Northern Territory Government

Department of Natural Resources, Environment and the Arts

Alice Springs Roe Creek Borefield – Hydrogeology of the Pacoota Aquifer

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Executive Summary

The Pacoota Sandstone lies to the north of and under the Mereenie Sandstone at Roe Creek, and is used to supplement the Alice Springs water supply from the Mereenie Sandstone. Its thickness at Roe Creek is between 400 and 500 m.

The Pacoota Sandstone acts as a single aquifer, though with low permeability normal to bedding. This vertical anisotropy results in a lower apparent transmissivity in a north south direction. Bedding plane transmissivity is about 500 m^2/d, and the ratio of horizontal to vertical hydraulic conductivity in the range 100:1 to 10 000:1.

Siltstone beds near the base of the Mereenie Sandstone appear to form a barrier between this unit and the Pacoota Sandstone.

Of the three production bores now in operation only RN 15097 has a significant operating life remaining, at a pumping rate of about 40 L/s.

A new production bore should be drilled to the south of RN 13409.

The extractable volume in the Pacoota Sandstone to a depth of about 300 m that could be extracted by two production bores pumping at 40 L/s (1.2 GL/year) each is about 290 GL. This estimate is conservative because it has not accounted for the fall in water levels in the Pacoota due to pumping from the Mereenie.

The aquifer system is too complex for simple analytical modelling and requires a numerical model.

A more detailed analysis of the life of the existing production bores should be undertaken in conjunction with the numerical modelling.

As many bores as possible in the Pacoota Sandstone should be geophysically logged with modern digital equipment to create a set of consistent records.

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1. Introduction

The Pacoota Sandstone underlies the Mereenie Sandstone at Roe Creek (Figure 1) and is an important aquifer at the Roe Creek borefield which supplies Alice Springs.

The objects of this study were to;

Assess the behaviour of the aquifers in the Pacoota Sandstone under pumping.

Predict its long term behaviour.

Identify gaps in knowledge requiring further research.

Estimate the probable life of the existing production bores.

It was hoped that a simple model could be found to describe the behaviour of the Pacoota Sandstone aquifers, as was found in the overlying Mereenie Sandstone (Jolly et al. 1994, Read 2004).

2. Geological Setting

The Pacoota Sandstone is part of the Amadeus Basin sequence. At Roe Creek it lies below the Mereenie Sandstone (Figure 1). The Pacoota Sandstone is underlain by the Goyder and Shannon Formations.

The Mereenie Sandstone is cut off by an unconformity some 9 km west of the borefield. The Pacoota Sandstone extends over 30 km to the west before being cut off by the same unconformity (Figure 1).

While there are numerous observation bores to the east of the borefield there are none in the Pacoota Sandstone to the west of the borefield. This poses a serious problem for analysis as it is necessary to assume the distribution of flow from the east and west is symmetrical. Given the variation in hydraulic gradient to the east this is highly unlikely.

Verhoeven and Knott (1982) reported on the results of investigation drilling and recommended the drilling of production bores. They divided the Pacoota Sandstone into three units, shown in cross-sections. Interestingly the sections show flattening and minor reversal of dip, apparently introduced to reconcile the then assumed thickness of the Pacoota with its width in sub-crop.

Ferguson (1988) divided the Pacoota Sandstone into 5 units. His work includes lithological descriptions of the units and their corresponding gamma ray trace, and sections showing the units in individual bores. No record was found documenting how these picks were derived, and later work by Lau (1989) showed the presence of a low permeability unit (Middle Pacoota) and another aquifer (Lower Pacoota) beneath this. The latter is the interpretation accepted by Jolly et al. (1994).

There is some confusion as earlier geological logs use the terms Upper and Middle Pacoota in a different sense to Lau (1989).

Gorter (1991), using oil bore data from across the Amadeus Basin divided the Goyder Formation and Pacoota Sandstone into a number of parasequences. The lowest two of these are the Goyder Formation.

The only bore in which the Middle Pacoota, as defined by Lau (1989), has been definitely identified is the cored hole RN 15022 described by Lau. Lau notes that it can be recognised by the khaki coloured siltstone. Unfortunately this has been noted in few other, if any bores. The gamma trace in this bore is not very distinctive. Unfortunately the log is a composite of several runs, some through casing and some not, and in the absence of digital files would be very difficult to correct.

Gamma ray logging is probably the most effective tool for correlating bores. Unfortunately the older logs exist only as paper copies, and have been run with different equipment, and various settings. There is a need to re-log all possible bores with digital equipment, and to digitise the old charts where this cannot be done.

Figure 5 to Figure 10 show cross-sections.

Figure 2 shows the approximate extent of the Pacoota Sandstone in the region near Roe Creek Borefield.

2.1. Aquifer Thickness and Dip

Table 1 shows estimates for the thickness of the Pacoota Sandstone and dips based on the section lines in Figure 5 to Figure 10. On the first pass estimates of true thickness ranged from 820 to 220 m. The outlying values are a result of incorrect estimates of dip resulting from spurious matches between bores. Eliminating or correcting these, the thickness of the Pacoota Sandstone at Roe Creek is between 420 and 520 m. Dip decreases from 35 ° at the western end of the borefield to 23 ° at 385 000 E. As shown in Figure 1 dips decrease to the east in the Rocky Hill area. At Roe Creek the Pacoota Sandstone extends down dip to great depth, and the aquifer is limited by the vertical extent of open fractures. At Rocky Hill at 397 000 E the Pacoota Sandstone is about 800 m from surface at the deepest, and the syncline becomes shallower to the east.

3. Production bores

The Pacoota Sandstone is tapped by three production bores as shown in Table 2. Location is shown in Figure 3. Extended observation bore locations are in Figure 4.

Table 1 Dip estimates on section lines

Section Line	Estimated Horizontal width of Pacoota	Apparent Dip on Section Line		Estimated vertical thickness of Pacoota	Estimated True thickness of Pacoota	Comments
		Estimate	Source			
379700 East	730	35	Nearby outcrop	510	420	
380800 East	No data	24 to 27	Matches between bores			
381400 East	Lower boundary of Pacoota not cut, no estimate possible					
382300 East	1270	40	Match between RN 15041, 10472	1079	821	Thickness too large, overestimate of dip?
382300 East, second estimate	1270	24	Sections to either side	564	515	
385000 East		21, apparent dip on NS section, 23 true dip	Excellent correlation between RN 18123, 3528. Assumed strike direction	Lower boundary of Pacoota not cut, no estimate possible		
NE SW line	840	15	Matches between bores	225	217	Dip estimate too low, thickness estimates too low

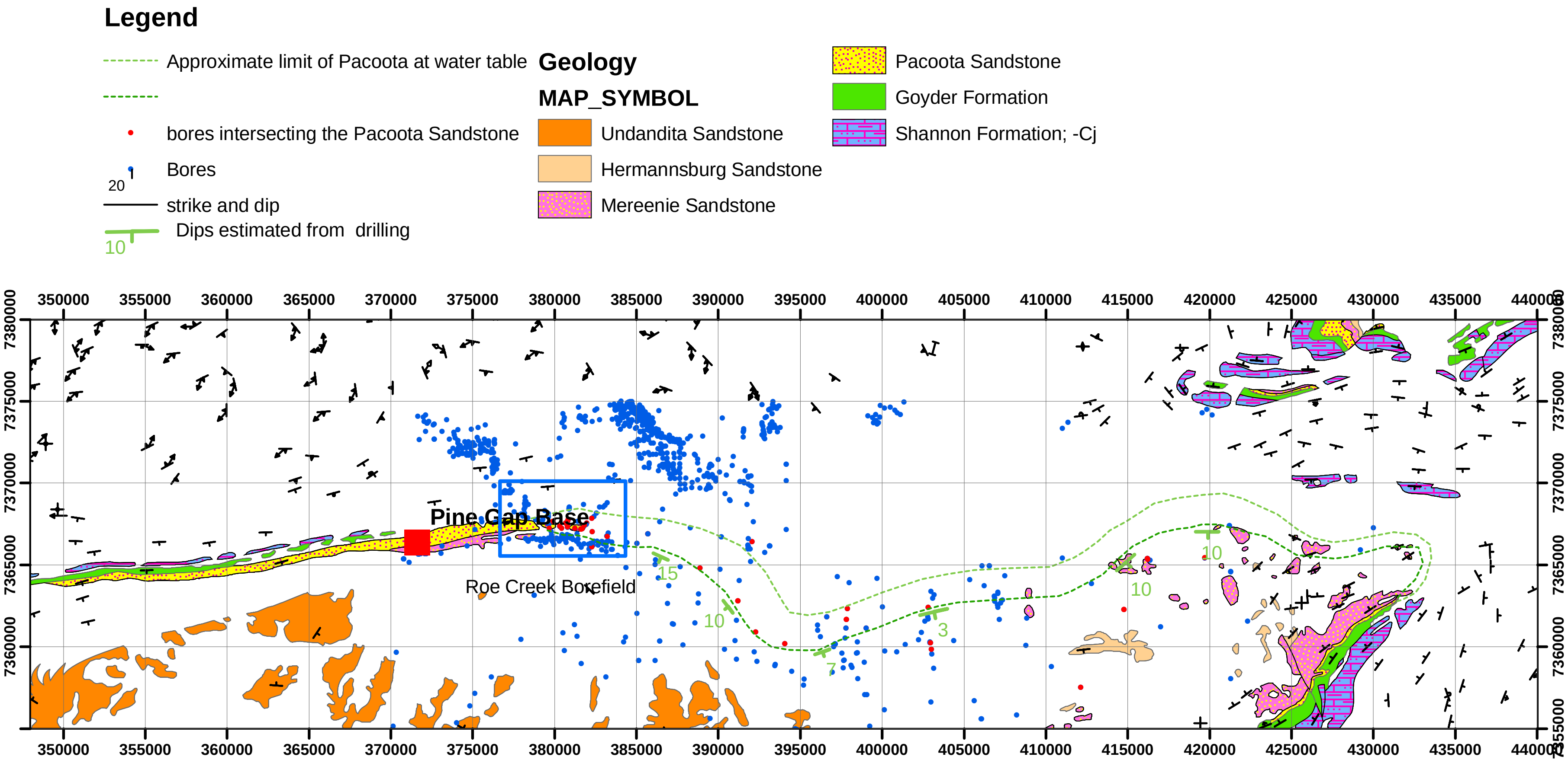

Figure 1 Simplified geological map, omitting units below the Shannon Formation (after Shaw et al (1983))

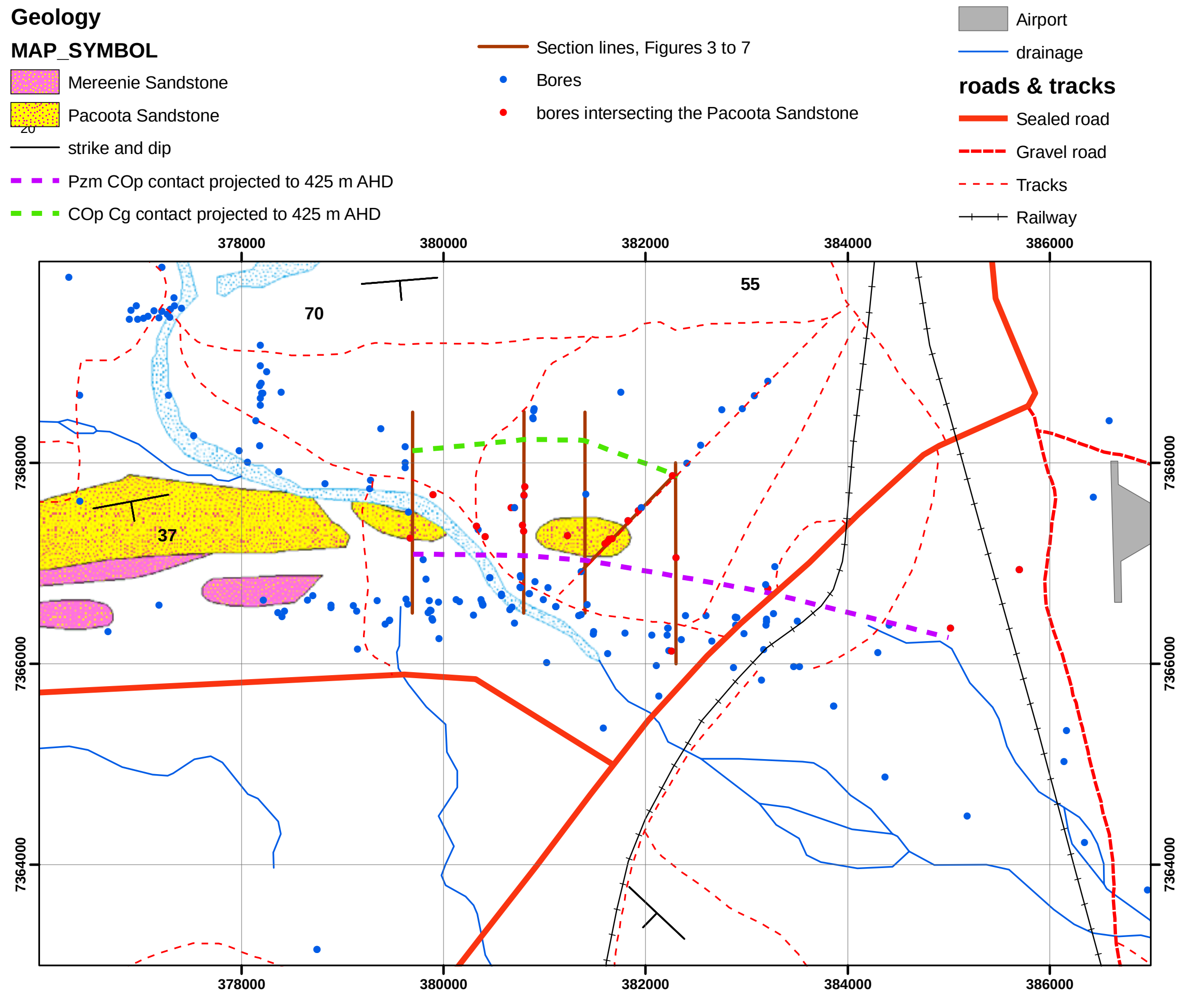

Figure 2 Detail of geology around Roe Creek borefield (after Shaw et al (1983))

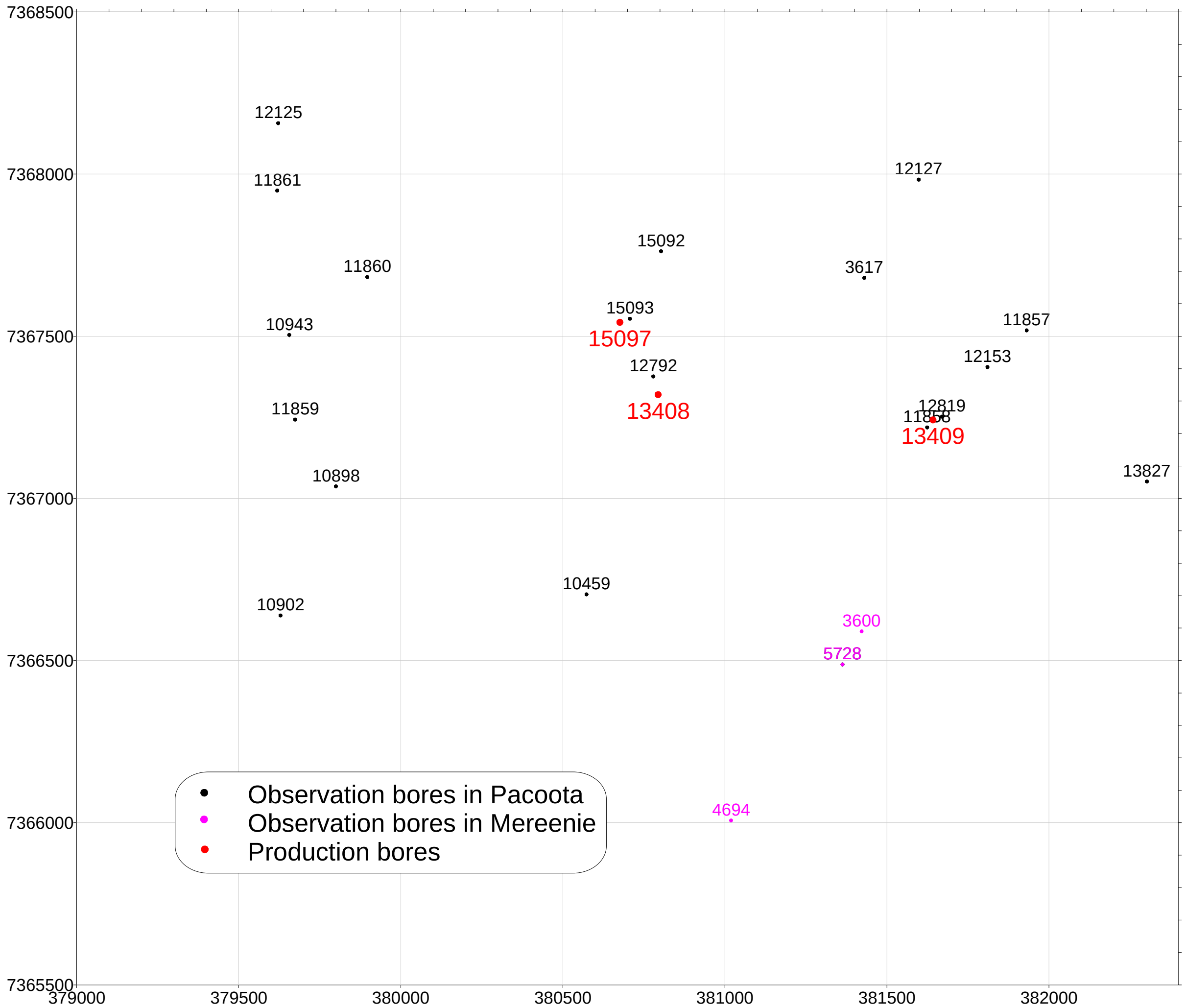

Figure 3 Location of production and observation bores in the borefield area

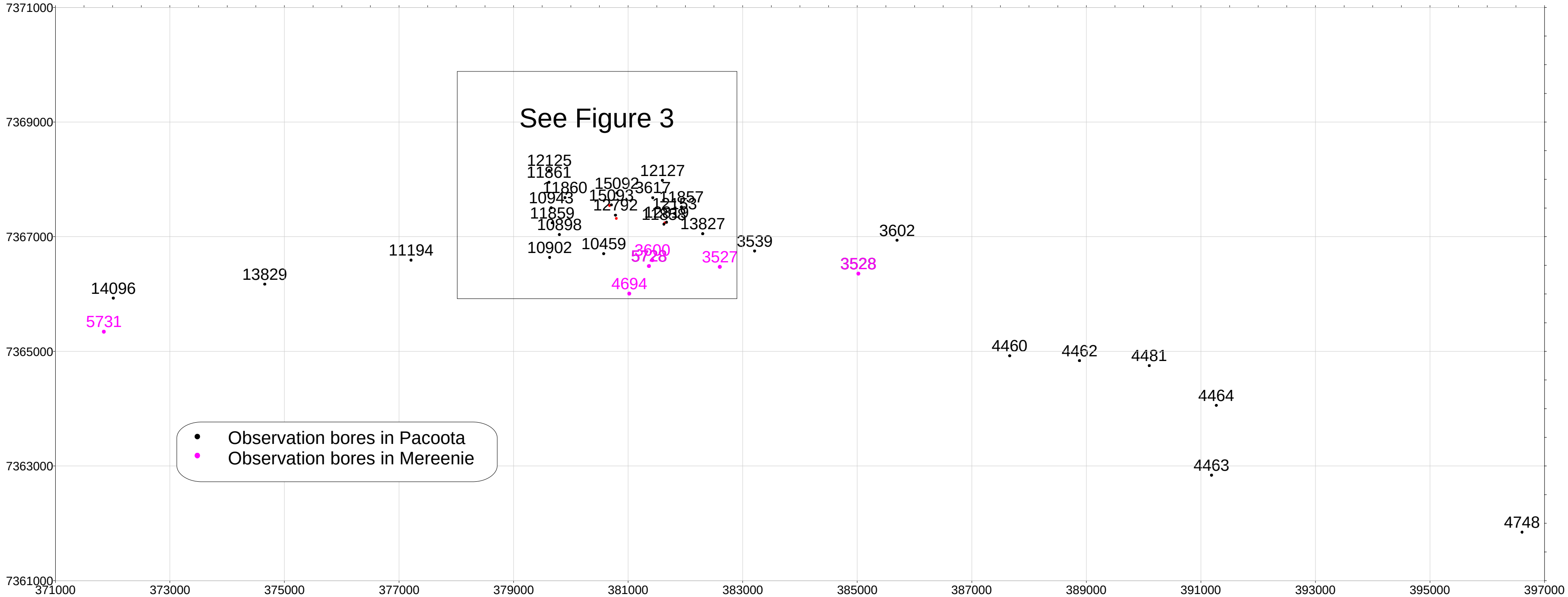

Figure 4 Location of observation bores

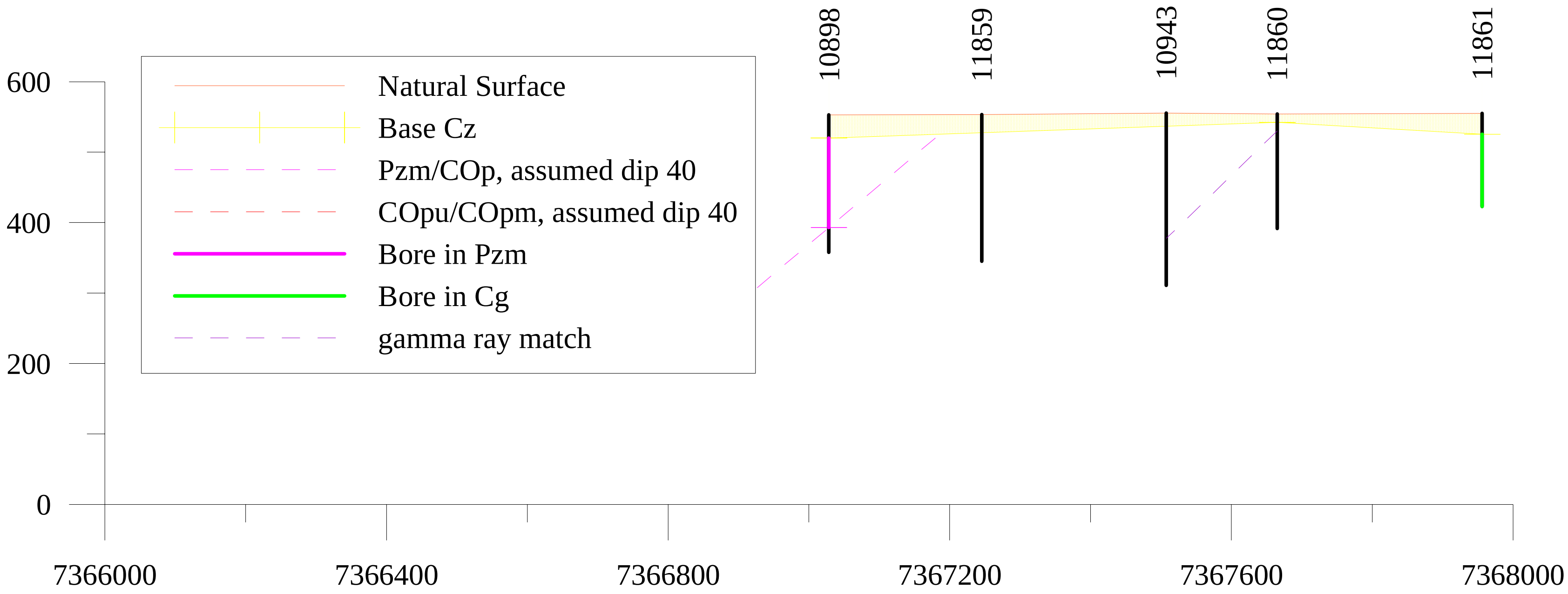

Figure 5 Section 379700 East

Location on Figure 2, key to symbols in Table 3

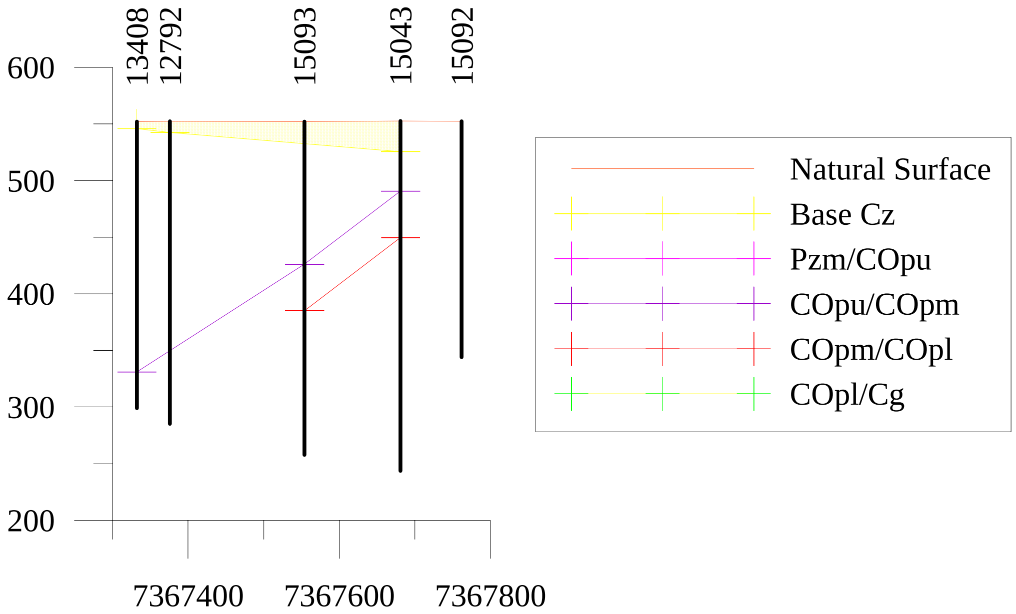

Figure 6 Section 380800 East

Location on Figure 2, key to symbols in Table 3, key to symbols in Table 3

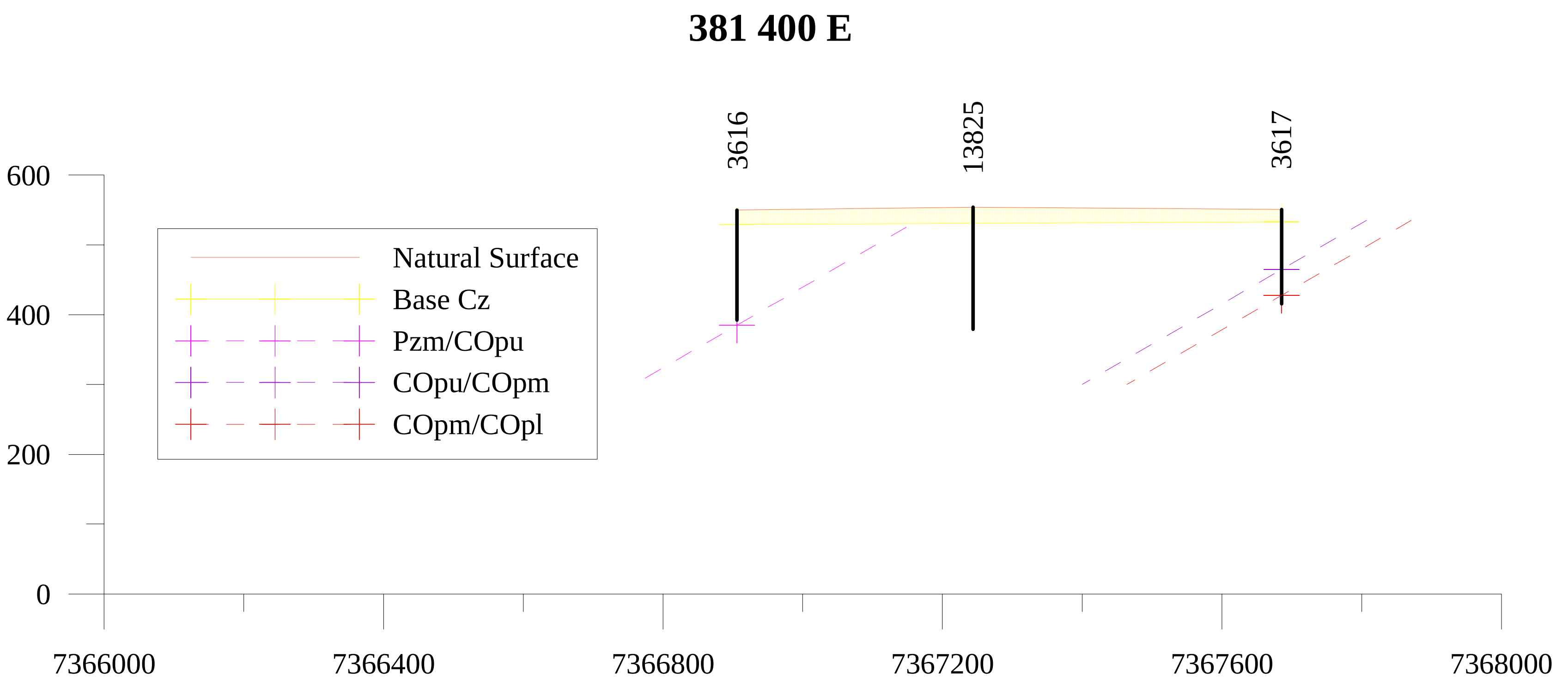

Figure 7 Section 381400 East

Location on Figure 2, key to symbols in Table 3, key to symbols in Table 3

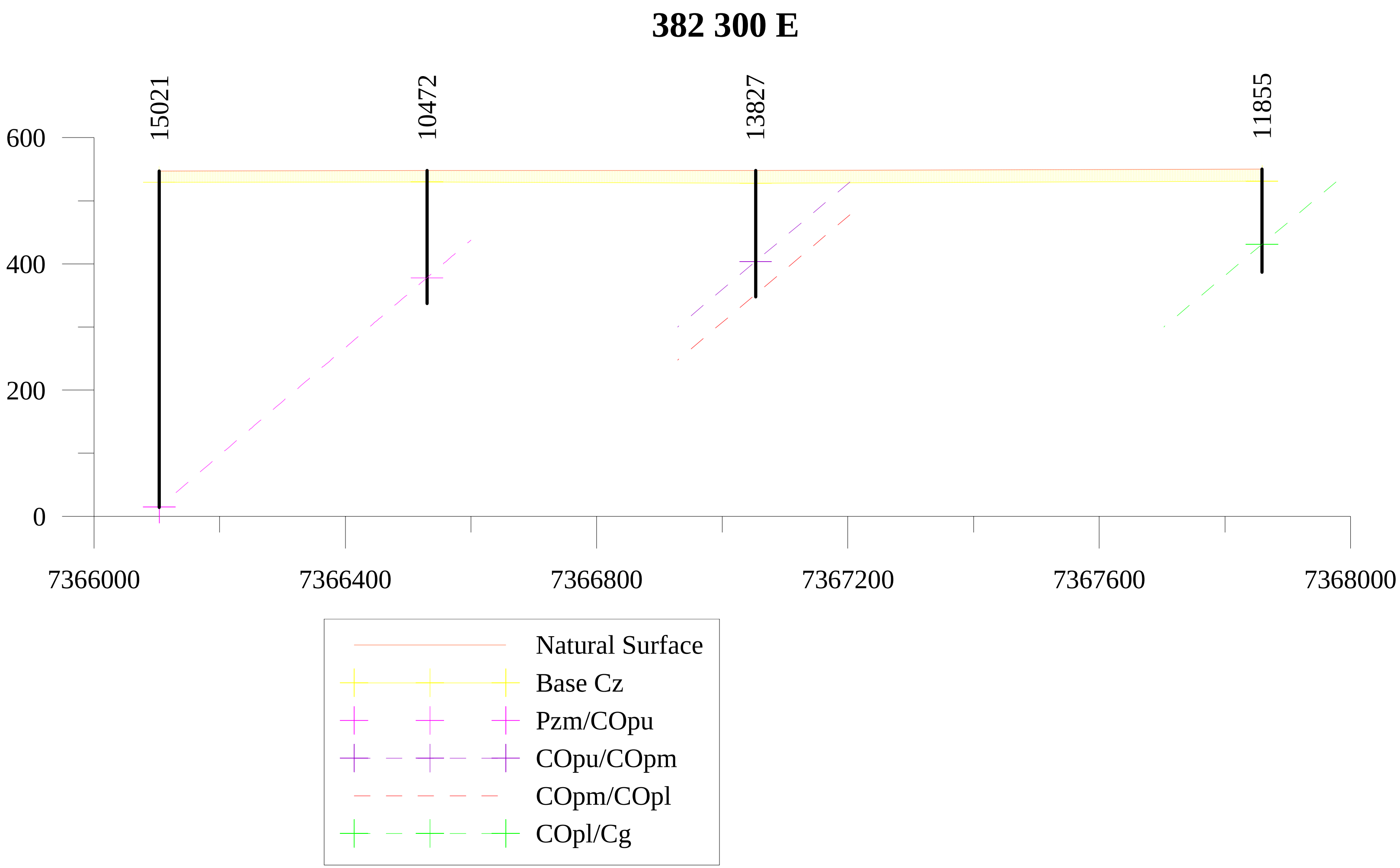

Figure 8 Section 382300 East

Location on Figure 2, key to symbols in Table 3, key to symbols in Table 3

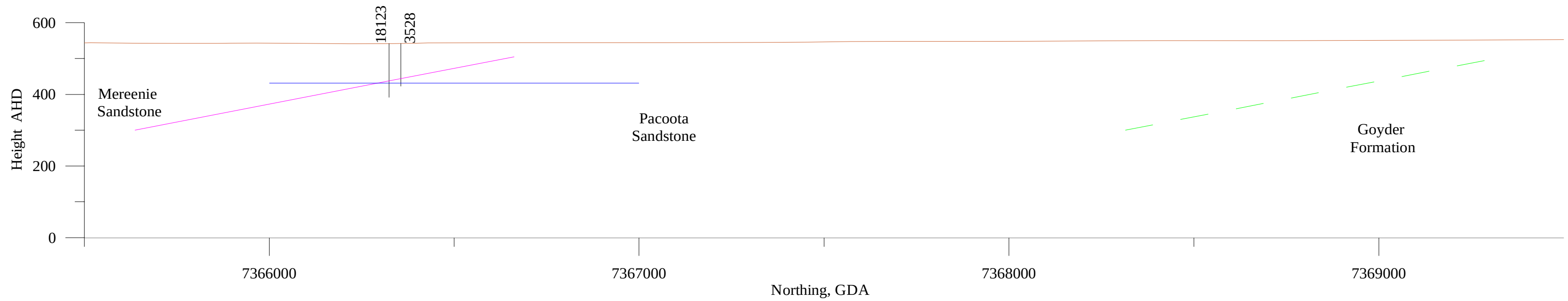

Figure 9 Section 385000 East

Location on Figure 2, key to symbols in Table 3

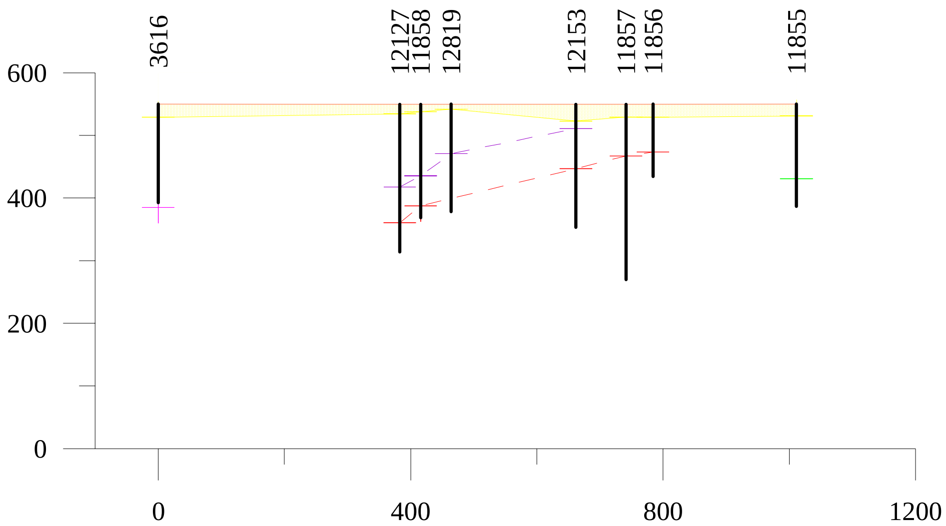

Figure 10 NE SW section line

Location on Figure 2, key to symbols in Table 3

Table 2 Production Bores in the Pacoota Sandstone

RN	P No.	Top of Packer (m)	Bottom of sump (m)	SWL in 2000 (m)	Well loss at 40L/s plus 2 m for motor and pump inlet (m)	Probable available Drawdown to pump inlet (m)	Aquifer units, after Lau (1994)	Production pumping started
RN 13408	P23	149.8	230	127	4	18	Pacoota Upper	1/10/1986
RN 13409	P22	165.8	227	127	9	29	Pacoota Upper	1/7/1984
RN 15097	P26	208	329	127	8	73	Pacoota Lower	25/1/1990

Table 3 Key to symbols in Figure 5 to Figure 10

Symbol	Unit
Cz	Cainozoic
Pzm	Mereenie Sandstone
ЄOpu, m, l	Pacoota Sandstone, upper middle and lower
Єg	Goyder Formation

4. Production pumping

The original recommended pumping rates of the Pacoota Sandstone production bores are shown in Table 4. These were revised downward in the light of operating experience by Jolly et al. (1994).

Table 4 Recommended pumping rates

	Original Recommended pumping rates	Recommendation of Jolly et al. (1994)
RN 13408	80 L/s	40 L/s
RN 13409	85 L/s	40 L/s
RN 15097	40 L/s	40 L/s
Total	205 L/s	120 L/s

Figure 11 shows the history of pumping from the three production bores in the Pacoota Sandstone. Figure 12 shows total monthly production. Pumping from the Upper Pacoota began in mid 1984, and from the Lower Pacoota in 1990. Figure 13 shows cumulative pumping against time.

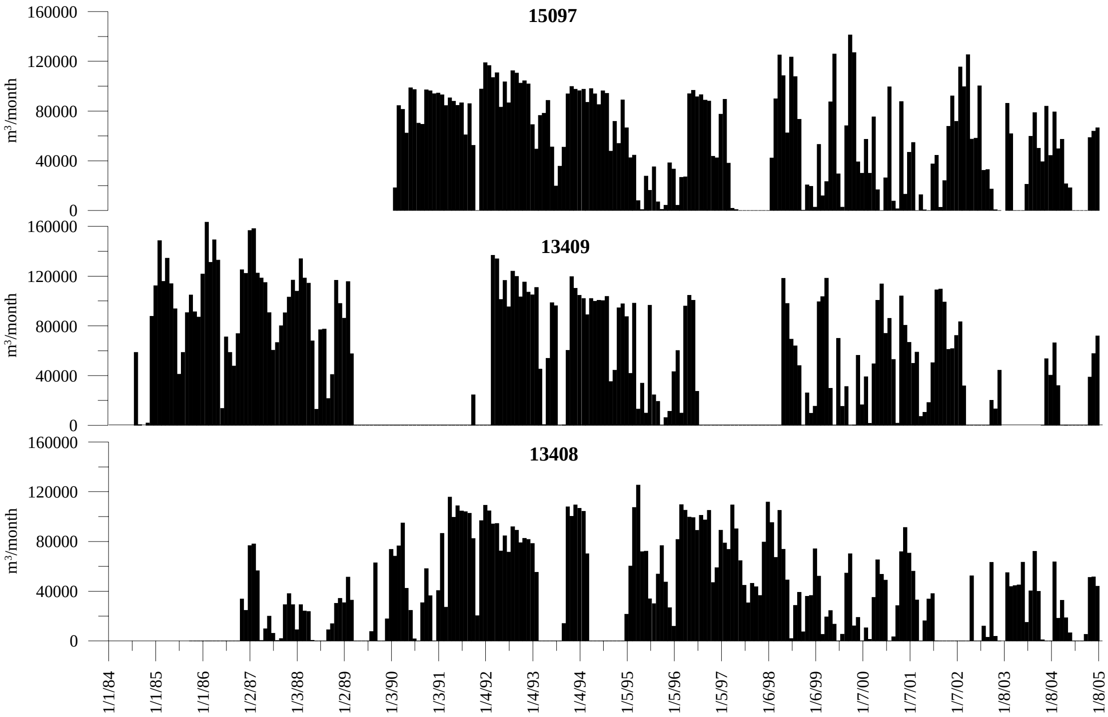

Figure 11 Monthly pumping from production bores in the Pacoota Sandstone

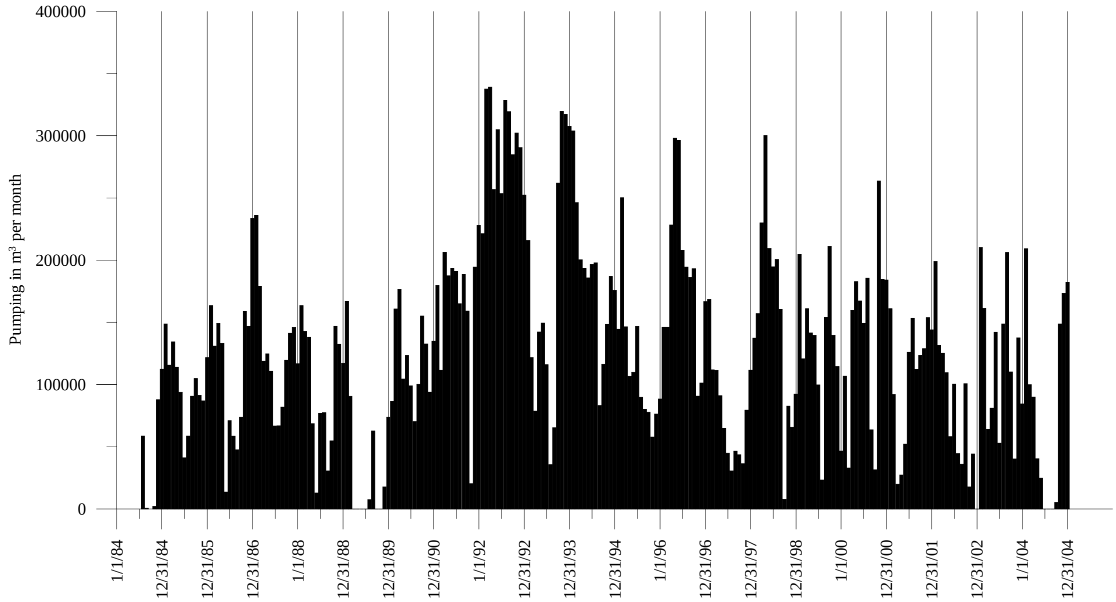

Figure 12 Total monthly pumping from the Pacoota Sandstone

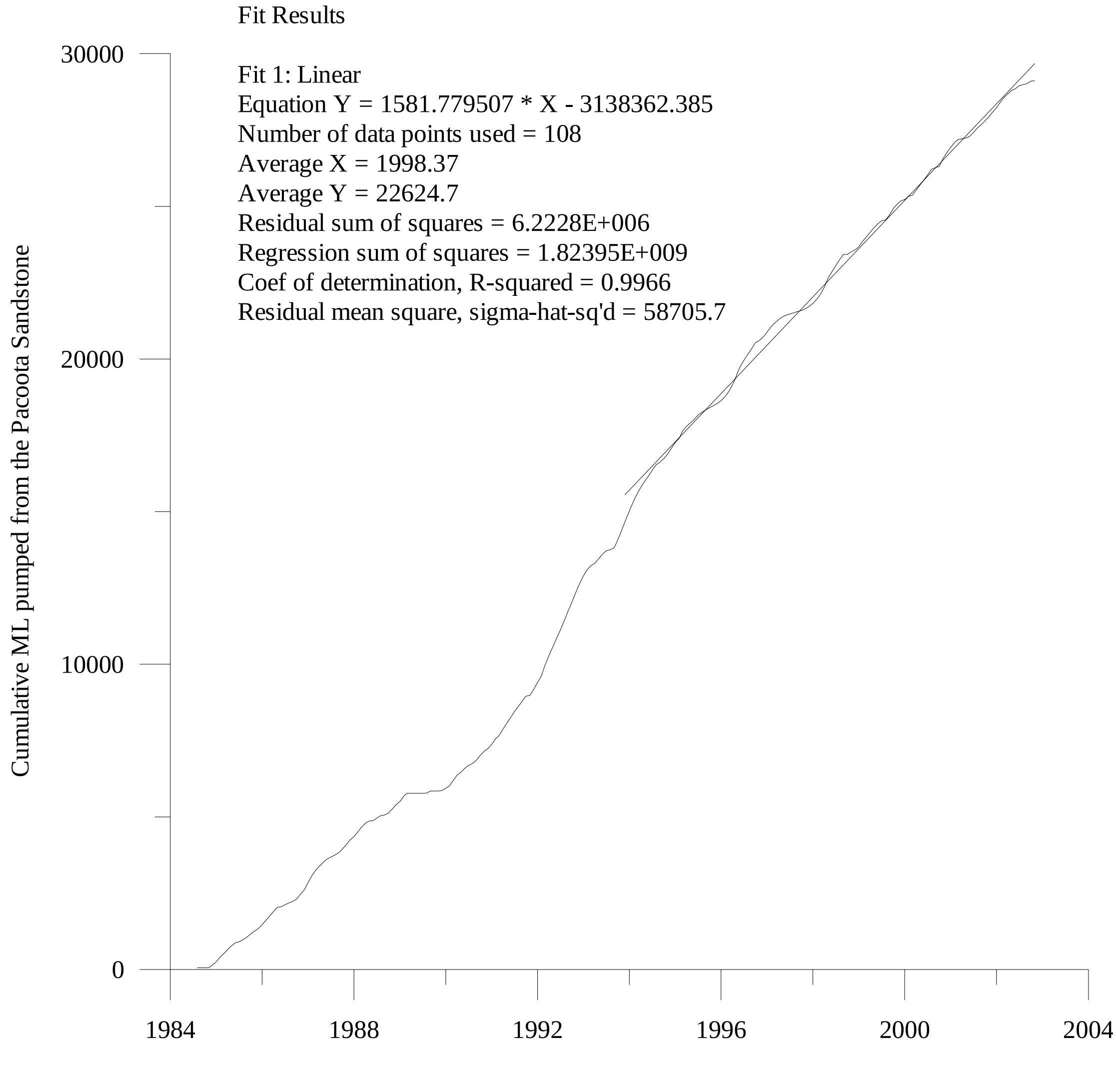

Figure 13 Cumulative pumping from the Pacoota Sandstone against time

5. Hydrogeological setting

The Pacoota Sandstone is part of the south dipping sequence near the north margin of the Amadeus Basin. It lies to the north of, and beneath, the highly transmissive Mereenie Sandstone aquifer. Prior to pumping the Mereenie Sandstone was a local groundwater sink, with the potentiometric surface sloping towards it from both north and south. With pumping the hydraulic gradients have steepened.

Figure 14 to Figure 16 show north south water table profiles through the Pacoota Sandstone. As would be expected there is a southerly gradient toward the Mereenie Sandstone that has steepened with time.

Figure 17 shows profiles along the NE SW section line. The northerly slope at the southern end is unexpected.

Figure 18 shows hydrographs along the NE SW line. It can be seen that the reversed gradient in between RN 12127 and RN 11858 existed for some time, and is not due to anomalous readings.

The thickness of the Pacoota Sandstone is about 500 m. Head differences across it range from some 20 m in 1984 up to perhaps 50 m today. This corresponds to average vertical gradients of 0.04 to 0.1. The gradient is not evenly distributed, but steepest across interbedded siltstone units. Most bores are open to fairly long sections of the aquifer, and the measured water level will be a weighted mean of aquifer heads, dominated by the most transmissive interval. This would appear to be the explanation of the apparently reversed gradient in Figure 17; the bores with the anomalously low water levels are measuring shallower aquifers.

Figure 14 Line 379700 E, water table profiles

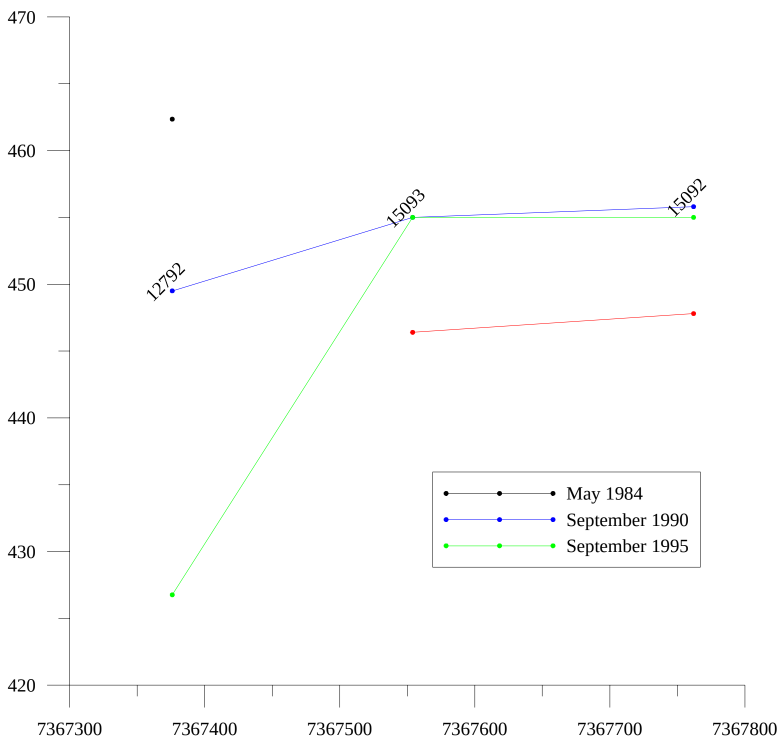

Figure 15 Line 380800 E, water table profiles

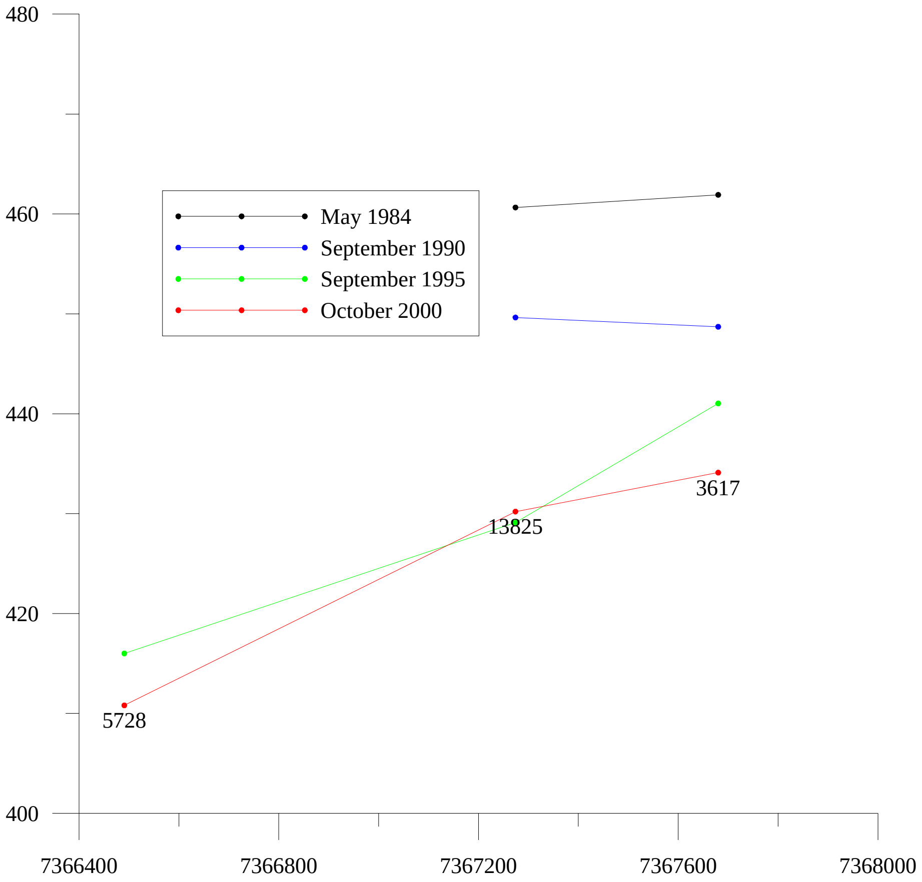

Figure 16 Line 381400 E, profiles on the water table.

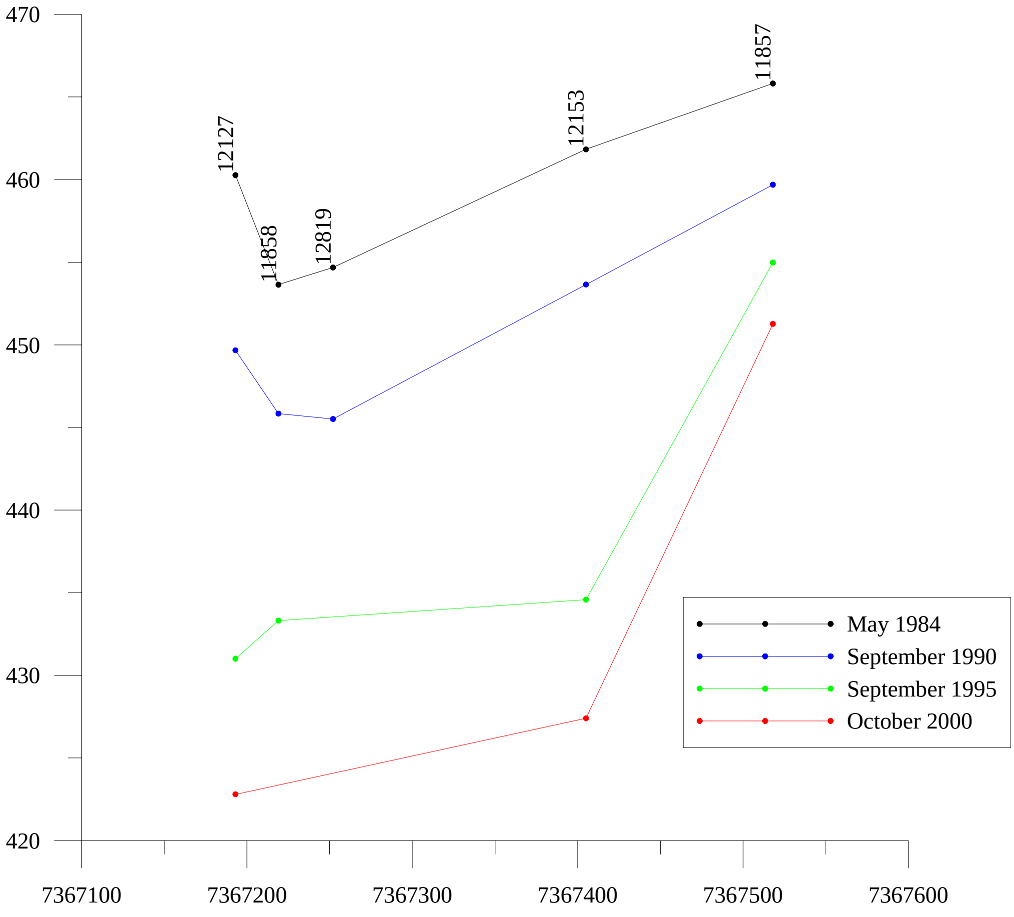

Figure 17 Profiles of water table on NE SW section line.

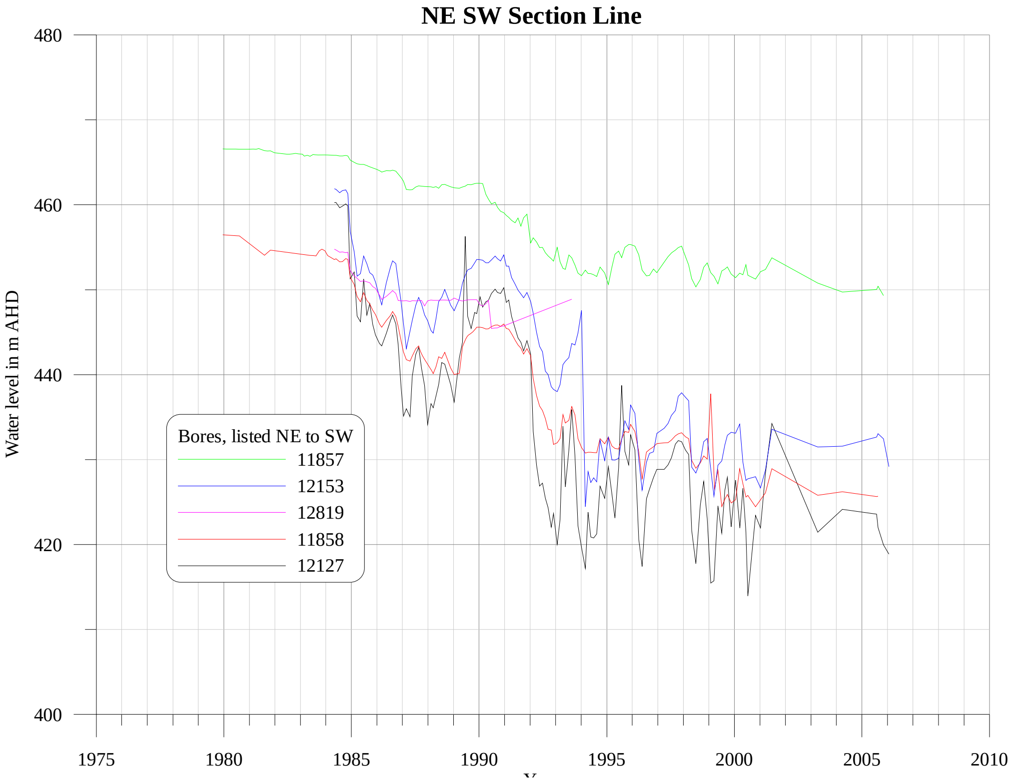

Figure 18 Hydrographs and bore location on NE SW line (See Fig. 10 for locations)

5.1. East West Section

An attempt was made to create east west profiles of the water table for different times (Figure 19). It can be seen that water levels have fallen over 10 m in the vicinity of the borefield. However the apparent reversal of the hydraulic gradient immediately to the east of the borefield predates pumping. It would appear that it is due to the strong up-sequence hydraulic gradient which makes the water level in individual bores very sensitive to the depth of the aquifer monitored.

East of 400 000 E there are no water level data for the Pacoota, and it is not clear how water levels in it relate to those in the Mereenie. Presumably at the eastern end of the syncline the hydraulic gradient must be from the Mereenie Sandstone to the Pacoota Sandstone.

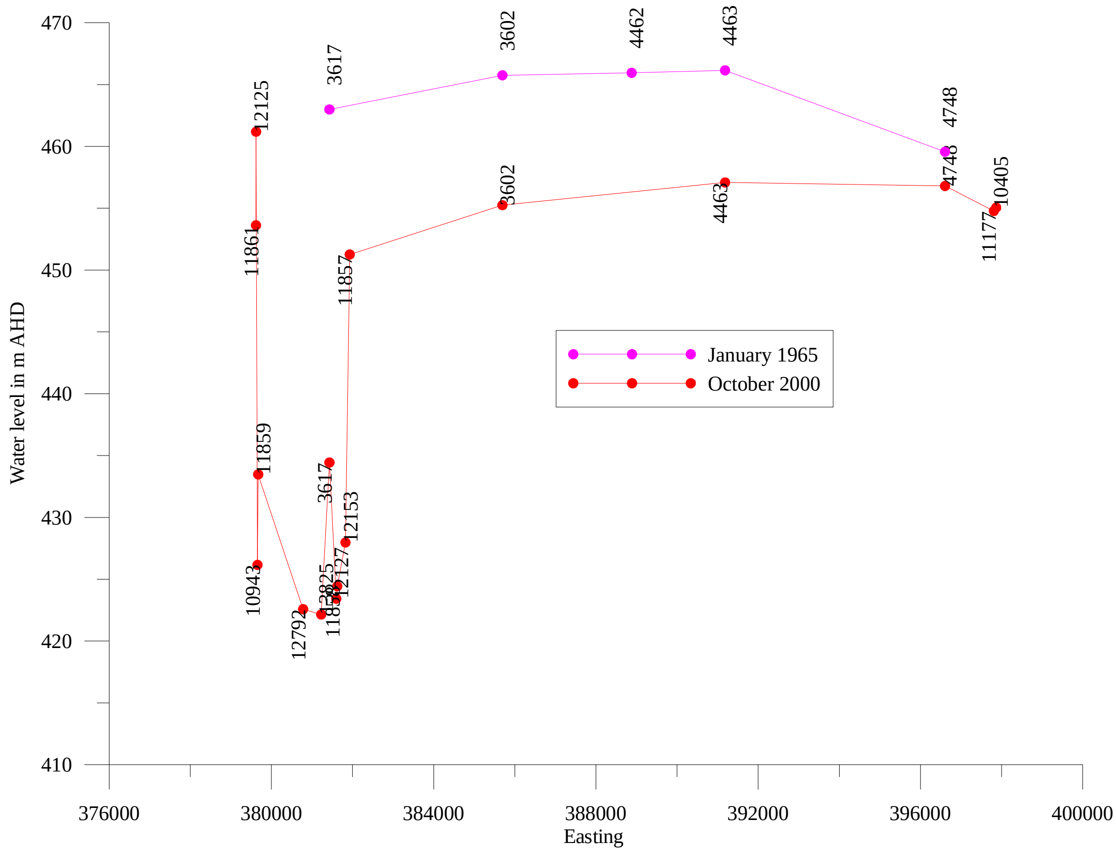

Figure 19 Water level profiles along the Pacoota Sandstone

6. Aquifer Properties

Information on aquifer properties is available from pump testing discussed in Read (2007a) and analysis of production pumping in Jolly et al. (1994). It can be seen that the transmissivities derived by pump test curve matching are consistently much higher than those based on production experience.

Table 5 Transmissivity estimates for production bores m^2/day

Production bore RN	Pumping test estimates, radial flow methods				Production estimate (Jolly et al. 1994)
	No. estimates	Max	Min	Median	
13409	9	1300	280	460	150
13408	1	-	-	950	150
15097	9	1220	46	890	

A significant number of observation bore drawdowns could be matched with type curves in fractional dimensions. For dimensions less than 2 these imply transmissivity decreasing with distance. However even for these models transmissivity does not decline to that inferred for production pumping for any realistic distance. In Section 7.1.1 transmissivity to the east of the borefield was estimated at 500 m^2/d.

500 m^2/d may be a reasonable estimate for the entire thickness of aquifer. Production bores are only open to a part of the aquifer, and the aquifer is highly anisotropic in the vertical plane. Since it is a dipping fractured aquifer it will be bounded by the water table and at depth by closing of the fractures.

Vertical permeability was estimated very roughly as follows:

Pre-pumping flow across the Pacoota Sandstone to the Mereenie Sandstone was 40 to 130 ML/year, and gradient normal to bedding 0.04. Assuming a length of 8 km and aquifer width of 1000 m vertical hydraulic conductivity would be in the range 0.001 to 0.003 m/d. The effective length and width are very imprecise, but the ratio of vertical to horizontal permeability is in the range 100:1 to 10 000:1.

7. Impact of Production Pumping

Figure 20 shows selected hydrographs for the Pacoota Sandstone and adjacent aquifers. Water levels in the Pacoota Sandstone have been affected by pumping from the Mereenie Sandstone as well as pumping from bores in the Pacoota. Similarly water levels in the underlying Goyder Formation have changed in response to water level changes in the Pacoota Sandstone. Pumping at relatively high rates in the period 1990 to 1993 caused large drawdowns in RNs 3617 and 11858. After 1993 average pumping slowed, and rates of drawdown fell similarly.

Figure 19 shows that the effects of pumping are clearly evident some 17 km to the east of the borefield.

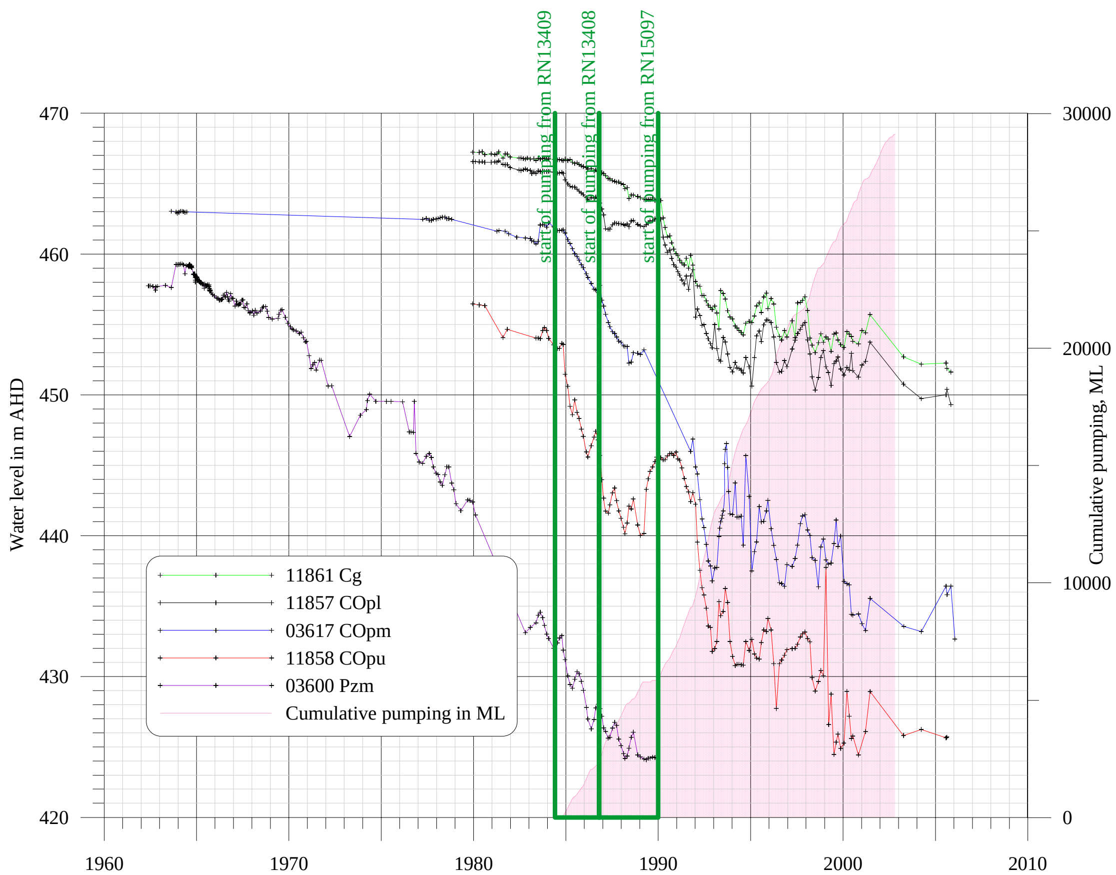

Figure 20 Hydrographs of bores in the Pacoota Sandstone and adjacent aquifers

7.1. *Long term hydrographs*

Bores with hydrographs from pre-1970 are shown in Figure 21. Locations are in Figure 3 and Figure 4.

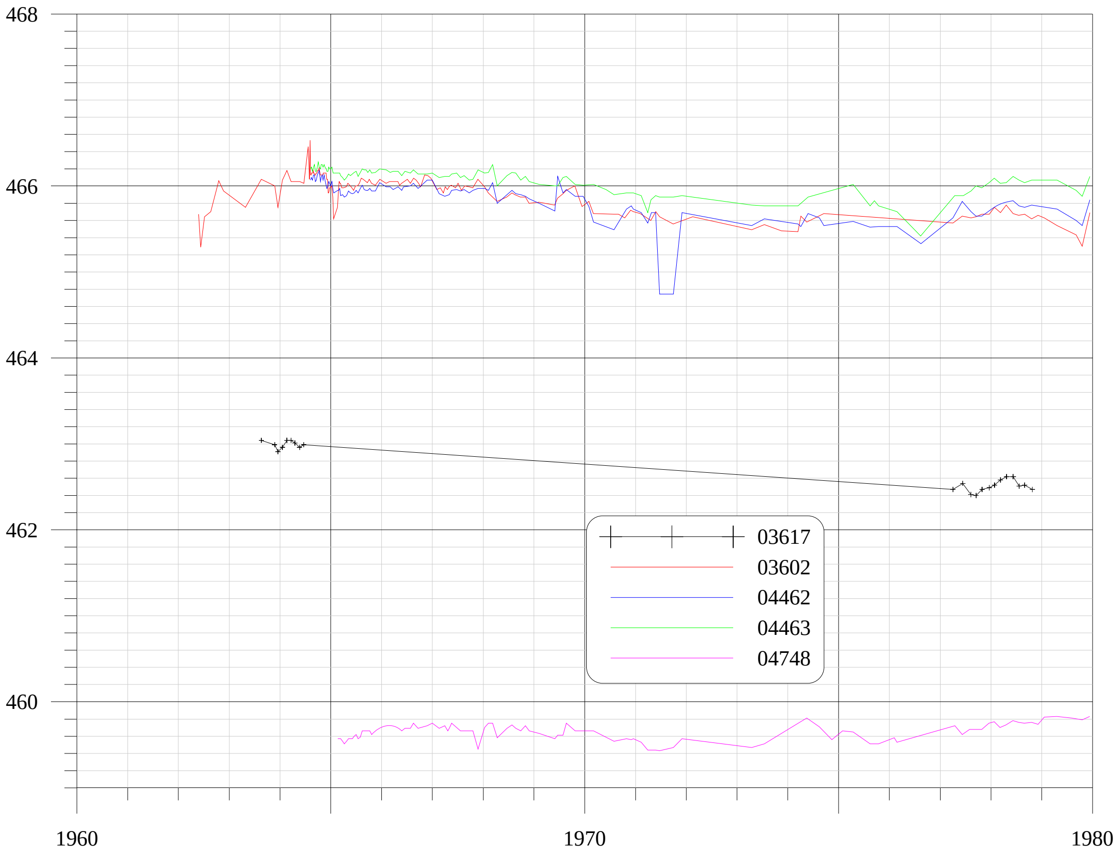

Figure 21 Pre-1970 hydrographs

7.1.1. Eastern Hydrographs

Hydrographs to the east of the borefield are in Figure 22. Figure 23 shows differences in water level between RN 4463 and RN 4748. It can be seen that prior to pumping the head difference was some 6.4 m.

Since 1995 the head difference has declined to about 1 m. On first inspection this implies a reduction in flow to 15 % of the pre-pumping value in the aquifer between these two bores.

Figure 24 shows the difference between RN 4748 and RN 10405. This implies that throughflow has been reduced to 62 % of the original. Since this flow cannot come from the west it must be provided by loss of storage in the region between RN 4463 and RN 4748. Table 6 shows the assumptions used for calculating this loss of storage. The 250 ML/year calculated for loss from storage implies a pre-pumping throughflow of about 400 ML/year. This is a very rough estimate, as the aquifer widths are very poorly known.

Applying the estimated throughflow above and the head difference between RN 4748 and RN 10405 gives a transmissivity width product of 535 000. If the down dip extent of the aquifer is 1 000 m transmissivity would be about 500 m^2/d.

The head differences between bores are very sensitive to the stratigraphic position of the dominant aquifer monitored. Therefore the hydraulic gradients are very approximate.

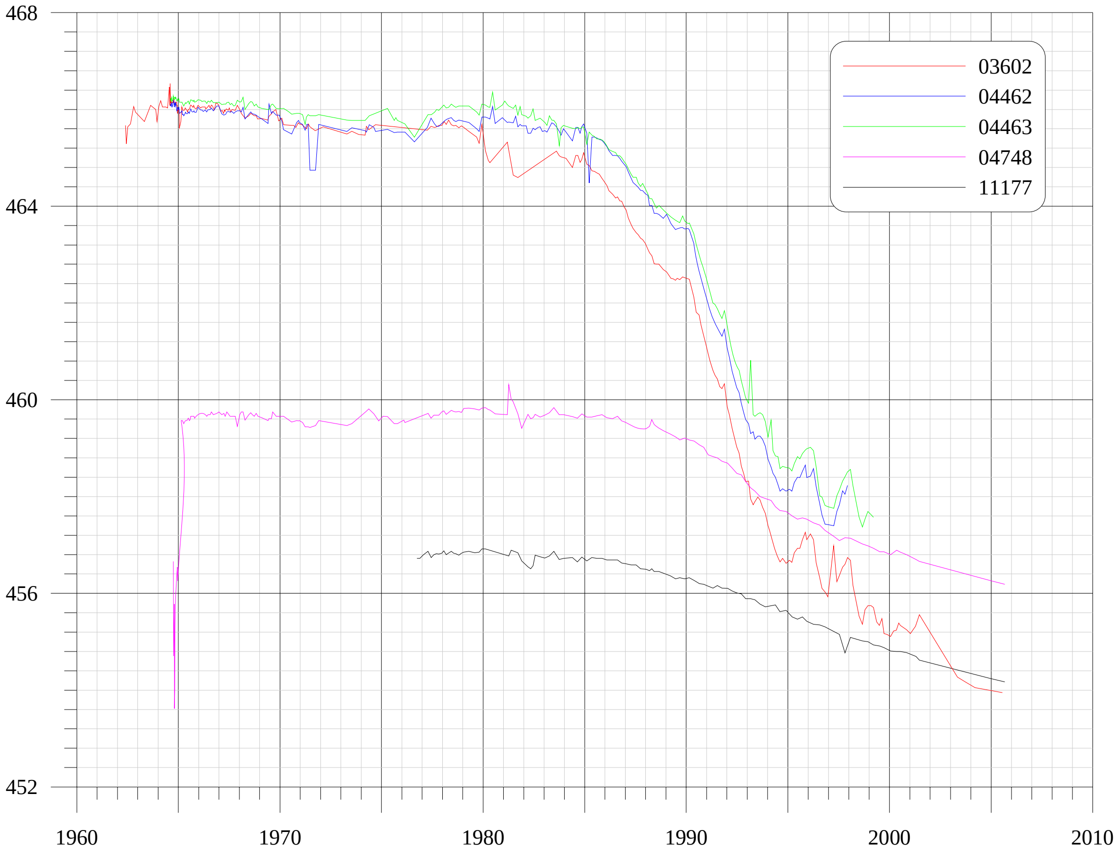

Figure 22 Hydrographs to the east of the borefield

Table 6 Calculation of loss in storage between RN 4463 and RN 4748 from head differences.

RN	Rate change m/y (1)	E	N	Distance	Aquifer width at water table m	Change in stored volume ML/year (2)
4463	-0.30828	391179.7	7362843	0	1800	
4748	-0.1364	396607	7361846	5520	2600	-250

(1) for period 1995 onwards

(2) Assuming specific yield is 0.1

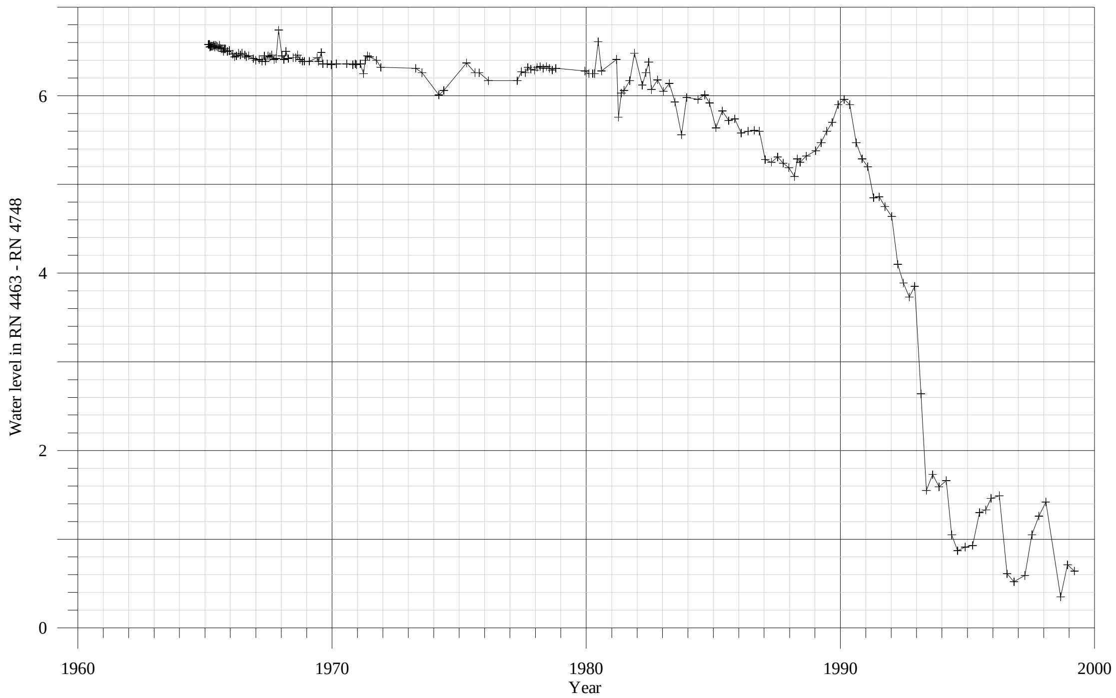

Figure 23 Water level difference between RN 4463 and RN 4748

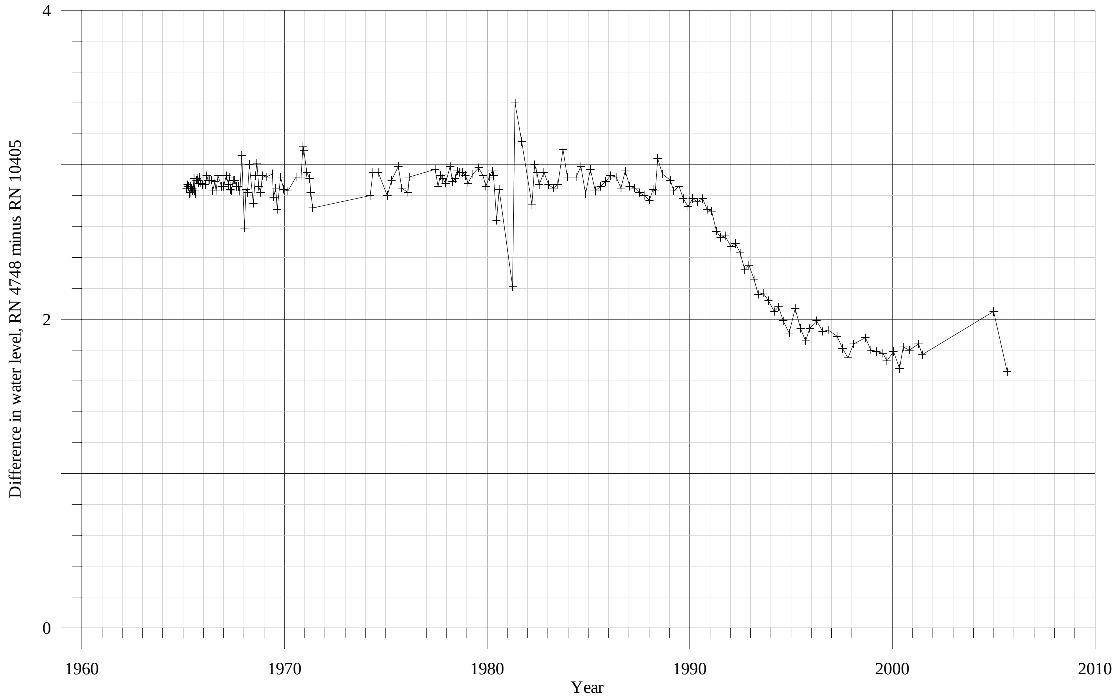

Figure 24 Water level difference between RN 4748and RN 10405

8. Recharge

Hydrographs of bores in the Pacoota Sandstone to the east of the borefield show a slight rise from about 1974 to 1980, which corresponds to a period of high rainfall. The observed rises are of the order of 0.3 m, showing that recharge is very small relative to pumping. Rises seem larger to the west, suggesting that this is direct recharge through outcrop, not from flow in the Todd River.

Figure 25 Hydrographs in Pacoota to the east of the Roe Creek borefield

See Figure 26 for locations

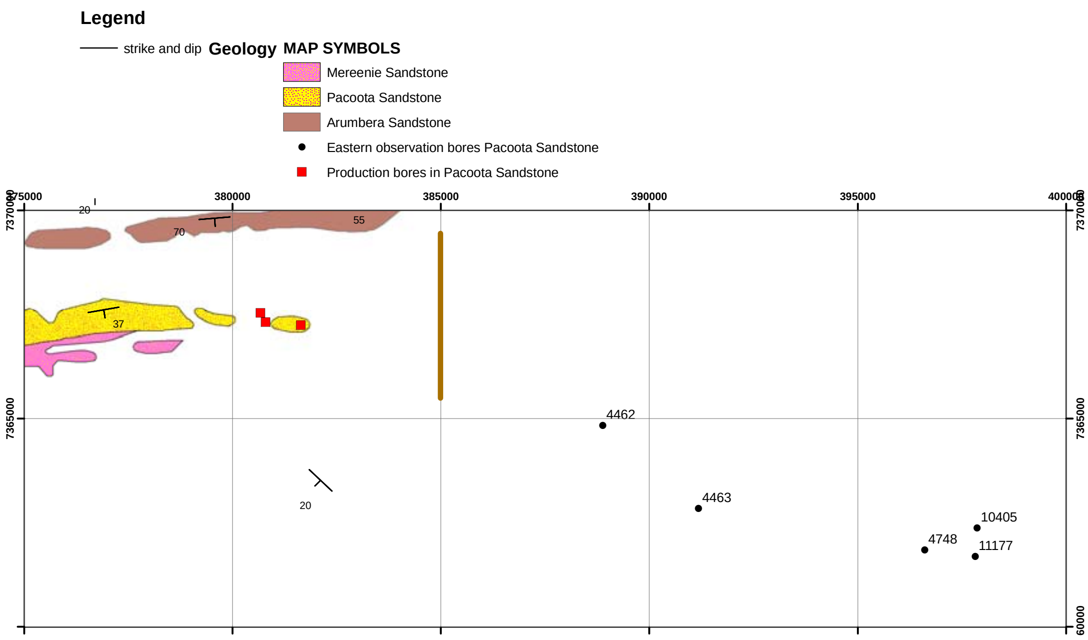

Figure 26 Location of eastern observation bores in Figure 25

9. Flow from the Pacoota Sandstone to Mereenie Sandstone

Pre-pumping there was a hydraulic gradient from the Pacoota Sandstone toward the Mereenie Sandstone. This has increased with pumping as shown in Figure 20.

The hydrograph for RN 3617 (Figure 20) shows that water level in the Pacoota Sandstone was falling as a result of pumping from the Mereenie Sandstone before 1984. The effect of pumping from the Mereenie Sandstone was investigated in RN 3617 and RN 11858 in Appendix A. Flow from the Mereenie to the Pacoota, prior to pumping from the Mereenie was estimated to be about 40 to 130 ML/year. Assuming that there was some outflow to the east inflow from the west would have been slightly larger than this, say 60 to 150 ML/year. Head difference has increased by a factor of 6, hence net flow to the Mereenie Sandstone would now be in the range 240 to 780 ML/year.

9.1. Nature of the Pacoota Mereenie contact

Only 5 bores are known to have been drilled through the Mereenie Pacoota contact, of which only two have both geological and gamma ray logs through the contact.

It has been suggested that drilling bores through the contact has created pathways between the aquifers resulting in increased flow. This is unlikely as most of the bores that penetrated the contact are partly blocked. However RN 5728 is production bore P3, and could draw some water from the Pacoota Sandstone.

Both geological and gamma logs indicate siltstone interbeds near the base of the Mereenie Sandstone. Presumably these form the hydraulic barrier between the units. More detail on the bores passing through the contact is in Appendix A.

10. Analysis of production pumping

Figure 19 shows profiles along strike of the potentiometric surface in the Pacoota Sandstone from before the beginning of production pumping onwards.

The following points are apparent:

- There is limited data for water levels in the Pacoota Sandstone to the west of the borefield.
- There are marked changes in pre-pumping hydraulic gradient with distance, reflecting reduced transmissivity away from the borefield.
- Even before the beginning of pumping, water level near the production bores had been lowered by drilling and testing operations.
- The effects of pumping extend at least 17 km east of the borefield.
- Drawdowns decline abruptly at the edge of the borefield.
- Hydraulic gradients have been reversed to at least 4 km east of the borefield.

10.1. Rate of water level fall with pumping

Water levels were plotted against the cumulative volume of water extracted from the Pacoota Sandstone (Appendix E).

Figure 27 shows the relationship between rate of water level decline and the Easting, which was used as a measure of the distance from the production bores. Figure 28 shows detail for the area nearer the production bores. Unlike a similar study of the Mereenie Sandstone (Read, 2004) there is no clear pattern. This is probably a consequence of the lower permeability of the aquifer; the development of localised cones of drawdown around the production bores' and the high vertical anisotropy of the aquifer.

Figure 29 shows rates of decline along the section line through RN 11859.

The division into rapid decline near the borefield and much slower decline further away is consistent with the profile in Figure 19.

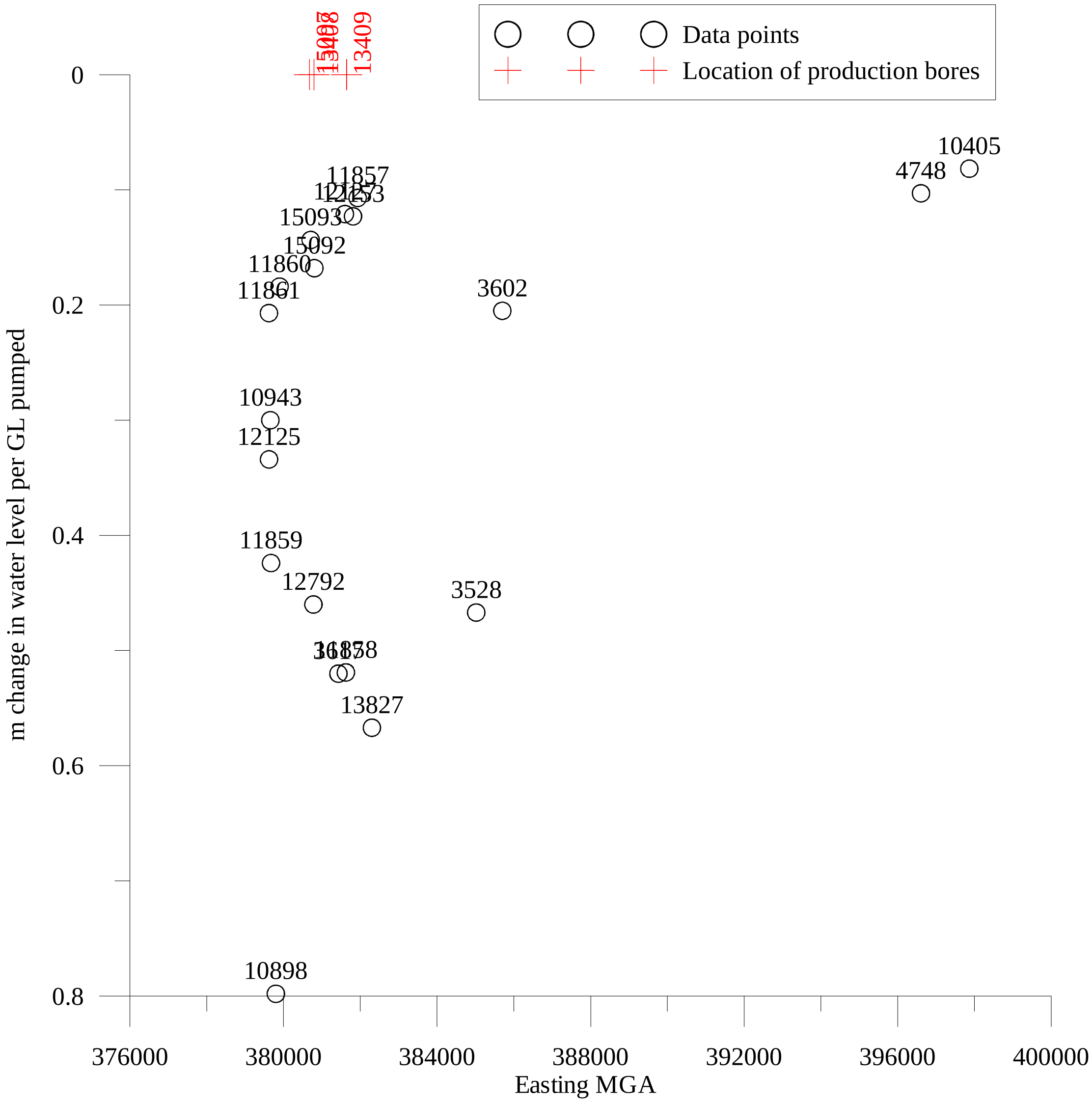

Figure 27 Rate of water level change versus easting

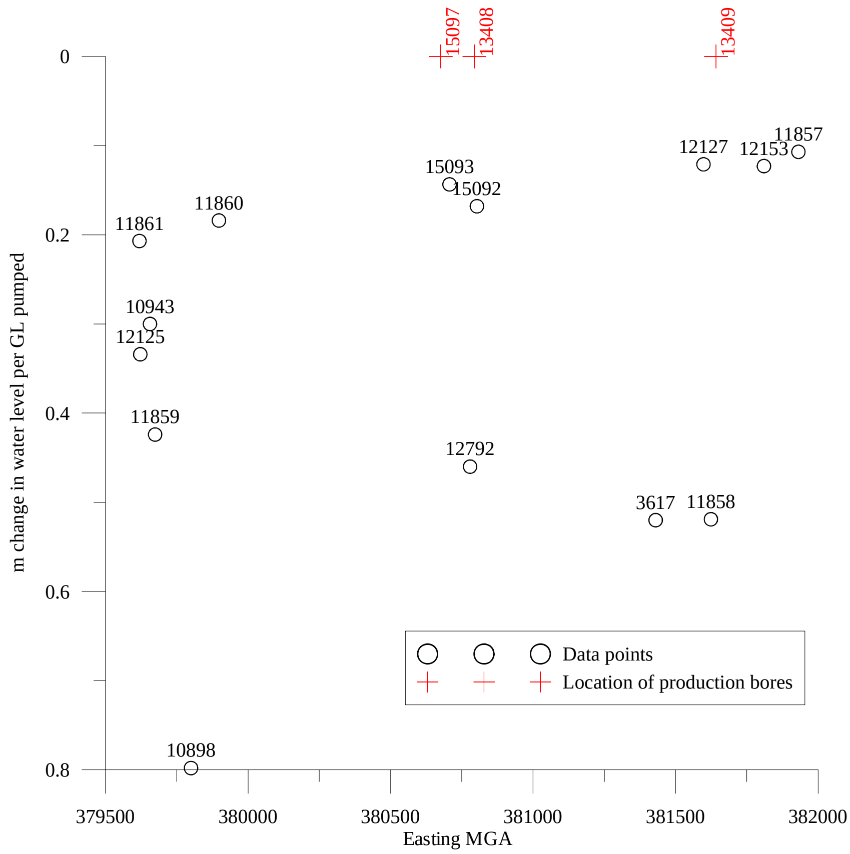

Figure 28 Rate of water level change versus easting, detail

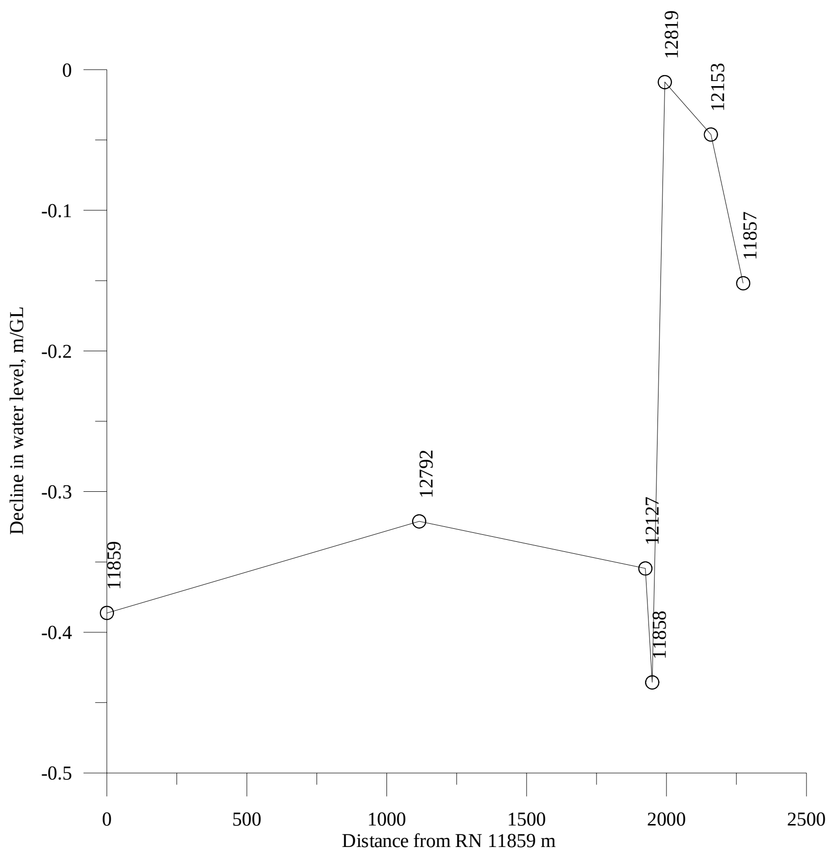

Figure 29 Rate of water level change per ML along NE SW section line

10.2. Volume in Storage

Read (2007b) contains a number of attempts to relate fall in water level to volume pumped. A wide scatter of estimates was obtained, both for different periods of extraction and for different observation bores in the same period.

The available stored volume was estimated empirically from the rate of decline observed above.

The period 1993 to 2002 appear to be the most reliable. Using the maximum figures for this period the following estimate of the remaining stored volume is shown below.

Water level decline in m/GL pumped (Section 10.1)	0. 6
The amount that can be pumped from the existing borefield, GL/m	1.67
WL below ground at RN 12792, m	127
Depth to which water level can be lowered, not including well losses	300
Remaining dewatering m	173
extractable volume GL	289

This estimate will be conservative as some of the water level decline is due to pumping from the Mereenie Sandstone.

11. Water Chemistry

Chemical data is discussed in Appendix B. Production bores show the following trends;

RN 13408 salinity has fluctuated but shows no clear trend.

RN 13409, salinity has decreased by about 4%.

RN 15097, salinity has increased by about 10%.

12. Predicted life of the Production Bores

Extraction for Alice Springs water supply commenced from the Pacoota Sandstone aquifer in the Roe Creek Borefield in 1984. Since then approximately 30 GL has been pumped from the three production bores- RN13408, RN13409 and RN 15097.

At differing times for extended periods, extraction has taken place from either one, two or all three of the production bores.

Monitoring of groundwater levels in the Pacoota Sandstone commenced in the 1960s, with the number of bores in the monitoring network increasing through the 1970s and 1980s.

Based on the data gained from these monitoring bores and metered extraction data from the three production bores the following relationship between groundwater levels and borefield extraction was determined.

All three production bores have only been operated on a continuous basis for one year or more once in 1992. In 1992 the production bores were in operation pumping at the rates shown in Table 6.

Table 7 Production Rates for bores exploiting the Pacoota Sandstone Aquifer

Bore RN	Production Rate (cubic metres per month)	Mean Monthly Rate (L/s)
13409	110,000	42
13408	100,000	39
15097	100,000	39

The rates shown in Table 6 are equivalent to a borefield rate of 3.7 GL per year.

During 1992 groundwater levels fell by the amount shown in Table 7.

Table 8 Fall in groundwater levels during 1992 in the Pacoota Sandstone aquifer

Bore RN	Change in SWL in 1992 (m)	Change in SWL per GL in 1992 (m/GL)
3617	9	2.4
10943	12	3.2
11858	11	3
11860	9	2.4
12792	13	3.5

Between 1994 and 2002 the borefield was operated in a fairly consistent manner and approximately 12.5GL was pumped from the Pacoota Sandstone. This equates to a mean monthly rate of 130,000 cubic metres and a mean pumping rate of 50 L/s.

The change in water level over this period has been about 0.5 to 0.8 m per GL or 0.8 to 1.3 metres per year in the borefield area if the borefield is operated in same manner as for the 1994 to 2002 period.

The relationship between observation bore drawdown and pumping rate was found to be non-linear. A borefield in a highly permeable fractured rock aquifer such as occurs in the Pacoota Sandstone could be considered to behave like a production bore with a large effective radius. Drawdown in the borefield could then be considered to have two components, formation loss and well loss. In this case well loss equates to the loss as water travels through the large fractures in direct connection with the production bores and formation loss the loss as water travels through the other fractures less well connected with these large fractures.

Formation loss in this case would be dependent on the hydraulic characteristics of the aquifer in the vicinity of the borefield and is directly proportional to the pumping rate. Well loss is caused by turbulent flow and friction head loss through the large fractures exploited by the production bores. It is generally considered proportional to the square of the pumping rate.

Therefore, the drawdown in the borefield could be expressed by the formula:

$$Sw = BQ + CQ^2$$

where: Sw = Groundwater level drawdown after 1 year (m)

Q = Pumping rate (L/s)

B = Formation loss factor

C = Well loss factor

For the drawdowns resulting from operational rates of 50L/s and 120L/s maximum, B would be between -0.026 and -0.033 and C would be between 0.00084 and 0.00118.

Expected possible ranges in drawdown in the borefield can then be determined using these ranges in values for B and C. Then using this relationship the probable life of each production bore can be determined for various borefield extraction rates. The probable life for each of the three production bores based on monitored borefield drawdowns at borefield extraction rates of 130 and 310 ML/month (equivalent to 50 and 120 L/s), and at 205 ML/month (80L/s) based on the derived formula, are presented in Table 8

Table 9 Probable life of production bores in the Pacoota Sandstone aquifer at the Roe Creek Borefield

Bore RN	Available drawdown in the borefield in 2000 (m)	Probable life of bore at 130 ML/month (years)	Probable life of bore at 205 ML/month (years)	Probable life of bore at 310 ML/month (years)
13409	29	20 to 35	5 to 8	2 to 3
13408	18	15 to 20	3 to 5	1 to 2
15097	73	55 to 95	15 to 22	5 to 8

A more accurate prediction of the life of each production bore should be determined by developing a numerical model for the borefield.

13. Conclusions and Recommendations

The Pacoota Sandstone, previously considered as two aquifers, acts as a single aquifer, though with low permeability normal to bedding. The three production bores in the borefield were originally recommended to be pumped as below:

	Original Recommendation
RN 13408	80 L/s
RN 13409	85 L/s
RN 15097	40 L/s
Total	205 L/s

This was revised by Jolly et al. (1994) as below:

	Recommendation of Jolly et al. (1994)
RN 13408	40 L/s
RN 13409	40 L/s
RN 15097	40 L/s
Total	120 L/s

It is now recommended that pumping continue from RN 15097 at 40 L/s, and the other two bores be decommissioned in the near future.

With construction of a new production bore to the south of RN 13409 the yield of the borefield could be increased to about 80 L/s.

The extractable volume in the Pacoota Sandstone to a depth of about 300 m that could be extracted by two production bores pumping at 40 L/s (1.2 GL/year) each is about 290 GL. This estimate is conservative because it has not accounted for the fall in water levels in the Pacoota due to pumping from the Mereenie.

The aquifer system is too complex for simple analytical modelling and requires a numerical model.

It is recommended that a numerical model of the Pacoota Sandstone aquifer be developed to better inform the location of new production bores and their performance.

As many bores as possible in the Pacoota Sandstone should be geophysically logged with modern digital equipment to create a set of consistent records.

14. References

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APPENDIX A

The Pacoota Mereenie contact

List of Contents

LIST OF TABLES

LIST OF FIGURES

1. Introduction

This appendix examines the hydraulics and geology of the contact between the Pacoota and Mereenie Sandstones.

2. Flow from the Pacoota Sandstone to Mereenie Sandstone

Pre-pumping there was a hydraulic gradient from the Pacoota Sandstone toward the Mereenie Sandstone. This has increased with pumping as shown in Figure 25.

The hydrograph for RN 3617 (Figure 17) shows that water level in the Pacoota Sandstone was falling as a result of pumping from the Mereenie Sandstone before 1984. The effect of pumping from the Mereenie Sandstone was investigated in RN 3617 and RN 11858 assuming that response to pumping in the Upper Pacoota Sandstone is relatively fast, and that the resulting rate of water fall has a linear relationship with the change in head difference between the Mereenie and the Pacoota.

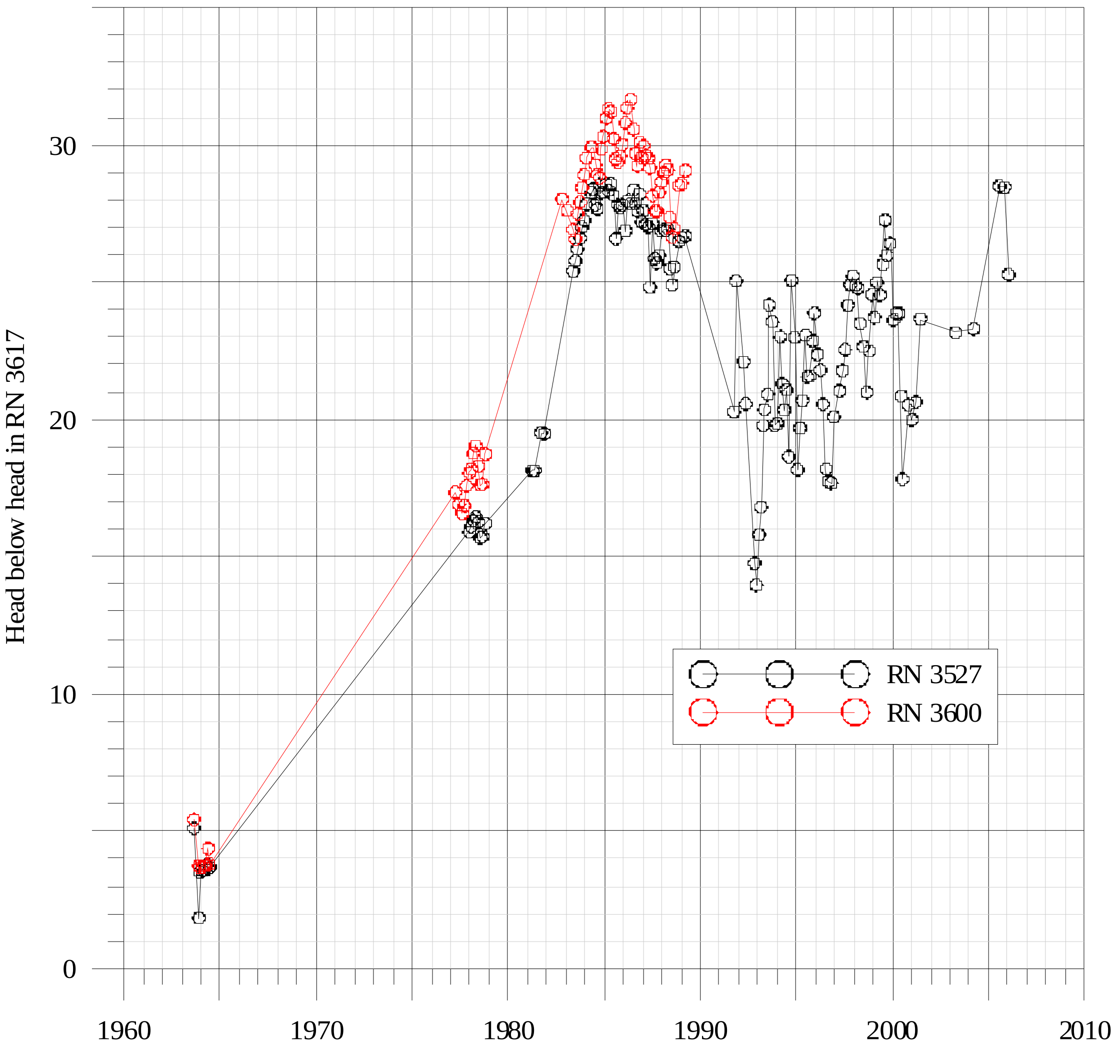

Figure 1 Head above Mereenie Sandstone

2.1. RN 3617

RN 3617 (see Table 1 for location) has the only really long record of water levels in the Pacoota Sandstone (Figure 17), and fell about 0.5 m in response to pumping from 1964 to 1977. The relationship between water levels in this bore and RN 3600 in the Mereenie Sandstone was investigated as follows:

The area under each hydrograph was calculated from 1964 to 1983.

The pre-pumping steady state head difference was taken as 3.7 m.

Head in RN 3617 was taken to have fallen 25.8 m.

Assuming that RN 3617 responds rapidly to falls in water level in the Mereenie Sandstone, and that the rate of fall is proportional to the head difference between the two bores the following equation was derived:

$$\frac{dh_1}{dt} = 0.010(h_1 - 3.7 - h_2)$$

h_1 is water level in RN 3617 m AHD.

h_2 is water level in RN 3600 m AHD.

$\frac{dh_1}{dt}$ is rate of water level decline in the RN 3617 in m/year.

The calculation was repeated for the period 1964 to 1977, to avoid interference from the intense testing and development pre 1983. This gave an equation

$$\frac{dh_1}{dt} = 0.006(h_1 - 3.7 - h_2)$$

Parameters are as above.

A crude estimate of pre-pumping flow to the Mereenie Sandstone can be made as follows:

In Section 9.2 below storage in the Pacoota Sandstone at the borefield was crudely estimated as 1.67 GL/m. Using this, steady state flow pre-pumping would be equivalent to 0.010 X 3.7 X 1.67 GL/year, that is 40 to 60 ML/year.

2.2. RN 11858

The hydrograph of RN 11858 only commenced in 1980 (Figure 39), but showed a fall in water level of about 2 m up to the start of pumping from the Pacoota Sandstone. This bore is in the Upper Pacoota aquifer. The effect of pumping on this bore was estimated similarly to RN 3617 above.

The area under each hydrograph was calculated from 1980 to 1983.

The pre-pumping water level in RN 11858 was estimated as 462.0 m, giving a steady state head difference from RN 3600 of 2.7 m.

Head in RN 11858 fell 2.27 m from 1980 to 1983.

Assuming that RN 11858 responds rapidly to falls in water level in the Mereenie Sandstone, and that the rate of fall is proportional to the head difference between the two bores the following equation was derived:

$$\frac{dh_1}{dt} = 0.028(h_1 - 2.7 - h_2)$$

h_1 is water level in RN 11858 m AHD.

h_2 is water level in RN 3600 m AHD.

Where $\frac{dh_1}{dt}$ is rate of water level decline in the RN 11858 in m/year

A crude estimate of pre-pumping flow to the Mereenie Sandstone can be made as follows:

Steady state flow pre-pumping would be equivalent to 0.028 X 2.7 X 1.67 GL/year that is 130 ML/year. With the shorter record and uncertain pre-pumping level this estimate is less accurate than that for RN 3617.

3. Interconnection by bores

Table 1 was compiled partly to examine the possibility that flow between the Mereenie and Pacoota Sandstones has been increased by the drilling of bores through the contact. Only RN 5728 and 18123 appear to have any risk of this. The water chemistry of RN 5728 (Appendix C) does not suggest significant input from the Pacoota Sandstone.

Table 1 Bores through Mereenie Pacoota contact

RN	East	North	Date Completed	Drilled Depth	Pzm/ЄOp contact	Geological Log	Gamma log	Potential for Interconnection
3528	385020	7366356	15/09/1962	139.3	122	Yes	to 122	Slight, bore blocked below contact
3539	383209	7366752	11/07/1962	113.4	103	Yes	To 76 m	Slight, bore blocked above contact
4462	388879	7364838	21/07/1964	222.8	165	Yes	To 111 m	Slight, bore blocked above contact
5728	381365	7366491	30/05/1963	304.8	250	No	305	Production bore open to 40 m of ЄOp.
10472	382396	7366485	16/10/1972	211	170	To 116 m	180	Slight, bore blocked below contact
10898	379799	7367042	4/03/1975	195	160	Only notes bys a non-geologist	156	Slight, bore blocked above contact
12792	380782	7367378	6/03/1981	267.3		Yes	176	Slight, bore blocked above contact
13408	380794	7367320	5/05/1984	252.9	60?	Yes, but only detailed field notes. 106 to 155 mostly siltstone	150-233?	None, contact above water table
15021	382254	7366128	5/10/1987	532.7	532	Yes, but very short penetration of ЄOp	Y	Slight, less than 1 m penetration into ЄOp.
18123	385027	7366234	22/09/2005	150	133	Yes	150	Possible,

RN 3528

This bore was logged by Quinlan, who interpreted the top of the Pacoota as 125 m (410'). The gamma tool only went to 122 m, just above the contact. The gamma ray log is consistent with the basal section of the Mereenie Sandstone, and the nearby bore RN 18123 passed through the contact. Quinlan recorded mostly clay and siltstone from 97 to 119 m.

RN 3539

This bore was logged by Quinlan, who interpreted the top of the Pacoota as 107 m (350'). Little siltstone was recorded, but there was a very silty fine sandstone from 70 to 85 m. The start of this is evident on the gamma log.

RN 4462

This was logged by Woolley who interpreted the top of the Pacoota as 165 m, mostly based on the presence of ferricrete just below the inferred contact. He recorded 18 m of clay immediately below the contact. The gamma log is of no use.

RN 5728

This is a production bore. No geological log could be found. The gamma log was run to total depth. There is a note on the gamma log putting the contact at 250 m.

The gamma log cannot be matched with that for RN 3528 and RN 18123

RN 10472

There is a very poor description of the cuttings in this bore. The contact depth based on the gamma log is very doubtful, and it is possible that the contact is in fact below the gamma log. Samples still in storage, should be logged.

RN 10898

This was not logged by a geologist. The pick is based on the presence of dark brown ferruginous silicified sandstone (palaeosol?) below 160 m. The gamma log looks like the basal section of the Mereenie Sandstone. From the description the bore could be in Mereenie for the full depth, or the samples could be Mereenie that was falling in.

RN 12792

This was logged by Knott who interpreted it as all Pacoota. However both the description and the gamma log down to 60 m are consistent with the basal section of the Mereenie Sandstone. Re-run gamma.

RN 13408

Field notes for this bore are on file, and a basic log was compiled from these. In use as a production bore.

RN 18123

This was drilled near RN 3528, and is one of the better documented bores through the contact.

GEOLOGICAL LOG RN 3528

From m	To m	Description of Samples.
0	3.0	Red. brown sandy silt.
3.0	6.1	Red brown fine to coarse grained silty sand.
6.1	9.1	Red brown fine to medium grained sand.
9.1	12.2	Red brown gravel.
12.2	15.2	Red brown fine to medium grained sand.
15.2	18.3	Red brown.
18.3	21.3	Brown and grey gravelly silt and clay.
24.4	30.5	Red brown fine to medium and coarse grained silty sand..
	33.5	Red brown gravel.
		UNCONFORMITY – TERTIARY TOP
	36.6	Red brown gravel and mottled salmon mid brown fine grained sandy clay**.**
38.4	39.0	Cuttings of fresh billy.
39.6	42.7	Pale brown fine to medium grained sand. (considerable portion of reworked Mereenie).
45.7	48.8	Mottled white and orange fine grained. clayey sand and sandy clay.
49.1		UNCONFORMITY — MEEREENIE TOP
51.8	57.9	Cuttings of pale khaki fine grained QUARTZ SANDSTONE.
61.0		Cuttings of white fine grained KAOLINITIC QUARTZ SANDSTONE. (Very- low porosity).
64.0	70.1	As above with cuttings of very fine grained ferruginous orange and red brown QUARTZ SANDSTONE.
73.2	76.2	Brown kaolinitic QUARTZ SILTSTONE.
79.2	85.3	Cuttings of Mottled white brown and orange very fine to fine grains a ferruginous QUARTZ SANDSTONE.
88.4		Cuttings of khaki fine grained QUARTZ SANDSTONE.

From m	To m	Description of Samples.
91.4	94.5	Brown fine to medium grained sand.
97.5		Red brown CLAY & SILT with fine to medium grained QUARTZ SAND.
100.6		Red brown micaceous SILTSTONE with some cuttings mottled brown and white very fine to fine grained kaolinitic QUARTZ SANDSTONE.
103.6		White fine to medium grained QUARTZ SAND with some coarse pebbles (chert).
106.7		Red brown micaceous SILTSTONE and CIAYSTONE.
109.7	112.8	Chocolate CLAY with cuttings of red brown micaceous SILTSTONE
115.8		Brown medium grained SAND and red brown micaceous SILT AND CLAY with fine pebbles white shale.
118.9		Pale brown medium grained SAND
121.9		(Red brown micaceous CLAYSTONE) and orange medium grained quartz SAND.
		UNCONFORMITY - PACOOTA TOP
125.0	126.8	Mottled brown white and orange fine and medium grained silicified ferruginized QUARTZ SANDSTONE.
127.4		Mottled orange and brown white silicified and ferruginized QUARTZ SANDSTONE.
129.8		Fine grained poorly sorted pale pinkish brown disaggregated sandstone.
132.9		Fine grained poorly sorted pale pinkish brown disaggregated sandstone with chips of white fine grained kaolinitic sandstone.
136.2		White and pale creamy grey fine grained disaggregated quartz sandstone.

T. Quinlan.

RESIDENT GEOLOGIST.

Retyped R.Read 12/1/2007

GEOLOGICAL LOG RN 3539

W R B ZM

From m	To m	Description of samples
0	12.2	Red brown medium to coarse grained sand
12.2	24.4	Red brown fine to medium grained silty sand. (?lag)
27.4		Mereenie
30.5		White fine grained quartz sand
33.5	36.6	Khaki and white fine grained silty quartz sand
39.6		Pale brown fine grained sand
42.7		Fine grained slightly silty pale pinkish brown sand (?disaggregated sandstone).
45.7		Pink fine grained slightly silty sandstone. Largely disaggregated.
48.8		Very fine pinkish brown very silty sandstone (largely disaggregated) with small(1/8') chips of dark brown ferruginous siltstone
51.8	61.0	Pale yellow fine grained kaolinitic sand
64.0		Pale yellow fine grained kaolinitic sand, with a few chips of original sandstone. Also many chips **of** ironstone, some coarse sand size quartz grains.
67.1		Medium grained red and cream clean sand with a few coarser grains.
70.1	85.3	Very fine very silty pinkish brown sand. Few small chips of dark brown red brown siltstone at 260'
88.4		Sample from bit. Dark red brown medium grained porous sandstone. Colour is due to ferruginous coating on the rounded quartz grains.
91.4	94.5	White medium grained clean sandstone.
97.5		Medium grained. pale brown clean sandstone.
100.6		Pebble conglomerate, with white clean sandy matrix Pebbles are very well rounded, quartzite, up to **1".**
103.6		Brown clean medium grained sandstone.
		UNCONFORMITY — TOP OF PACOOTA QUART ZITE

106.7	109.7	—Grey medium grained strongly silicified sandstone. (chips)
109.7	112.2	—Poorly sorted fine to medium grained pinkish brown sandstone clean, with some black grains and ? mica. Red siltstone at top of this interval.

D. Woolley.

RESIDENT GEOLOGIST.

Retyped R.Read 12/1/2007

GEOLOGICAL LOG RN 4462

From m	To m	Description of Samples
0.0	3.0	Brown coarse silty sand.
3.0	6.1	Brown coarse sandy c1ay
6.1	15.2	Brown very coarse silty sand
15.2	21.3	Brown coarse to very coarse .sand and gravel. Fragments are quartzite, ferricrete, quartz, rock fragments (granite), feldspar.
21.3	24.4	Brown coarse sandy clay
		UNCONFORMITY TOP OF TERTIARY
24.4	27.4	Coarse to very coarse pale grey sand, with a few lumps of pale grey coarse very sandy clay
27.4	30.5	Very coarse and gravelly sand
30.5	36.6	Coarse to very coarse sand
36.6	39.6	Coarse very clayey sand
39.6	42.7	Very coarse and gravelly sand
42.7	45.7	Deep red brown silty clay
45.7	48.8	Mid grey silty clay
48.8	57.9	Dark red brown clayey alt
57.9	61.0	As above, with some grey silty clay
61.0	67.1	Pale grey, mottled red brown very fine sandy, or silty, very sandy clay
67.1	76.2	Mottled grey and brown silty clay, with some fine to coarse sand
76.2	79.2	Mottled grey yellow and brown silty clay
79.2	88.4	Mottled grey and grey brown clay
88.4	97.5	Pale grey clay
97.5	109.7	Pale grey calcareous silty clay. Some medium to coarse translucent quartz grains in last 10 feet.

109.7	121.9	White slightly clayey silt
		UNCONFORMITY TOP OF .PALAEOZOIC (MEREENIE SANDSTONE)
121.9	125.0	White and pale brown very fine to fine grained kaolinitic sandstone. Some red and yellow ferruginised siltstone
125.0	128.0	Brick red siltstone or very fine sandstone
128.0	140.2	Pale grey to pale brownish grey fine grained quartz sandstone. Slight to moderate silicification of the matrix. Some brick red siltstone (?Cavings)
140.2	140.8	Core 1 (Recovery one foot) White to pale buff medium grained friable sandstone. Subrounded clear colourless quartz grains. No kaolinitic matrix. Very small amount of siliceous cement. Small scale cross bedding. Dip of main bedding appears to be 35 to 40 degrees.
140.8	146.3	Olive grey claystone and dazzling white clayey siltstone cuttings.
146.3	152.4	Yellow and cream very fine grained kaolinitic sandstone
152.4	155.4	White cream and yellow clayey siltstone.
155.4	161.5	White and pink clayey siltstone.
161.5	164.6	Very friable pink to orange fine grained clean quartz sandstone (very few chips).
		?? TOP OF PACOOTA SANDSTONE
164.6	182.9	Brown and purple clay; some chips of ferricrete and fine grained grey quartz sandstone
182.9	185.9	Orange, fine quartz sandstone, with purple ferricrete and grey claystone.
185.9	189.0	Black ferricrete
189.0	192.0	Dark red-brown ferruginous clay and siltstone.
190.2		(sample from bit) Brick red siltstone.
192.0		Brick red siltstone
192.0	222.5	White and cream fine sandy kaolinitic siltstone, with minor amounts of very fine grained white siliceous silty sandstone.

D. Woolley•

Resident Geologist

29.7.64.

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Log re-typed, R.Read 12/1/2007

GEOLOGICAL LOG RN 10898

39 Z 51

Representative Log

From	To	Description
0	27	Moderate reddish brown silty fine grained Aeolian sand. Quartz gravel grading in size from 5.00 mm to 25.00 mm. Very minor particles of travertine.
27	48	—Light brown fine to medium grained weathered sandstone with some hematitic (Fe) encrustations and fine to medium fairly sorted silty quartz sand. Minor quartz gravel Occasional chips of fine grained consolidated sandstone
48	60	—Conglomerate containing quartzite, quartz, pebbly sandstone, dark brown silicified 'sandstone, heavily ferruginized silicified sandstone, light brown chert and fine to medium grained consolidated sandstone chips.
60	66	Fine to medium grained well sorted quartz sand (Pzm). Angular pebbles of quartzite , dark brown ferruginized silicified sandstone, pebbly sandstone.
66	72	Orange pink coloured fine grained sandstone chips interstitial kaolin. Fine grained quartz sand, well sorted. Minor small chips of dark brown ferruginized silicified sandstone. Pzm
72	81	—Orange pink coloured well sorted fine grained quartz sand. Pzm
81	111	Chips of fine grained sandstone with interstitial kaolin. Very minor chips of ferruginized silicified sandstone. Fine grained well sorted quartz sand. Note: A decrease in sandstone from 105 to 111 and an increase in quartz sand.
111	132	—80% Chips of moderate reddish orange coloured fine grained sandstone with banded structure evident. Fine grained well sorted quartz sand. Occasional chips of dark brown silicified ferruginized sandstone. Samples 132 to 150 are the same as for samples 111 to 132 but with a gradual alteration in colouration to pale yellowish orange possible limonitic.
150	156	Moderate orange pink fine grained well sorted quartz sand.
156	162	Chips of fine grained moderate reddish brown ferruginized

		sandstone, sandy siltstone and minor chips of dark reddish brow silicified sandstone. Fine grained well sorted quartz sand.
162	168	Moderate reddish orange fine grained well sorted quartz sand. Small chips of white and ferruginized fine grained sandstone.
168	180	Chips of white fine grained sandstone with interstitial kaolin. Fine grained quartz sand, approximately 15%. A decrease in sandstone from 174 metres and an increase in quartz sand.
180	195	Fairly sorted medium grained brownish grey quartz sand with small fragments of limonite disseminated.

—J. Butler (Lab)

11 March 1975

Note: Colours are taken from the Rock Colour Chart of the Geological Society of America, New York.

Retyped R.Read 15/1/2007

GEOLOGICAL LOG RN 12792

SUMMARY LOG

Depth (m)		Lithology	Stratigraphic Unit
0	12	Sand, Gravel	Cainozoic
12	103.4	Sandstone	ꞒOp$_3$
103.4	148 *	Siltstone	Ꞓop$_2$
148	264	Sandstone	Ꞓop$_1$

*Depth from geophysical log

GEOPHYSICAL LOGS AVAILABLE Gamma TO 176 m

MAJOR AQUIFERS : APPROX. SWL 96 m

Depth	**Yield L/s**	**Type**
136	2.0	Sandstone
143	1.0	Sandstone
152	1.0	Sandstone
162	16.0	Sandstone

DETAILED LOG

From	**To**	**Description**
0	12	SAND, GRAVEL Poorly sorted subangular sand & gravel
12	63	SANDSTONE Reddish brown silty sandstone, fine grained, poor to moderately sorted. Becoming lighter coloured with depth until by 39 it is a white friable sandstone.
63	69	SILTSTONE White to pink siltstone.
69	78	SANDSTONE White silty sandstone, fine grained, poorly sorted.

78	105	SANDSTONE, SILTSTONE. As above with interbedded red brown siltstone.
105	144	Red brown siltstone with interbedded white to light green siltstone. Occasional sandstone beds.
144	165	SANDSTONE Yellow white moderately sorted medium grained sandstone.
165	171	SANDSTONE Reddish brown siltstone with interbedded SILTSTONE sandstone.
171	234	SANDSTONE. White poorly sorted fine to medium grained friable sandstone. Occasional bands of red siltstone.
234	249	SILTSTONE Blue grey hard micaceous siltstone
249	264	SANDSTONE White to light brown medium rained sandstone, moderately sorted

LOGGED BY G. G. KNOTT MARCH 1982

Re-typed R. Read 15/1/2007

GEOLOGICAL LOG RN 13408

From	To	Description
0	6	Red soil and creek sand.
6	73	SANDSTONE, pink
73	80	SAND. Fine grained, light red and yellow.
80	86	SAND, yellow.
86	94	SAND. Fine, yellow, with small amount of clear quartz.
94	100	SANDSTONE, red.
100	106	SANDSTONE, red, light brown, yellow.
106	141	SILTSTONE. Red grey and yellow and broken brown sandstone.
141	147	SILTSTONE. As above plus 50% red brown medium grained sandstone?
147	160	SILTSTONE. As above plus grey sandstone.
160	164	SANDSTONE, grey and light brown.
164	183	SANDSTONE, brown and light brown.
183	200	SANDSTONE, as above, grey, white and red brown.
200	239	SANDSTONE, red and grey sand.
239	246	SANDSTONE & SILTSTONE, banded hard and soft.
246	252	SILTSTONE, grey.

Compiled from field log sheets on the bore file that appear to have been written on site, May 1985. Original believed to be by Stevens.

Robert Read, 11/1/2007

GEOLOGICAL LOG RN 18123

From	To	Description
0	6	GRAVEL. Brown sandy gravel.
6	24	GRAVEL. Brown sandy gravel, some fragments of cobbles up to about 100 mm.
24	36	GRAVEL. Change colour to pale yellow sandy gravel, some fragments of cobbles up to about 100 mm.
36	39	SANDSTONE. Sample is disaggregated sub-rounded quartz sand, predominantly coarse, ranging down to very fine. Yellow 10YR7/6
39	54	SANDSTONE. Similar to above, plus chips of medium grained poorly sorted well indurated quartz sandstone with white matrix.
54	57	SANDSTONE. Medium to very fine grained poorly sorted quartz sand. Pink, 7.5YR7/3
57	69	SANDSTONE. Similar to above, pink 5YR8/3
69	72	SANDSTONE. White coarse to very fine sandstone, some white kaolinitic siltstone.
72	99	SILTY SANDSTONE. Red fine to very fine silty sandstone, 10R6/8
99	102	SILTY SANDSTONE. Red coarse to fine silty disaggregated quartz sand.
102	105	SANDSTONE. Chips pale yellow brown fine to medium grained friable quartz sandstone plus disaggregated fine to coarse silty quartz sand.
105	114	SANDSTONE. Chips white fine grained well indurated quartz sandstone.
114	117	SILTSTONE. Red micaceous siltstone plus poorly sorted quartz sand.
117	126	SILTSTONE. Light red micaceous siltstone, 10R6/6
126	132	SANDSTONE AND SILTSTONE. Red coarse to fine quartz sand plus siltstone.
132	135	SANDSTONE. Disaggregated quartz sand, mostly fine, fanging to coarse, pink 10R8/4

From	To	Description
135	138	SANDY SILTSTONE. Chips fine red brown sandy siltstone.
138	141	SANDSTONE. Chips well indurated grey and white medium grained quartz sandstone.
141	144	SANDSTONE. Fine grained quartz sandstone with white kaolinitic matrix, well indurated.
144	147	SANDSTONE. Chips white medium grained quartz sandstone, well indurated.
147	150	SANDSTONE. White (coloured red by siltstone from above) coarse to medium grained rounded to sub-rounded quartz sandstone.

Summary

0-36	Cainozoic gravels
36-54	Mereenie Sandstone, II
54-133	Mereenie Sandstone, I, (basal unit)
133-150	Pacoota Sandstone

The top of the Pacoota Sandstone is not clear, and could be at 105.

Logged R. Read

Appendix B

Chemistry of Pacoota aquifer.

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LIST OF FIGURES

1. Introduction

Figure 1 shows a Durov plot of samples from production bores in the Mereenie and Pacoota aquifers. Except for P3 (RN 5728) analyses from all Mereenie production bores have been lumped together. The following features are apparent:

Except for some wild points, which are probably a result of analytical error or mis-labelling analyses for the Mereenie plot in a small area.

Analyses for all three production bores in the Pacoota Sandstone plot close together, and significantly further from the sodium corner and slightly further from bi-carbonate corner than the Mereenie analyses.

Samples from RN 5728 do not correspond to a mixture of Mereenie and Pacoota water. In particular the ionic sum is slightly lower than either the Pacoota or remaining Mereenie.

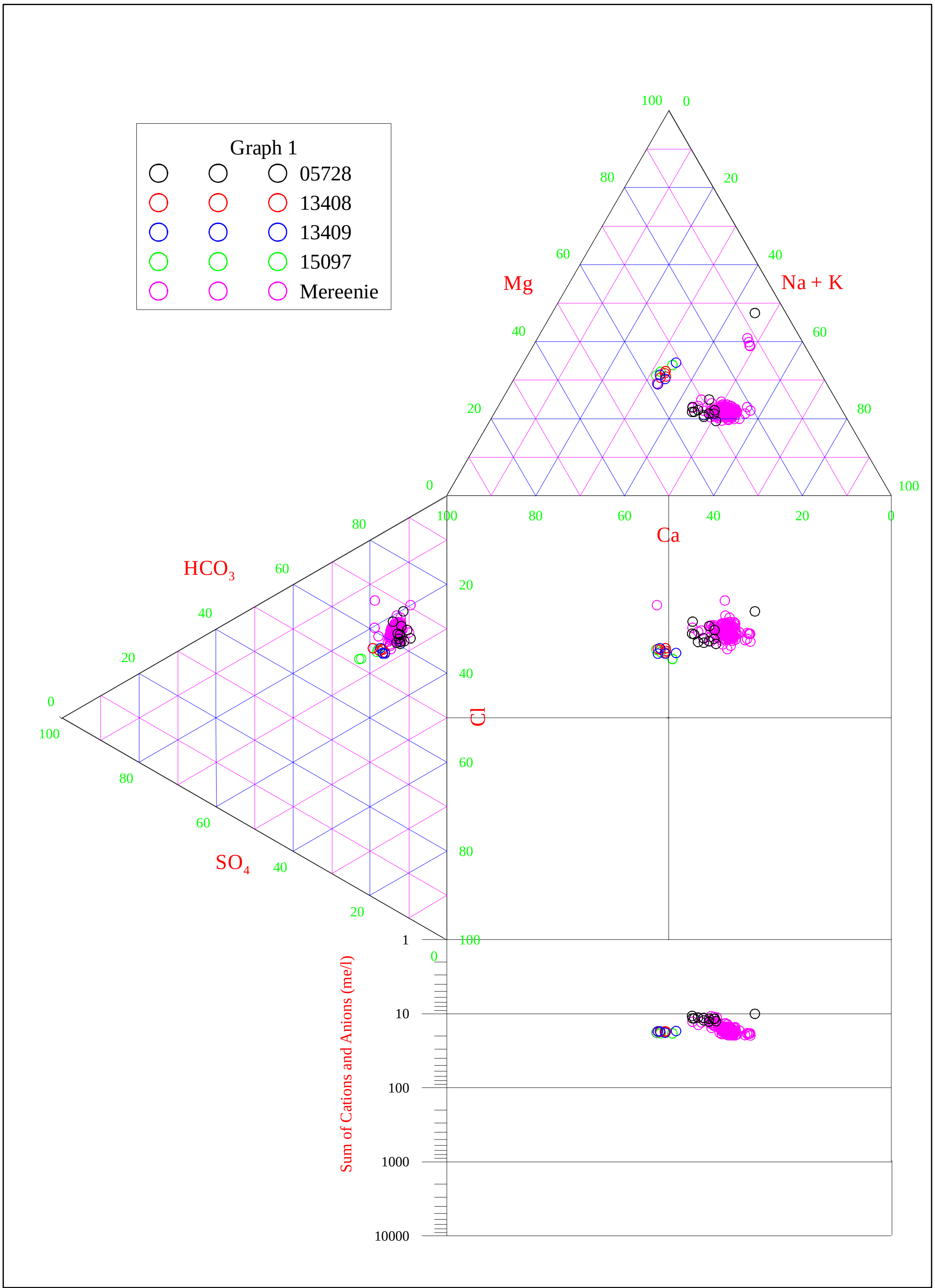

Figure 1 Durov plot of Pacoota and Mereenie production bores

2. Trends with time

Figure 2 to Figure 4 show trends in the three production bores with time. Three parameters, TDS, chloride, and EC have been plotted to reduce the effect of laboratory errors. The available data is limited. The latest results in the HYDSYS database are for 1996. Some results for 2004 and 2005 were available, but other analyses that are believed to exist have not been found.

RN 13408 shows no clear trend.

RN 13409, salinity has decreased by around 20 mg/L or 4%.

RN 15097, salinity has increased by around 60 mg/L or 10%.

With the relatively small number of samples and the likelihood that sample chemistry is influenced by the history of pumping immediately before sampling no conclusions can be made about future trends.

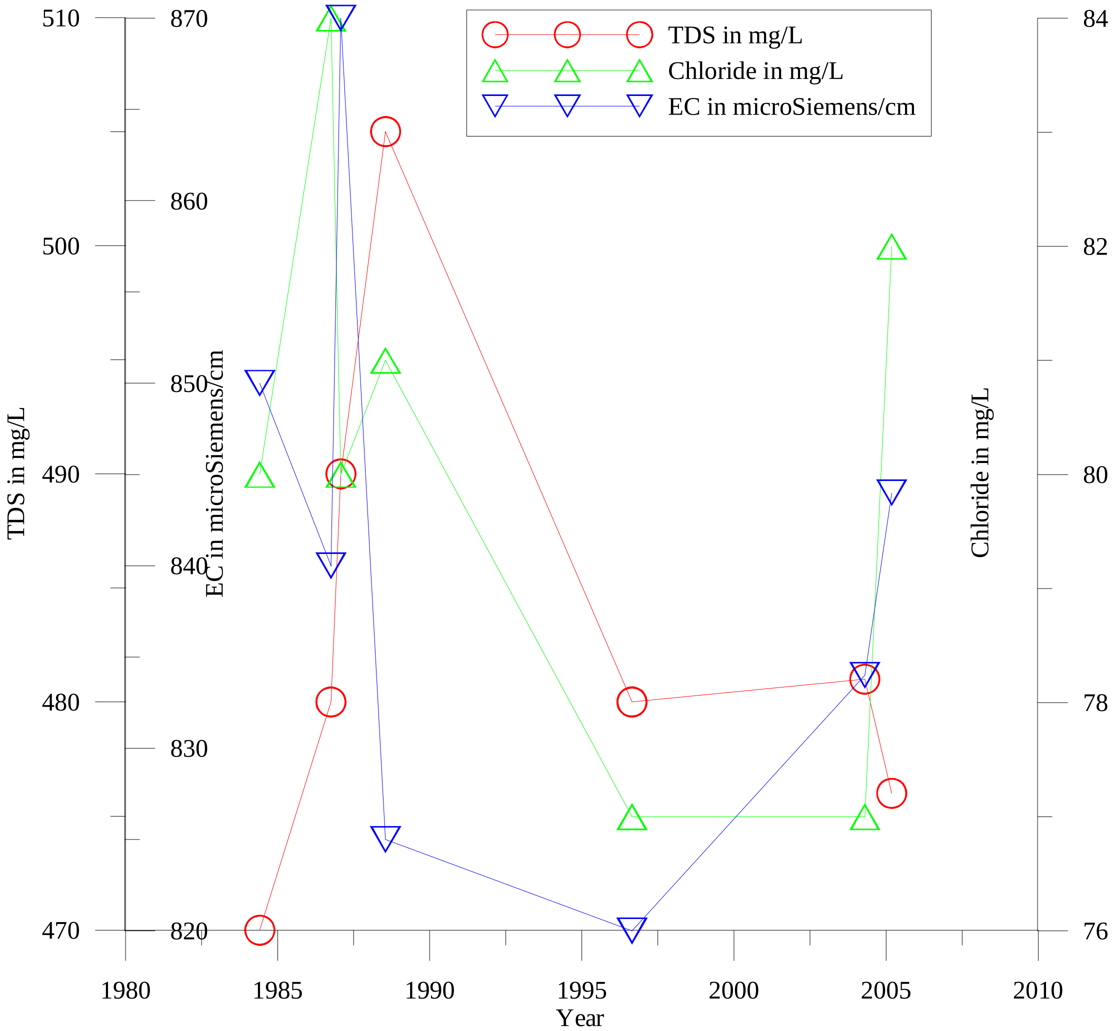

Figure 2 RN 13408

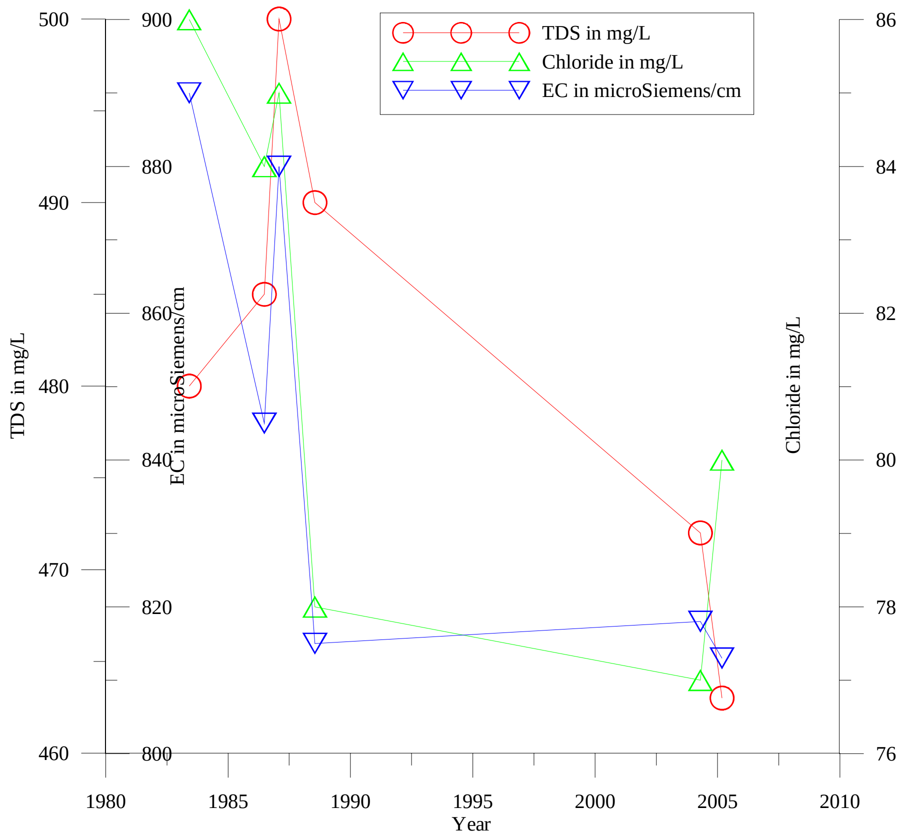

Figure 3 RN 13409

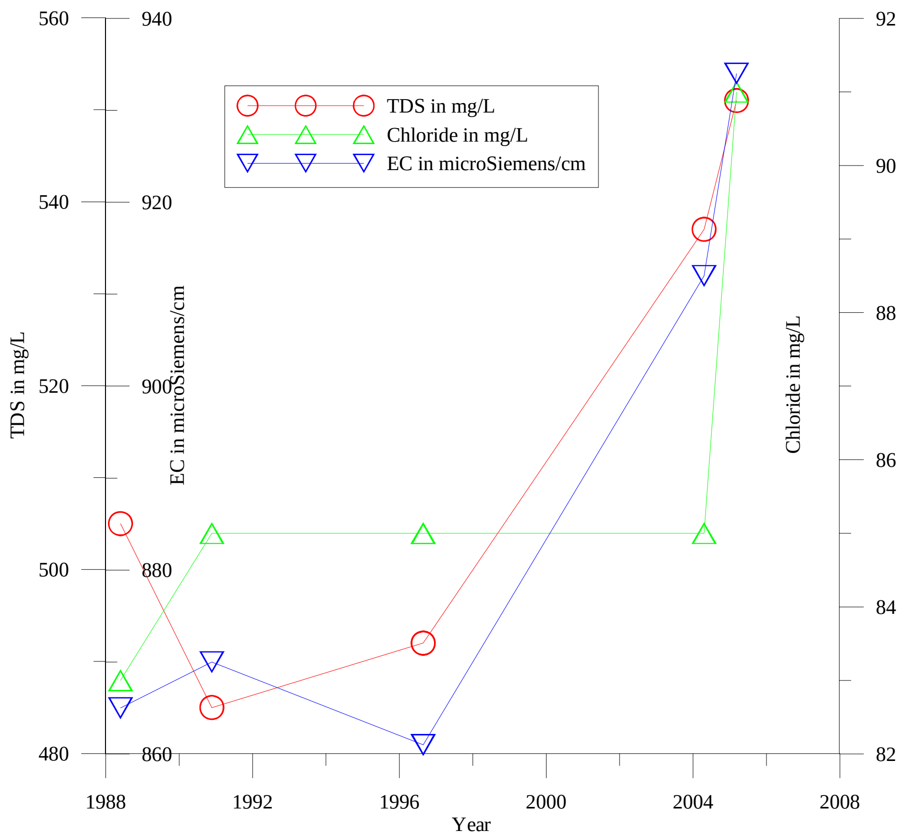

Figure 4 RN 15097