^2/d. The drain elevations and timing were defined by a preliminary mine plan which involves backfilling of pits 12 months after excavation. No additional dewatering (or evaporation) of water occurs in the pits after backfilling. Since the pits are to be excavated into the hill side a significant portion of the higher pits are initially dry (above the water table) and thus pit dewatering is only required when the pits actually reach the water table.

Future Work

The modelling study requires additional work as recommended in Groundwater Flow Modelling Guideline (MDBC, 2000), including:

1. model sensitivity, and
2. uncertainty analyses.

The current base-case model will be refined as more field data becomes available. Model features that are identified for refinement include:

1. Water table elevations, from new and existing bores;
2. Evapotranspiration, including aerial zonation and rooting depths of major vegetation types;
3. Recharge, including aerial zonation of major recharge zones; and
4. Stratigraphic elevations, including alluvial and basement thicknesses.

Other potentially important issues for the model development, calibration, and predictions, are also being considered. These include:

1. Refinement of the whole-of-model water budget, including (a) the catchment water balance, and (b) the estimated regional inflows/outflows connecting the current study area with neighbouring aquifers.
2. Examination of the historical rainfall for the region and the assessment of impacts of rainfall variability and droughts on water table fluctuations and drawdown.

The above tasks are programmed to commence in mid-2005.

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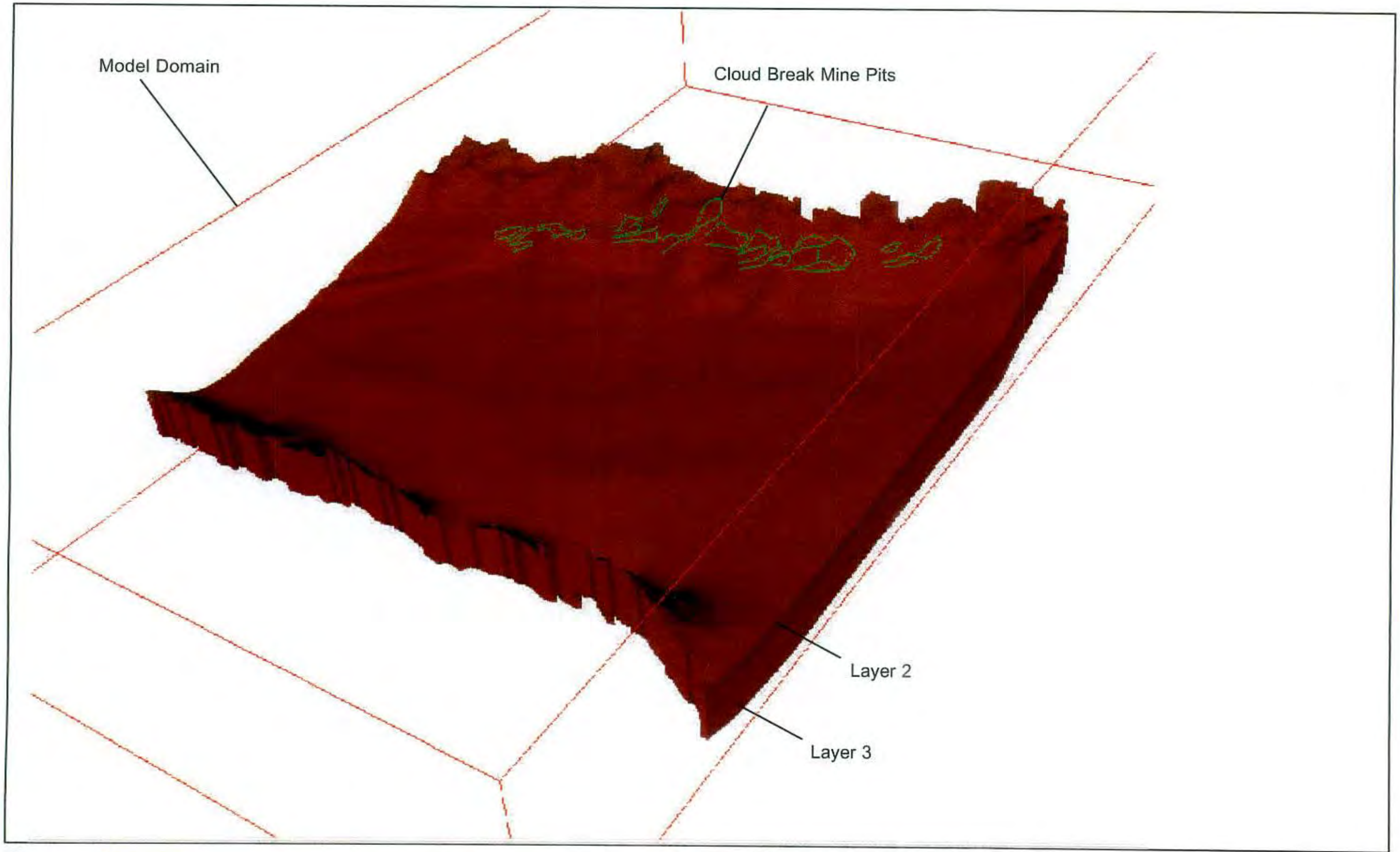

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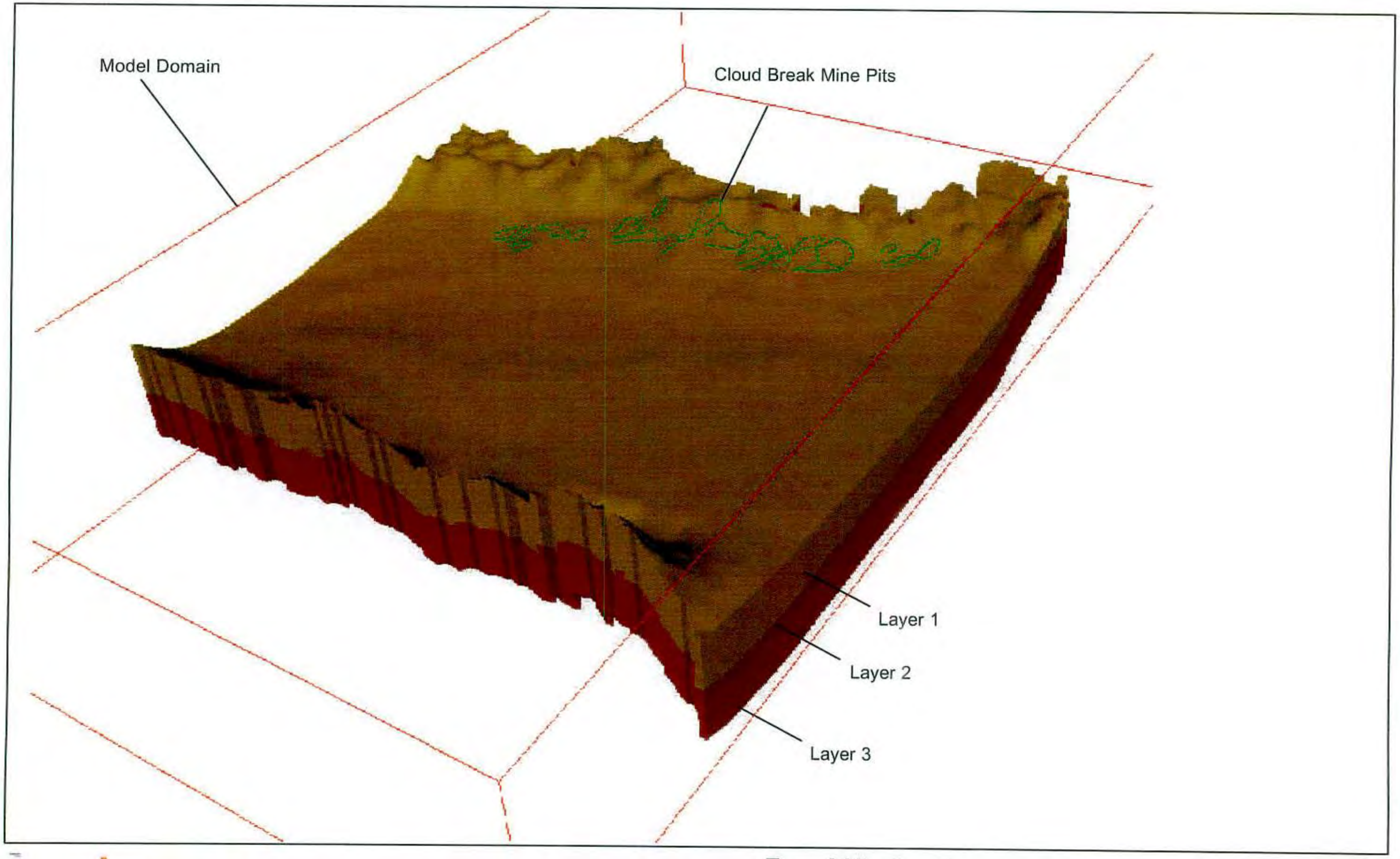
Top of Basement Perspective: Interpreted from Field Data

Figure E1



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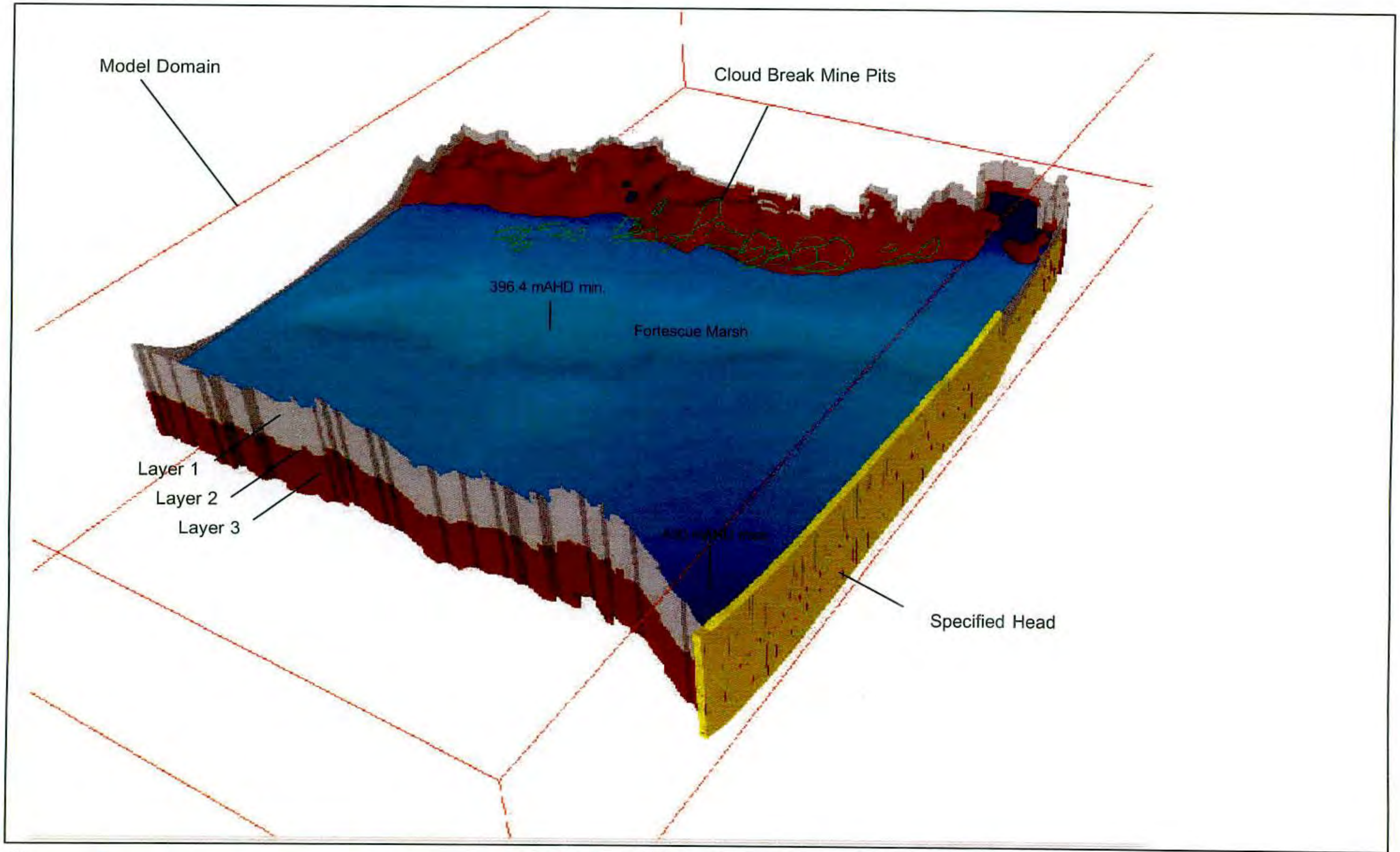
Top of Alluvium Perspective: Interpreted from Field Data

Figure E2



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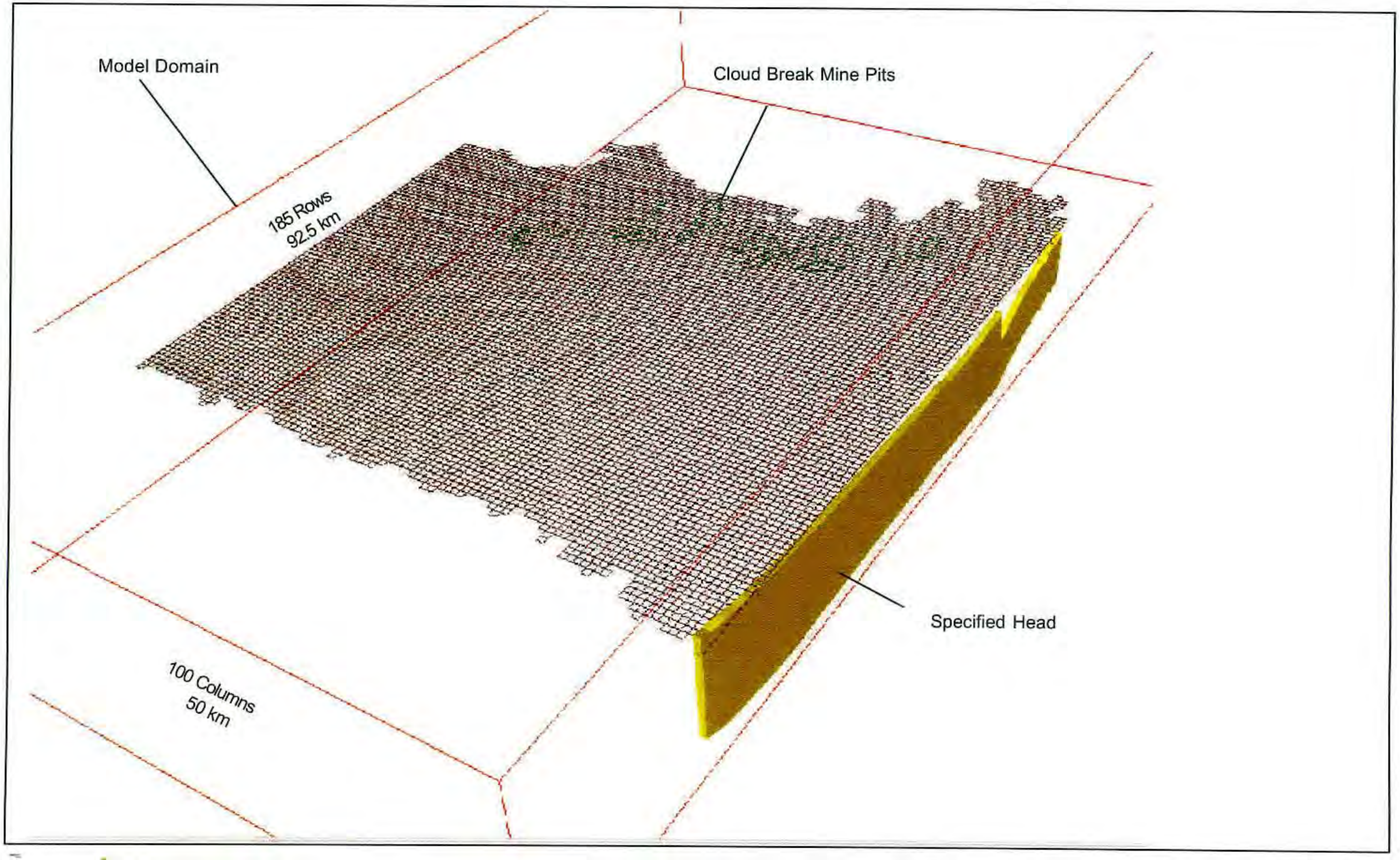
Regional Water Table Perspective: Interpreted from Field Data and Modelling

Figure E3



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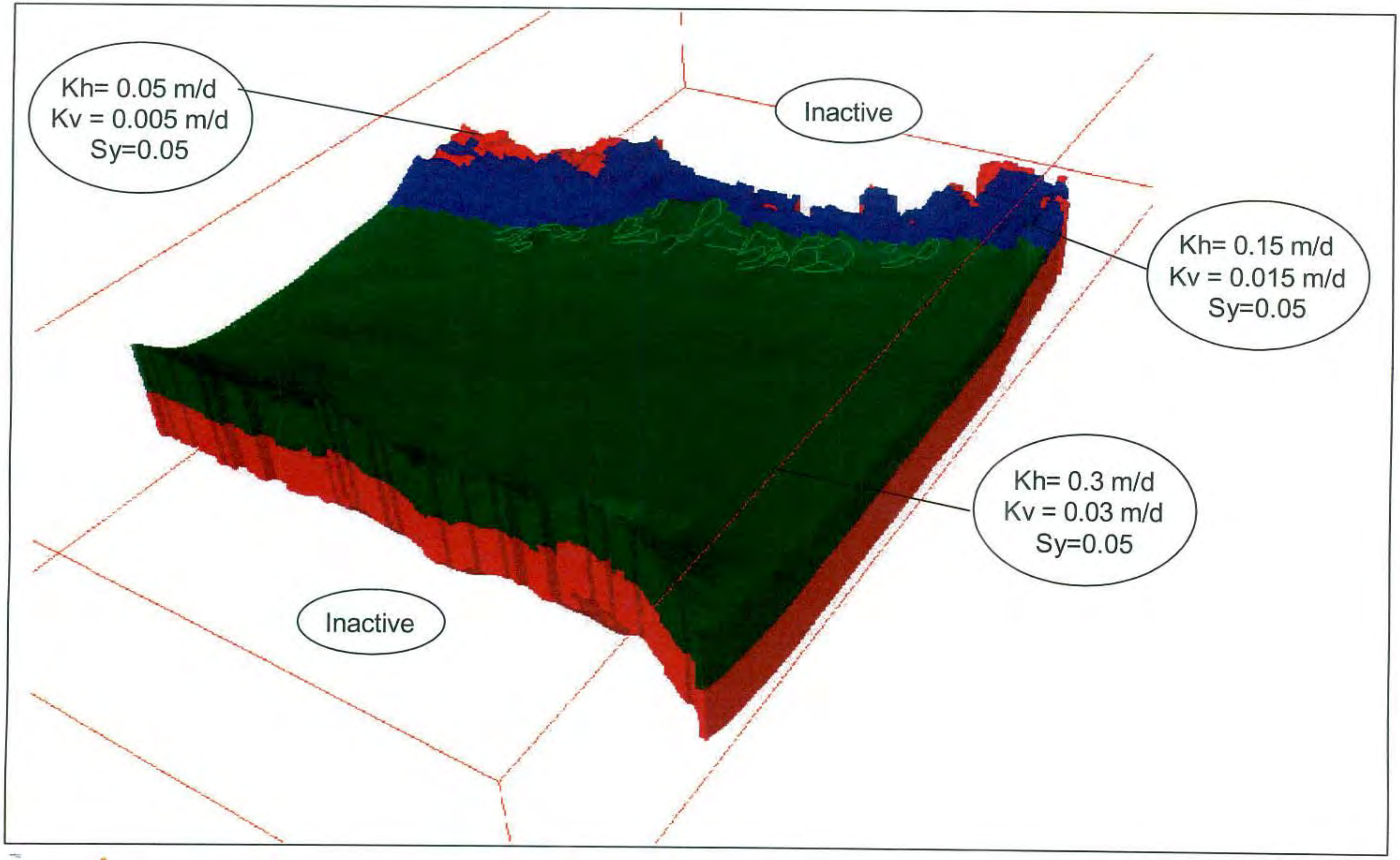
Model Grid (Layer 1)

Figure E4



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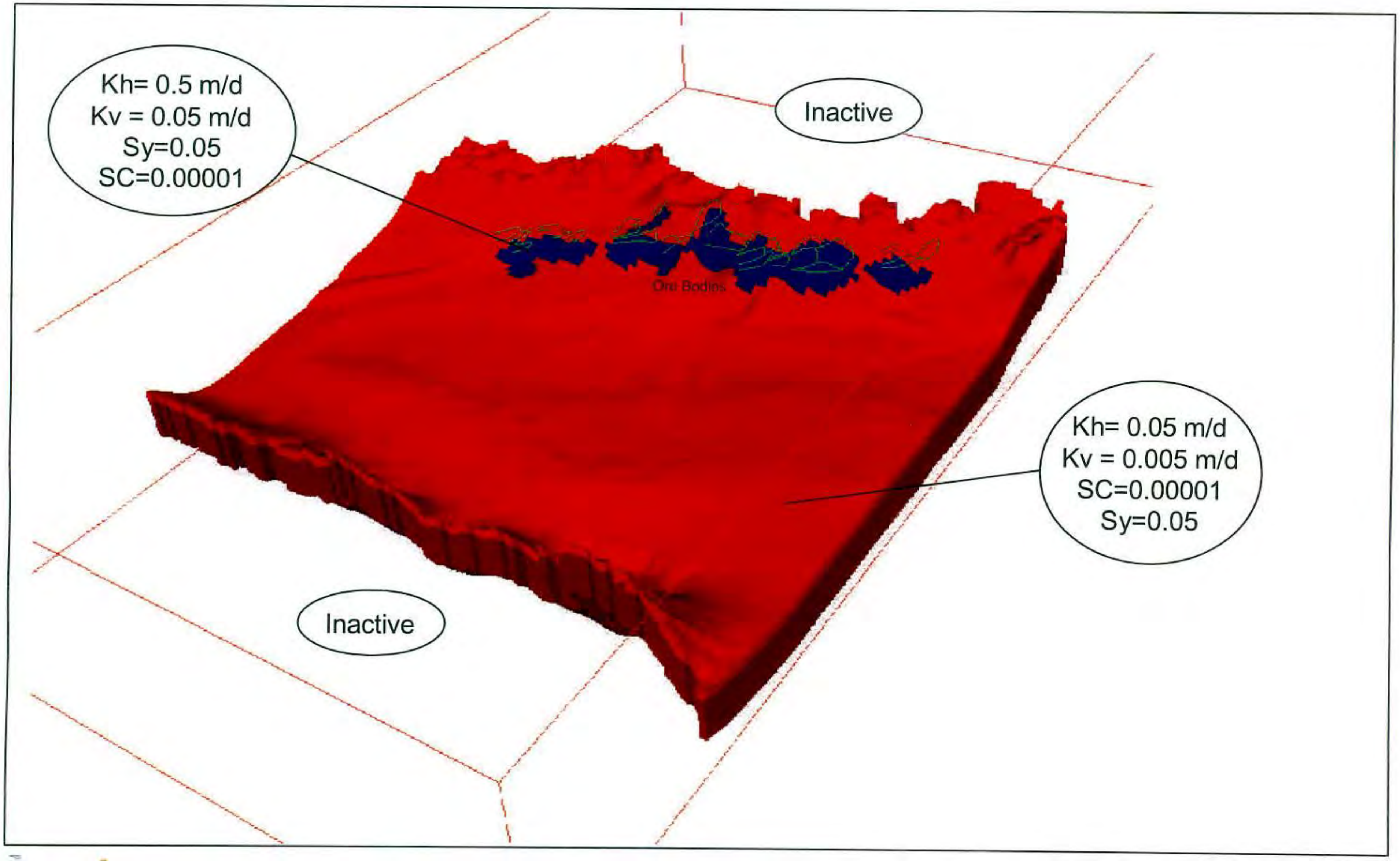
Hydraulic Properties of Alluvium (Layer 1)

Figure E5



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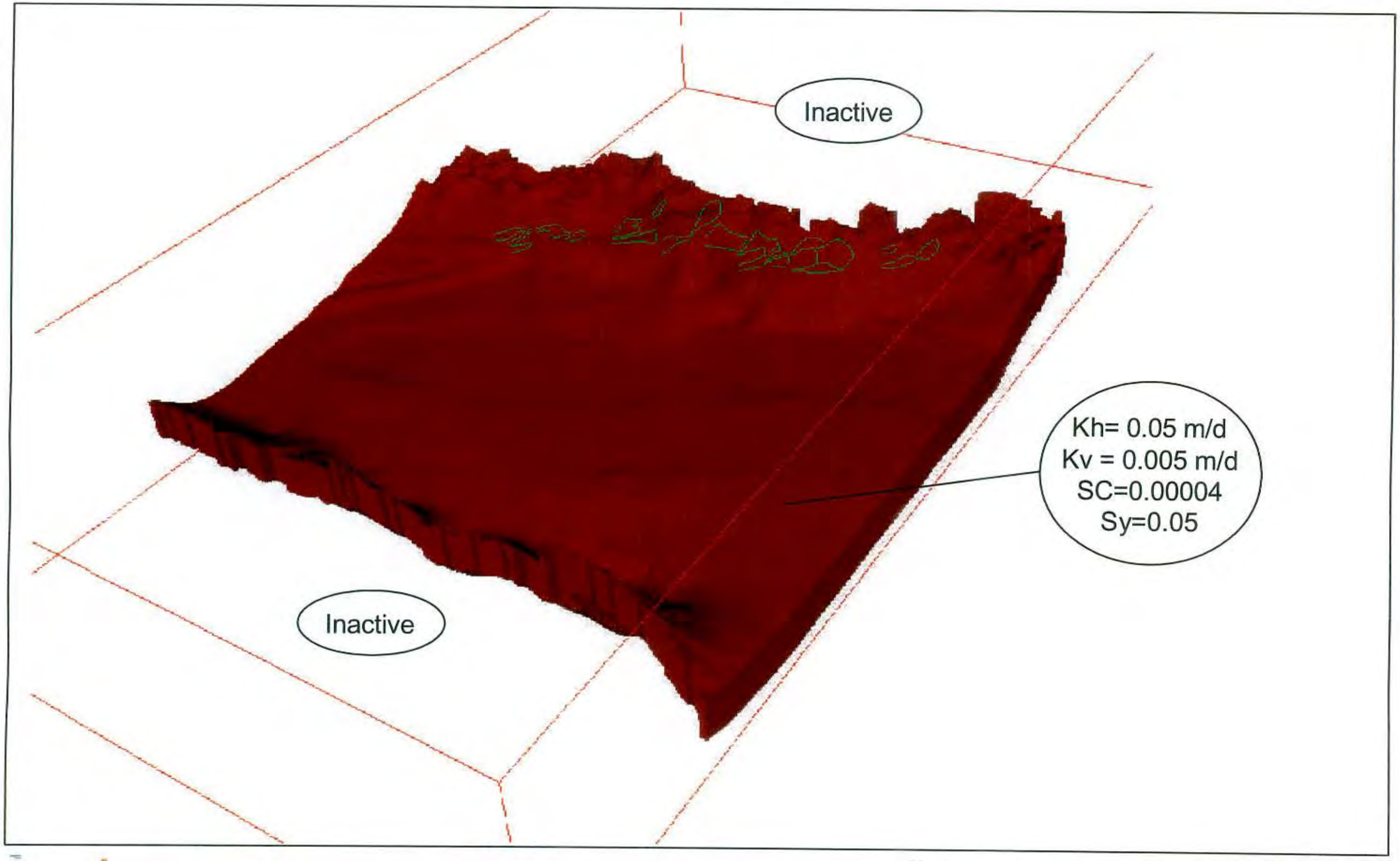
Hydraulic Properties of Basement (Layer 2)

Figure E6



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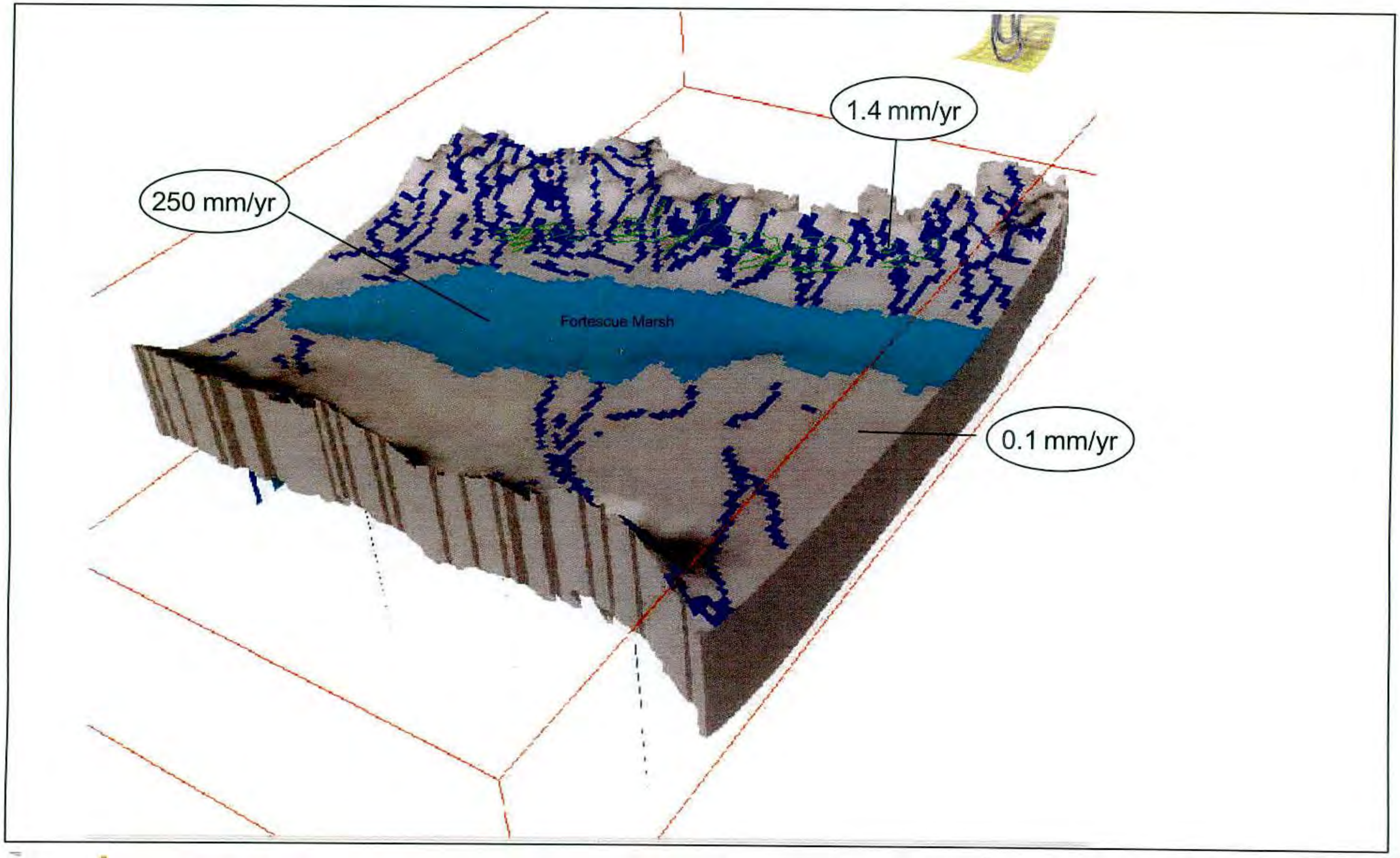
Hydraulic Properties of Basement (Layer 3)

Figure E7



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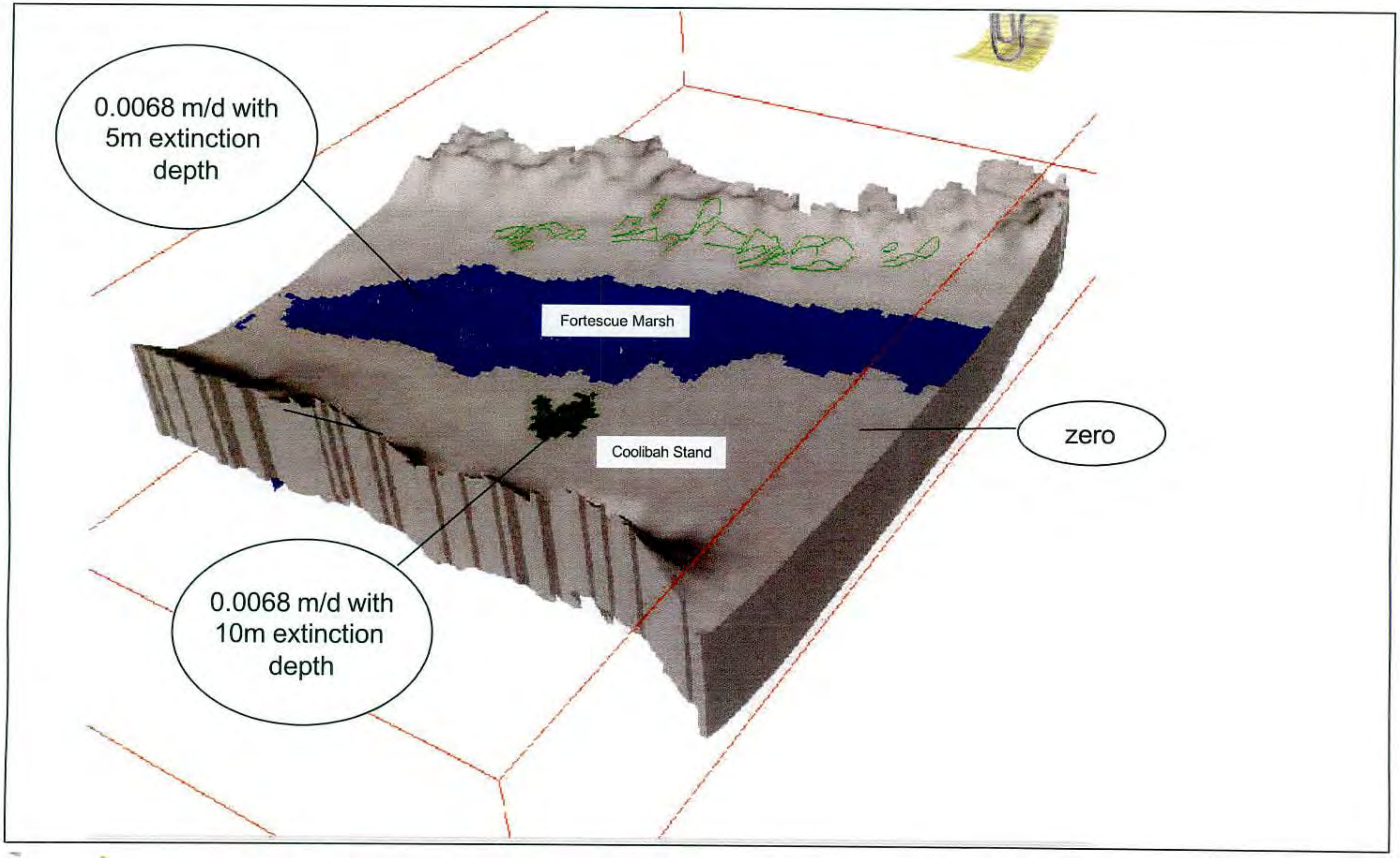
Recharge Zones and Average Rates

Figure E8



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Evaporation Zones and Average Rates

Figure E9

CALIBRATION PARAMETERS		VALUE
Scaled Mean Sum of Residuals	SMSR	0.50 %
Root Mean Square	RMS	1.35 m
Scaled RMS	SRMS	4.16 %
Root Mean Fraction Square	RMFS	0.33 %
Scaled RMFS	SRMFS	4.17 %
Coefficient of Determination	CD	3.45

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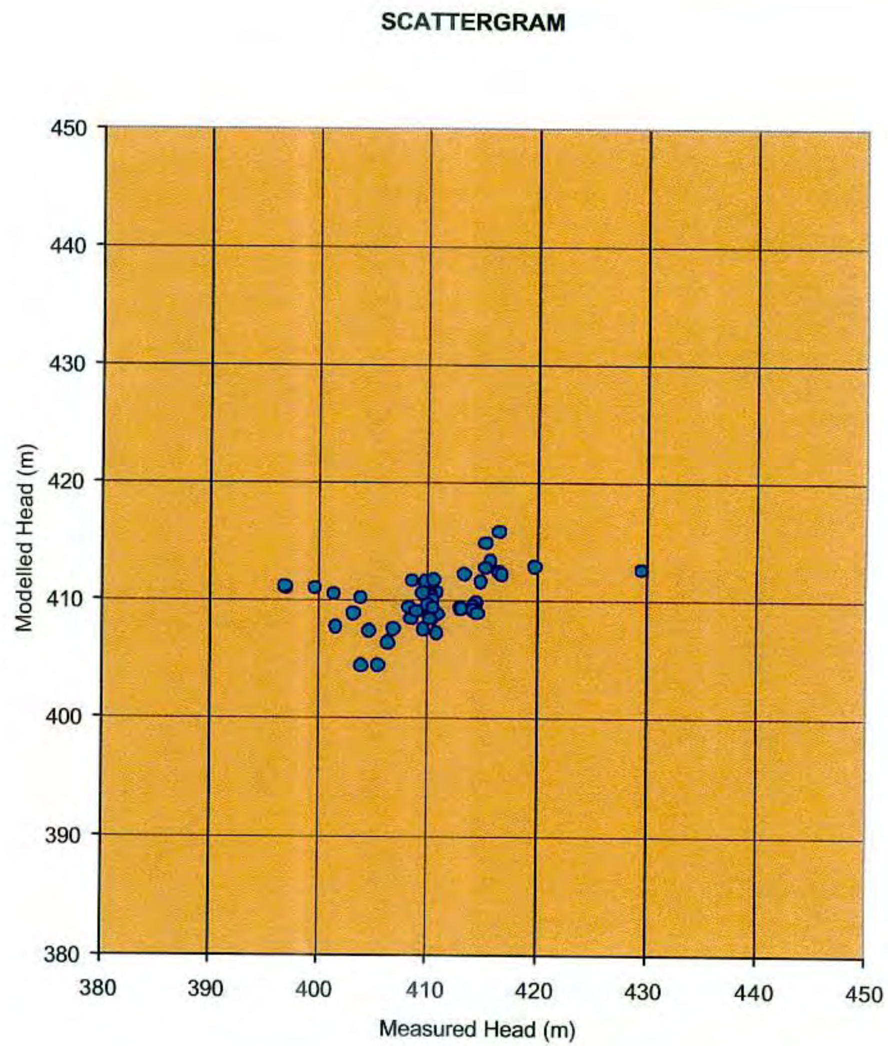

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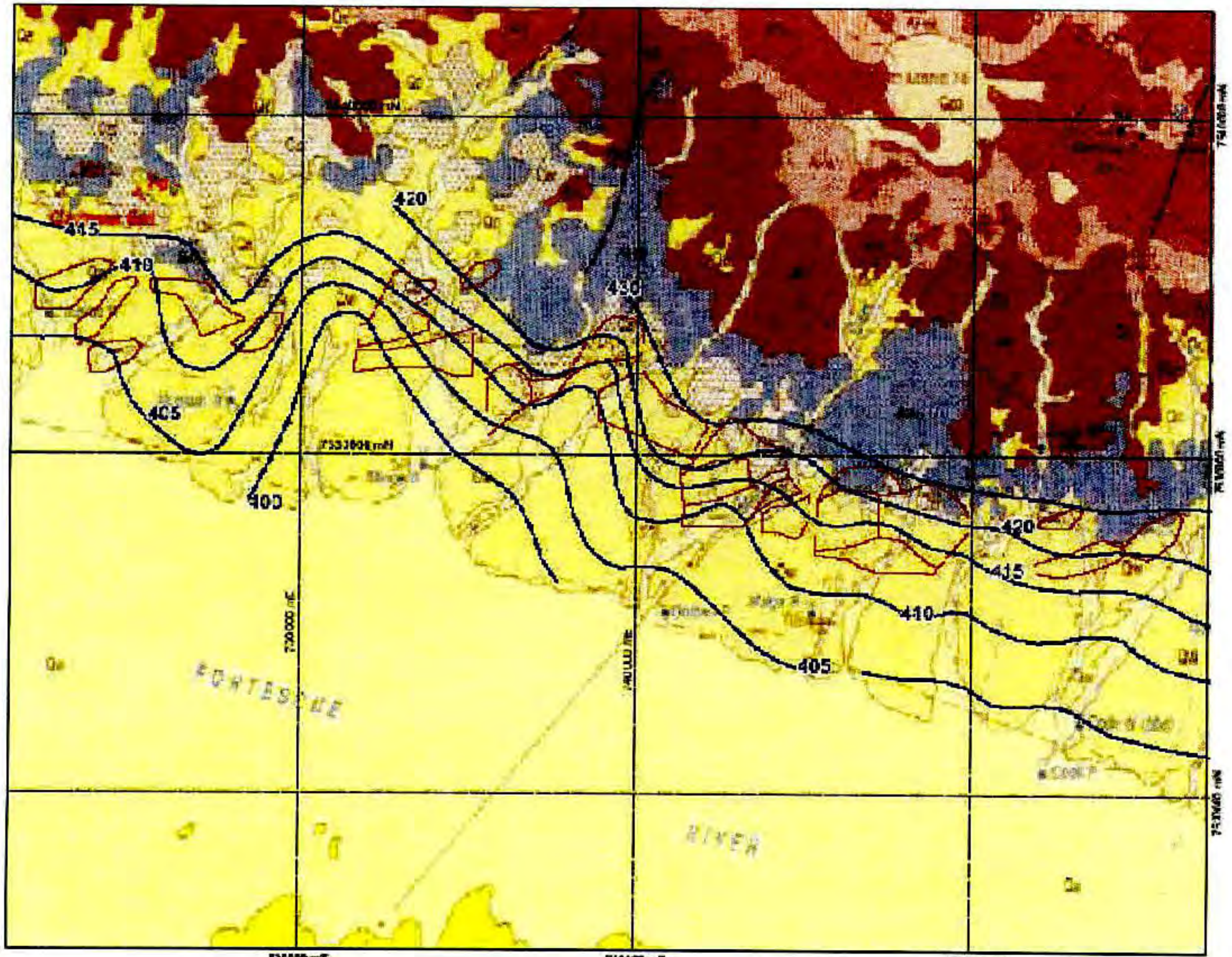
Calibration Scatter Diagram

Figure E10



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Average Water Table Contours (mRL): Estimated from Available Field Data and Modelling

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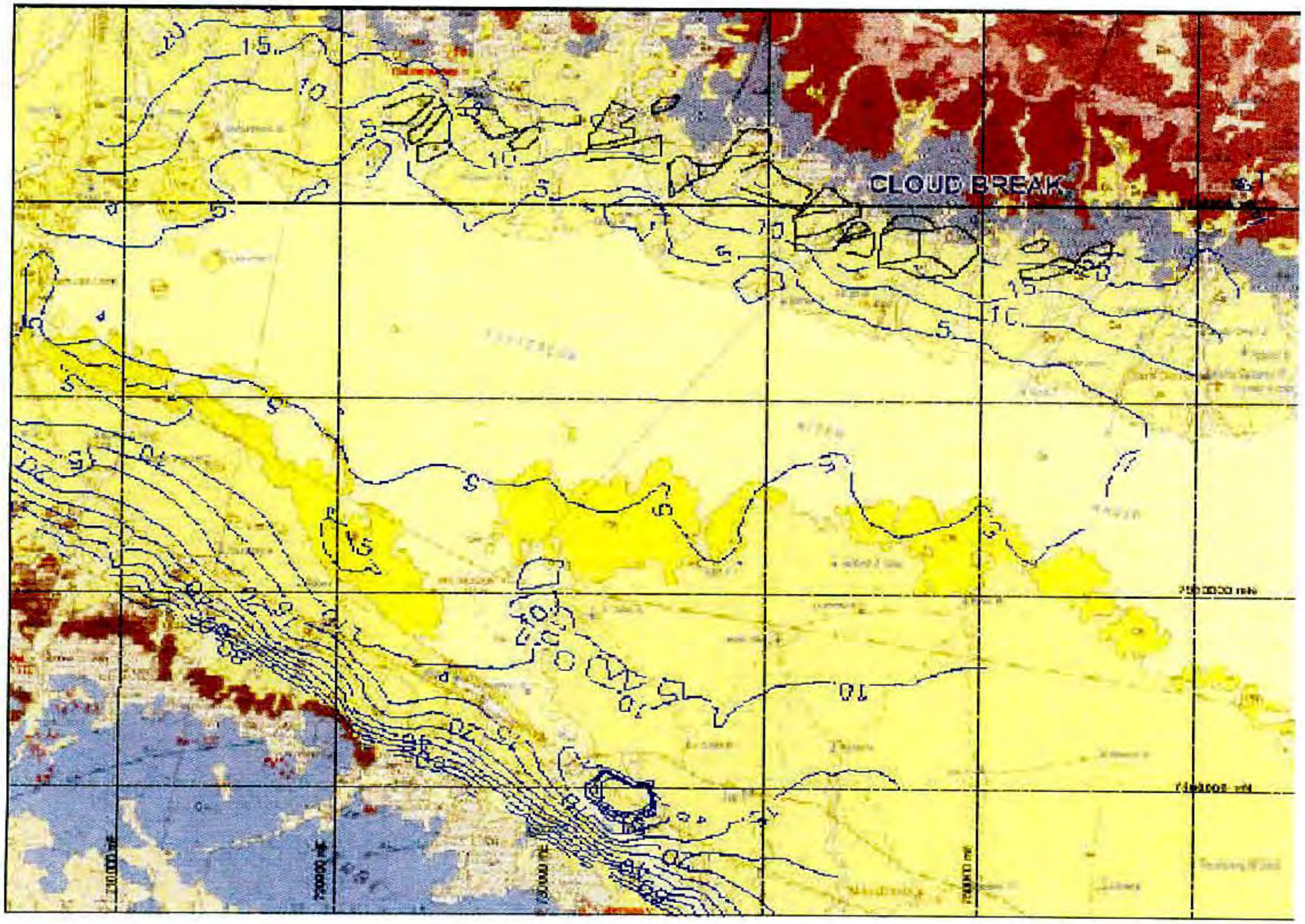
Figure E11



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Average Water Table Depths Below Ground (mbgl): Estimated from Available Field Data and Modelling

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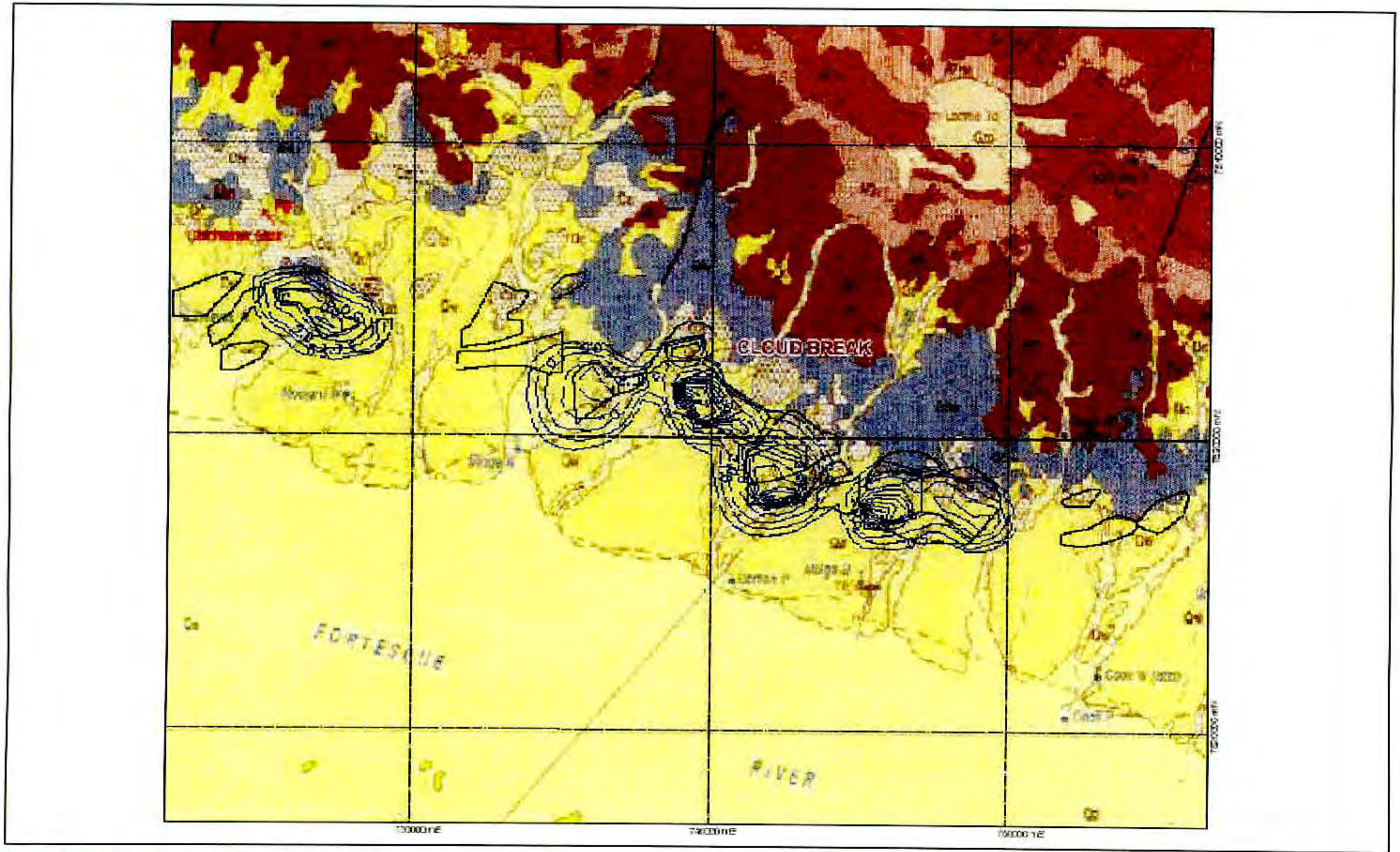
Figure E12



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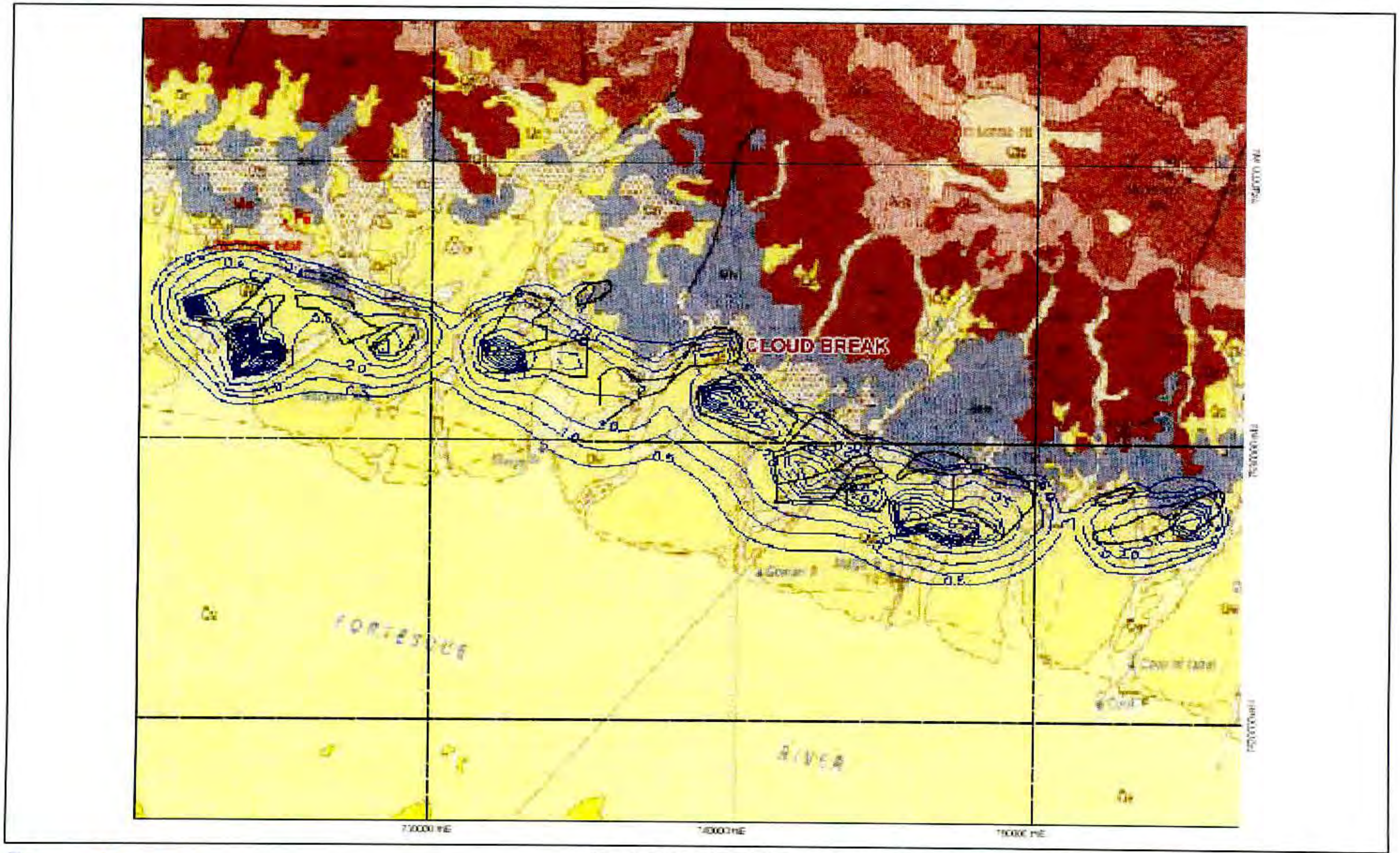
Model Predicted Drawdown after 5 years of Mining (m)

Figure E13



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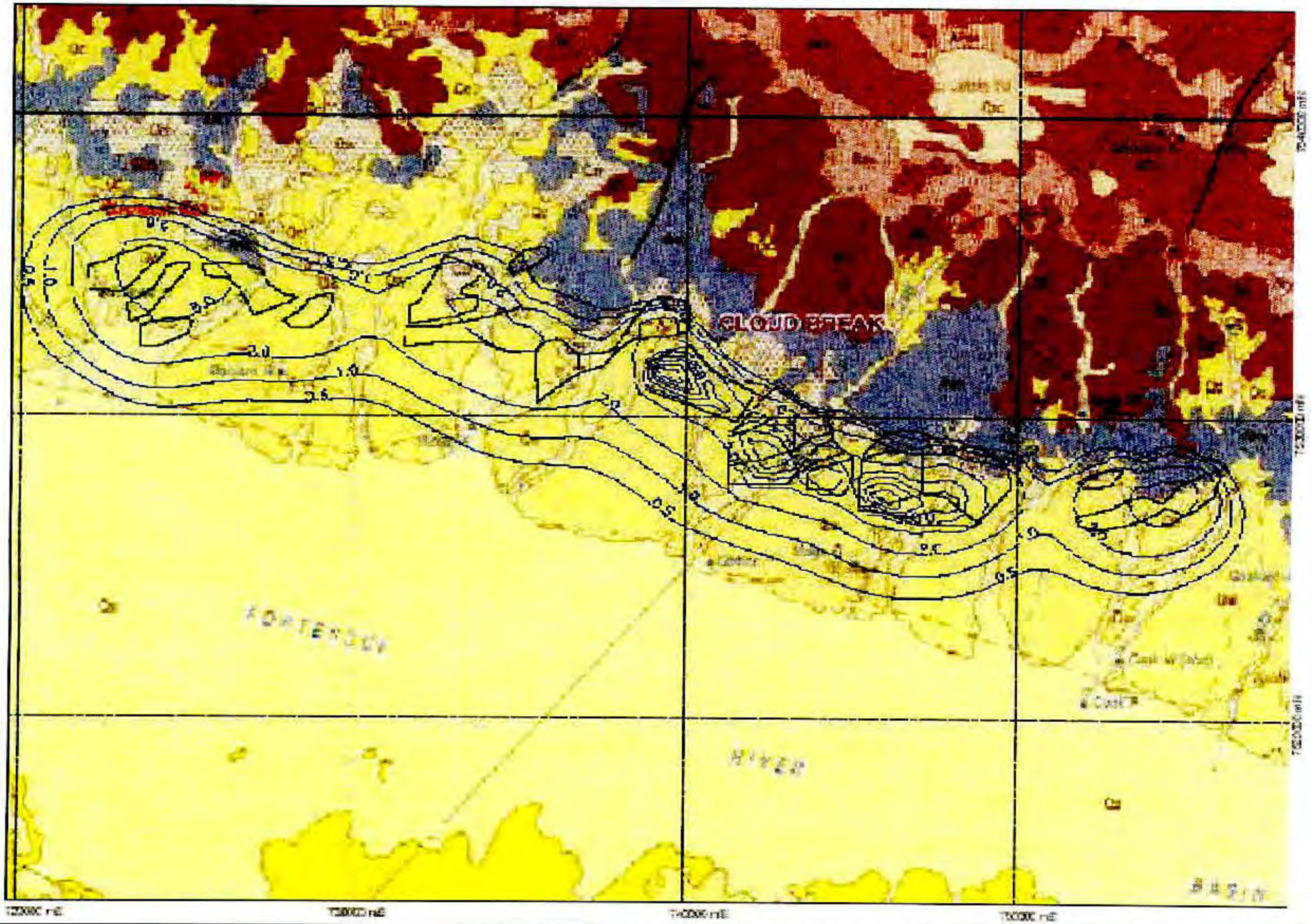
Model Predicted Drawdown after 12 years of Mining (m): at end of mining

Figure E14



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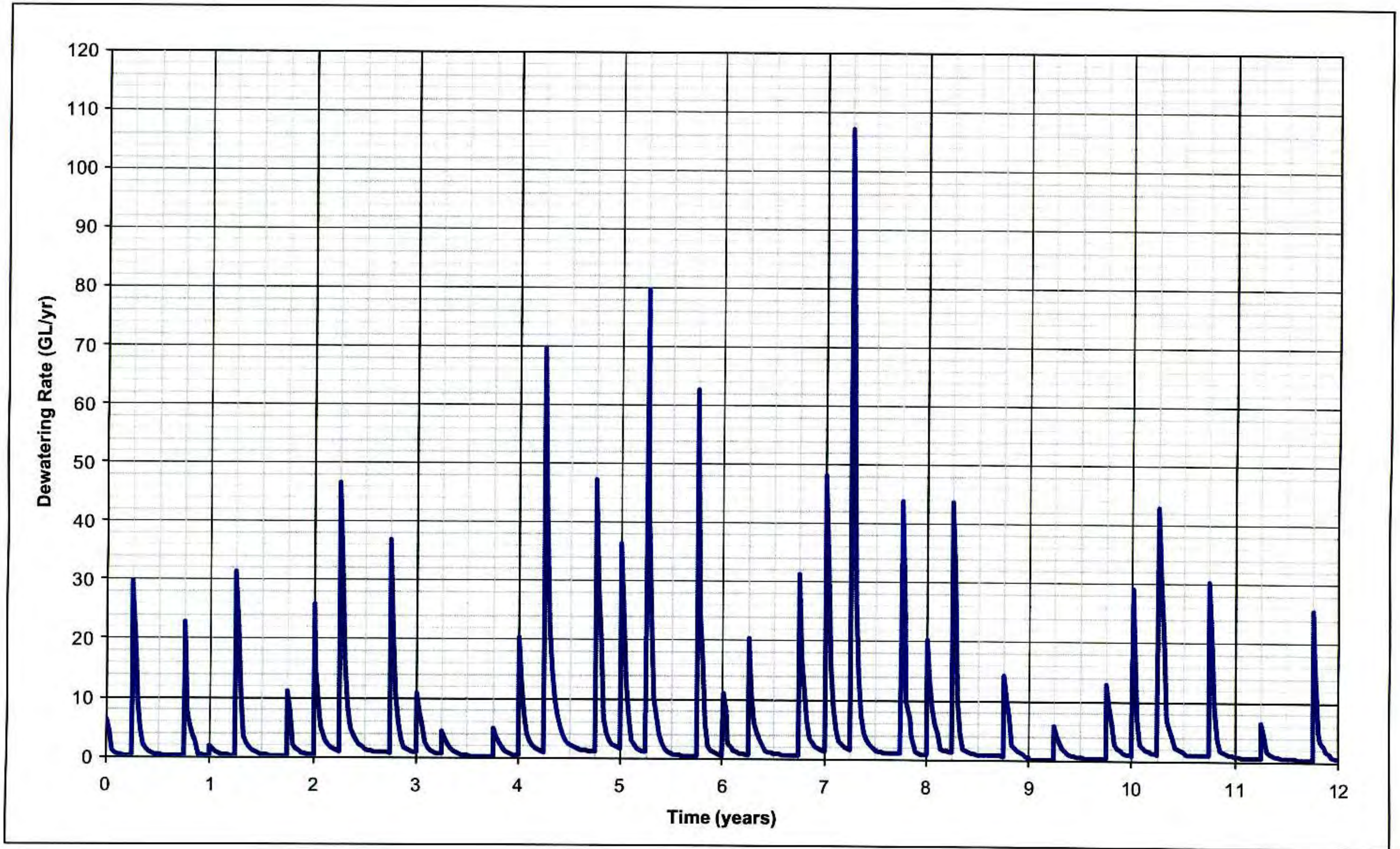
Model Predicted Drawdown after 20 years (m): 8 years post-mining

Figure E15



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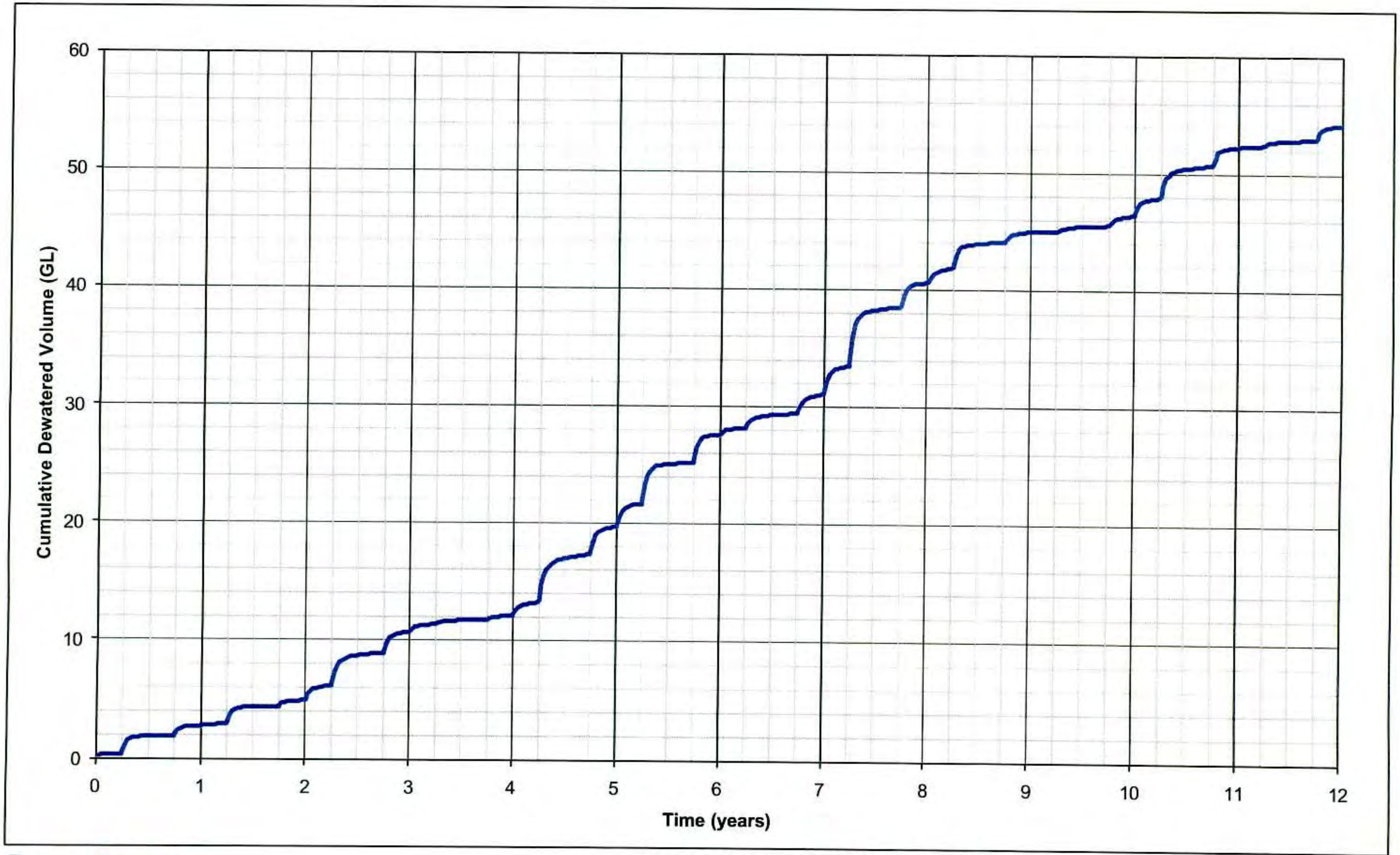
Model Predicted Pit Dewatering Rates: during 12 years of mining

Figure E16



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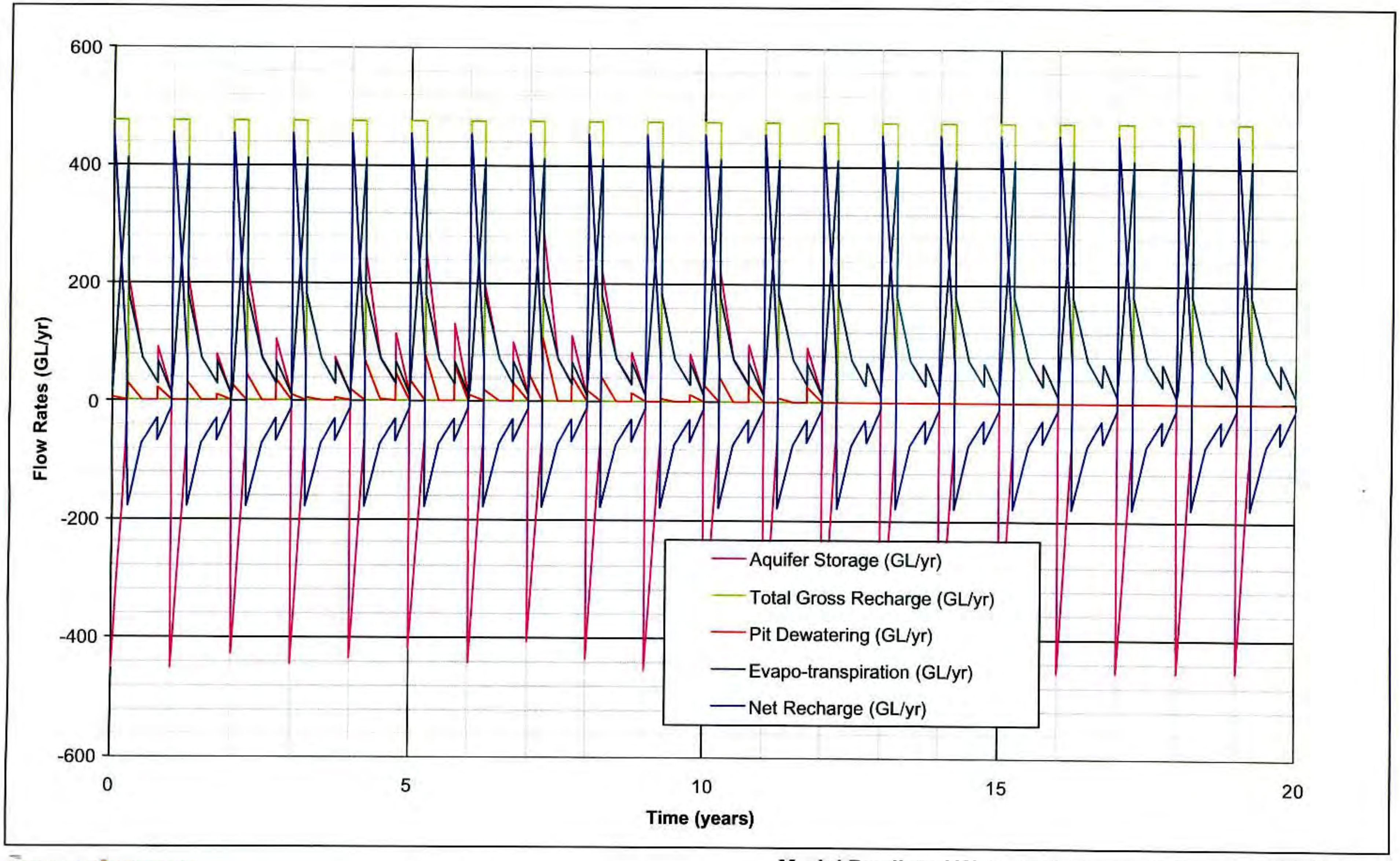
Model Predicted Pit Dewatering Volumes: during 12 years of mining

Figure E17



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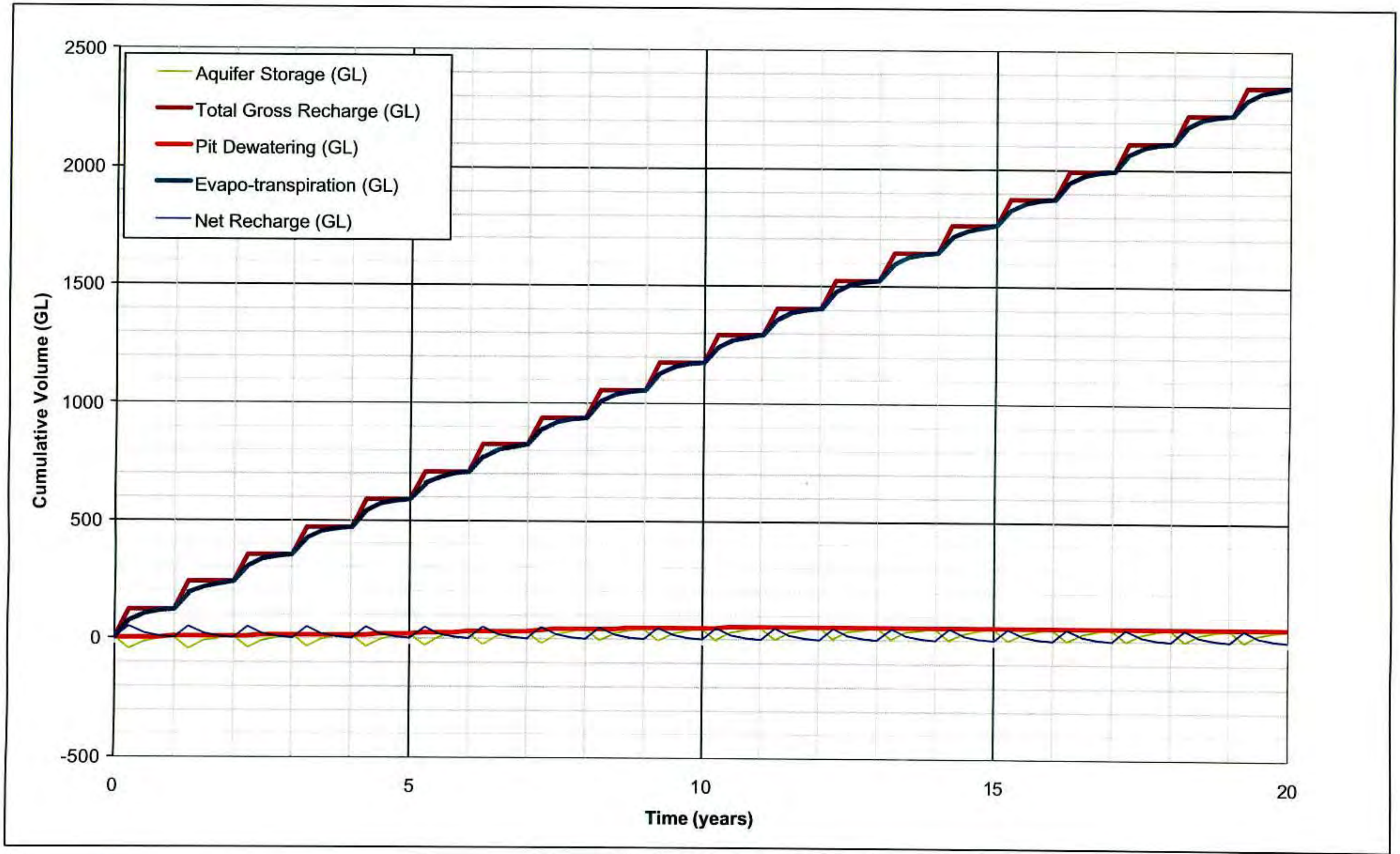
Model Predicted Water Balance as Rates: over 20 Years

Figure E18



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Model Predicted Water Balance as Cumulative Volumes: over 20 Years

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Figure E19

APPENDIX F

DEWATERING MANAGEMENT PLAN

APPENDIX F – DEWATERING MANAGEMENT PLAN

INTRODUCTION

FMG proposes to commence a new Project in the Pilbara. The Project is a new iron ore mine known as Cloud Break. Cloud Break consists of a series of pits, where the ore lies mostly below the water table, therefore dewatering is required in advance of mining.

Some of the abstracted water will be used for dust suppression and camp supplies. In the first year of mining water will also be required for moisture control in the ore. In later years it may be possible to use the dewatering water in the ore beneficiation plant proposed for Christmas Creek. However there is uncertainty as to the quality of water that will be abstracted during the dewatering, and the ore beneficiation plant can only use water with a salinity (as TDS) of less than 35,000 mg/L.

This Dewatering Management Plan sets out FMG's proposals to manage the dewatering of the Cloud Break deposit.

Dewatering Volumes

The calculations undertaken to determine the volumes of water that will be abstracted during the dewatering are set out in the Cloud Break PER. The results of the analysis are set out in Table F1 below:

Table F1
Dewatering Requirements at Cloud Break

Year	Quarter 1 (ML/d)	Quarter 2 (ML/d)	Quarter 3 (ML/d)	Quarter 4 (ML/d)	Average (ML/d)
1	0.0	3.8	3.3	5.7	3.2
2	5.7	4.6	4.1	3.9	4.6
3	3.9	9.1	6.8	9.5	7.3
4	9.5	3.9	3.1	1.8	4.6
5	1.8	11.3	9.2	12.2	8.6
6	12.2	15.3	11.4	13.9	13.2
7	13.9	6.8	5.5	6.2	8.1
8	6.2	21.5	15.8	15.7	14.8
9	15.7	11.6	8.8	8.2	11.1
10	8.2	2.1	1.9	2.2	3.6
11	2.2	10.8	9.0	10.9	8.3
12	10.9	3.8	3.3	4.0	5.5
13	4.0	1.8	1.3	0	1.8

Impacts from the Cone of Depression

Abstraction of groundwater results in a depression of the water table, known as a cone of depression. At Cloud Break numerical groundwater modelling has been undertaken which has predicted the extent of the cone of depression throughout the life of mining. The results are presented in the PER.

Four potential environmental impacts have been determined from the cone of depression:

- Where the water table is initially close to the ground surface, and is then drawn-down by the dewatering, this may impact upon phreatophytic vegetation. The risk of this is considered unlikely (Libby Mattiske, June 2004).

- If the cones of depression extend to the Fortescue Marsh then the marsh may drain more quickly than at present. (Modelling has predicted that this will not occur as the cone of depression is predicted to not extend below the Marsh and therefore an impact on the marsh is unlikely.
- Dewatering may impact on subterranean fauna (including stygofauna) if habitats are dewatered.
- There may be a reduction in the yields of stock bores as a result of lowering of groundwater levels or an increase in salinity.

The Salinity of the Abstracted Water

Work undertaken to determine the extent of saline water is described in the PER. However the work has shown that the distribution of salinity is complex, and analysis of the data is complicated because of the structural geology of the area and the presence of conductive shales of the Jeerinah Formation, which mask analysis from a TEM survey.

What is known is that water dose to the Fortescue Marsh is hyper-saline (>35,000 mg/L TDS) and that this saline water dips to the north below fresh water. Calculations have shown that in the first year of dewatering the abstracted water is likely to have TDS of around 7000 mg/L. After the first year of dewatering the water quality is likely to deteriorate, with the abstracted water becoming more saline, however the change is salinity has not been modelled because of the uncertainty of the current salinity distribution.

Careful management of abstracted saline water will be required to prevent escape into the environment, which may result in vegetation deaths or contamination of fresh aquifers.

PROPOSED METHOD OF DISPOSAL

A range of options has been considered for disposal of the water abstracted during dewatering. These are described in the PER report.

Given the complexity of the distribution of saline water, and uncertainty in the salinity of the abstracted water, FMG has assumed a worst-case scenario. That is that all the water abstracted during dewatering will be hyper-saline. Because of this FMG considers that only one disposal mechanism is environmentally acceptable, that is disposal via evaporation from specially constructed ponds, lined with a geotextile membrane to prevent escape of the saline water. However FMG is committed to investigate alternative methods of disposal which may be more environmentally acceptable.

STRUCTURE OF THE DEWATERING MANAGEMENT PLAN

This Dewatering Management Plan is in three phases:

1. Describes work that FMG proposes to undertake immediately to better understand the salinity of abstracted water.
2. Describes the work FMG proposes to undertake to investigate alternative methods for disposal of the water.
3. Describes the long-term monitoring FMG proposes to undertake to protect the environment from both the cones of depression and disposal of the saline water.

PHASE 1 PROPOSED ADDITIONAL WORK

FMG recognises the importance of being able to accurately predict the salinity of water abstracted during the dewatering of the Cloud Break pits.

Field Programme

It therefore proposes a comprehensive programme of additional field investigations and advanced numerical groundwater modelling. The field investigation will commence with the drilling of approximately 14 deep bores to a depth of 100m into the basement material (coincident with the base of the numerical groundwater model). Samples will be taken every 10m during drilling to determine the change in salinity with depth. Piezometers will be installed at any of the 14 sites where saline water (>10,000 mg/L) is encountered. These piezometers will be installed at 10m depth intervals throughout the saline water so that accurate measurements of salinity can be taken both initially to understand baseline salinity conditions, and in the long term so that monitoring of the movement of saline water can take place.

The deep bores will be lined with well screen throughout the saturated thickness. Three of the bores will be test pumped for approximately 48 hours so that aquifer parameters can be obtained for each 10m thickness. This will only be in areas where saline water is present.

The data obtained from the field programme will be used to revise the existing numerical groundwater model.

Numerical Modelling

The model will initially simulate pre-mining water quality, and then be used to predict the change in water quality as dewatering occurs. The model results will indicate the quality of the abstracted water at each dewatering point. It is anticipated that water quality will vary from pit to pit, depending upon the depth of saline water, dewatering rates and aquifer properties.

The model outputs will be the salinity of the abstracted water at each pit. Therefore it will be possible to identify different methods of use/disposal of the water for each of the different dewatering streams.

PHASE 2 ALTERNATIVE METHODS OF DISPOSAL

On completion of the numerical groundwater modelling a report will be presented to the DoE describing the predicted water quality results. At this stage FMG will discuss alternative options for disposal of the water, in addition to evaporation ponds. FMG will describe which alternative options for disposal it plans to pursue, and what additional fieldwork and modelling it proposes to determine the environmental impacts from those methods.

It is not possible at this stage to describe the likely outcome of the Phase 1 study, however possible options for disposal include re-injection of water into a nearby aquifer or in-pit disposal of water.

Depending upon the methods of disposal additional fieldwork may be required at this stage.

On completion of the studies the preferred method of disposal will be discussed with the DoE and, if necessary, licences will be applied for.

PHASE 3 – LONG TERM MONITORING AND MANAGEMENT

Groundwater Monitoring

FMG has already commenced a programme of groundwater monitoring throughout the vicinity of Cloud Break. This monitoring includes the collection of groundwater levels from seven bores, (including station bores), plus water levels in the Fortescue Marsh. In addition water quality samples are being taken monthly at each of the seven monitoring sites and analysed to determine variations in background groundwater water quality.

The monitoring programme will be extended to include the bores drilled in the Phase 1 field investigation. In addition new monitoring bores will be installed between the Cloud Break pits and the Marsh to determine the extent of the cone of depression and monitor changes in groundwater salinity. This monitoring will provide information in a timely manner, so that changes in the salinity of the abstracted water are predicted in advance.

FMG will also undertake down-hole geophysics studies on an annual basis in areas where water quality has been shown to change.

Monitoring of Dewatering Water

FMG has also committed to long-term monitoring of water quality and volume from the dewatering operation. The frequency of the monitoring will be agreed with the DoE, and is likely to be dependent upon the final method of disposal of the excess dewatering water. However, weekly might be considered typical. Water quality monitoring will be undertaken at each abstraction bore, so that streams of different salinity water can be kept separate.

Monitoring at Disposal Sites

If evaporation ponds are used as the method of disposal of the water then best-practice design and construction of the pits will be undertaken to minimise the risk of escape of saline water. Monitoring points will be installed to detect leaks, and systems will be developed to contain any escapes of water.

If an alternative method of disposal is used then FMG will agree a detailed monitoring programme with the DoE prior to commencement.

Numerical Groundwater Models

FMG will update the numerical model (developed in Phase 1) on an annual basis, and re-calibrate the model using the latest field data. The model will be used to predict changes of groundwater levels, abstraction rates and the salinity in a timely manner.

Vegetation

Vegetation monitoring design must address the enormous variation in vegetation health that occurs as a consequence of natural events, as well as the impacts of water table drawdown caused by dewatering and abstraction for the FMG project. The most difficult task in the monitoring will be to differentiate between these impacts.

- Natural variations in vegetation health will be caused by: Variations in rainfall reliability. The Division of National Mapping (1986) shows the study area to have a Rainfall Variability Index of 1.5 to 2.0, the highest level of variability in Australia and exceeded only by a small area south-east of Alice Springs. By comparison the rainfalls of the extreme south-west of Western Australia have a variability of under 0.5 and are therefore highly reliable. It can be expected that there will be considerable variations in rainfall from year to year and therefore vegetation health will also fluctuate;
- Natural changes in xeric period. Xeric period is the period of time each year (and even between rainfall events) where vegetation is not receiving direct rainfall. In explanation; two rainfalls of 100 mm do not necessarily equal four falls of 50 mm, especially if the interval between falls has increased or decreased. The period of time between rainfall events or rainfall periods is not the same in any given year and so vegetation health (especially in xerophytes [plants not dependent on soil moisture to any great extent] and vadophytes [plants dependent on moisture held within the soil profile but not accessing the water table]) can vary as a result. Provided the drought period is not too long, phreatophytes (species that primarily draw directly on the water table) are generally unaffected. These three physiological groups of plants (called ecotypes) will each behave differently under water stress;
- Changes to surface hydrology. Much of the vegetation in the study area will be xerophytic and this will persist through most drought periods. Other vegetation, especially along drainage lines, is dependent on moisture held within the soil profile, even if the roots do not intercept the groundwater table. The moisture held in the soil in this manner is sometimes derived from direct infiltration by rainfall or by infiltration during surface runoff. Any activity that alters the interception (e.g. soil compression), or changes overland flow (eg tracks, mines) will alter the sheet flow characteristics and hence the degree of infiltration at any given point. This may affect vegetation health by causing "shadows" of decreased health that are not related to changes in groundwater depth;
- Pest attack may affect vegetation health very quickly if conditions are right for the pest to rapidly increase in population (mostly insects) or influence (eg fungi during longer than usual wet periods);
- Fire can have a sudden impact, removing all foliage from a plant and sometimes killing it. Conversely, regrowth from epicormic shoots (trunk and branch shoots) can be rapid, dense and extremely healthy after fire, even if the tree is water-stressed. A monitoring programme cannot statistically evaluate this impact, but must record the influence so that numerical data can be compared rationally against real situations;
- Variability affecting individuals. These lesser, but significant impacts include termite attack which may affect health of individual plants.

Accordingly, the vegetation monitoring programme must have approaches that will differentiate between natural and non-groundwater impacts versus groundwater drawdown impacts. To arrive at a suitable methodology the following reasoning has been applied.

Table F2
Approach to Vegetation Monitoring

Methodological Approach	Issues Addressed	Reasoning
Control sites	Variations in rainfall reliability, natural changes in xeric period	These influences tend to be regional rather than local and establishment of control sites that will not be affected by anthropogenic impacts will be essential
All ecotypes monitored	Variations in rainfall reliability, natural changes in xeric period, changes to surface hydrology	Minor changes to groundwater depth or overland flow will affect vadophytes most, phreatophytes less so and xerophytes the least. Major changes to groundwater depth will affect phreatophytes and vadophytes the most and xerophytes least. It will be important to distinguish between these impacts
Numerous individual plants monitored	Variations in rainfall reliability, natural changes in xeric period, changes to surface hydrology, pest attack, fire	Reduces influence on the data from individual variations in susceptibility to the various potential causes of changes to health, thereby improving statistical reliability. Compensates for the occasional loss of plants through flood damage, insect attack or fire.
More than one species monitored	Variations in rainfall reliability, natural changes in xeric period, changes to surface hydrology, pest attack, fire	Reduces influence on the data from individual variations in susceptibility to the various potential causes of changes to health
Transects	Changes to surface hydrology	Surface hydrology impacts can change both across contour, such as might occur in the shadow below a track which alters overland flow, and along contour if the flow down-gradient is changed in one area compared to another. Transects should therefore be in both directions. Transects along major creek banks are especially useful, as individual trees can be lost during flood events and the transect approach maximises the number of trees monitored
Vegetation canopy size	Canopy size can vary seasonally and individually	This is not a particularly useful measure of plant health. Measurements can be collected but should be used only as background information
Canopy density	Canopy density (average foliage density - AFD) is directly related to plant health	While an excellent measure of plant health, AFD varies seasonally, with cloud cover, and with time of day as leaves turn to gather the maximum sunlight or to reduce their intra-cellular temperature. This measure can only be used if the measurements are taken at the same time, in the same month, under similar climatic conditions. They are worth recording, but the methodology of survey will need to be precise
Plant height	Growth rate	Depends on plant age and soil conditions. Young plants of phreatophytic species are vadophytic or even xerophytic in the early stages of development and so their responses to impacts will change over time. This information can be recorded but is of limited value unless monitoring recruitment
Stem diameter	Growth rate	Usually only of value on large perennials such as trees. Data are unreliable because of bark decortication (loss after fire) and oval trunks on individuals affected by flooding
Health rating	Overall health status	This method allows for all influences as it measures (albeit subjectively) the overall status of the plants, regardless of the cause of the changes in health. It is critical to compare results with control sites, thereby removing the regional influences caused by climate. This method is largely independent of season and time of day providing there is some degree of consistency in sampling
Photographic monitoring (normal colour)	Overall health status	Photographs are useful, but are greatly influenced by season, climatic conditions (eg overcast) and time of day. They are useful references but are not reliable for health monitoring
Photographic monitoring (infra-red)	Overall health status	More reliable than normal photography because infra-red photographs reveal leaf cell stress rather than general visual appearance. Less influenced by season but affected by overcast and time of day. Date and time of photographs must be carefully controlled. Processing is difficult, expensive and has technical problems. This method is not recommended.

Based on the above reasoning, the methodology of vegetation health monitoring will be based on use of as many control sites as is practical, as well as several impact sites. All ecotypes will be monitored, using numerous individual plants of more than one species. Transects will be used wherever possible, preferably in pairs at right angles across and along the contour. Health rating will be the primary measurement taken, complemented by average foliage density measurements.

Data collected to supplement the health information will include canopy size, plant height and stem diameter on large plants. Photographic monitoring using normal colour will record the features of the transects, and notes will be taken on aspects of each plant or group of plants to assist in interpretation of results.

Environmental Triggers

A series of environmental triggers will be developed by FMG in consultation with CALM and the DoE. In the event of one of these triggers being exceeded (e.g. the salinity in a station bore increasing to above a threshold level), then mitigation measures will be implemented. In the case of station bores this may involve providing an alternative supply of water to replace the station bore, or drilling a replacement bore in a fresher part of the aquifer.

Management of Excess Water

In addition a series of operating rules will be developed. These will ensure effective management of the excess dewatering water.

These rules are likely to include the following:

- The volume of water abstracted for dewatering will be minimised.
- Wherever possible water from the dewatering will be used for dust suppression, camp supplies and ore-beneficiation before being discharged back to the environment.
- Wherever possible streams of different water qualities (i.e. fresh, brackish and saline) will be kept separate.
- The regulators will immediately be informed of any escapes of saline water.
- Evaporation ponds (if used) will be rehabilitated on completion of mining to prevent subsequent escape of salt. If an alternative method of water disposal is used then all equipment will be removed on completion of mining and all sites re-habilitated.

Data Collection

The draft monitoring programme is set out in the table below.

Table F3
Draft Monitoring Programme

Parameter		Frequency	Monitored By
Abstraction	From dewatering	Monthly with annual total	FMG
Water Levels (Production)	Water levels in all dewatering Bores	Monthly	FMG/third party
Water Levels (Environmental	Water levels in environmental monitoring and	Monthly	FMG/third party

Parameter		Frequency	Monitored By
Bores and Station Bores)	station bores		
Vegetation Condition Surveys	Surveys of phreatophytic vegetation.	Annual	FMG/third party
Salinity (EC) and pH	Salinity in dewatering bores	Weekly	FMG/third party
Hydrochemistry*	Hydrochemistry, environmental bores and stock bores.	Quarterly	FMG/third party
Stage Readings	Surface water levels in the Fortescue Marsh	Weekly	FMG/third party
Stygofauna	Monitoirng for the presence of Stygofuana	Bi-annually	FMG/third party

* Analytes include: pH, EC, TDS, Na, Ca, Mg, K, Al, Mn, Fe, Cl, SO_4, CO_3, HCO_3 and NO_3.

Data Collection

As detailed in Table F3, FMG are responsible for monthly groundwater abstraction and water use data. It is the responsibility of FMG for all flow meters to be re-calibrated annually.

FMG are responsible for the collection of all production bore and regional water levels, site rainfall data, pH and EC monitoring and bore water sampling for hydrochemical analyses.

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

Water samples will be analysed for a standard hydrochemical suite and will include pH, EC, TDS, Na, Ca, Mg, K, Mn, Al, Fe, Cl, SO_4, CO_3, HCO_3, and NO_3. Analyses will be conducted quarterly from the dewatering, water supply, environmental and station bores. The final quarterly samples will be collected between March and May to allow sufficient time for analyses and reporting. Monthly monitoring of EC will be carried out in the monitoring bores.

Data Verification & Management

All monthly monitoring data from FMG will be forwarded on a monthly basis to a third party who will verify the data and collate it in a database.

The third party will assess on-going data both numerically and graphically to identify any erroneous readings. Readings that appear erroneous will be remeasured. Should there be any unexpected trends in the ongoing monitoring data, the third party will inform FMG's Environmental Manager immediately.

The third party will report the hydrochemical analysis results to FMG as soon as they are received for verification. If the analyses appear erroneous, the bore(s) in question will be re-sampled. Should there be any unexpected trends in the ongoing monitoring data, the third party will inform FMG's Environmental Manager immediately.

Daily rainfall totals (July to June) will be collated by FMG. This data will be entered into a database for the preparation of the Annual / Triennial Aquifer Review.

All verified data will immediately be forwarded to FMG's Environment Manager.

Data Review

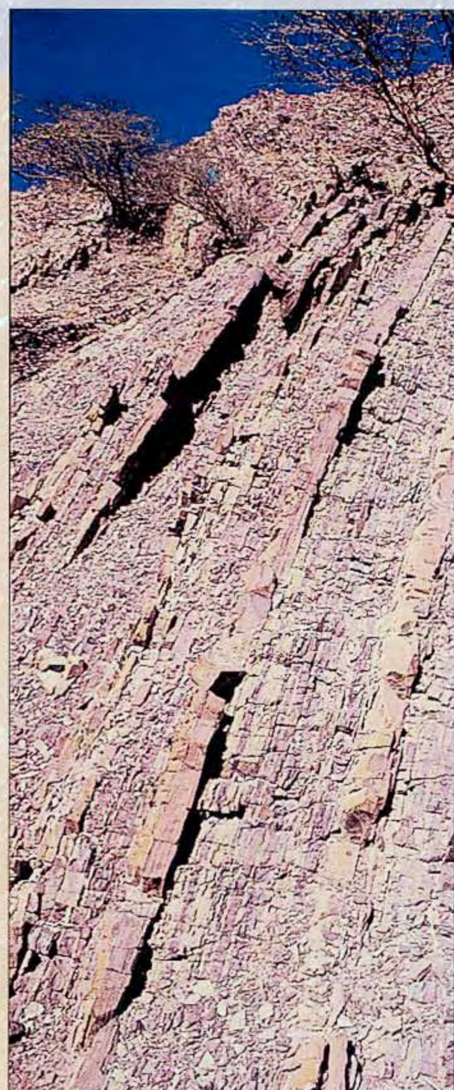
FMG's Environment Manager will be responsible for reviewing abstraction and water use data each month and all other monitoring data at the end of each year. The nominated monitoring sites and monitoring frequencies will be reassessed in conjunction with WRC, CALM and the station owners, and confirmed as part of this annual review.

Data Reporting

FMG will submit a monitoring report to the Water & Rivers Commission (WRC) by the 30th July each year.

The review will detail the results of the monitoring for the previous 12 month period (1st July to 30th June). Once available, three years' of data will be presented graphically and the current year's data will be presented in tabular format. The report text will focus on the current water year; however, comment will be made of any apparent trends over the three-year period.

Every three years a Triennial Aquifer Review will be submitted. This will present and comment on the previous three years' of monitoring data.



aquaterra

water resource and environmental solutions

Aquaterra Consulting Pty Ltd
ABN 49 082 286 708

PERTH
Suite 4, 125 Melville Parade
Como Western Australia 6152
Ph (08) 9368 4044
Fax (08) 9368 4055

ADELAIDE
Suite 3, 17 Hackney Road
Hackney South Australia 5069
Ph (08) 8363 9455
Fax (08) 8363 9199