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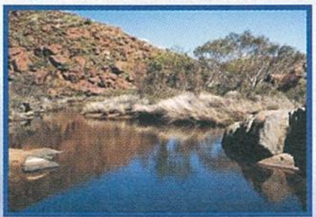
ROBERTSON RANGE DEWATERING STUDY



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ROBERTSON RANGE DEWATERING STUDY

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EXECUTIVE SUMMARY

An assessment of the potential for de-watering was undertaken by Aquaterra for FerrAus Limited, at the proposed Robertson Range iron ore mine site. The assessment included the construction and pump testing of four test production bores. Yields from these four bores were variable, although the quality of groundwater at the site was generally good. Analysis of the drilling and testing data has resulted in the development of an estimate of the potential de-watering requirements at the site, based upon mining to a max depth of -100m RL (below ground surface).

Several scenarios were considered and a possible range of potential inflows were determined. Dewatering rates that might be expected at the site range from 19 to 93L/s (1,600 to 8,000 m^3/d), for the scenarios considered. However, hydrogeological conditions are variable and these proposed dewatering rates are based on a number of assumptions. To reduce uncertainty, further data collection would be required and a numerical model developed to more accurately predict dewatering. The current analysis has taken a conservative approach with maximum figures tending to the high side.

Surface discharge of any water that results form the de-watering process was considered and several discharge options were identified and assessed, including discharge to nearby creeks and distributed surface flow. A conceptual design the discharge pumping and pipeline system has also been provided.

It is very likely that extra dewatering capacity (in addition to those bores constructed as part of this programme) will be required at the site. Any future dewatering borefield design should be undertaken in a staged approach, such that the first stage be used for additional data gathering to refine the final borefield design.

Any future update of de-watering at Robertson Range should incorporate the latest changes to pit design. It is recommended that the location of future de-watering bores be sited as close to the mine pit boundary as possible to assist in de-watering of the groundwater storage in the ore body itself and the capture of the in-flow from outside of the pit boundary.

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SECTION 1 - INTRODUCTION

Australasian Manganese (FerrAus) Limited have undertaken extensive iron ore resource characterisation and quantification of an area of Iron mineralisation (haematite based Marra Mamba ore) at the Robertson Range Site, located approximately 120km east of Newman and within 50km of the Jimblebar rail spur and loading area in the eastern Pilbara region. Results to date have indicated that the proposed development of the site is economic. Resource investigation is on going however an initial proposed area for mining has been designated.

At this stage it is our understanding that open pit mining would be undertaken to a depth of approximately 100m RL. Extensive drilling in the area has indicated the presence of significant quantities of groundwater at depths less than 100m within the ore body. As de-watering would appear to be a requirement of any development of the site, FerrAus Limited has requested that Aquaterra undertake a groundwater investigation to determine primarily what these de-watering requirements will be.

This report details the results of the field data collection programmes, and subsequent analyses to estimate pit de-watering estimates at the Robertson Range site. It also considers surface discharge issues as a result of de-watering.

SECTION 2 - BACKGROUND

2.1 LOCATION

Robertson Range is located approximately 120km east of the township of Newman. It is located on the Jiggalong Aboriginal Reserve. Access is via either Jimbelbar access road or alternatively the Coobina Road. Site position is shown on Location Plan (Figure 2.1).

2.2 TOPOGRAPHY

In the immediate area of the proposed pit, the land slopes gently to the south east and rises abruptly to the north and west of the most northern part of the proposed pit. A predominant hill upon which a telephone tower is located lies approximately 1 – 2km to the west of the pit. Approximately 3 – 4km west of the proposed pit, there appears to be a divide where drainage is approximately eastward to the east and westward to the west.

2.3 CLIMATE

The Pilbara Region (where the study area occurs) is characterised by an arid climate resulting from the influence of tropical maritime and tropical continental air masses, receiving summer rainfall. Cyclones occur during this period, bringing heavy rain and causing potential destruction to inland and coastal towns.

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

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

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

2.4 GEOLOGY

Regional Geology

The Robertson Range area is situated in the Hamersley Iron Province in north western Western Australia. The ore body at Robertson Range is contained within the Marra Mamba Formation which is of Archaean age. This formation is part of The Hamersley Group which is commonly characterised by banded iron formation (BIF). Structurally, folding and faulting within The Hamersley Group is a common feature. Alluvial deposits of Cainozoic age often overlie the sequence.

Local Geology

At the Robertson Range site, an alluvial cover of variable thickness has been observed from past drilling investigations. This alluvial cover contains significant iron detrital material, as a result of past erosion of nearby iron bearing formation.

The underlying Marra Mamba formation occurs as a series of interbedded BIF, shales and cherts. Iron enrichment is locally observed and is variable, often over comparatively short lateral distances. Variability of iron mineralisation is also observed with depth with discontinuous shale and chert horizons.

Mineral exploration studies have suggested that generally, the Marra Mamba unit dips to the east and this dip is believed to increase more steeply toward the eastern edge of the current prospect. Faulting to the east may truncate the unit however this would be confirmed subsequent to further investigation and interpretation.

2.5 HYDROGEOLOGY

During mineral exploration drilling at Robertson Range groundwater has been encountered in variable quantities and a range of groundwater in-flows to bores have been noted anecdotally. Very low in-flow rates have been common however at some locations in-flow rates have been high enough to impede the progress of drilling. At ‘Davidson’ (some 17 to 18km to the west of the site) a bore has provided reliable stock water of good quality for over 50 years. Details of bore construction are not available however the groundwater level at Davidson is believed to be within 30m of surface. It is likely that some portion of recharge is the result of periodic flooding during significant rainfall events.

SECTION 3 - ROBERTSON RANGE DRILLING AND TEST PUMPING

Four groundwater test production bores have been drilled and completed in the study area. All bores were subsequently pump tested.

3.1 TEST PRODUCTION BORE DRILLING PROGRAMME

In September 2007 Connector Drilling Ltd (Connector) were contracted by Australasian Manganese to drill four test production bores to a depth of approximately 120m bgl (refer to Figure 2.1 for location plan). The purpose of constructing these holes was primarily to assess aquifer conditions. Additionally, the bores were completed as test production bores to serve as water supply during continuing exploration and also to allow de-watering operation should mining commence. Connector mobilised to site on 23rd September 2007 and commenced drilling the first pilot hole on 24th September 2007 using air hammer techniques with a 155mm (6”) bit. (Note: At hole RRRC 348 B drilling method changed to mud rotary, due to unstable hole condition.) Drill cuttings were collected at 1 m intervals and logged onsite. Representative cuttings were collected in chip trays for subsequent reference.

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

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

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

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

Drilling details are summarised in Table 3.1, while full logs (including gamma traces) are contained in Appendix A. Table 3.2 provides details of observation bores utilised in this study – the observation bores used were old vertical mineral exploration bores, adjacent to the test bores.

3.2 TEST PUMPING

Test pumping of the four production bores was undertaken by Test Pumping Australia (TPA) who were contracted to FerrAus Limited. The four bores were tested between 13 October and 01 November 2007, after the completion of the drilling programme.

Flow rates were monitored with a digital flow meter that yields instantaneous and cumulative flow measurements. The pump intake depth was generally set about 70m below the top of the casing. The turbine pump used for the testing was capable of lifting greater than 25L/s depending on the depth to static water level.

3.2.1. Test Pumping Methods and Analysis Tools

Step Discharge Test

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

Constant Rate Test and Recovery

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

For the recovery phase, data was interpreted using the Theis Recovery method where residual drawdown is plotted against t/t' (time since start of test / time since pumping ceased). The hydraulic parameters for Theis Recovery test have again been calculated using Aquifer Test Pro software.

Table 3.1
Drilling Summary

Bore ID		RRRC 345 B	RRRC 346 B	RRRC 347 B	RRRC 348 B	RRRC 349 B
Description		Test Dewatering Bore	Abandoned Bore	Test Dewatering Bore	Test Dewatering Bore	Test Dewatering Bore
GDA94 Zone50	Easting	261942	261639	261799	261926	261867
	Northing	7393414	7392650	7392810	7393939	7393712
Date Drilled		25 - 29/09/07	30 - 01/10/07	01 - 06/10/07	06 - 13/10/07	14 - 18/10/07
Elevation (AHD)		577.5	578	577	581	579
SWL (mbgl)		30.43	-	32.95	34.73	32.56
Casing Stick-up (m)		0.28	0	0.21	0.30	0.20
SWL (mbtoc)		30.71	-	33.16	35.03	32.76
Date of SWL Reading		18/10/2007	-	13/10/2007	28/10/2007	23/10/2007
Drilled Depth (m)		126	64	138	126	126
Depth open to (mbgl)		120	-	121	120	120
Slotted Interval (mbgl)		30 - 120	not cased	30 – 120[1]	72 - 120	30 - 120
Field pH		6.90	-	7.3	8.40	7.1
Field EC mS/cm		997	-	772	1570	1309
Airlift yield L/s		22	-	9	4	17
CRT pumping rate (L/s)		18	N/A	4	2.5	18
Drawdown (after 72 hrs)		7.13	N/A	26.87	22.85	5.15
Comments		Equipped	Abandoned[2]	Completed	Completed	Equipped

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

[2] Hole RRRC 346 B abandoned due to lost air circulation through adjacent open exploration holes.

Table 3.2
Observation Bore Data

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

Table 3.3
Robertson Range Test Pumping Summary 2007

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

Table 3.3 (continued)
Robertson Range Test Pumping Summary 2007

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

3.2.2 Observations from Pumping Tests

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

RRRC 345 B (Appendix B)

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

RRRC 347 B (Appendix C)

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

RRRC 348 B (Appendix D)

- It was very difficult to maintain a constant flow rate during this test because of the relatively low flow rate at which the test was run. As a result, the drawdown curve proved difficult to analyse.

- It is likely that a low permeability boundary was observed at the pumping well very early during the 72 hour CRT. The drawdown curve appears erratic as repeated attempts were made to control the low flow rate of 2.5L/s. This made analyses difficult, however a fairly stable section of the curve between approximately 900 minutes and 2000 minutes was analysed for aquifer parameters and is believed to be representative of the entire test. It is thought likely that (as in the test at 347 B) the impact of the early observed boundary was maintained during the remainder of the test. The total drawdown at the end of the 2.5L/s test was 23.84m, with only approximately 11m of this occurring within the first 10 minutes of the test. Sudden repeated changes in the drawdown pattern are largely due to adjustments made with the pumping rate.
- This pumping test is believed to represent the relatively low permeability conditions when extensive ore body is not present.
- Observed drawdowns at the three observation wells provided insufficiently valid data for analyses due to the low pumping rates at which the test was run.
- Within 2 hours of the termination of pumping at the end of the CRT, water levels in the pumping well had recovered to within approximately 1 m of the original static water level.
- The location of this bore is within the proposed pit boundary. The bore did not intersect extensive ore material and the hydraulic conductivity in the area immediately near the bore has been estimated to be low. This area of lower hydraulic conductivity would however be in close proximity to an area of higher permeability (i.e. fractured ore body) which could therefore account for the good 2-hour recovery observed. This is on contrast to the recovery observed at RRRC 347 B where similar drawdowns were observed during similar constant rate tests however recovery patterns observed were markedly different. Being situated at some distance from the proposed pit boundary, the location of RRRC 347 B would not be in relative close proximity to the relatively permeable ore resulting in poorer water level recovery.

RRRC 349 B (Appendix E)

- A low permeability boundary was observed at the pumping bore during the 72 hour constant rate test (CRT) after approximately 2 days of pumping. The total drawdown at the end of the 18.0L/s test was 5.15m, with approximately 3.00m of this occurring within the first 2.0 minutes, and 0.12m drawdown over the last 24 hours.
- Drawdowns at the observation wells (RRRC 355 - 206m away, RRRC 258 - 157m away, and RRRC 255 - 87 m) were approximately 0.2m, 0.4m, and 1.0m respectively over the duration of the CRT.
- Within 2 hours of pump turn-off, at the end of the CRT, water levels in the pumping well had recovered to approximately 0.80m of the original static water level.
- A clear low permeability boundary was observed in both the pumping bore and all observation bores supporting the concept that higher permeabilities are a function of groundwater flow through fractured ore zones.
- Aquifer parameters were estimated using the portion of the curves that reflected the low permeability boundary as there is at this time no modelling planned.

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

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

3.3. WATER QUALITY

Water quality (electrical conductivity [EC] and pH) was monitored in the field during the airlift development of each bore constructed. The airlift was continued until the field parameters stabilised and the visual appearance of the discharge water was clear. This ensured that all finer grained material had been removed from the formation in the vicinity of the bore (and in the case of RRRC 348 B all drilling fluid used during drilling was removed). Stabilised values for EC and pH at the end of airlifting for all constructed bores are given in Table 3.4. These are also shown on the drill logs (Appendix A).

Field water quality parameters were also monitored during the pumping tests to identify any variability in measurements as the tests proceeded. Water samples were collected at the termination of each constant rate pump test and submitted to SGS laboratory for full chemical analyses. The results of these analyses are presented on Table 3.4. Laboratory test reports are presented in Appendix F. An expanded Durov plot is shown in Figure 3.1 and graphically depicts the relative concentrations of the major ions.

Analyses show that groundwater sourced at the Robertson Range site from the Marra Mamba Formation (or equivalent) appears to be relatively good quality with total dissolved solids (TDS) values ranging from 420mg/L to 900mg/L (laboratory analyses) with a slightly alkaline pH ranging from 7.6 to 7.7 (field determinations). Total dissolved solids (TDS) is significantly higher in the three bores drilled within the proposed pit boundary (i.e. the general area of economic mineralisation) when compared with the bore drilled outside of the boundary. The highest value however is only approximately twice that of the lowest value and in no case does TDS exceed 1000mg /L in any of the samples analysed. Further characterisation of the groundwater also shows some variation in terms of chemical signature on the basis of the cation / anion content. In all cases, no one cation species dominates. All groundwater sample analyses indicate that Sodium is the major cation with the highest concentration but with significant Magnesium and Calcium content as well. The characterisation of the groundwater samples however shows somewhat more variability in terms of anion signatures. Again, no one anion species dominates at any location and sulphate is present in all samples, but some separation can be made on the basis of Chloride / Bicarbonate content although in no case does one species clearly dominate. An observation can be made that Bicarbonate content however tends to be higher than Chloride away from the pit boundary while Chloride content tends to be higher than Bicarbonate inside the proposed pit boundary. These variations in the chemical character of the groundwater samples are likely to be more a function of location, and water – rock interaction rather than position in the flowpath with respect to recharge area. It is possible that the ore body particularly, and groundwater either in close proximity to it or having passed through it could have its chemical characterisation primarily determined by this association. Additional investigation would be required to comment on this further.

3.4. WATER LEVELS

Water levels in the Robertson Range area determined in the bores drilled vary between 30 and 35 mbgl (Table 3.1). The depth to water level generally decreases to the south and southeast. As a result water levels toward the southeast area of the proposed pit tend to fall above the top of the ore body and toward the northwest area of the proposed pit, below the ore body. Groundwater gradient appears to be in the south – southeasterly direction.

Table 3.4
Groundwater Chemistry

Parameter	Unit	LOR	Sample Number				Australian Drinking Water Guideline Values (2004)
			1	2	3	4	
Sample Location			347B 261799mE 7392810mN	349B 261876mE 7393712mN	345B 261942mE 7393414mN	348B 261926mE 7393939mN	**Australian Drinking Water Guideline Values (2004)**
Date of sample			17/10/2007	27/10/2007	21/10/2007	01/11/2007	
pH	pH Units	0.1	7.6	7.6	7.6	7.7	6.5-8.5**
Conductivity @25^{0}C	µS/cm	2	800	1500	1300	1800	
Total Dissolved Solids @ 180^{o}C	mg/L	5	420	770	690	900	500**
Soluble Iron, Fe	mg/L	0.02	0.13	0.02	0.04	0.1	0.3
Sodium, Na	mg/L	0.5	80	170	130	180	180**
Potassium, K	mg/L	0.1	26	33	26	48	
Calcium, Ca	mg/L	0.2	37	54	44	73	
Magnesium, Mg	mg/L	0.1	29	67	65	72	
Chloride, Cl	mg/L	1	88	240	200	310	250**
Carbonate, CO_3	mg/L	1	<1	<1	<1	<1	
Bicarbonate, HCO_3	mg/L	5	230	260	230	270	
Sulphate, SO_4	mg/L	1	49	180	160	180	500*, 250**
Nitrate, NO_3	mg/L	0.2	42	6.2	3.4	20	50*
Fluoride, F	mg/L	0.1	0.8	0.8	0.7	0.8	1.5*
Manganese, Mn	mg/L	0.005	0.007	<0.005	0.006	0.082	0.5*, 0.1**
Silica, SiO_2	mg/L	0.05	24	46	24	50	
Cation/Anion balance	%	-	2.3	3.9	3.8	3.9	
Sum of Ions (calc.)	mg/L	-	582	1010	860	1153	

[1] Australian Drinking Water Guidelines, 2004.
National Water Quality Management Strategy – 6.
National Health and Medical Research Council.
* Health based Guideline Value
** Aesthetic Guideline Value
Exceeds Guideline Value Exceeds Guideline Value

3.5. HYDROGEOLOGY SUMMARY

Drilling at Robertson Range has suggested that:

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

Two of the bores constructed intersected thick sections of ore body which acts as an aquifer of relatively high hydraulic conductivity. These bores (RRRC 345 B and RRRC349 B – see Figure 2.1) were capable of yielding up to 20L/s in the short term. Transmissivity would appear to be governed by fractures in the ore body itself. In boreholes where little or no ore body was intersected hydraulic conductivity (and resultant yields) were much lower. The potentiometric head of water lies above the top of the ore body in those holes drilled. From the data gathered, it would appear that hydraulic conductivities are likely to be comparatively high in the proposed pit area, but are likely to be surrounded by an area of much lower hydraulic conductivity – sands and silts that are variably clayey.

4.1 PROPOSED DEWATERING AT ROBERTSON RANGE

For the purpose of the analysis, it was assumed that mining at Robertson Range will be carried out to a depth of up to -100mRL (below ground surface). Static water level has been assumed to be uniform and at -30mRL. Therefore 70m of de-watering is assumed over the life of the mine. The conceptual model proposed at Robertson Range is that the ore body itself is a unit of comparatively high permeability surrounded by much lower permeable material. As such, proposed de-watering has encompassed two components:

- de-watering of the storage in the ore material, and
- the interception of in-flow to the pit void from outside of the pit (area of significantly lower permeability).

4.1.1. Component 1 – Removal of storage water within the ore body

The calculation of groundwater storage within the ore to be mined took into account the proposed pit dimensions, storage coefficient, and a theoretical time over which de-watering is proposed to occur. It was assumed that dewatering of the ore body only occurs once (in advance of mining), after which water flows into the pit area from the surrounding area of lower permeability.

Volume of water in storage = $\pi \times r^2 \times h \times$ Sy

Where: r = 400m (Pit radius)

h = 70m (De-watering depth: -30mRL to -100mRL)

Sy = .033

The volume of water in storage for removal was calculated at 1160ML. If two alternative mine plans are considered where increase of vertical depth occurs at 5m/y and 10m/y, the required rate of removal of this water from storage, to allow dry mining, will be:

At 5 m/y (14 years): 2.6L/s, and At 10 m/y (7 years): 5.3L/s

4.1.2. Component 2 – Removal of water flowing into the pit from outside the proposed pit area

To calculate this inflow, an Excel based program developed by Aquaterra (“Mine Inflow”), was used to determine indicative volumes of inflow of groundwater into a proposed pit, as it is dewatered. Mine Inflow is based on an estimation of inflow using the Dupuit-Theim Calculation for unconfined aquifer conditions.

The equation used is shown below:

$$Q = \frac{\pi \ k \left(h_o^2 - h_w^2\right)}{\ln \left(r_o / r_w\right)}$$

Q = inflow or outflow from large diameter well or pit (kL/d)

ho = height of SWL above base of aquifer (m)

r_w = radius of well or equivalent radius of pit (m)

t = time since pumping or inflow started (days)

Sy = specific yield

b = aquifer thickness (m)

r_o = radius of max extent of cone of drawdown (m) = $\sqrt{(2.25.k.b.t/Sy)}$

Hydraulic conductivities used for the assessment were determined from pumping tests carried out at RRC 347 B, and RRRC 348 B. These bores intercepted little or no ore body when drilled and are therefore thought to be representative of aquifer hydraulics outside of the pit area and therefore represent the aquifer from which inflow will take place. Values for ‘S’ were only determined at the RRC 345 B and RRRC 349 B locations as these were the only locations where adequate observation bore data was obtained. An average of these has been used in the assessment. Table 4.1 lists the input parameters used in the analytical assessment.

Table 4.1
Mine Inflow Parameters

Parameters	Values	Derivation of Parameters
k=hydraulic conductivity (m/d)	1.8 – 0.4	1.18 (Hydraulic conductivity determined for RRRC 348 B) 0.40 (Hydraulic conductivity determined by RRRC 347 B)
Ho=height of SWL above base of aquifer (m)	70	Difference between SWL and base of Aquifer (Pit) – Assumes mining to a depth of - 100m RL
rw=radius of well or equivalent radius of pit (m)	400	The current proposed pit plan is not circular, however a 400 m radius was used as an approximation of the area where ore body is believed to be present below the groundwater potentiometric head.
Sy=specific yield	0.033	0.033 (Average 'S' determined from pumping tests at RRRC 345 B and RRRC 349 B)

The de-watering assessment was aimed at estimating a range (and maximum) rate of de-watering that will be required during the life of the mine. The values for hydraulic conductivity used for the mine inflow component are believed to best represent hydraulic properties of the groundwater system surrounding the pit. Indeed the higher value 1.18 m/day for hydraulic conductivity was derived from a hole that was drilled inside of the proposed pit boundary but did not encounter a thick section of ore body. Use of this value as an upper limit is therefore believed to be higher than what would be encountered outside of the pit and is therefore considered conservative in that an inflow figure derived from it is unlikely to be exceeded.

Similarly, a pit radius of 400m is also considered conservative in that calculations will assume that all of this area will contain ore body to 100m RL and that the pit walls will be vertical. Both assumptions are likely to be over-estimates. Pit walls will not be vertical (and radius will decrease with depth) and the base of ore body will, in some sections of the pit, be shallower than 100m RL and will not therefore be mined that deep. As such storage estimates are also believed to be high.

For the purposes of this analysis and development of a range of potential de-watering rates, four scenarios were developed that varied the minimum and maximum values of hydraulic conductivity, and also the rate of mining.

Scenario 1 (14 years / low hydraulic conductivity):

- Hydraulic Conductivity of 0.4, and
- Rate of vertical depth increasing at 5m per year.

Scenario 2 (7 years / low hydraulic conductivity):

- Hydraulic Conductivity of 0.4, and
- Rate of vertical depth increasing at 10m per year.

Scenario 3 (14 years / high hydraulic conductivity):

- Hydraulic Conductivity of 1.18, and
- Rate of vertical depth increasing at 5m per year.

Scenario 4 (7 years / high hydraulic conductivity):

- Hydraulic Conductivity of 1.18, and
- Rate of vertical depth increasing at 10m per year.

Inflow to the pit was calculated using a transient state model with calculated radius of influence and using the maximum and minimum hydraulic conductivities for a scenario where the pit is dewatered from -30m RL to -100m RL over a seven year period (10m/y) and a fourteen year period (5m/y). Results were considered at rates of dewatering over ten-metre intervals. The outcome of the analysis is summarised in Table 4.2.

Table 4.2
Predicted Dewatering Rates: Groundwater Inflow into Pit: Scenarios 1 through 4

Scenario	Rate of inflow (L/s)						
	-30 to -40 m RL	-40 to -50 m RL	-50 to -60 m RL	-60 to -70 m RL	-70 to -80 m RL	-80 to -90 m RL	-90 to -100 m RL
1 (14 years)	17	25	31	34	36	37	37
2 (7 years)	26	29	33	36	38	38	38
3 (14 years)	34	54	68	77	83	85	85
4 (7 years)	44	59	71	80	85	87	87

4.1.3 Total potential de-watering required at Robertson Range (Component 1 + Component 2)

Table 4.3 shows a potential range of de-watering that might be required at Robertson range if mining is undertaken to a depth of -100m RL. It includes the removal of storage from the ore material within the pit, plus continued inflow of water from outside the pit. Essentially, it represents Table 4.2 but with added de-watering from the storage in the ore body.

Table 4.3
Range of potential total de-watering requirements at Robertson range

Scenario	Rate of inflow (L/s)						
	-30 to -40 m RL	-40 to -50 m RL	-50 to -60 m RL	-60 to -70 m RL	-70 to -80 m RL	-80 to -90 m RL	-90 to -100 m RL
1 (14 years)	19	28	33	37	39	40	40
2 (7 years)	31	34	38	41	43	44	44
3 (14 years)	36	56	70	80	86	88	88
4 (7 years)	49	64	77	85	91	93	93

Total possible rates of de-watering for the proposed scenarios vary from 618ML per year to approximately 2,898ML per year. These are summarised in Table 4.4. The likelihood is that the actual volume de-watered will lie somewhere between these end values. (A mine life that is shorter than that assessed in the scenarios would require faster de-watering, and discharge rates would be greater.)

Important features of the assessment:

- Inflows derived from the analytical model are particularly sensitive to changes in hydraulic conductivity, with significant differences in-flows derived when high-end and low-end hydraulic conductivities are alternatively used. Additionally, the model assumes zero recharge to the system.

- Hydraulic conductivities have only been determined at four locations. If actual hydraulic conductivities differ form these, calculated in-flows will be outside of the range given.
- Evaporation and precipitation do not have a large effect on total predicted pit inflow volumes due to the relatively limited surface area of the pit and have not been accommodated in the calculations. However, some standby capacity may be necessary to deal with flooding from cyclonic rainfall events.
- The Geology in the pit area is variable and creates a complex hydrogeological situation, which the simple Mine Inflow model cannot easily accommodate. If more confidence in the inflow values is required a numerical model may be able to address this problem after further drilling is undertaken and the variation of aquifer hydraulic parameters in the proposed pit location can be determined.
- A conservative approach has been taken: i.e. the maximum de-watering rates are likely to be overestimates. This is considered prudent considering the number of unknowns and assumptions made. Results are estimates only and are intended to represent the order of magnitude of de-watering that might be expected.

Table 4.4
Range of potential total de-watering requirements (ML / year)

Scenario	Water Discharged (ML/y)						
	-30 to -40 m RL	-40 to -50 m RL	-50 to -60 m RL	-60 to -70 m RL	-70 to -80 m RL	-80 to -90 m RL	-90 to -100 m RL
1 (14 years)	618	890	1065	1180	1245	1265	1244
2 (7 years)	987	1089	1227	1323	1375	1387	1358
3 (14 years)	1154	1789	2228	2529	2711	2786	2761
4 (7 years)	1555	2039	2434	2710	2874	2935	2898

This assessment suggests that dewatering rates required at the proposed Robertson Range Site are likely to be in the range of 2 to 8ML/d. In this range, the lower rate is indicative of mining scenario 1 (fourteen year mining / comparatively low in-flows) and the higher rate, indicative of mining scenario 4 (seven year mining period / comparatively high in-flows). Cumulative volumes of water discharged over the life of the mine for each scenario are summarised in Table 4.5.

Table 4.5
Cumulative Volume of Water Discharged Over Mine Life (ML)

Scenario	Total Volume Discharged (ML)
1 (14 years)	15,013
2 (7 years)	8,746
3 (14 years)	31,914
4 (7 years)	17,446

5.1. GENERAL

Many iron ore mining projects in Western Australia mine below the water table. Typically, the water derived from mine dewatering is relatively fresh and is used in the process plants, for dust suppression and for community facilities, with the excess discharged to existing drainage systems.

There is an expectation that the potential environmental impacts of mining below the water table will be addressed through the environmental impact assessment process on a project by project basis. The community expects that this process will ensure that unacceptable impacts will not occur outside the mine area after the conclusion of mining.

A range of potential environmental impacts are known to be associated with mining below the water table. The potential magnitude of the impact may range from small and insignificant in low permeability rocks in fresh groundwater, to considerable in high permeability rocks with high salinity groundwater. The natural environment may be affected where there are changes to groundwater quality or levels. Those environmental systems associated with surface water expressions of groundwater, shallow groundwater aquifers or subterranean groundwater ecosystems are particularly sensitive to such changes, but discharge of water may change or enhance environments during the discharge into arid environments, with a resultant decline of these environments when mining is completed.

Dewatering at the Robertson Range Mine is planned for 2010. The water is expected to be relatively fresh and may be disposed of using various methods. The preference is the on-site use of water for dust suppression, processing, washing, irrigation, etc. with the excess water being discharged off-site. Disposal options may include aquifer re-injection some distance from the pit, piping the water to a third party consumer, seepage into the ground or evaporation (in a pond), or disposal to the environment (i.e. a creek system). The main criteria associated with any option include the reliability of the method, the capital and operating costs, environmental issues, regulatory requirements and the ongoing management required.

5.2. REGIONAL DRAINAGE AROUND THE SITE

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

The project area is located at the head of the upper Fortescue River catchment, which has an effective catchment area of approximately 30,000km^{2,} draining to the Fortescue Marsh Area (~350km from the coast). Catchments located to the south and the east of the site drain generally in the direction of Lake Disappointment, 200 km to the east.

5.3. ENVIRONMENTAL OBJECTIVES

The EPA's environmental objectives are to maintain the integrity, functions and environmental values of watercourses and sheet flow; and to maintain the quality of surface water to ensure that existing and potential uses, including ecosystem maintenance, are protected.

Excess mine water discharged off-site needs to be discharged at specific discharge points and is subject to licence conditions under the Environmental Protection Act 1986.

The licence conditions would specify, as appropriate, limits for the quantity and quality of discharge water (sediment, salinity, contaminants), and control requirements. Water released from the site would be discharged through appropriate sediment reduction controls as required. Hydrocarbons and oily waste would be managed separately through appropriate storage and handling procedures, clean-up procedures for spills, and environmentally acceptable recycling or disposal of waste.

Water discharges have the potential to impact vegetation by changing surface and groundwater conditions at the licensed discharge points. Water will not infiltrate (or evaporate) immediately at the discharge point, and as a result there will be additional water on the surface and near-surface alluvial material within the creek, that would not have otherwise occurred.

Based on experience from other mining operations, where there has been a discharge continuously into gravel bedded ephemeral creeks, increased surface water would be expected to promote the growth and condition of phreatophytic species (native vegetation dependant on the watertable displays increased lushness), while riverine vegetation along the creeks may decline (dependant on the water or moisture held above the watertable, causing regeneration of water tolerant species).

The impacts may include changes to composition and/or density of vegetation growth, weeds, reduction in the distribution of vegetation, potential problems with exotic flora and fauna; as well as other issues such as attraction of pest animal species, water contamination, cultural heritage issues, wastage of water, potential impact of surrounding aquifers, objections to mining, etc. Overloading the creek system (i.e. flooding) would exacerbate the effects, causing vegetation shifts such as water tolerant reeds and grasses, less larger trees due to water logging.

Ecological surveys are required to provide baseline assessments of aquatic habitat and fauna, as well as riparian and terrestrial vegetation that might be sensitive to flow and water level increase. Management plans are required to ensure the creek ecosystem returns to its pre-development condition at the completion of the dewatering program.

After cessation of discharge, the new phreatophytic species will reduce over time, and the dominant vegetation will revert to pre-development conditions. Some death of vegetation is expected to occur whilst the area re-adjusts, but this may be expected to be localised and mainly restricted to the additional trees that have grown whilst discharge occurred.

There will always be some uncertainty regarding the long-term effects on downstream areas and it is difficult to predict what these impacts may be. The overall management objective is therefore to minimise impacts to the extent practicable, and to minimise the potential for weed and pest species to become established. A hydrological and vegetation monitoring program is therefore required to ascertain the affects of the additional water in the creek system.

Remediation measures include bush regeneration, weed eradication, implementation of pest control measures, the cessation or reduction of mine water discharge at the discharge point, evaluation and if appropriate/viable, approval for alternative discharge points and/or alternative discharge methods.

5.4 SELECTION OF DISPOSAL OPTIONS

Creek disposal may be acceptable provided the creek is hydraulically capable of handling the discharge, the discharge is not located in the dewatering cone of depression, the discharge will not adversely affect the local or downstream environment, and the discharge location is not situated prohibitively far from the dewatering bores.

The potential creek systems include:

- Bobbymia Creek and its tributaries to the south east of the site (drains into the eastern flowing Savory Creek).
- Jigalong Creek and its tributaries to the east of the site (drains north towards the Fortescue Marshes).
- Davidson Creek and its tributaries to the west of the site (drains north towards the Fortescue Marshes).

Discharge water quality is reportedly suitable for discharge to the environment. For the purposes of this assessment, a design excess water discharge of 100-200L/s has been adopted.

Potential locations have been assessed on the following basis:

- Distance from site – Pumping and pipeline costs increase with increasing distance from site, therefore preference is for locations closest to the mine site.
- Hydraulic capacity of the receiving creek – A discharge location was only considered viable if the dewatering discharge was less than a nominal 5% of the estimated 2 year Average Recurrence Interval flow at that location.
- Ability to introduce flexibility into the system if necessary – In the event that monitoring shows environmental degradation due to the discharge, that area can be rested or the flow reduced and water divert to another location (e.g. further downstream or into another catchment). The system may rotate between several discharge locations.
- Position in relation to tenement boundaries – it is preferable that the dewatering pipeline does not extend beyond the tenement boundaries. Additionally it is beneficial to reduce the proportion of dewatering discharge leaving the tenement in the form of surface flow, as this may potentially affect third parties downstream. Therefore the system should ideally promote infiltration/evaporation inside the tenement. The lease boundaries extend about 4 km east to west and 6 km north to south.

5.5 INVESTIGATION OF OPTIONS

5.5.1. Bobbymia Creek

Bobbymia Creek is located approximately 25km from the mine site. The distance between the mine site and discharge location is prohibitive in this case, and this option has been discounted. There are some locations approximately 9kms from the mine site where the flat country starts to form a defined stream bed, but this stream will probably not be suitable to carry the anticipated disposal volumes.

5.5.2. Jigalong Creek

An acceptable discharge location into Jigalong Creek is located approximately 10km from the mine site. This lies further from the mine site than the Davidson Creek options, and also lies outside the tenement boundary (and may not be viable from an approvals perspective). This option also appears unattractive.

5.5.3. Davidsons Creek

Discharging into tributaries of Davidsons Creek to the west of the mine site, appears the most viable and flexible option. An acceptable location exists approximately 5.5km from the mine site. In the event that environmental monitoring demonstrated adverse effects, additional pipelines could be introduced, to direct water to other tributaries (refer Figure 5.1). For example, a pipeline length of ~1.5km could be constructed to divert water to a tributary to the north, and or ~2-3km further to the west, if required. All tributaries combine to form the main channel of Davidson Creek several kilometres downstream, so diversion would only offer environmental relief to the area directly downstream of the affected discharge location.

The proposed mine discharge flows at any point are low in terms of the hydraulic capacity of the creeks (i.e. flows are <5% of Q2 flow). The distance over which the discharge will flow in the creek is dependent on the concentration of flow in the channel, with seepage and evaporation losses greater if the flow is spread over a larger area. The presence of alluvial deposits also promotes infiltration, but noting that at Robertson Range, all water courses are at the commencement of the watershed, near the head of drainage systems, and as such alluvial beds are not existent or incipient nearby. It is therefore difficult to determine how far water would travel down a creek, but based on experience it is likely that such flows would travel several kilometres along the creek bed before infiltrating. This infiltration is unlikely to have unacceptable impacts on the proposed Davidsons Creek mine, located approximately 20km downstream of the disposal point. Further, the Davidsons Creek mine will be adjacent to the western arm of the Davidsons Creek, not the eastern arm, which is the one, proposed for the disposal of water from the Robertson Range mine.

5.6 DISTRIBUTED FLOW

As an alternative to concentrated flow, disposal via evaporation and seepage may be considered. For this option, a large distribution surface is desirable, rather than immediately concentrating flow in creeks. Any runoff from the proposed disposal areas would reach water courses however.

Based on a discharge rate of 100L/s, calculations show that approximate 4km² of surface area is required (say 2km x 2km). This calculation assumes that water could be distributed uniformly over the area.

Normal methods of irrigation aim to aim to conserve water, but in this case, the goal is to maximise seepage and evaporation, by maximising the surface area over which the water is applied. Distribution methods include furrow irrigation / flood irrigation, overhead sprays, low level sprinklers, and drippers.

The pipe delivery system would consist of perforated pipe laid above ground. The main pipeline would run from the pit dewatering system to a centralised distribution manifold(s), and then radiate out in a number of smaller diameter pipes.

This system is not viable due to the very large surface areas required, lack of creeks in the area to remove any excess flow and the damage that would be caused to vegetation.

5.7 SEDIMENT REDUCTION

The ground water is expected to be clean and acceptable for surface disposal. If dewatering by way of pit sumps is used however, then appropriate sediment reduction controls would be required. Sedimentation basins promote settling of sediments through the reduction of flow velocities and temporary detention, before releasing water to the environment. Storage volume consists of the permanent pool settling zone and sediment storage zone.

The minimal internal size is calculated to match the settling velocity of the target sediment size with the design flow (in this case, the pumped inflow). A target of medium sized silt particles > 0.02mm (20µm) is commonly used (for the design event, the sediment trap is expected to be effective in removing sand and medium to coarse silt).

To encourage efficient sedimentation, the length to width of the basin should be at least 3:1, and ideally longer. Assuming a pumped inflow of 200L/s, then the required basin water surface area would be 830m² (e.g. 17m x 50m) or 415m² for 100L/s.

5.8 PUMPS AND PIPELINES (GENERAL)

Polyethylene pipe (PE) is commonly used in mining applications. One of the features of PE pipe is that costs are substantially less for lower pressure rated pipe (PN6.3 is the lowest generally considered) and costs rise rapidly as the pressure rating is increased. Wherever possible, PE100 PN6.3 pipe should be used to reduce infrastructure costs. Buried pipelines provide protection against fire, flood events and vandalism. Burial of the pipeline also reduces the visual impact of the pipeline, and the effect that the pipeline would have on local hydrology, and being a potential barrier to small sauna.

The employment of a transfer pump station (intermediate) rather than pumping directly from bore pumps or for the sedimentation basin may assist in reducing the pressure rating required in pipelines.

Scour valves are provided along the pipeline at low points, enabling emptying of the pipe. Air-valves are provided similarly at pipe high points and regular intervals to remove accumulated air.

Pumping options include direct pumping from bores, or diesel pumping from sumps; or via a sedimentation basin (or turkeys nest if the water is clean) prior to on-pumping to disposal. Three main pump types are typically used for surface water duties. These are submersible (Flygt style pumps), ISO centrifugal pumps or mining centrifugal pumps.

Submersible Flygt style pumps are suitable for pumping water with high or low solids content and are often used in sump dewatering. The disadvantage is that they are comparatively expensive and require dedicated generators and connecting power cable. The pumps can achieve only a medium level of efficiency. Due to the high capital and operating costs, these pumps are not used unless considered necessary.

ISO centrifugal pumps (e.g. Stalker, Southern Cross) can be trailer or skid mounted, and supplied coupled to a diesel motor. The pumps have relatively low capital costs and high efficiencies. The primary disadvantage is that they have limited solid handling ability, and higher maintenance requirements if high solids levels are present.

Mining centrifugal pumps (e.g. Sykes or Allight) are designed for mining environments, and can be trailer or skid mounted and are normally supplied coupled to a diesel motor. The pumps are generally more expensive than ISO centrifugal pumps and have relatively lower efficiencies, but are designed to handle solids.

5.9 REQUIRED PUMPING SYSTEM

Pipeline costs are the major cost of the water transfer system. Although larger diameter pipelines have a higher initial capital cost, energy savings associated with reduced friction losses may make the extra pipeline cost economically feasible. Hence the life, over which the pumping is required, is important. Based on the following assumptions, a conceptual pumping system has been designed by way of example:

- A design excess water discharge of 200L/s
- Discharge water quality is reportedly suitable for discharge to the environment
- Diesel pumpset located at a sedimentation basin near the top of the pit, at ~RL580m
- The discharge pipeline crosses a high point at RL592m (~2.5 km from the sedimentation basin) and then runs down to a discharge point at RL565m 8.5km from the sedimentation basin.

Based on these assumptions, a DN400 or DN450 PE pipeline would be suitable. The smaller diameter pipeline would require 150kW pumping power to pump the required flows, and the larger diameter pipeline would require 70kW of pumping power, depending on the efficiency of the pumps. The diesel pumpsets to match these duties would generally have a higher power rating.

If the discharge was 100L/s, DN315 or DN355 PE pipeline would be suitable with required pumping powers of ~60kW and ~35kW) respectively. A final design is dependent on the exact pipeline route, the selected design discharge, accurate surveyed information along the proposed route and a proprietary pumpset matched to the required duty.

5.10 DEWATERING DISCHARGE SUMMARY

The Davidson Creek tributaries appear to provide the most suitable and environmentally appropriate discharge locations. These defined creeks are the closest drainage system to the mine site, and allow flexibility should changes to the discharge location need to be made for environmental reasons. A sediment basin would be required as part of the discharge system, if dewatering from open sumps is used. In this case, a pumping system would pump from the sedimentation basin via a PE pipeline to the discharge point in Davidson Creek.

SECTION 6 - CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

An assessment of pit in-flows has been made at the proposed Robertson Range Iron Ore mine site. A range of possible inflows has been predicted based on analyses utilising aquifer hydraulic parameters derived from on-site aquifer testing. A conservative approach has been taken which has tended to result in the derivation of higher rather than lower de-watering values. Both the maximum and minimum calculated inflows are considered to both be unlikely, however useful in determining the overall range of inflows possible and an order of magnitude that might be expected. Results ranging from 19 to 93L/s are possible however are likely to be lower then the top end of the range.

The analysis has assumed a maximum mining depth of -100m RL. The two higher yielding bores that have been drilled have been completed so that they can operate as future initial de-watering bores, having been drilled deeper than -100m RL. They are however likely to be removed during the course of mining, so additional de-watering bores will be required to undertake sufficient de-watering at the site.

A range of options for the discharge of water from the mine de-watering process has also been considered. A number of practical possibilities exist for surface discharge including discharge to nearby creek beds and ‘distributed’ surface flow. Discharging into tributaries of Davidsons Creek to the west of the mine site, appears the most viable and flexible option. Other possibilities include Jigalong Creek, and less favourably, Bobbymia Creek. Distributed disposal via evaporation and seepage may be considered, but this system is not viable, due to the very large surface areas required, lack of creeks in the area to remove excess flow and the damage that would be caused to vegetation.

6.2 RECOMMENDATIONS

To increase the accuracy of this assessment, it is proposed that future construction of de-watering bores be used as an opportunity to gather additional data which can be used to update this analysis.

The construction of further bores should be located such that they are as close as possible to the proposed pit edge to maximise effectiveness of both removing storage water from the ore body itself and also intercepting inflow from outside of the pit. Further work would be required however before the quantity of water necessary to be removed during the proposed mining period could be more accurately predicted along with the specific design of a borefield necessary to achieve this. At that time, a decision can be taken whether or not develop a numerical model to improve accuracy of de-watering estimates.

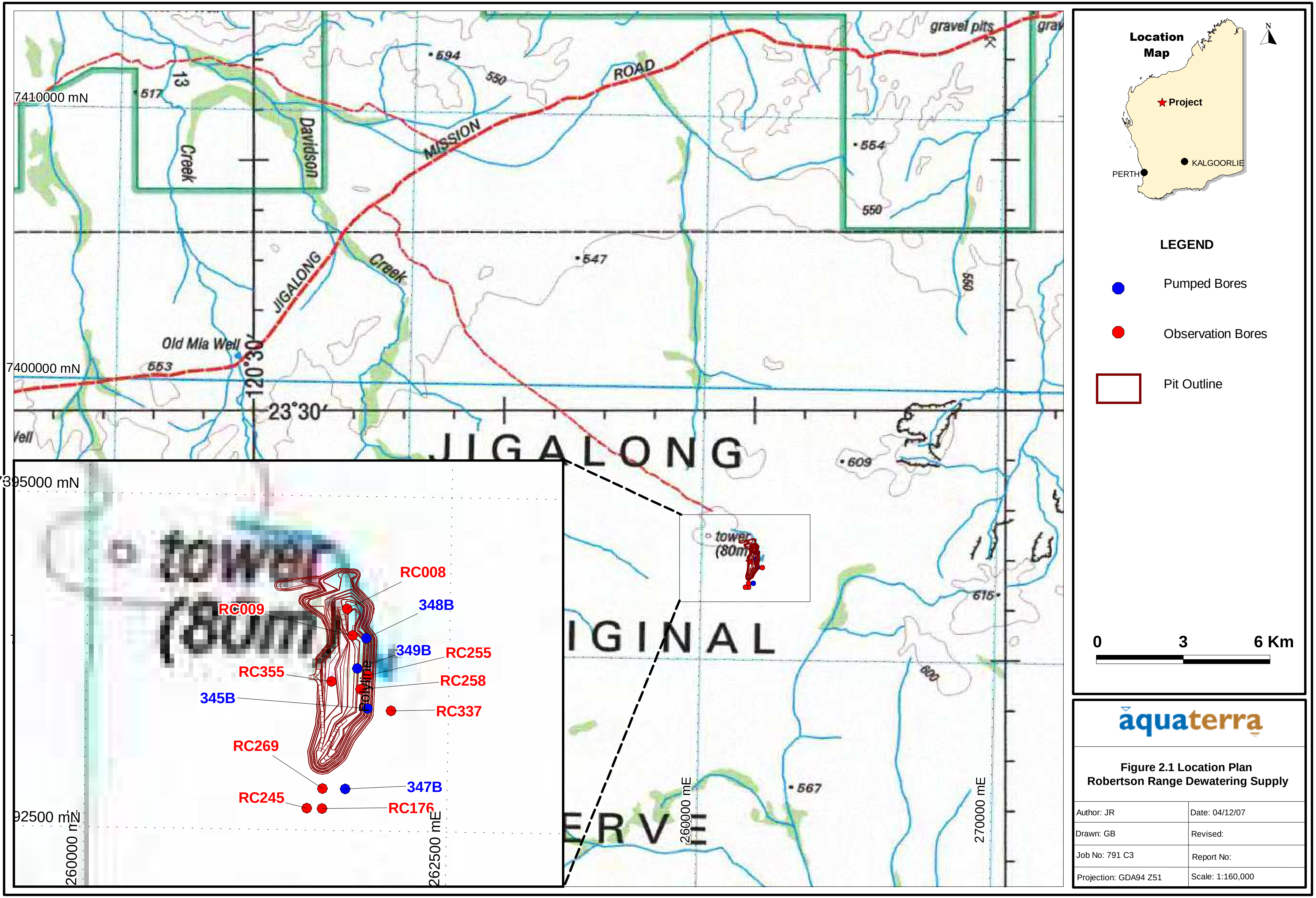
In the interim, it is recommended that records be kept of any groundwater pumping of existing bores including flow rates, volumes pumped and time of pumping. Additionally, regular water level monitoring of nearby observation bores should be undertaken and the data recorded and archived for future assessment. Additionally, any groundwater data gathered in the course of the ongoing ore delineation should be recorded and archived. Consideration might also be given to the future development of a groundwater numerical model subsequent to the collection of sufficient data to support it. A numerical model can be used to improve the predictive capacity for de-watering at the site.

SECTION 7 - REFERENCES

RSG Global, March 2006. *Robertson Range Iron Project – Resource Estimate*.

RSG Global, November 2006. *Robertson Range Iron Project – Resource Estimate*.

FIGURES

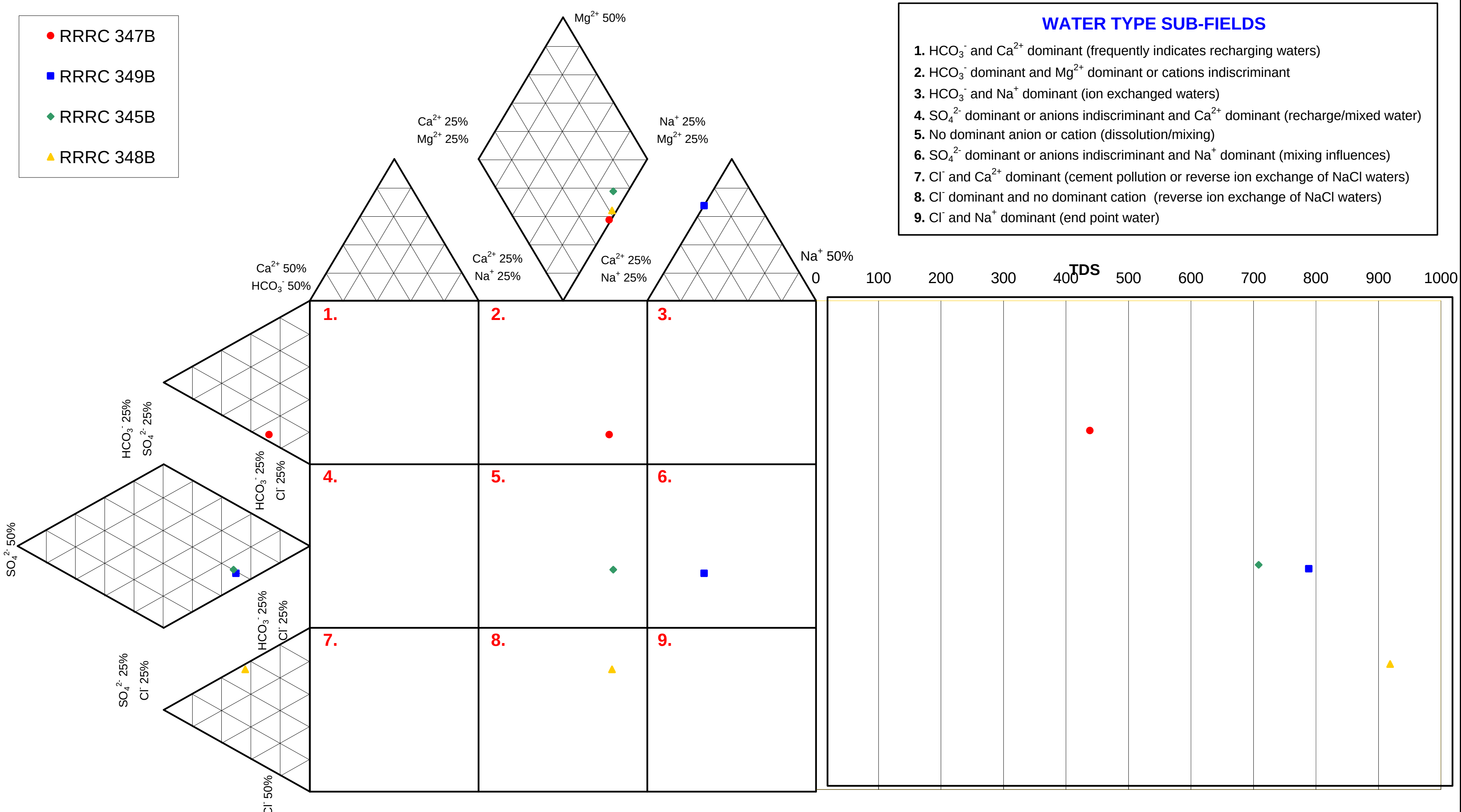


aquaterra

Figure 2.1 Location Plan
Robertson Range Dewatering Supply

Author: JR	Date: 04/12/07
Drawn: GB	Revised:
Job No: 791 C3	Report No:
Projection: GDA94 Z51	Scale: 1:160,000

F:\Jobs\791\Map Info

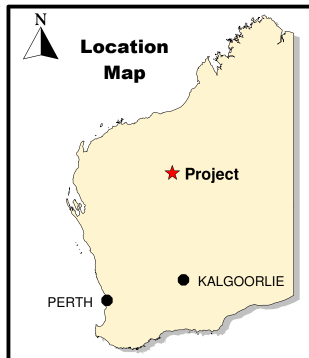


aquaterra

Expanded Durov Diagram

Figure 3.1

Date: 05/12/07	Project:	Robertson Range	Description:	Dewatering	HydroCHEM 2.0
C:\SHC\791\[Joe'sHydro.xls]EXPANDED DUROV (1)	Project No:	791	Client:	FerrAus	



Discharge Pipeline

Potential Diversion Pipeline
(to be constructed if environmental degradation
occurs at discharge locations)

Discharge Location

Potential Alternative Discharge Location

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Figure 5.1
Dewatering Discharge
Conceptual Layout

Author: MS	Date: 3/12/07
Drawn: MS	Revised:
Job No: 791/B	Report No: doc031a
Projection	Scale: NTS

F:\Support

APPENDIX A

DRILL LOGS

(INCLUDING GAMMA LOGS)

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COMPOSITE WELL LOG

Well No: 345 B

Client: FerrAus | **Project:** Robertson Range

Commenced:	25/09/2007	**Method:**	Air	**Area:**	Jigalong Reserve
Completed:	29/09/2007	**Fluid:**	Foam	**East:**	261942 mE
Drilled:	Connector	**Bit Record:**	0 - 6 mbgl 14"	**North:**	7393414 mN
Logged By:	Joe Ross		6 - 126 mbgl 10.5"	**Elevation:**	TBA

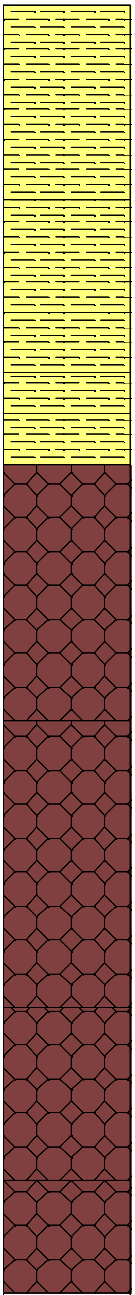
Static Water Level: 30.43 mbgl | **Date:** 18/10/2007

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes

Depth (mbgl): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150

Geology: Cainozoic; Marra Mamba

Graphic Log:



Lithological Description:

CLAY: Dark brown, silty, sandy, (sub-angular to sub-rounded, fine to medium grained). Common detrital Haematite and Goethite fragments observed with some Limonite apparent. Detrital Iron component increasing and sand component decreasing with depth over interval. Detrital Iron component becoming more Limonitic with depth.

CLAY: Dark brown, generally as above but with Iron detrital material increasing in abundance and accounting for up to 50% of material.

CLAY: Generally as above but changing in colour to light brown.

CLAY: Generally as above but changing in colour to light grey and detrital Iron content becoming variable

CLAY: Generally as above but changing in colour to medium to dark grey.

HAEMATITE: and Goethite. Dark grey with a variably red hue. Occasional Limonitic horizons, and very occasional 'cherty' horizons near the base of interval.

HAEMATITE: and Goethite. Dark grey and frequently Limonitic and cherty. Siliceous Shale horizons increasing in thickness toward base of interval.

HAEMATITE: Goethite and silaceous Shale interbedded. Common Limonitic horizons and occasional cherty sections.

HAEMATITE: and Goethite, dark grey and hard, commonly Limonitic. Some siliceous Shale horizons observed.

Field Notes:

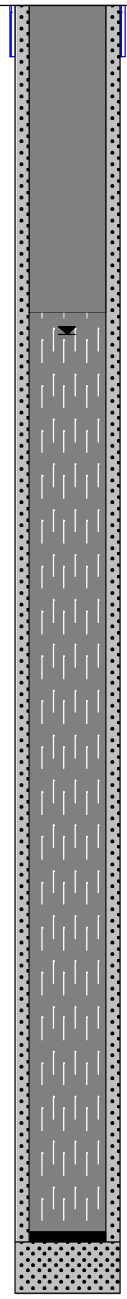
Developed by airlift pumping
Duration: 6 hrs
Max airlift yield: 22 L/s
Field pH: 6.9
Field EC: 997 uS/cm

Switched to foam to help discharge cuttings.

First water strike at 55 mbgl.

End of Hole at 126 mbgl.

Well Completion Diagram:



Well Completion Notes:

12" (310mm ID) steel surface casing (0 - 5 mbgl)

6" (155mm ID) blank steel casing (0 - 30 mbgl)

Gravel pack (3.2 - 6.4mm)

6" (155mm ID) slotted steel casing (30 - 120 mbgl)

Steel end cap @ 120mbgl

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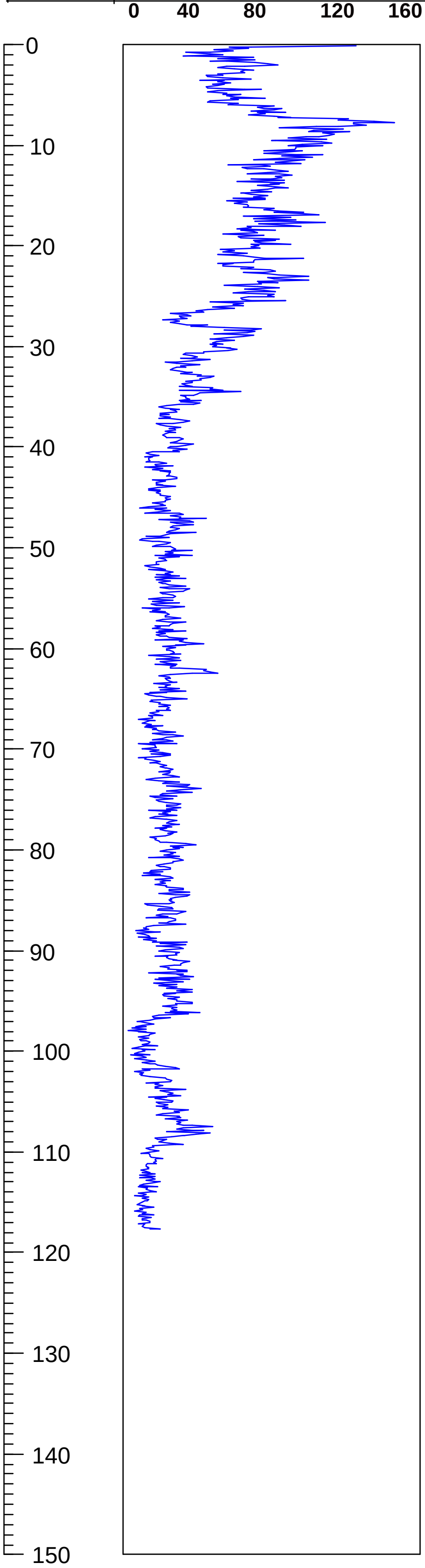
COMPOSITE WELL LOG

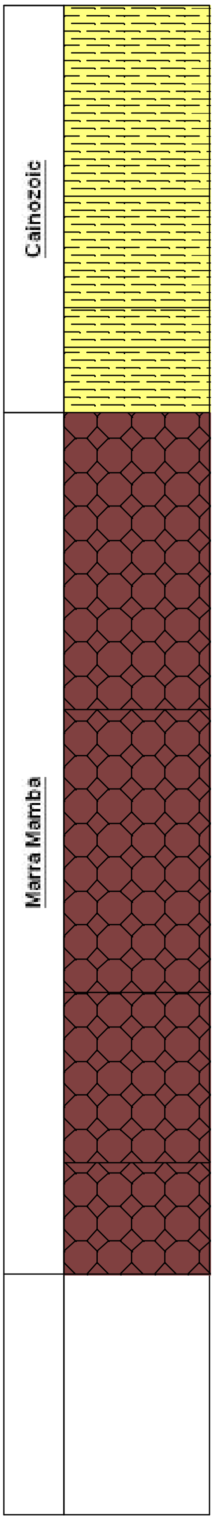
Well No: 345 B

Client: FerrAus **Project:** Robertson Range

Commenced:	25/09/2007	**Method:**	Air	**Area:**	Jigalong Reserve
Completed:	29/09/2007	**Fluid:**	Foam	**East:**	261942 mE
Drilled:	Connector	**Bit Record:**	0 - 6 mbgl 14"	**North:**	7393414 mN
Logged By:	Joe Ross		6 - 126 mbgl 10.5"	**Elevation:**	577.5 AHD
Static Water Level:	30.43 mbgl			**Date:**	18/10/2007

Depth (mbgl)	Natural Gamma Counts Per Second	Geology	Graphic Log	Lithological Description	Well Diagram





CLAY: Dark brown, silty, sandy, (sub-angular to sub-rounded, fine to medium grained). Common detrital Haematite and Goethite fragments observed with some Limonite apparent. Detrital Iron component increasing and sand component decreasing with depth over interval. Detrital Iron component becoming more Limonitic with depth.

CLAY: Dark brown, generally as above but with Iron detrital material increasing in abundance and accounting for up to 50% of material.

CLAY: Generally as above but changing in colour to light brown.

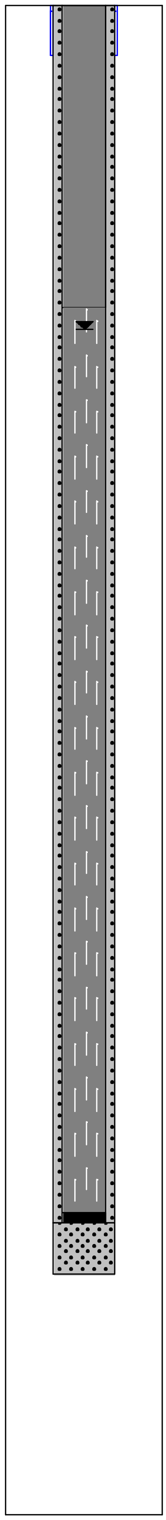
CLAY: Generally as above but becoming variably grey (light to dark) in colour, and detrital Iron content becoming variable

HAEMATITE: and Goethite. Dark grey with a variably red hue. Occasional Limonitic horizons, and very occasional 'cherty' horizons near the base of interval.

HAEMATITE: and Goethite. Dark grey and frequently Limonitic and cherty. Siliceous Shale horizons increasing in thickness toward base of interval.

HAEMATITE: Goethite and silaceous Shale interbedded. Common Limonitic horizons and occasional cherty sections.

HAEMATITE: and Goethite, dark grey and hard, commonly Limonitic. Some siliceous Shale horizons observed.



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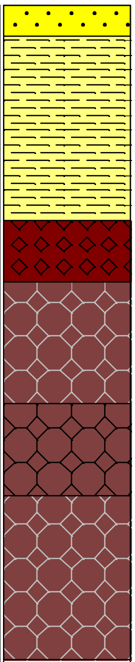
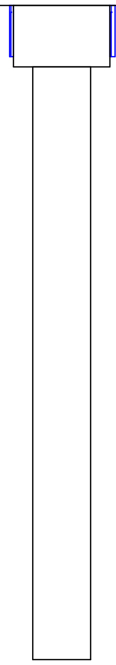
COMPOSITE WELL LOG

Well No: 346 B

Client: FerrAus **Project:** Robertson Range

Commenced:	30/09/2007	**Method:**	Air	**Area:**	Jigalong Reserve
Completed:	01/10/2007	**Fluid:**	Foam	**East:**	261639 mNE
Drilled:	Connector	**Bit Record:**	0 - 6 mbgl 14"	**North:**	7392650 mN
Logged By:	Joe Ross		6 - 64 mbgl 6.5"	**Elevation:**	TBA

Static Water Level: - **Date:** N/A

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes
0	Cainozoic		Sand: Medium to coarse grained, sub-angular to sub rounded, some clays, meduim brown, occasional gravel, common iron detrital material.			12" (310mm ID) steel surface casing (0 - 5 mbgl). To be removed.
10			CLAY: Medium brown, sandy; fine to medium grained, sub angular to sub rounded, firming with depth, increasing in detrital material.			
20	Marra Mamba		DETRITAL: Iron material, moderately sandy.			
30			LOST CIRCULATION: No returns. Inferred Haematite.	Hole abandoned. Loss of circulation with no returns. Air escaping out surrounding RC holes.		6.5" open hole (0 - 64 mbgl)
40			HAEMATITE: Black and hard, with shale interbeds, silaceous.			
50			LOST CIRCULATION: No returns. Inferred Haematite.			
60						
70						
80						
90						
100						
110						
120						
130						
140						
150						

COMPOSITE WELL LOG

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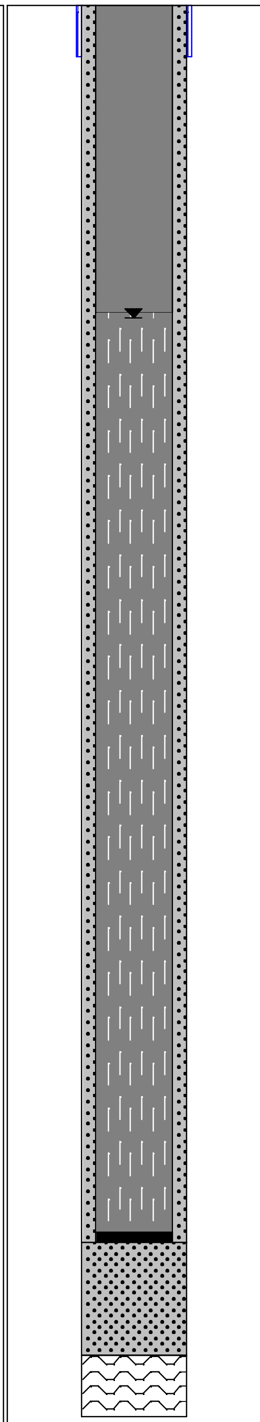
Well No: 347 B

Client: FerrAus **Project:** Robertson Range

Commenced:	01/10/2007	**Method:**	Air	**Area:**	Jigalong Reserve
Completed:	06/10/2007	**Fluid:**	Foam	**East:**	261799 mE
Drilled:	Connector	**Bit Record:**	0 - 6 mbgl 14"	**North:**	7392810 mN
Logged By:	Joe Ross		6 - 138 mbgl 10.5"	**Elevation:**	577 AHD

Static Water Level: 32.95 mbgl **Date:** 13/10/2007

Depth (mbgl)	Geology	Lithological Description
0 - 7	Cainozoic	Sand: Medium brown, medium to coarse grained, sub-angular to sub-rounded, quartzose, clayey, occasional gravel, common iron detrital material (variable in content - up to 40% in horizons).
7 - 21	Cainozoic	CLAY: Medium brown, variably sandy - grading locally to a clayey sand, occasional gravel, variable iron detrital material - up to 40% of total but often less.
21 - 32	Cainozoic	CLAY: Mottled grey / red, plastic, variably sandy, iron detrital material - variable in content: occasional to abundant.
32 - 38	Cainozoic	CLAY: Light grey, plastic, some iron detrital material - occasionally limonitic
38 - 44	Cainozoic	CLAY: Red/brown, plastic with some iron detrital material.
44 - 48	Cainozoic	CLAY: Yellow / brown, plastic, sandy, some iron detrital material.
48 - 62	Cainozoic	Sand: Red / brown, very fine grained, quartzose, moderately clayey, occasional iron detrital material - often limonitic.
62 - 68	Cainozoic	Sand: Brown / grey to grey grading to buff, fine to medium grained, quartzose, sub-angular to angular, slightly clayey, becoming gravelly at 65m, common iron detrital material - often limonitic.
68 - 138	Marra Mamba	Shale: Grey and medium red to purple, soft and friable at the top of the sequence becoming harder with depth, occasional cherty horizons and Hematite / Goethite interbeds.



Field Notes

Developed by airlift pumping
Duration: 14.5 hrs
Max airlift yield: 8.5 L/s
Field pH: 7.37
Field EC: 743 mS/cm

Well Completion Notes

12" (310mm ID) steel surface casing (0 - 5 mbgl).

6" (155mm ID) blank steel casing (0 - 30 mbgl)

Gravel pack (3.2 - 6.4mm)

6" (155mm ID) slotted steel casing (30 - 120 mbgl).

Steel end cap @ 121mbgl

Fallback (132 - 138 mbgl)

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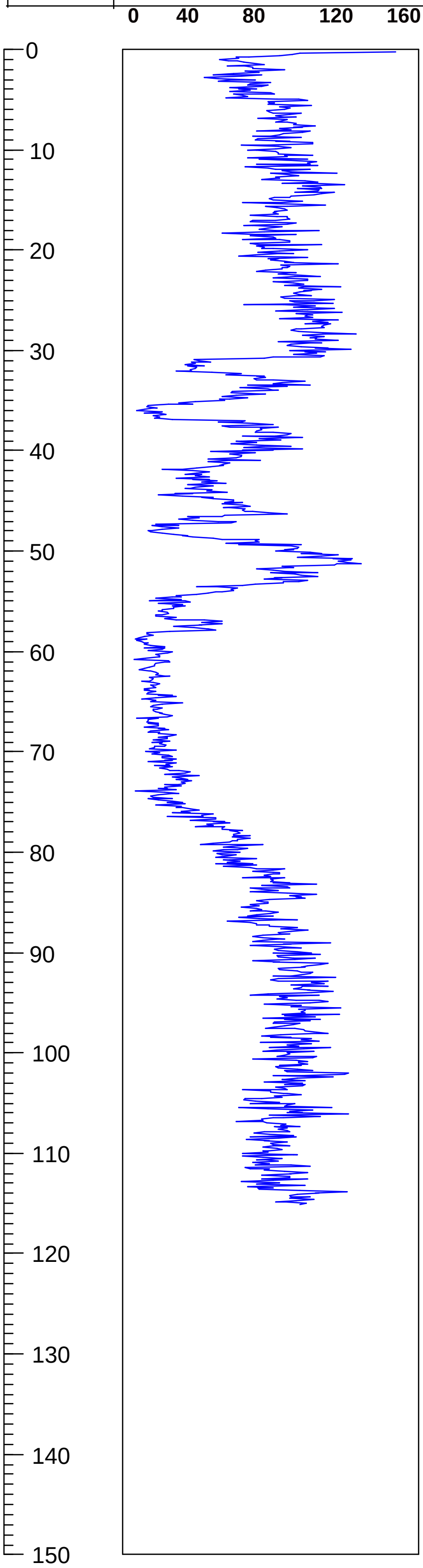
COMPOSITE WELL LOG

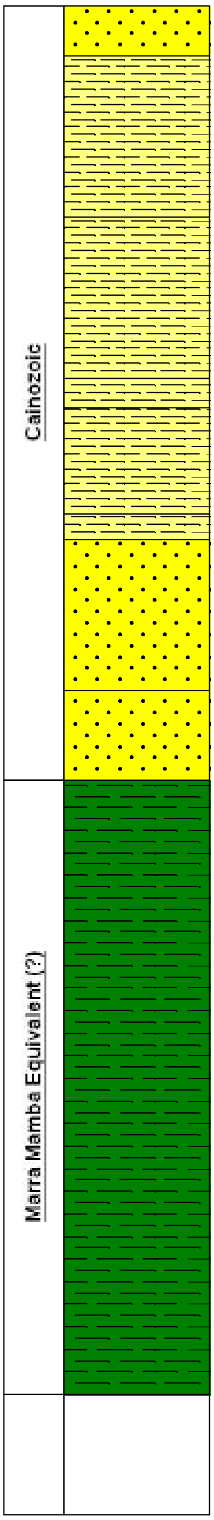
Well No: 347 B

Client: FerrAus | **Project:** Robertson Range

Commenced: 01/10/2007	**Method:** Air	**Area:** Jigalong Reserve	
Completed: 06/10/2007	**Fluid:** Foam	**East:** 261799 mE	
Drilled: Connector	**Bit Record:** 0 - 6 mbgl 14"	**North:** 7392810 mN	
Logged By: Joe Ross	6 - 138 mbgl 10.5"	**Elevation:** 577 AHD	
Static Water Level: 32.95 mbgl		**Date:** 13/10/2007	

Depth (mbgl) | **Natural Gamma** Counts Per Second | **Geology** | **Graphic Log** | **Lithological Description** | **Well Diagram**





Sand: Medium brown, medium to coarse grained, sub-angular to sub-rounded, quartzose, clayey, occasional gravel, common iron detrital material (variable in content - up to 40% in horizons).

CLAY: Medium brown, variably sandy - grading locally to a clayey sand, occasional gravel, variable iron detrital material - up to 40% of total but often less.

CLAY: Mottled grey / red, plastic, variably sandy, iron detrital material - variable in content: occasional to abundant.

CLAY: Light grey, plastic, some iron detrital material - occasionally limonitic

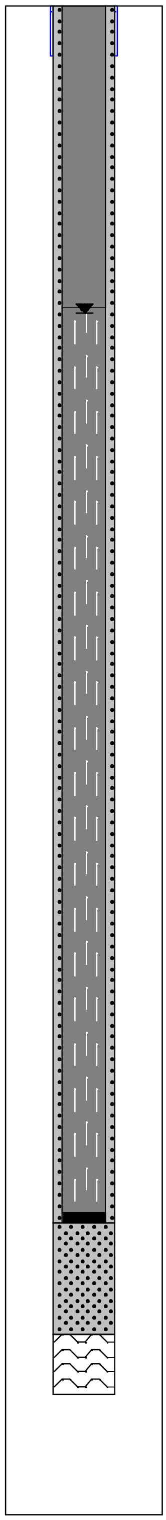
CLAY: Red/brown, plastic with some iron detrital material.

CLAY: Yellow / brown, plastic, sandy, some iron detrital material.

Sand: Red / brown, very fine grained, quartzose, moderately clayey, occasional iron detrital material - often limonitic.

Sand: Brown / grey to grey grading to buff, fine to medium grained, quartzose, sub-angular to angular, slightly clayey, becoming gravelly at 65m, common iron detrital material - often limonitic.

Shale: Grey and medium red to purple, soft and friable at the top of the sequence becoming harder with depth, occasional cherty horizons and Hematite / Goethite interbeds.



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COMPOSITE WELL LOG

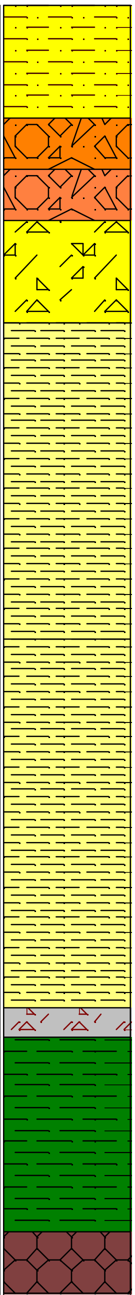
Well No: 348 B

Client: FerrAus | **Project:** Robertson Range

Commenced:	06/10/2007	**Method:**	Air/Mud Rotary	**Area:**	Jigalong Reserve
Completed:	13/10/2007	**Fluid:**	Foam	**East:**	261928 mNE
Drilled:	Connector	**Bit Record:**	0 - 6 mbgl 14"	**North:**	7393939 mN
Logged By:	Sam Cook		6 - 126 mbgl 10.5"	**Elevation:**	TBA

Static Water Level: 34.73 mbgl **Date:** 28/10/2007

Depth (mbgl)	Geology	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes
0–150 (scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150)	Cainozoic; Marra Mamba	see graphic log	see below	see below	see diagram	see below



Lithological Description

Silt: Red brown, very fine particles with some fine to medium, well sorted, sub angular to sub rounded gravels.

GRAVEL AND SILT: Medium to coarse black Haematite fragments and brown medium grained, poorly sorted, miscallaneous pebbles in a red brown silt matrix.

SILTY GRAVEL: Black, coarse, medium sorted, angular Haematite fragments and brown, fine to medium, sub rounded, ferruginised, miscallaneous pebbles with fine red brown silt (30%)..

CLAY WITH GRAVEL: Red brown clay with 20% white, red, black and brown assorted gravels, fine to coarse, poorly sorted, sub angular, minor white shale.

CLAY: Tan orange, dense with 15 to 30% assorted ferruginised gravel fragments, fine to medium, poorly sorted, sub angular. Chert, Shale and Pisolite, some very coarse Haematite/Goethite fragments.

CLAY: Orange brown, as above with less gravel content. Coarse, medium sorted Haematite, some red Chert, minor Quartz.

CLAY AND GRAVEL: Detrital iron fragments, fine to coarse, poorly sorted with Shale, Weathered Haematite and Chert, 10 to 20% orange brown clay.

Shale: Purple to black/grey, coarse, sub angular, silaceous, some Goethite and Chert horizons, evident fracture zones.

HAEMATITE: and GOETHITE. Black/grey (manganese staining), coarse, solid, some fractures.

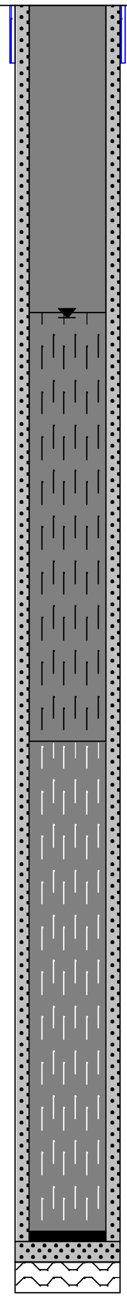
Field Notes

Developed by airlift pumping
Duration: 12 hrs
Max airlift yield: 3.5 L/s
Field pH: 8.4
Field EC: 1570 uS/cm

Minor water strike at 63mbgl

Major water strike at 96mbgl

Well Completion



Notes

12" (310mm ID) steel surface casing (0 - 5.6 mbgl)

6" (155mm ID) blank steel casing (0 - 30 mbgl)

Gravel pack (3.2 - 6.4mm)

6" (155mm ID) blank (slots blocked with silicon) steel casing (30 - 72 mbgl)

6" (155mm ID) slotted steel casing (72 - 120 mbgl)

Steel end cap @ 120mbgl

Fallback
(123 - 126 mbgl)

aquaterra	COMPOSITE WELL LOG	Well No: 348 B

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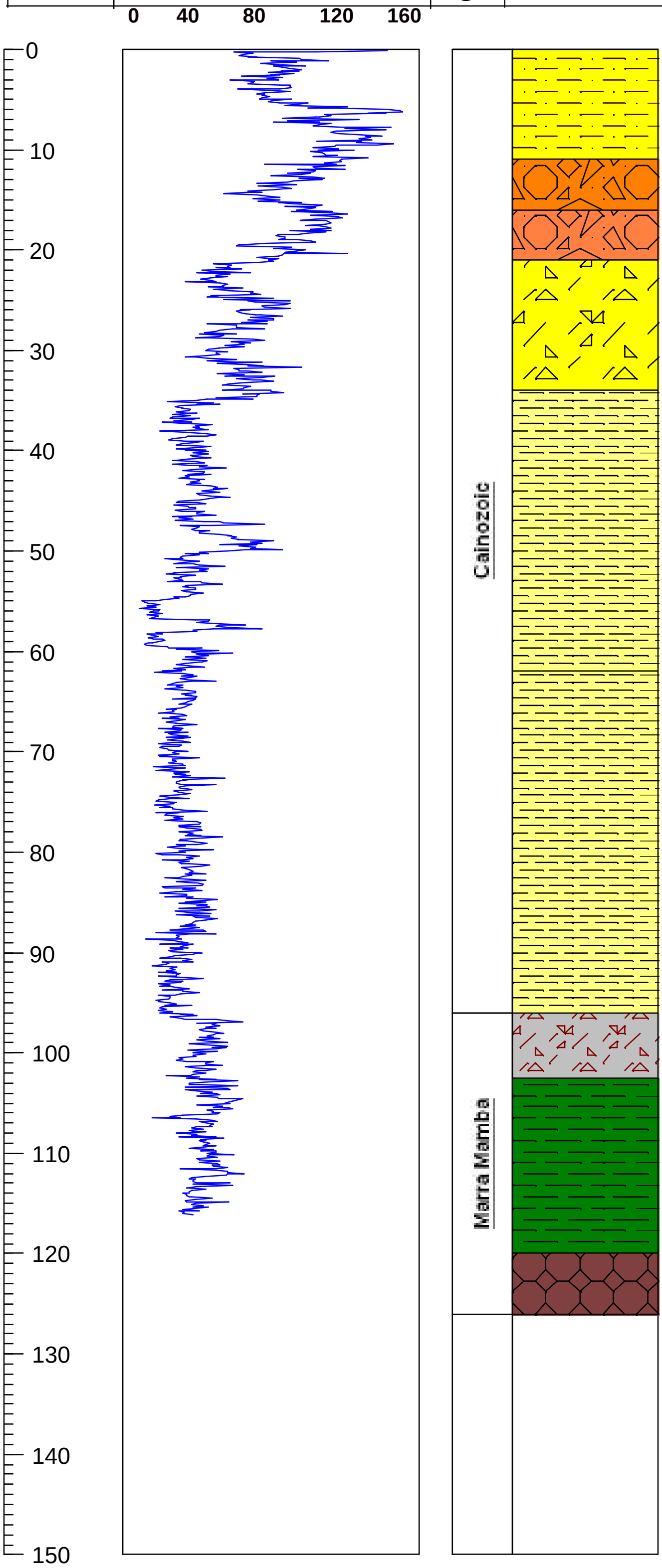
Client: FerrAus | **Project:** Robertson Range

Commenced:	06/10/2007	**Method:**	Air/Mud Rotary	**Area:**	Jigalong Reserve
Completed:	13/10/2007	**Fluid:**	Foam	**East:**	261928 mNE
Drilled:	Connector	**Bit Record:**	0 - 6 mbgl 14"	**North:**	7393939 mN
Logged By:	Sam Cook		6 - 126 mbgl 10.5"	**Elevation:**	581 AHD
Static Water Level:	34.73 mbgl			**Date:**	28/10/2007

Depth (mbgl)	Natural Gamma Counts Per Second	Geology	Graphic Log	Lithological Description	Well Diagram



Silt: Red brown, very fine particles with some fine to medium, well sorted, sub angular to sub rounded gravels.

GRAVEL AND SILT: Medium to coarse black Haematite fragments and brown medium grained, poorly sorted, miscallaneous pebbles in a red brown silt matrix.

SILTY GRAVEL: Black, coarse, medium sorted, angular Haematite fragments and brown, fine to medium, sub rounded, ferruginised, miscallaneous pebbles with fine red brown silt (30%)..

CLAY WITH GRAVEL: Red brown clay with 20% white, red, black and brown assorted gravels, fine to coarse, poorly sorted, sub angular, minor white shale.

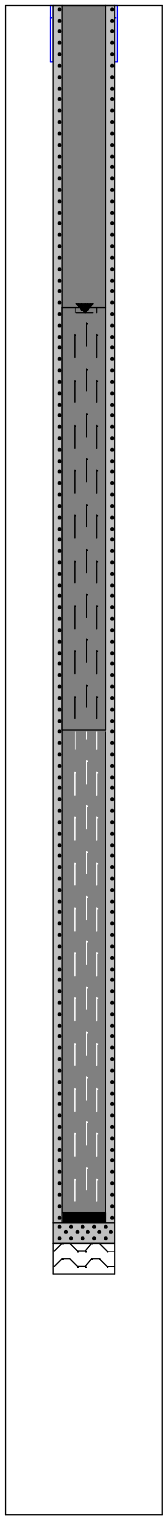
CLAY: Tan orange, dense with 15 to 30% assorted ferruginised gravel fragments, fine to medium, poorly sorted, sub angular. Chert, Shale and Pisolite, some very coarse Haematite/Goethite fragments.

CLAY: Orange brown, as above with less gravel content. Coarse, medium sorted Haematite, some red Chert, minor Quartz.

CLAY AND GRAVEL: Detrital iron fragments, fine to coarse, poorly sorted with Shale, Weathered Haematite and Chert, 10 to 20% orange brown clay.

Shale: Purple to black/grey, coarse, sub angular, silaceous, some Goethite and Chert horizons, evident fracture zones.

HAEMATITE: and GOETHITE. Black/grey (manganese staining), coarse, solid, some fractures.



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COMPOSITE WELL LOG

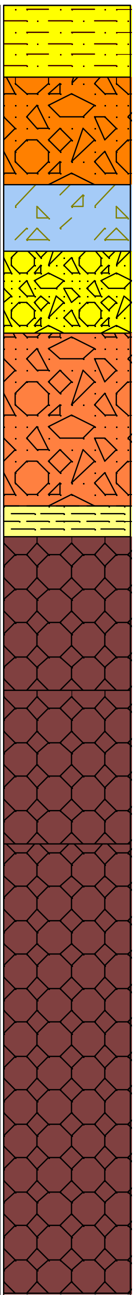
Well No: 349 B

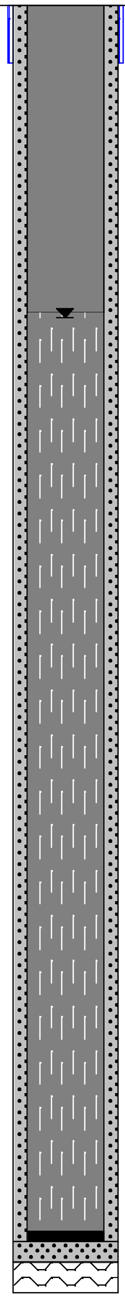
Client: Ferraus **Project:** Robertson Range

Commenced:	14/10/2007	**Method:**	Air	**Area:**	Jigalong Reserve
Completed:	18/10/2007	**Fluid:**	Foam	**East:**	261867 mE
Drilled:	Connector	**Bit Record:**	0 - 6 mbgl 14"	**North:**	7393712 mN
Logged By:	Sam Cook		6 - 126 mbgl 10.5"	**Elevation:**	579 AHD

Static Water Level: 32.56 mbgl **Date:** 23/10/2007

Depth (mbgl)	Geology	Lithological Description	Field Notes	Well Completion Notes
0	Cainozoic	Silt: Red brown, silty, sandy, very fine with assorted fine to medium grained, poorly sorted, sub angular to sub rounded detrital iron fragments.		12" (310mm ID) steel surface casing (0 - 5.6 mbgl)
10		GRAVEL AND SILT: Red brown, fine, silt with 30 to 50% blue/black Haematite/Goethite, fine to medium grained with minor Quartz fragments.	Developed by airlift pumping Duration: 3.5 hrs Max airlift yield: 16.5 L/s Field pH: 7.12 Field EC: 1309 uS/cm	6" (155mm ID) blank steel casing (0 - 30 mbgl)
20		CLAYEY GRAVEL: Light brown clay (15%) with high gravel content (detrital Haematite/Goethite), blue and brown, fine to coarse grained, poorly sorted.		
30		Gravel: Black (Manganese stained) Haematite and Goethite fragments, medium to coarse, angular grains, medium sorted, 20-30% red brown silt.		
40		SILTY GRAVEL: Dark blue/grey, red and brown gravels, coarse grained, medium sorted, predominantly red Haematite and red brown silt (up to 30%).		Gravel pack (3.2 - 6.4mm)
50	Marra Mamba	CLAY: Tan brown, clayey impermeable zone.		
60		HAEMATITE: and GOETHITE, blue grey and red, coarse, well sorted, angular cuttings, some Pisolite, Limonite and Shale, minor yellow brown clay.		6" (155mm ID) slotted steel casing (30 - 120 mbgl)
70		HAEMATITE: GOETHITE and PISOLITE, red, purple and yellow, coarse angular cuttings, well sorted with highly permeable fractures, some silaceous Chert, minor brown clay.	First water returns at 76mbgl	
80		HAEMATITE: and GOETHITE. Blue grey, red and purple, coarse ore cuttings, fractured, highly permeable, considerable black Manganese staining, thin white clay layering from 124mbgl, minor Quartz veins.		
90				
100				
110				
120				Steel end cap @ 120mbgl
				Fallback (123 - 126 mbgl)
130				
140				
150				





COMPOSITE WELL LOG

Well No: 349 B

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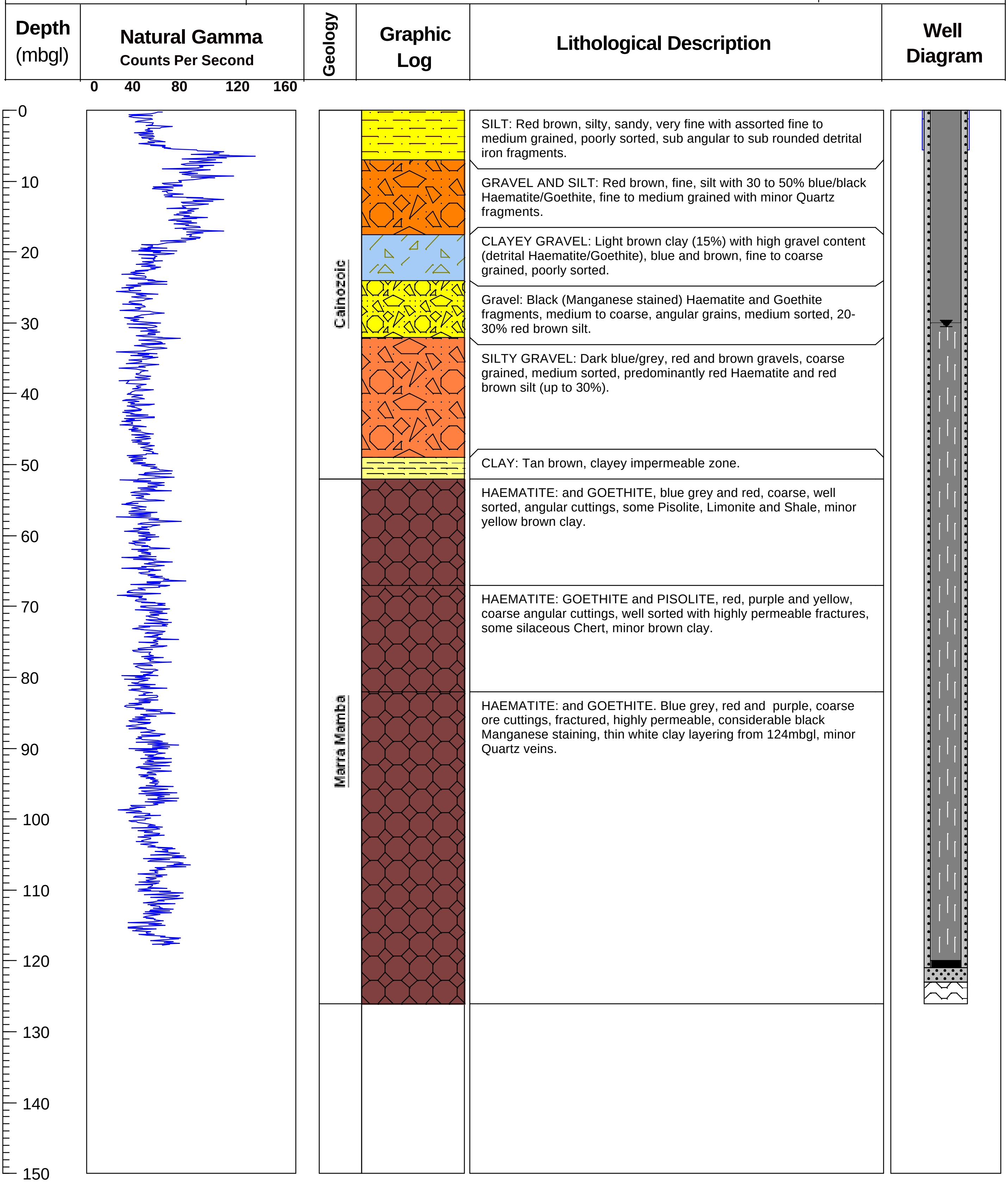
Client: Ferraus
Project: Robertson Range

Commenced: 14/10/2007
Completed: 18/10/2007
Drilled: Connector
Logged By: Sam Cook

Method: Air
Fluid: Foam
Bit Record: 0 - 6 mbgl 14"
6 - 126 mbgl 10.5"

Area: Jigalong Reserve
East: 261867 mE
North: 7393712 mN
Elevation: 579 AHD

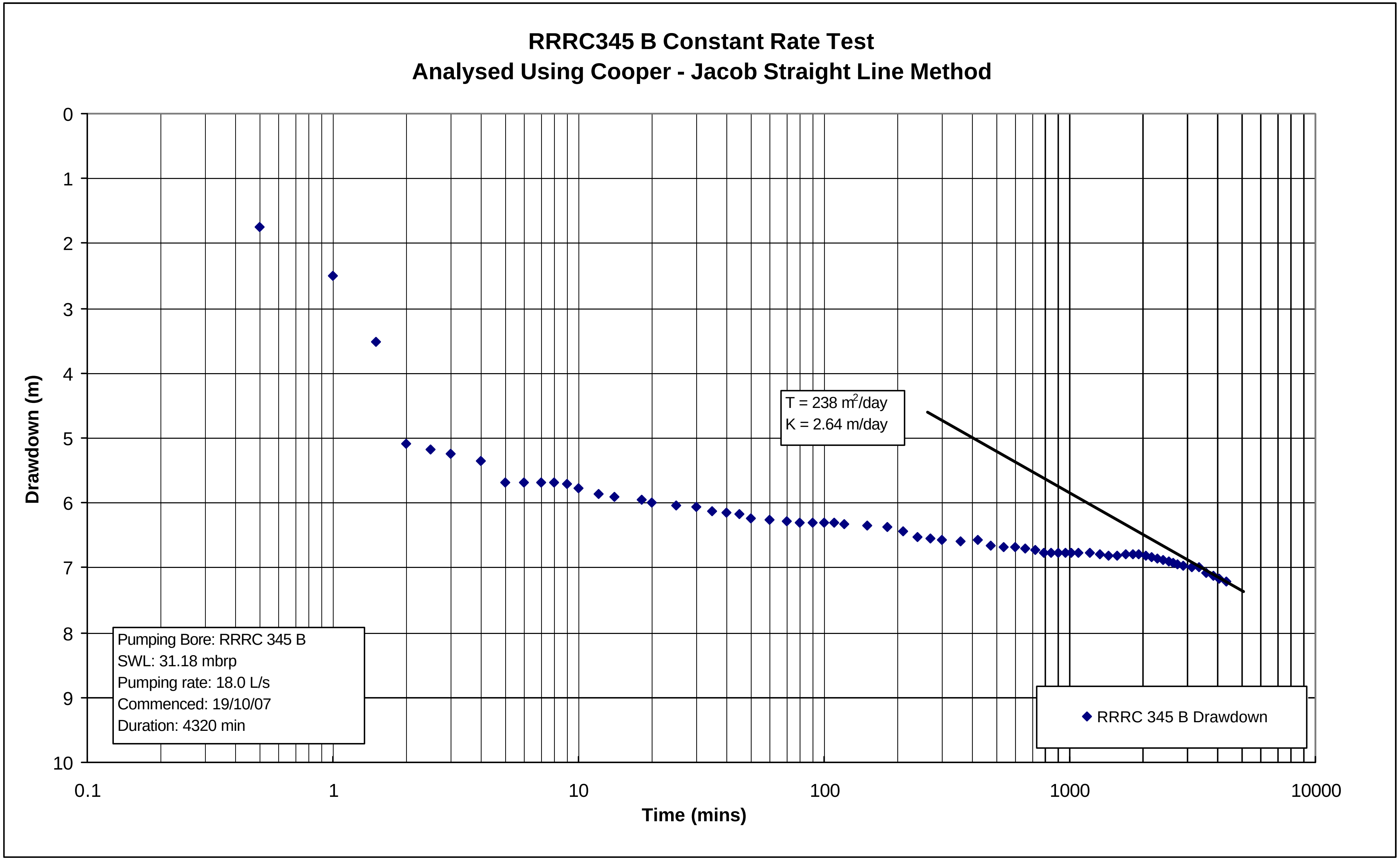
Static Water Level: 32.56 mbgl
Date: 23/10/2007

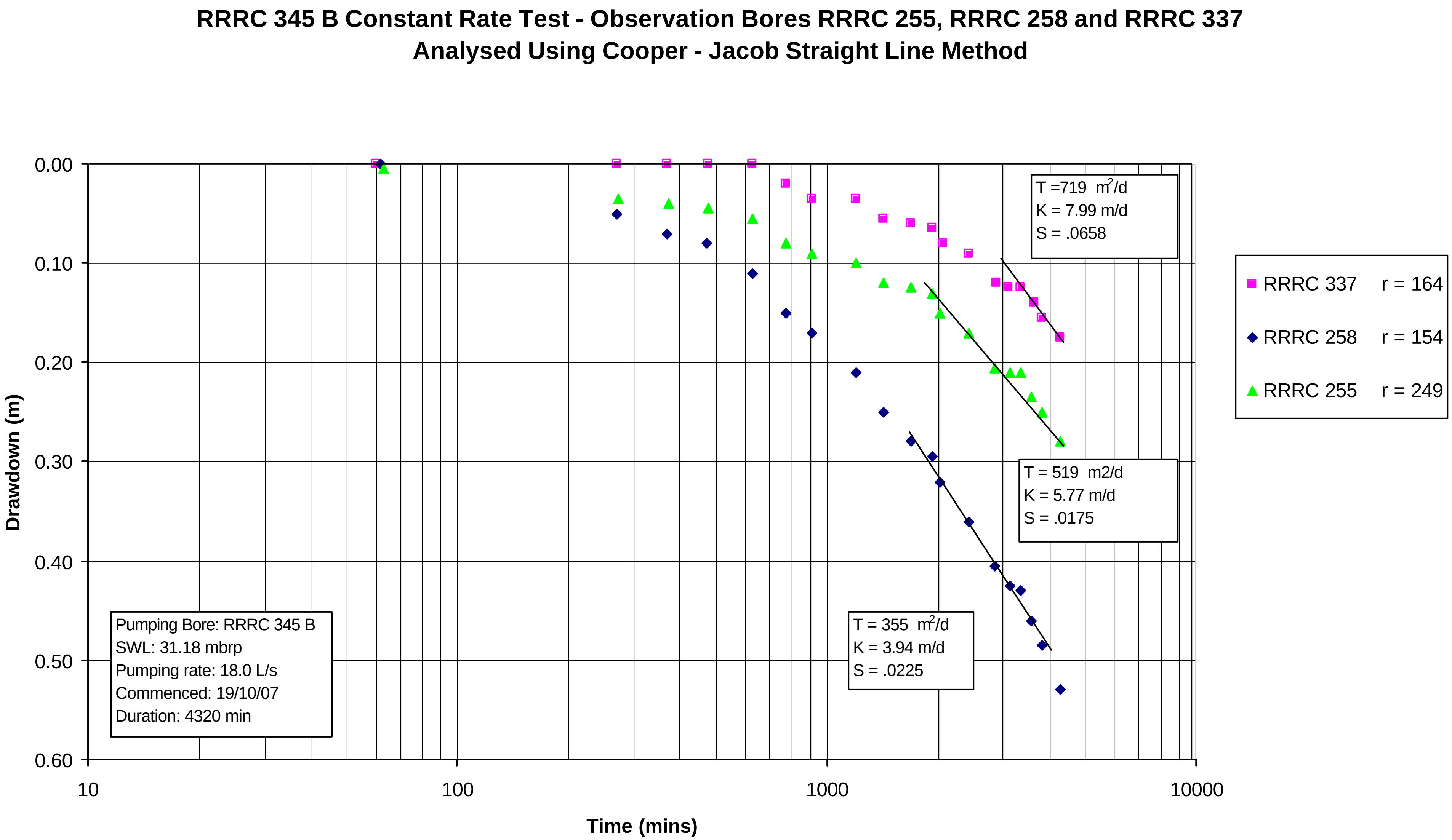


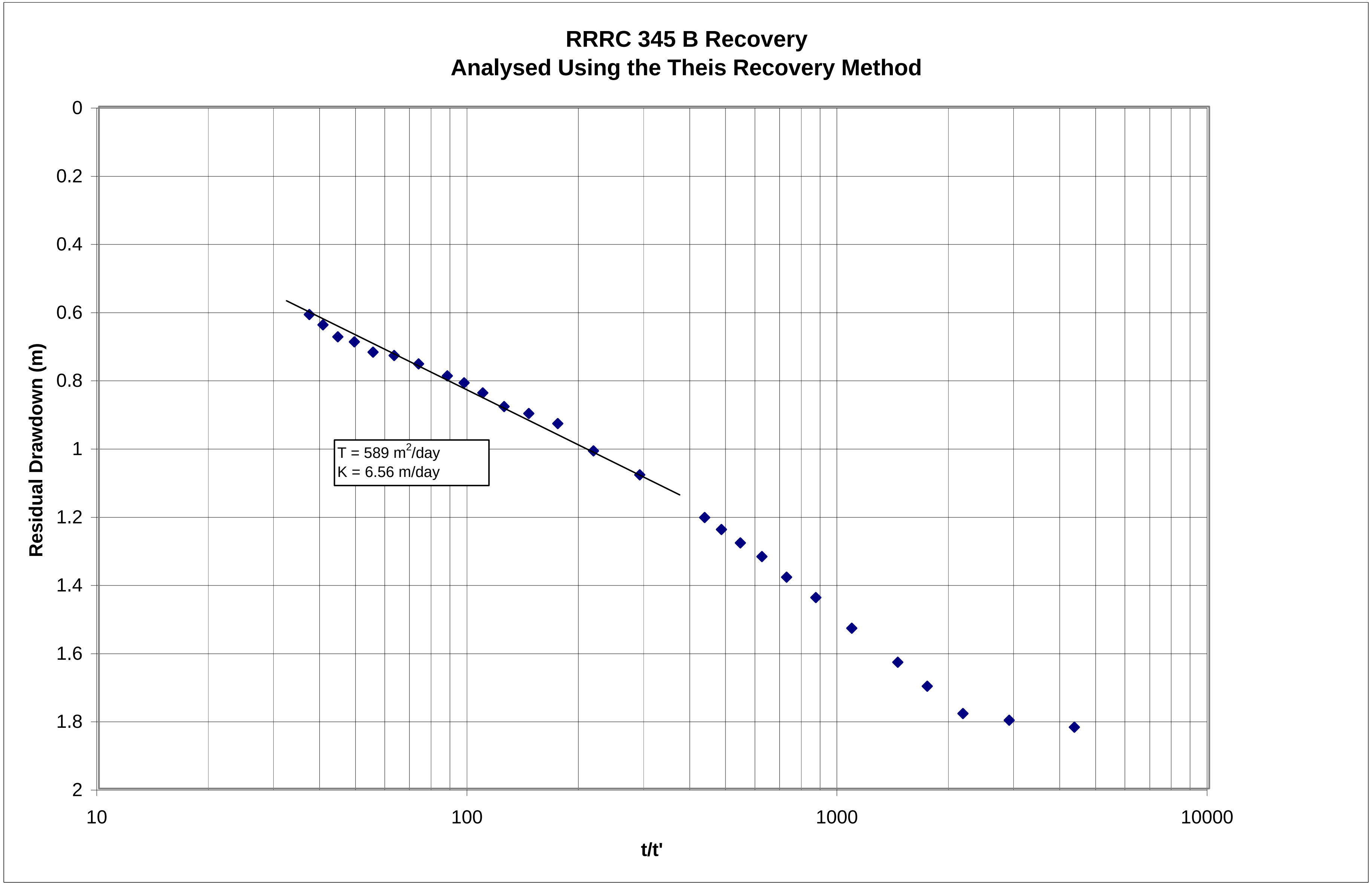
APPENDIX B

RRRC 345 B

CONSTANT RATE TEST
RECOVERY TEST


RRRC345 B Constant Rate Test
Analysed Using Cooper - Jacob Straight Line Method
Drawdown (m)
0
1
2
3
4
5
6
7
8
9
10
0.1
1
10
100
1000
10000
Time (mins)
T = 238 m2/day
K = 2.64 m/day
Pumping Bore: RRRC 345 B
SWL: 31.18 mbrp
Pumping rate: 18.0 L/s
Commenced: 19/10/07
Duration: 4320 min
RRRC 345 B Drawdown


RRRC 345 B Constant Rate Test - Observation Bores RRRC 255, RRRC 258 and RRRC 337
Analysed Using Cooper - Jacob Straight Line Method
Drawdown (m)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
10
100
1000
10000
Time (mins)
T =719 m2/d
K = 7.99 m/d
S = .0658
T = 519 m2/d
K = 5.77 m/d
S = .0175
T = 355 m2/d
K = 3.94 m/d
S = .0225
Pumping Bore: RRRC 345 B
SWL: 31.18 mbrp
Pumping rate: 18.0 L/s
Commenced: 19/10/07
Duration: 4320 min
RRRC 337 r = 164
RRRC 258 r = 154
RRRC 255 r = 249

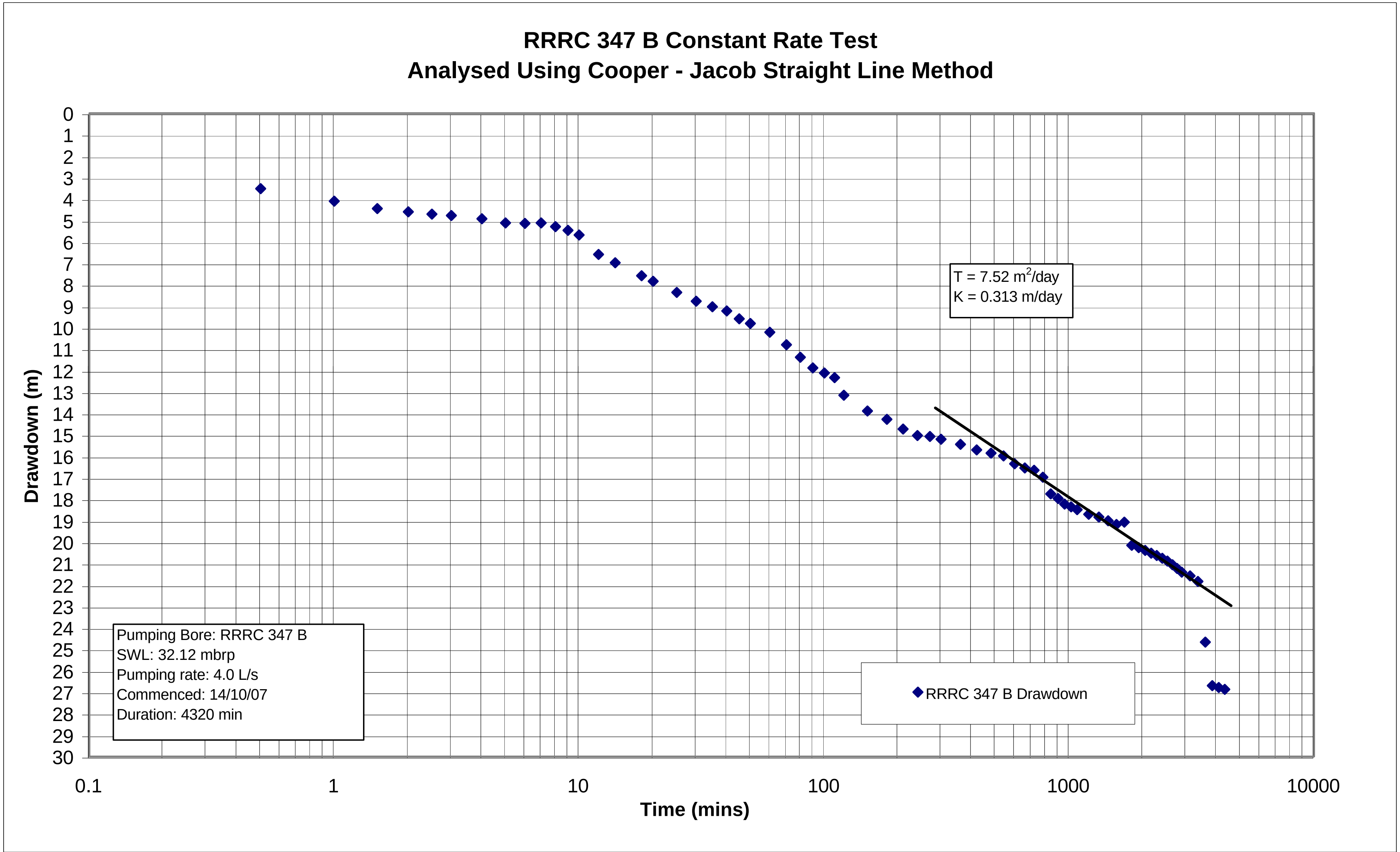


RRRC 345 B Recovery
Analysed Using the Theis Recovery Method
Residual Drawdown (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
10
100
1000
10000
t/t'
T = 589 m2/day
K = 6.56 m/day

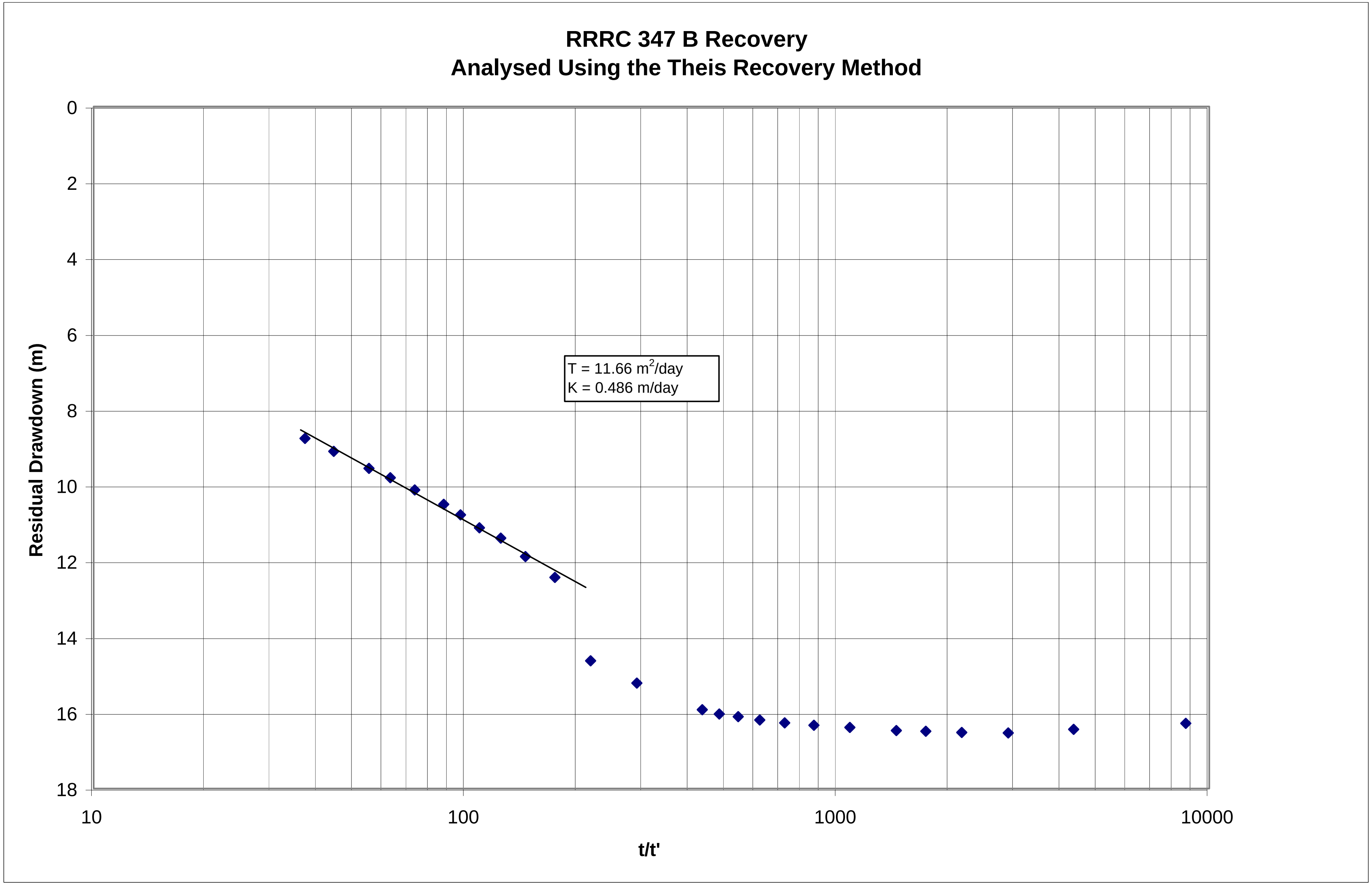
APPENDIX C

RRRC 347 B

CONSTANT RATE TEST
RECOVERY TEST



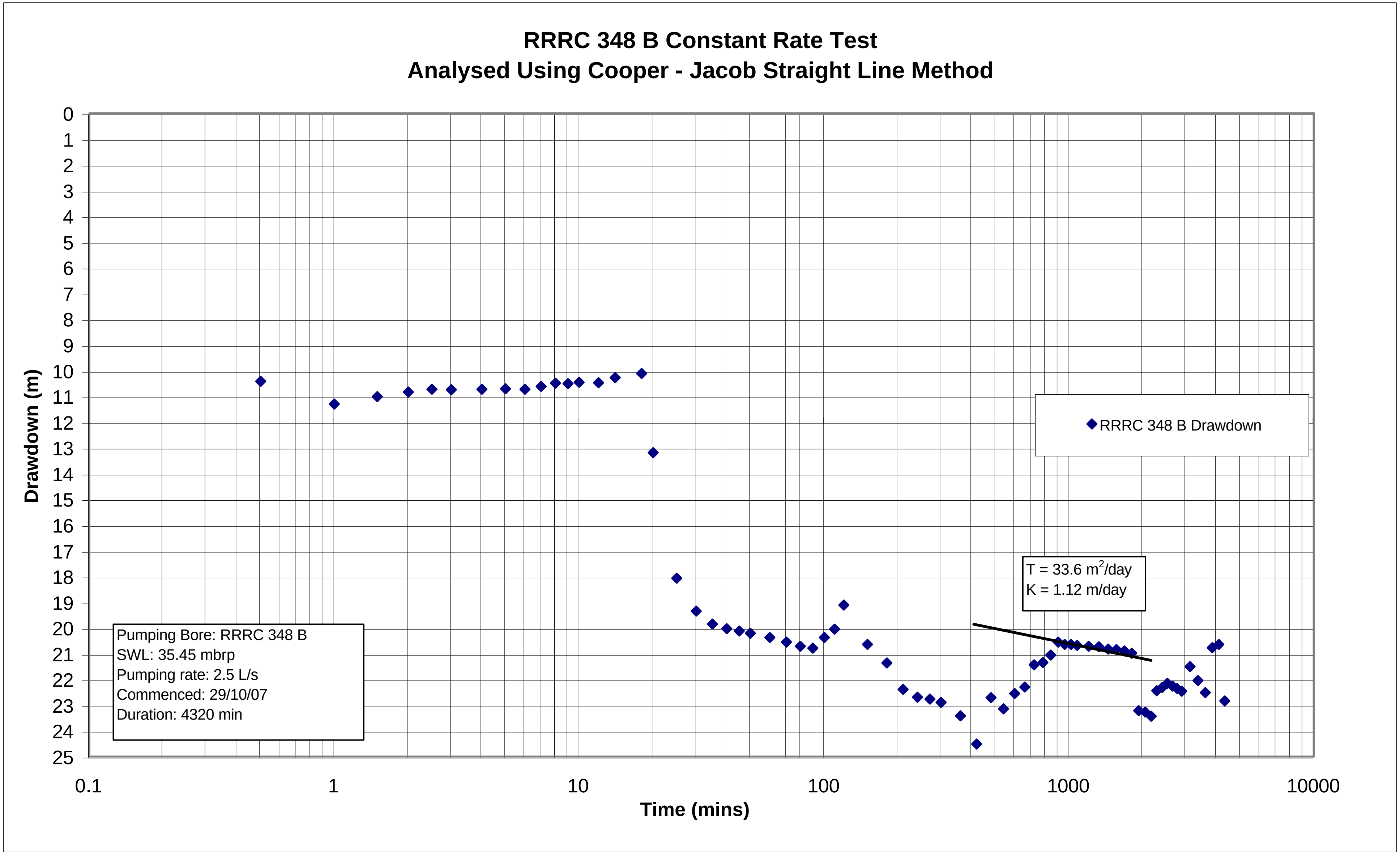
RRRC 347 B Constant Rate Test
Analysed Using Cooper - Jacob Straight Line Method
Drawdown (m)
Time (mins)
0.1
1
10
100
1000
10000
T = 7.52 m²/day
K = 0.313 m/day
Pumping Bore: RRRC 347 B
SWL: 32.12 mbrp
Pumping rate: 4.0 L/s
Commenced: 14/10/07
Duration: 4320 min
RRRC 347 B Drawdown

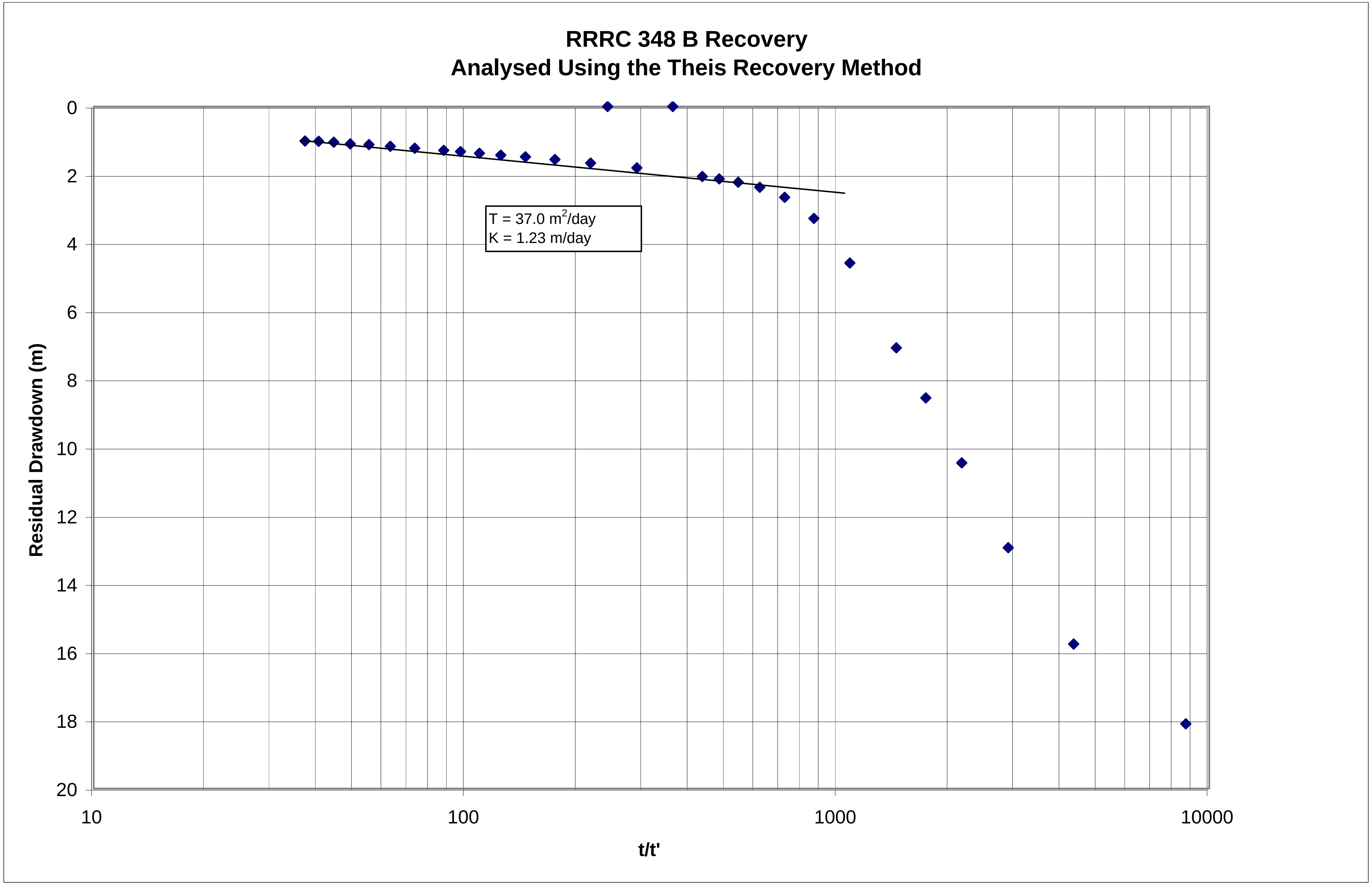

RRRC 347 B Recovery
Analysed Using the Theis Recovery Method
T = 11.66 m2/day
K = 0.486 m/day
Residual Drawdown (m)
0
2
4
6
8
10
12
14
16
18
10
100
1000
10000
t/t'

APPENDIX D

RRRC 348 B

CONSTANT RATE TEST
RECOVERY TEST

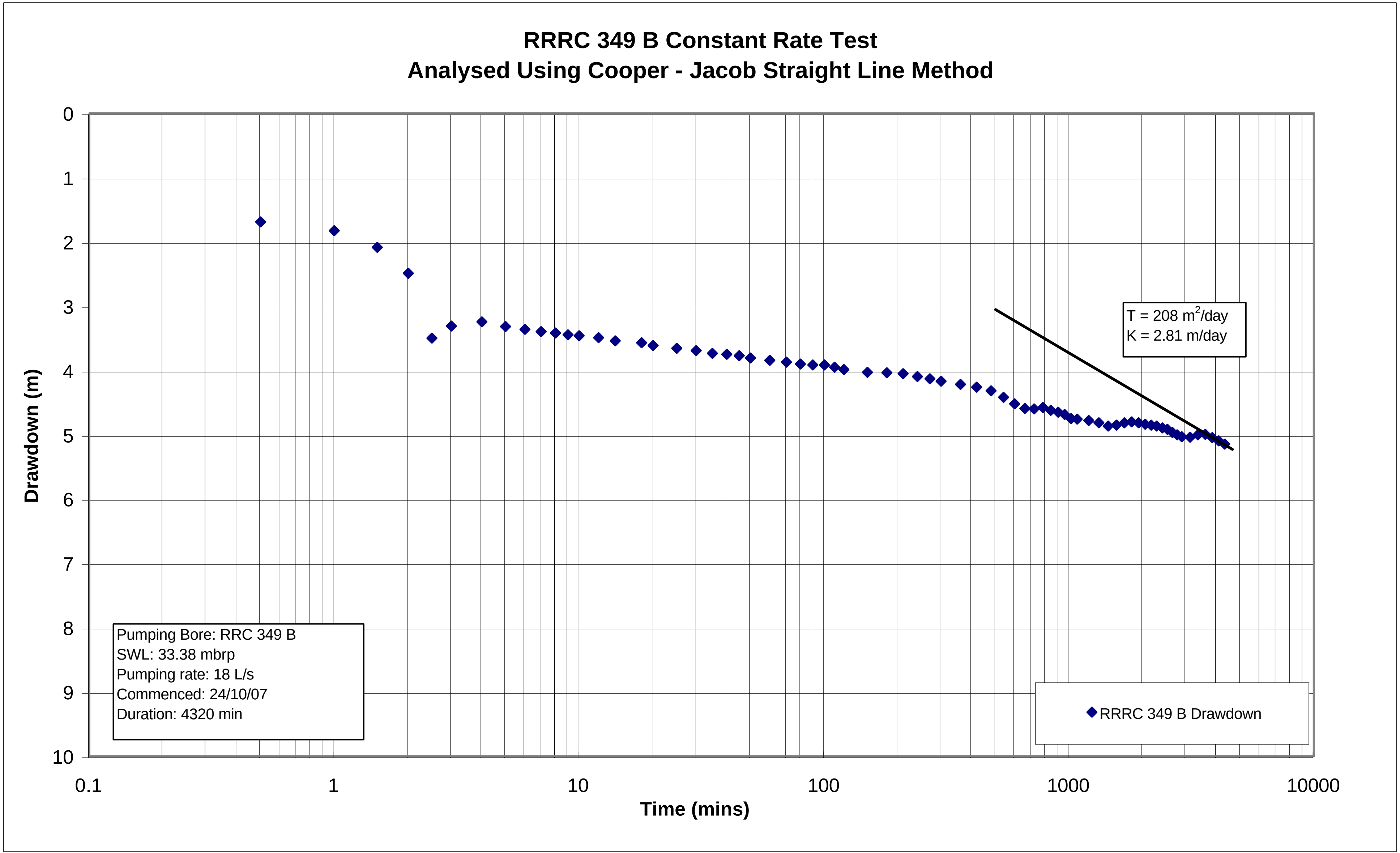

RRRC 348 B Constant Rate Test
Analysed Using Cooper - Jacob Straight Line Method
Drawdown (m)
Time (mins)
0.1
1
10
100
1000
10000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
RRRC 348 B Drawdown
T = 33.6 m2/day
K = 1.12 m/day
Pumping Bore: RRRC 348 B
SWL: 35.45 mbrp
Pumping rate: 2.5 L/s
Commenced: 29/10/07
Duration: 4320 min


RRRC 348 B Recovery
Analysed Using the Theis Recovery Method
T = 37.0 m²/day
K = 1.23 m/day
Residual Drawdown (m)
t/t'
0
2
4
6
8
10
12
14
16
18
20
10
100
1000
10000

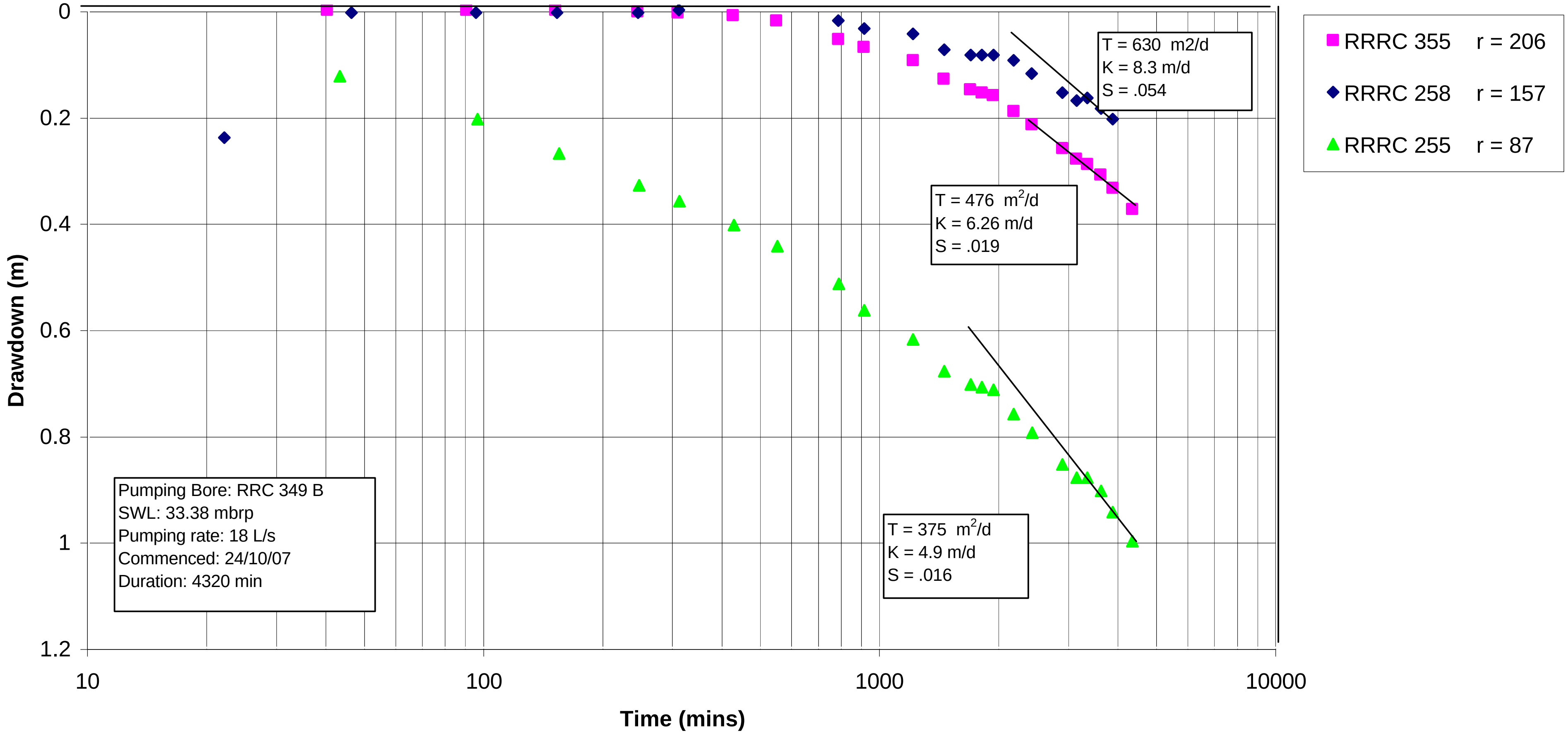
APPENDIX E

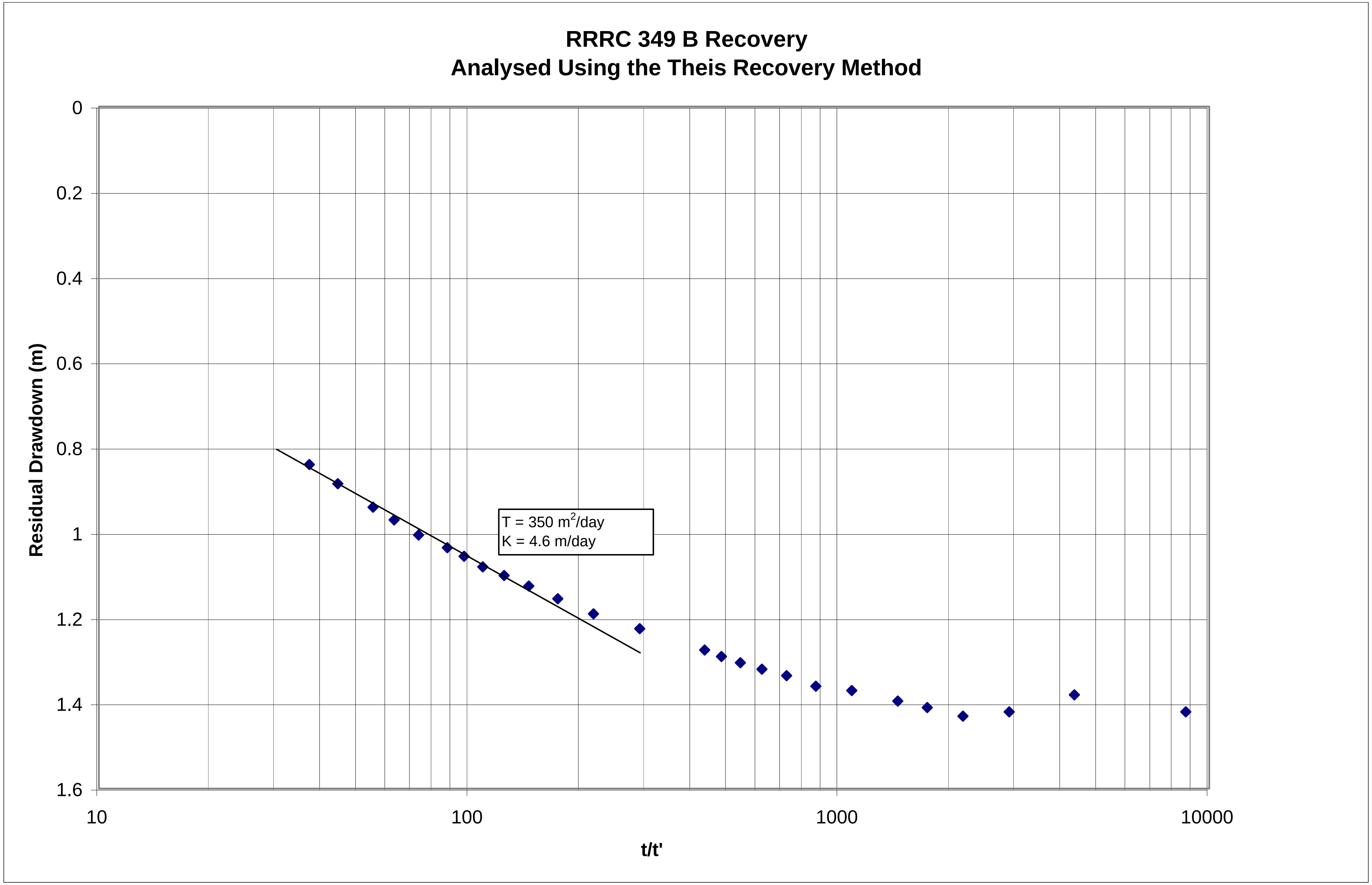
RRRC 349 B

CONSTANT RATE TEST
RECOVERY TEST


RRRC 349 B Constant Rate Test
Analysed Using Cooper - Jacob Straight Line Method
T = 208 m2/day
K = 2.81 m/day
Pumping Bore: RRC 349 B
SWL: 33.38 mbrp
Pumping rate: 18 L/s
Commenced: 24/10/07
Duration: 4320 min
RRRC 349 B Drawdown
Drawdown (m)
Time (mins)
0
1
2
3
4
5
6
7
8
9
10
0.1
1
10
100
1000
10000

RRRC 349 B Constant Rate Test - Observation Bores RRRC 355, RRRC 258, and RRRC255
Analysed Using Cooper - Jacob Straight Line Method




RRRC 349 B Recovery
Analysed Using the Theis Recovery Method
Residual Drawdown (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
10
100
1000
10000
t/t'
T = 350 m2/day
K = 4.6 m/day

APPENDIX F

CERTIFICATES OF CHEMICAL ANALYSIS

CLIENT: Aquaterra **OUR REFERENCE:** 14060

PROJECT: Robertson Range, Job# 791, Task# C

LABORATORY REPORT

Your Reference Our Reference Date Sampled Type of Sample	Units	347B 14060-1 17/10/2007 Water	349B 14060-2 27/10/2007 Water	345B 14060-3 21/10/2007 Water	348B 14060-4 01/11/2007 Water
pH	pH Units	7.6	7.6	7.6	7.7
Conductivity @25°C	µS/cm	800	1,500	1,300	1,800
Total Dissolved Solids @ 180°C	mg/L	420	770	690	900
Soluble Iron, Fe	mg/L	0.13	0.02	0.04	0.10
Sodium, Na	mg/L	80	170	130	180
Potassium, K	mg/L	26	33	26	48
Calcium, Ca	mg/L	37	54	44	73
Magnesium, Mg	mg/L	29	67	65	72
Chloride, Cl	mg/L	88	240	200	310
Carbonate, CO_3	mg/L	<1	<1	<1	<1
Bicarbonate, HCO_3	mg/L	230	260	230	270
Sulphate, SO_4	mg/L	49	180	160	180
Nitrate, NO_3	mg/L	42	6.2	3.4	20
Fluoride, F	mg/L	0.8	0.8	0.7	0.8
Soluble Manganese, Mn	mg/L	0.007	<0.005	0.006	0.082
Soluble Silica, SiO2 #	mg/L	24	46	24	50
Cation/Anion balance	%	2.3	3.9	3.8	3.9
Sum of Ions (calc.)	mg/L	582.0	1,010	860.0	1,153

SGS

CLIENT: Aquaterra **OUR REFERENCE:** 14060
PROJECT: Robertson Range, Job# 791, Task# C

LABORATORY REPORT

TEST PARAMETERS	UNITS	LOR	METHOD
Standard Water Analysis			
pH	pH Units	0.1	AN-101
Conductivity @25°C	µS/cm	2	AN-106
Total Dissolved Solids @ 180°C	mg/L	10	PEI-002
Soluble Iron, Fe	mg/L	0.02	PEM-007
Sodium, Na	mg/L	0.5	PEM-007
Potassium, K	mg/L	0.1	PEM-007
Calcium, Ca	mg/L	0.2	PEM-007
Magnesium, Mg	mg/L	0.1	PEM-007
Chloride, Cl	mg/L	1	PEI-071
Carbonate, CO_3	mg/L	1	PEI-006
Bicarbonate, HCO_3	mg/L	5	PEI-006
Sulphate, SO_4	mg/L	1	PEI-072
Nitrate, NO_3	mg/L	0.2	PEI-073
Fluoride, F	mg/L	0.1	PEI-027
Soluble Manganese, Mn	mg/L	0.005	PEM-007
Soluble Silica, SiO2 #	mg/L	0.05	PEM-007
Cation/Anion balance	%		Calculation
Sum of Ions (calc.)	mg/L		Calculation

SGS

CLIENT: Aquaterra **OUR REFERENCE:** 14060
PROJECT: Robertson Range, Job# 791, Task# C

LABORATORY REPORT

QUALITY CONTROL	UNITS	Blank	Replicate Sm#	Replicate Sample||Replicate	Spike Sm#	Matrix Spike (%)
pH	pH Units	-	[NT]	[NT]	Control	-
Conductivity @25°C	µS/cm	-	[NT]	[NT]	Control	-
Total Dissolved Solids @ 180°C	mg/L	<10	[NT]	[NT]	Control	87%
Soluble Iron, Fe	mg/L	<0.02	[NT]	[NT]	Control	112%
Sodium, Na	mg/L	<0.5	[NT]	[NT]	Control	104%
Potassium, K	mg/L	<0.1	[NT]	[NT]	Control	113%
Calcium, Ca	mg/L	<0.2	[NT]	[NT]	Control	97%
Magnesium, Mg	mg/L	<0.1	[NT]	[NT]	Control	104%
Chloride, Cl	mg/L	<1	[NT]	[NT]	Control	101%
Carbonate, CO_3	mg/L	-	[NT]	[NT]	Control	-
Bicarbonate, HCO_3	mg/L	-	[NT]	[NT]	Control	-
Sulphate, SO_4	mg/L	<1	[NT]	[NT]	Control	99%
Nitrate, NO_3	mg/L	<0.2	[NT]	[NT]	Control	106%
Fluoride, F	mg/L	<0.1	[NT]	[NT]	Control	101%
Soluble Manganese, Mn	mg/L	<0.005	[NT]	[NT]	Control	104%
Soluble Silica, SiO2 #	mg/L	-	[NT]	[NT]	Control	-
Cation/Anion balance	%	-	[NT]	[NT]	Control	-