DWLBC REPORT

Willochra Basin Groundwater Monitoring Status Report 2005

2005/39

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Willochra Basin Groundwater Monitoring Status Report 2005

Paul Magarey and David Deane

Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

May 2005

Report DWLBC 2005/39

Government of South Australia
Department of Water, Land and Biodiversity Conservation

action Salinity & Water AUSTRALIA

Government of South Australia
Northern and Yorke Natural Resources Management Board

Knowledge and Information Division

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ISBN 0-9758235-7-4

Preferred way to cite this publication

Magarey, P and Deane, D 2005. *Willochra Basin Groundwater Monitoring Status Report 2005,* DWLBC Report 2005/39, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

ACKNOWLEDGEMENTS

Special thanks is conveyed to members of the community who provided a wealth of information on groundwater and horticultural issues within the Willochra District.

The assistance of the following people who contributed valuable time, knowledge, information, ideas and constructive criticism during the preparation of this report is gratefully acknowledged.

Northern and Yorke Natural Resource Management Board:

Trudie Stanley, Anita Crisp, Kerry Ward, Phyllis Robinson, Lindy Pearson, David Sloper, Saideh Kent and Michael Head.

Landholders and Community Members:

Rob Smart, John Loechel, Margaret Hancock, Robert Hancock and the Late Malcolm Orrock.

State Agencies:

Judy Tan (DWLBC), Scott Evans (DWLBC), Laura Phipps (DWLBC), Bruce Murdoch (DWLBC), Anne Walters (DWLBC), Carice Holland (PIRSA), Sharon Conner (PIRSA), Chris Badenoch (PIRSA) and Anne Young (PIRSA).

This work was funded by the Natural Heritage Trust and National Action Plan for Salinity and Water Quality.

Photography

Unless noted otherwise all photographs within this report were taken by the authors during field surveys in February, June and September 2005.

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1. INTRODUCTION

The Willochra Basin is a north south-oriented intermontane (between mountain) basin located approximately 300 km north of Adelaide in the Southern Flinders Ranges. The basin has a length of 80 km, extending from Booleroo Centre in the south to Simmonston area in the north. The width of the basin is between 11 and 25 km. The region has productive agricultural and grazing land, beneath which are a number of sedimentary and fractured rock aquifers.

The Tertiary and Quaternary Sediments which constitute the Basin are up to 200 m thick. The main source of recharge to the system is from the south-west where there is significantly higher rainfall due to orographic effect (Mt Remarkable).

Concerns over the water resources have been expressed due to below average rainfall and an increase in irrigated horticulture. The capacity of the groundwater resources to sustain further development is small to zero given current climatic conditions. Declining groundwater levels have been observed particularly in the Quaternary aquifers, with reduced water course baseflow, rising salinities and poor plant health observed along sections of the Willochra Creek (Risby et al, 2003).

A figure for an acceptable safe yield for the Basin is hard to quantify due to the complexity of the groundwater systems, however current knowledge of the groundwater resources suggests there is approximately 1000 ML/yr available of stock quality water or better (Read, 1979). Initial work on the hydrogeology has given baseline data, although detailed investigations have not taken place since 1956.

The following presents a review of existing literature, community information and data gathered on the groundwater resources of the Willochra Basin, with an analysis of groundwater monitoring records from 1985-2005.

2. AIMS

The aim of this study was to collate previous hydrogeological work done in the Willochra Region, update knowledge on groundwater resources and analyse observation well data including standing water levels and salinity trends. Recommendations have been made for future work in the region which will help to preserve the integrity of groundwater resources and prevent over development.

3. METHODOLOGY

The methodology involved three components: (1) Literature review; (2) community and Agency consultation; and (3) analysis of monitoring records for standing water level and salinity.

Literature Review

Literature was obtained on previous hydrogeological investigations and geophysical surveys for the Willochra district which included reports by O'Driscoll (1956), Frith (1975), Clarke (1978), Read (1979), Read (1980), Read (1991), Clarke (1996), Martin et al (1998) and Risby et al (2003).

O'Driscoll (1956) undertook hydrogeological investigative work to quantify "safe yield" in the main Tertiary Aquifer. Frith (1975) undertook geophysical investigations to understand the Basins structure and setting. Clarke (1978) and Read (1979) investigated the effects of uncontrolled flowing wells which incorporated a water well survey, while Read (1980) and Read (1991) undertook technical work for the Wilmington and Melrose town water supplies.

A brief overview of groundwater resources in the Mid-North and Yorke Peninsula which included the Willochra Basin was undertaken by Clarke (1996), while a hydrological and ecological assessment was undertaken by Risby et al in 2003. This work included the development of a hydrological model for the southern Willochra Creek subcatchments, mapping of watercourses in the form of aerial videography and ecological assessment of vegetation and biological surveys at selected locations.

Community and Agency Consultation

The aims of the consultation phase were to raise awareness regarding the project objectives, improve estimates of average water use and provide opportunities for the community to relate their experience and understanding of resource condition. As irrigation is the largest demand on water resources in the region, irrigators were the main focus of consultations. The process included public and targeted meetings, surveys, telephone or personal interviews and field inspections.

Known irrigators in the area were initially identified through meetings with members and staff of the Northern and Yorke Agricultural Districts INRM Committee, Primary Industries and Resources, Jamestown, Local Government and Animal and Pest Plant Control Board. These interviews also provided opportunity for some historical resource use to be identified.

Irrigators were initially contacted by telephone. Water use surveys were sent out and irrigators were invited to document details of their water use and return them to the project team for collation.

A public meeting was held in Wilmington at project commencement to present findings on the Willochra Hydrological and Ecological Assessment and to enable participation of members of the broader community not specifically targeted through identified use of water for irrigation.

The meeting introduced the project, and outlined the aim and scope of work. Opportunity was given to those present to make comment or raise any concerns with regard to water resources in the region.

Field visits took place to a number of landholders to gain further insight into farming practices and to quantify application rates for irrigated crops. A survey sheet was handed to the irrigators asking for information on, application, groundwater use rates, well yield, water quality and whether there were any wells that had been abandoned or required rehabilitation. A copy of the survey form can be seen in Appendix A.

Where appropriate, a water sample was taken from landowners wells and analysed for salinity (EC).

Analysis of Monitoring Network

The groundwater monitoring network was assessed to determine trends in groundwater level and salinity. Since the installation of the monitoring network in 1985, no significant analysis of monitored data has taken place. Components of the analysis involved:

- Collation of rainfall records and climatic trends for the monitored period in question.
- Analysis of groundwater level trends in current wells
- Observed changes in salinity.

This information was used to determine the level of risk imposed on the resource, suggest volumes (ML) in which annual groundwater use can be considered sustainable, and to present management options where appropriate.

4. REGIONAL SETTING

The Willochra Basin in a north south-oriented intermontane (between mountain) basin located approximately 300 km north of Adelaide in the Southern Flinders Ranges. The basin has a length of 80 km, extending from Booleroo Centre in the south to Simmonston area in the north. The width of the basin is between 11 and 25 km.

The Plain is bounded on the west by the eastern scarp of an irregular range extending from Mount Remarkable near Melrose, northwards to Mount Ragless. Topographically, the structure is relatively open at the southern end, but is almost closed at the north by a prominent ridge with narrow gaps cut by the Willochra and Kanyaka creeks. On the eastern flank, the hills are relatively low, this probably being a reflection of the rock types, in which the ABC and Pound (Subgroup) quartzites do not occur (O'Driscoll, 1956).

The Kanyaka, Pine, Boolcunda, Papoonda, Coonatto , Booleroo and Old Booleroo Creeks enter the valley from the east, their flood flows ultimately joining the Willochra Creek which runs northward along the valley floor. From the west, Castle, Pichi Richi, Richman, Mount Brown, Mimbadoggie, Yapoona, Beautiful Valley, Stony, Spring and Mt Remarkable Creeks are the main tributaries, with Wild Dog Creek entering from the south. A location map including surface drainage features can be seen in Figure 1.

Geology

The rock types adjacent to and beneath the Willochra Basin have their origins from sedimentary material deposited in a series of rifts that occurred during the Neoproterozoic Era. Rifting and deposition occurred over a period of 350 Million years, in what is known as the Adelaide Geosyncline (Preiss, 1987). Today, rocks of the Adelaide Geosyncline are exposed as ranges extending from Kangaroo Island in the south to Freeling Heights in the north of South Australia (Love et al, 2001), and incorporates rocks within the Mt Lofty Ranges, Southern Flinders Ranges, Northern Flinders Ranges, Mt Painter/Olary region and the Stuart Shelf.

The Southern Flinders Ranges comprise rocks of the Callana, Burra, Umberatana and Wilpena Groups. Basement to the Willochra Basin consists of Cambrian Archaeocyathinae limestone and Pound Quartzites, extending downwards to Sturtian Tillite and Torrensian slates (O'Driscoll, 1956). The main rock types on the western fringe of the Basin include the Ryanie Sandstone (Mt Remarkable Range), Angepina Formation, Wilmington Formation and ABC Range Quartzite. The ABC Range Quartzite makes up a significant component of the Mt Remarkable National Park and western hills in the northern part of the basin. To the east, rock types have a softer composition and include the Saddleworth Formation, Auburn Dolomite, Appila Tillite, Tarcowie Siltstone, Tapley Hill Formation, Brachina Formation and Cradock Quartzite. The Geology of the Willochra Area can be seen in Figure 2.

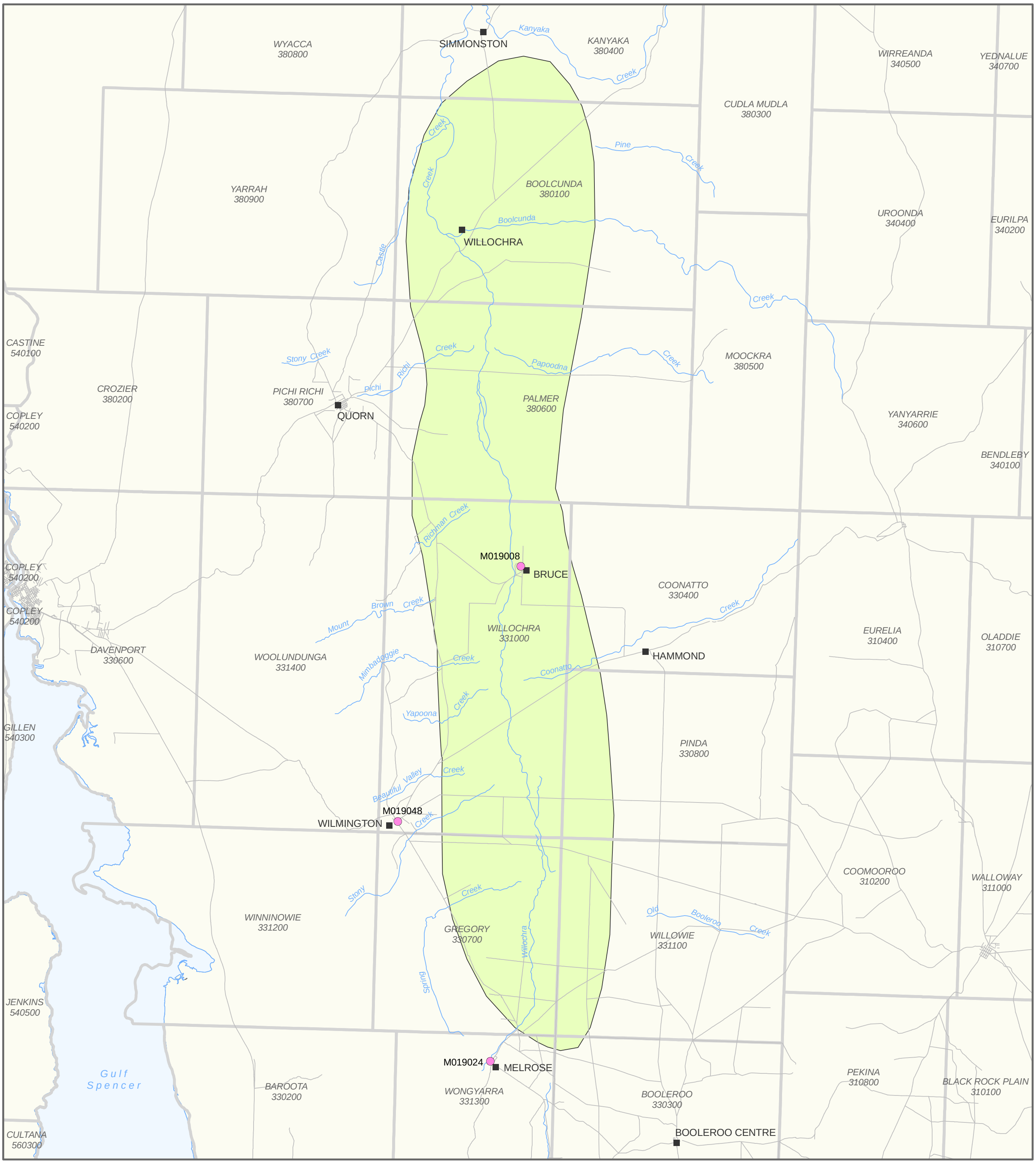


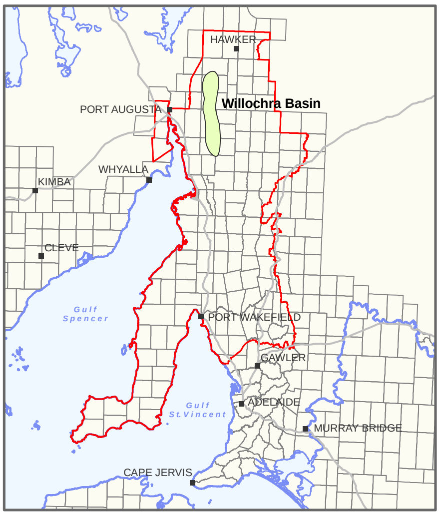
Figure 1.
Willochra Basin Location Map

Town	Willochra Basin
Rainfall Station	Hundred Boundary
Drainage	NYAD Boundary
Road	

N

0 5 10 km

GDA Datum: Geocentric Datum of Australia 1994 South Australia Lambert
Projection: Lambert Conformal Conic



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Date: November 2005

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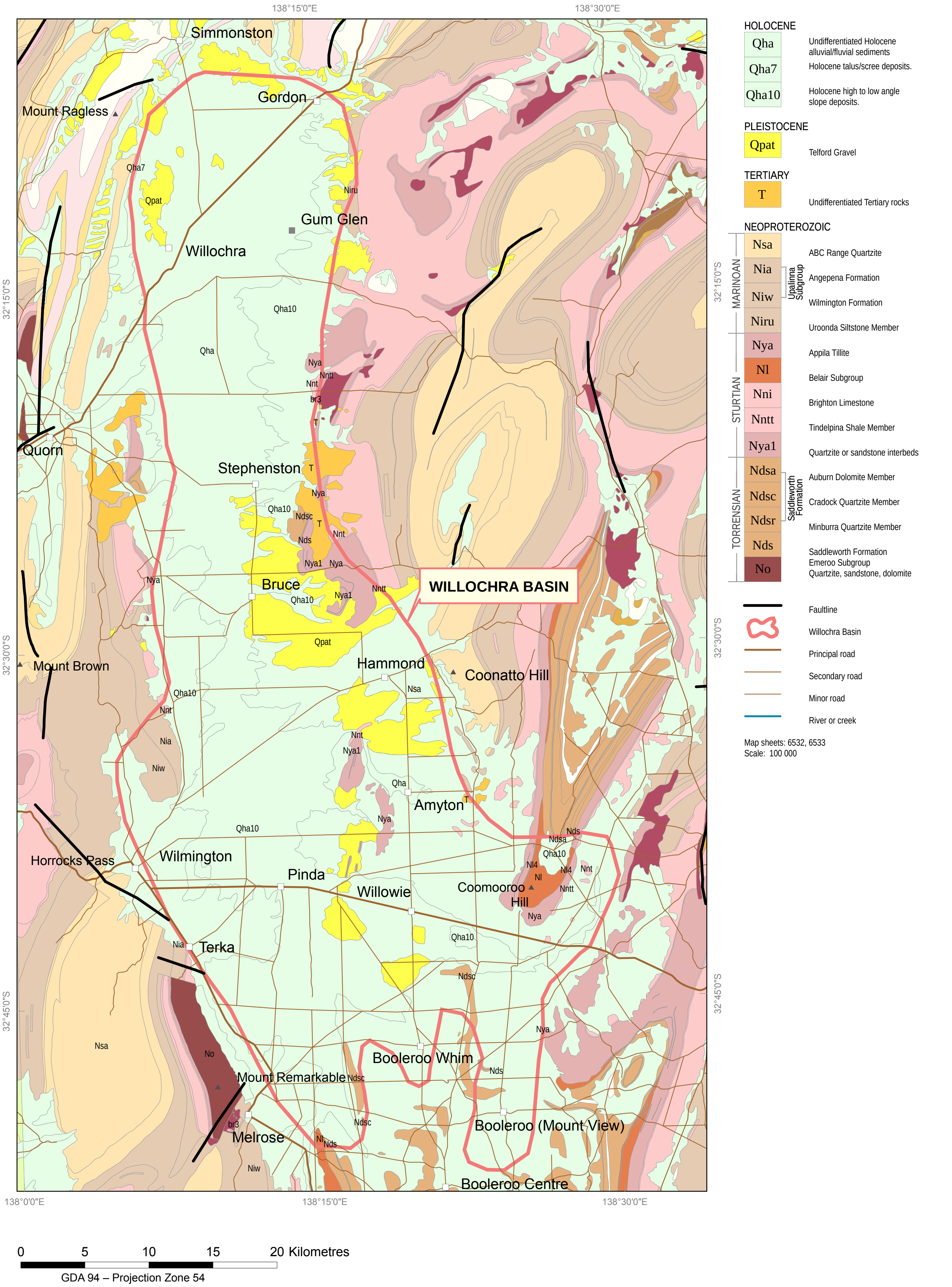
Figure 2 Geology, Willochra Basin and surrounds



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100 000 GEOLOGY – SOUTH AUSTRALIA

WILLOCHRA BASIN

PIRSA: 202897_001

Groundwater

The Basin sediments and fractured rock aquifers on the basin margins play an important role in storing quantities of fresh groundwater that are used for town water supplies, stock, domestic and irrigation purposes. Fractured rock aquifers on the Basin margins have played an increasingly important role in recent years due to low rainfall and higher demand from the Wilmington TWS. Sedimentary aquifers on the plain provide fresh groundwater for irrigation and stock while the northern portion is suitable for stock only. A summary of Basin sediments and hydrogeology is seen in Chapter 5 – Summary of Aquifers.

Surface Water

The electrical conductivity (EC) of surface flows within the Willochra Catchment varies from 600 EC units during flood flow, to approximately 80,000 EC units at low flow in the northern part of the basin (Clarke, 1978). Creeks on the Plain which exhibit permanent water are reliant on discharge from sedimentary aquifers during the dry seasons and are typically of high salinity due to high evaporation rates experienced throughout the catchment.

Historical Use

Settlement of the Willochra Basin took place in the mid-to late 1800s as the land was opened up for sheep and cattle runs and for cereal cropping. Coupled with the introduction of cropping included the surveying of mile blocks and towns, of which remnants remain in the form of abandoned cottages and settlements (eg Simmonston and Willochra).

The capability of the northern Willochra Plain to sustain agricultural activity was made clear in the first 20 years of establishment. Early plant species suggested that the soil was not indicative to agriculture, with the northern section having duplex soils which are highly sodic and saline (Lay pers. comm., 2005). Extensive draught, crop failures and soil erosion resulted in the demise of cropping in the northern section of the basin, and today the whole northern part of the Willochra Plain is used only for stock grazing. Forest reserves were established around the time of land surveying – Boolcunda Forest an example – which subsequently failed (Lay pers. comm. 2005).

Current Landuse

Current landuse on the Willochra Plain is principally grazing in the north, tending to cereal cropping in the south. Irrigated horticulture is limited to the southern section of the plain near Wilmington, Spring Creek and the hills around Melrose. There is also irrigation in the central part of the Willochra Plain where groundwater is extracted from the confined Tertiary Aquifer.

Figure 3 is a pie graph of landuse in the southern Willochra Catchment collected by Bureau of Rural Sciences (BRS) 1999.

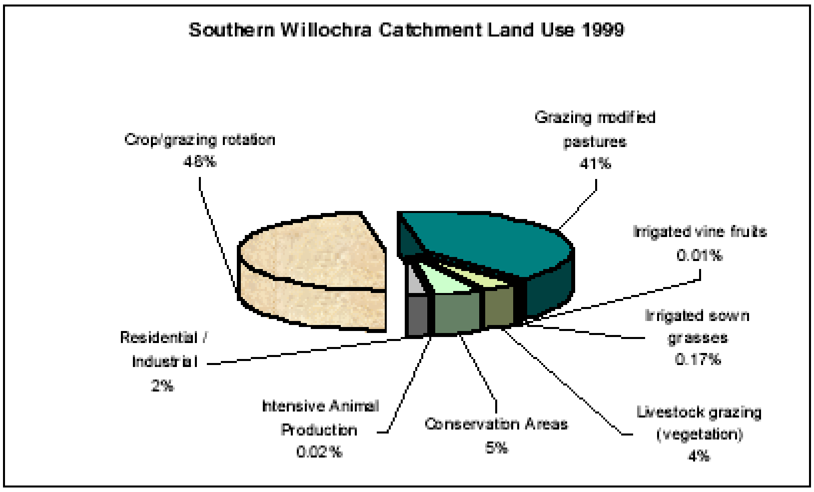


Figure 3. Landuse – Southern Willochra Catchment (after Risby et al, 2003).

Climate

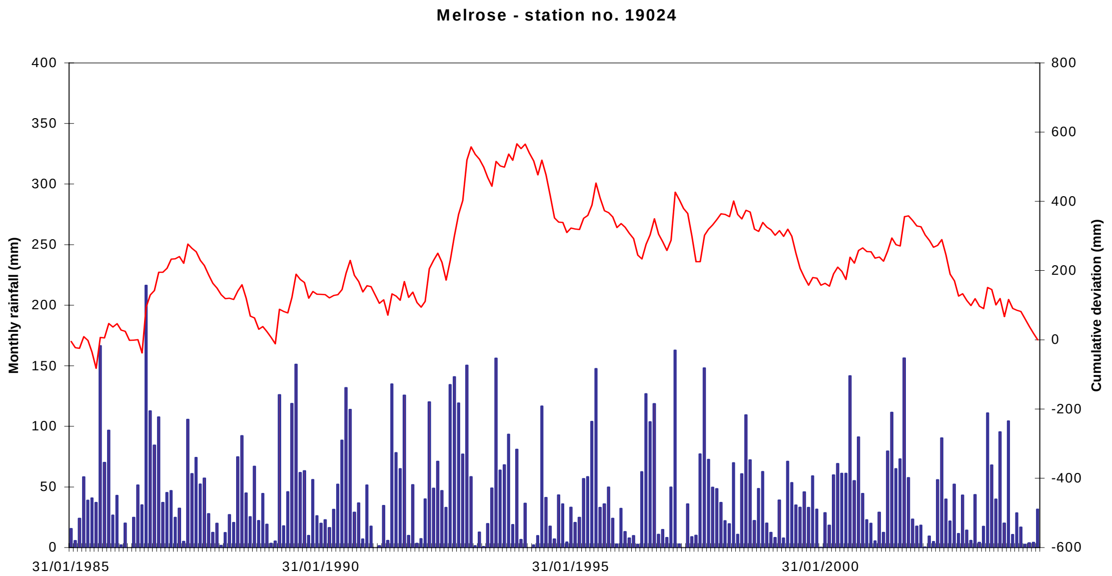
The climate is of Mediterranean type in the south, tending to semi-arid in the north. Most rain falls in the cooler winter months, with the south western part having a much higher rainfall than elsewhere.

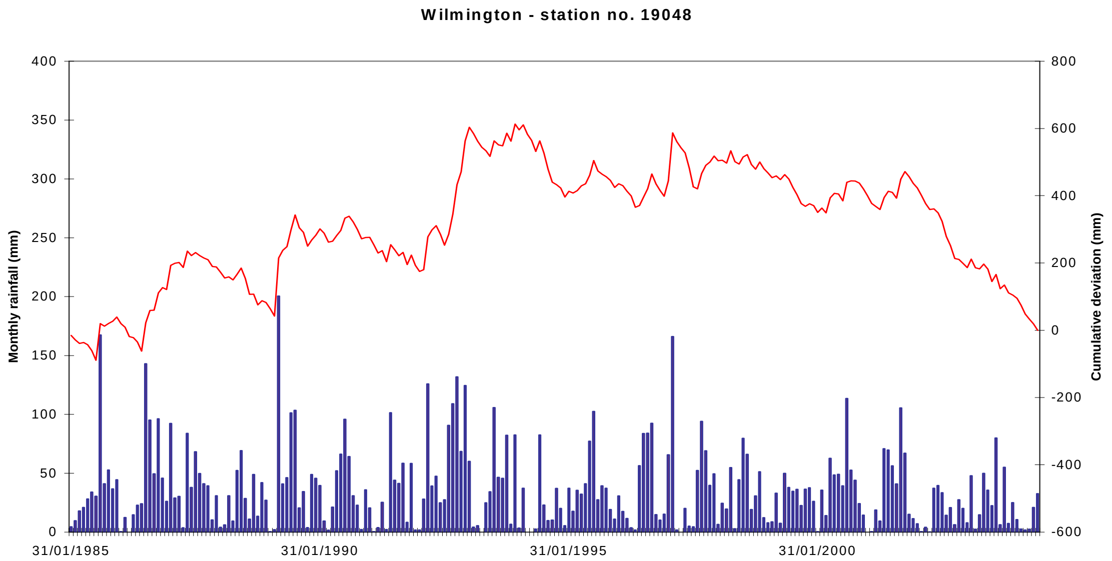
Three rainfall stations were selected as representative of the rainfall pattern throughout the area: Melrose (station 19024), Wilmington (station 19048) and Bruce (station 19008). Annual average rainfalls for selected stations are 576, 439 and 260 mm respectively. The average monthly rainfall is shown in Table 1.

Table 1. Average monthly rainfall (mm).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Melrose	20.2	23.8	25.9	24.3	50	73.9	84.1	77.1	71.9	55	36.8	33.6
Wilmington	20	22.9	27.9	18.1	35.2	51.1	59.2	58.4	48.5	44.6	30	32
Bruce	16.3	24	20	14.1	21.8	29.4	27.1	30.1	32.7	27.5	23.2	25.9

The rainfall records are available for a period of 120 years for Melrose station, 120 years for Wilmington, and 109 years for Bruce. Figure 4 shows the monthly rainfall and cumulative deviation from the monthly mean for the period 1985 - May/June 2004.





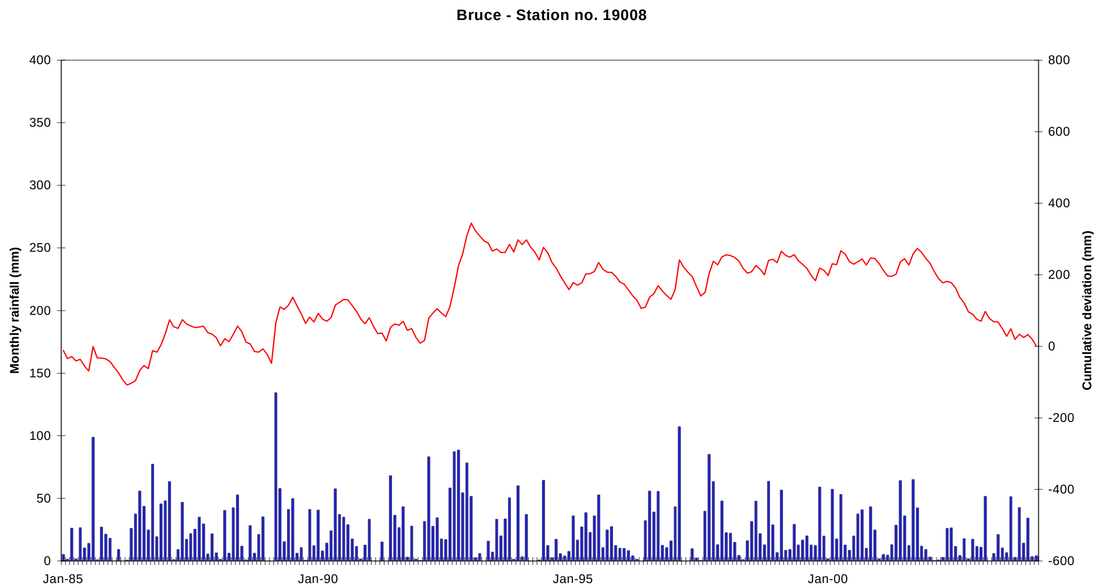


Figure 4. Monthly rainfall and cumulative deviation (mm).

5. SUMMARY OF AQUIFERS

The first major hydrogeological assessment was undertaken by O'Driscoll (1956). Since then the understanding of the hydrostratigraphy has not considerably changed. Generally 3 aquifer systems, Quaternary, Tertiary and Fractured rock are recognised in the area.

A representative cross section of Willochra Basin sediments is seen in Figure 5.

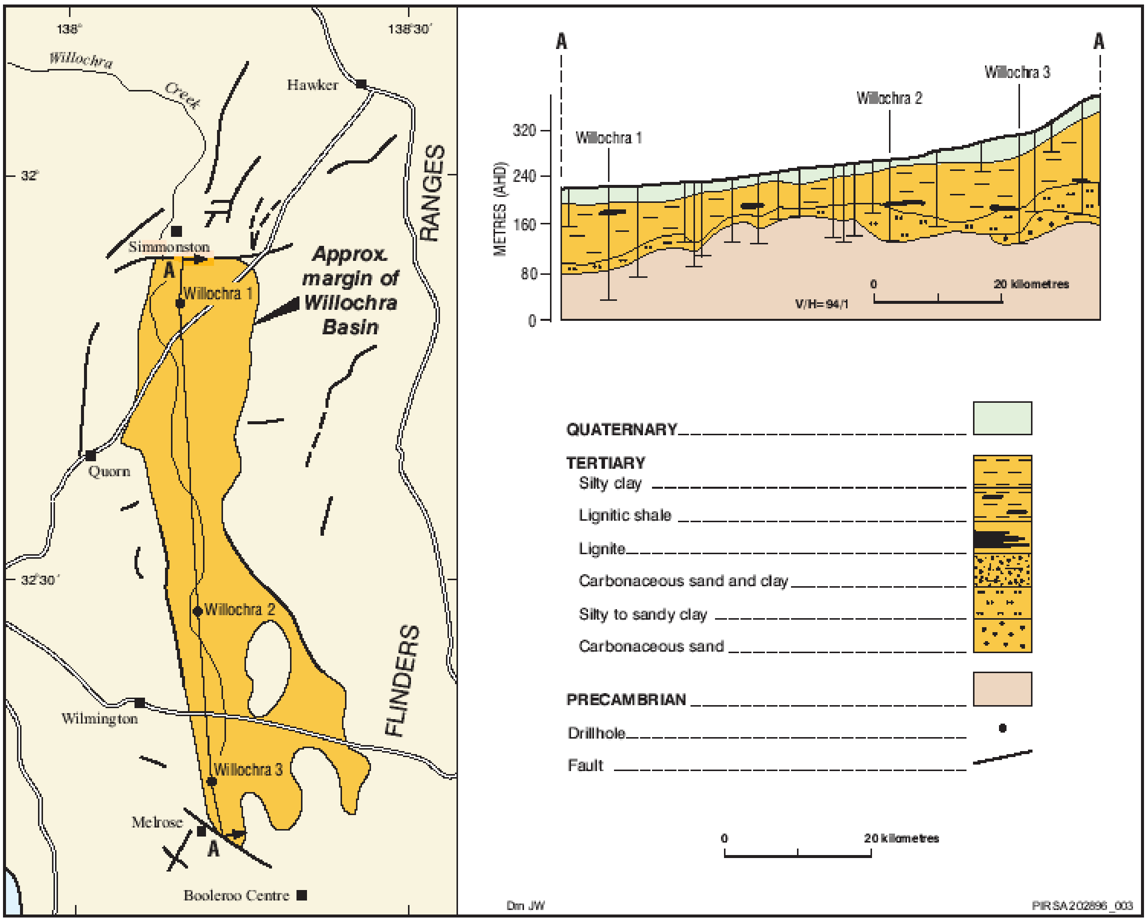


Figure 5. Representative cross section of Willochra Basin sediments (Alley and Lindsay, 1995 after Kwitko, 1982 b).

Shallow Quaternary Aquifers

Quaternary sediments consist of mottled sandy clays, thin sandy clays and thin sandy beds, overlain by hard marly limestone (O'Driscoll, 1956; Shepherd, 1978). The Quaternary Aquifers provide sources of stock quality water basin wide, with small sections having water of suitable quality for irrigation. The best quality groundwater is found in the vicinity of Spring Creek where salinity is a low as 400 mg/L TDS. Elsewhere, salinity is variable suggesting that local influences are important (Clarke, 1978).

Recharge to the Quaternary Aquifers is from the south and south-west and from inputs from local creeks. There is also a component of upward leakage from the underlying Tertiary Aquifer particularly in the north (Read, 1979). The maximum thickness of sediments is estimated at 90 m.

Tertiary Confined Aquifer

Except for an area in the south where a basement low was initially infilled with carbonaceous-swamp type sediments, the Confined Tertiary Aquifer lies directly over bedrock and is continuous over the full length of the basin (O'Driscoll, 1956). Its effective thickness is 15 m in the south, declining to less than 6 m in the north (O'Driscoll, 1956).

The Aquifer varies considerably in composition, from a pipe clay through various gradations of fine sandy clay and silt to a fine slightly clayey sand, with the less permeable types forming the bulk of the vertical section (O'Driscoll, 1956). Salinity varies, being less than 1000 mg/L TDS near the intake areas, increasing to 7000 mg/L TDS in the north.

The aquifer is under pressure over the whole of the basin, with artesian flows occurring in a central zone on the Plain. Due to the fineness of sands and pressure this aquifer has caused a number of wells to fail (Clarke, 1978).

The sustainable yield of the Confined Tertiary Aquifer was calculated at 400 ML/yr by O'Driscoll (1956). No investigative work has been done to refine this estimate, however field studies by Read (1979) noted this as an underestimate and the actual available yield is in the order of 1000 ML/yr. This included stock wells basin wide, and did not differentiate between wells that yielded good, fair or poorer quality groundwaters.

Fractured Rock

Basement is directly overlain by Tertiary Sediments and appears in at least some places to be in direct hydraulic connection (Read, 1991). Yields depend on degree of fracturing and formation encountered, with salinity and pressure similar to that of the Confined Tertiary Aquifer (Read, 1991). The volume of groundwater stored in the basement rock is currently unknown, and was not given considerable attention during the study by O'Driscoll in 1956. The Melrose town water supply is reliant on groundwaters extracted from basement rock which has a salinity and pressure very similar to the overlying Tertiary Confined Aquifer. This suggests that at least in some places that basement rock and the confined Tertiary Aquifer are in hydraulic connection.

The Wilmington TWS extracts groundwater from Tapley Hill Formation on the fringes of the basin (Spring Creek mine shaft) which has a water quality of around 600 mg/L TDS. The Wilmington TWS is recharged from outcrops in the ranges that have reliable rainfall and is expected to maintain good quality. A number of bores have recently been constructed in the Wilmington area which have intersected basement rock (SA Geodata, 2005). Anecdotal evidence suggests that groundwater in this area is available from both shallow Quaternary creek sediments and fractured rock aquifers but the quantity available is unknown.

6. CURRENT GROUNDWATER USE

Groundwater is the dominant water source for reticulated water supplies, irrigation, stock and domestic use on the Willochra Plain. The Murray River pipeline extends to Booleroo Centre on the southern most extent of the Plain, and settlements north of this point rely on independent sources for their water supply needs.

Table 2 is a summary of current groundwater use from the Willochra Basin and surrounding hard rock areas. Volumes indicated by '?' show where there is not enough information to confidently report on groundwater use for a particular area.

Of note in Table 2 is the extraction from the Tertiary Confined Aquifer that is estimated at 380 ML/yr for irrigation. Further extractions in the order of 700 ML/yr are estimated for stock purposes, given that there are approximately 400 stock wells on the Plain with an estimated use of 5 kL/day (Read, 1979). This gives a total of 1080 ML/yr used for irrigation and stock from the Tertiary Aquifer.

An estimated 120 ML/yr is used for irrigation at Spring Creek. Other water use includes ~112 ML for irrigation of vines and 244 ML/yr for irrigation of olives around the Wilmington township. These estimates have been made from pumping and application rate figures returned from survey sheets and where this information was not available an average application rate multipied by the crop parcel size was used.

Further water use for town water supplies includes 140 ML/yr for Wilmington, 60 ML/yr for Melrose, and 30 ML/yr for the non potable supply for Hammond/Willowie (Magarey and Deane, 2004).

This gives a total water use for the basin sediments and surrounding hard rock aquifers at 1750 ML/yr, with the proportion of this considered to be fresh (salinity less than 1500 mg/L TDS) equal to 700 ML/yr.

Table 2. Willochra Basin aquifers and surrounding hard rock areas – recorded extractions and estimated groundwater use.

Groundwater Use/Purpose	Aquifer Type	Recorded/ Estimated Use (ML/yr)	Comment
Wilmington TWS	Fractured rock	140	Volume indicative of average yearly extraction from Spring Creek mine shaft.
Melrose TWS	Fractured rock	60	Extraction bore constructed into fractured rock. In direct connection with Tertiary Aquifer.
Bruce/Hammond TWS	Fractured rock	25	Unpotable supply only. TDS > 3000 mg/L
Spring Creek Irrigation	Quaternary	120	Water used for irrigation of lucerne, vines.
Lucerne Irrigation, Willochra Plain	Tertiary	380	Bores yield artesian water. Best quality artesian water on the plain.
Irrigation: Wilmington and surrounds	Quaternary/Fractured Rock	25 (vines) 34 + (olives)	Irrigation supports olives and vines. Not all irrigators surveyed.
Stock wells	Mostly Tertiary	700	Estimate based on average use of 5 KL/day per well. Initial estimate made by Read (1979) assuming there are 400 stock wells on the Plain.

7. GROUNDWATER MONITORING NETWORKS

The groundwater monitoring network for the Willochra Basin was established in 1985 in order to monitor groundwater levels and salinity. The purpose of the monitoring network is to observe the aquifer's response to groundwater extraction, rainfall, and identify areas that may be under stress from over pumping or areas that may be at risk of salinisation. From analysis of the monitoring data, steps can be taken to ensure the groundwater resource is not overstressed to the point of irreversible degradation.

Currently there are 20 observation wells on the Willochra Plain that monitor groundwater levels and salinity (Figure 6). The Field Services Group (Knowledge and Information Division) within the Department of Water Land and Biodiversity Conservation carries out the monitoring on a 6 monthly basis. The observation wells that monitor each of the aquifers is presented in Table 3.

Table 3. Current monitoring wells.

Aquifer	Government owned wells (SA Water, Investigation)	Privately owned wells
Quaternary		GRG 11 GRG 8 GRG 9 GRG 5 GRG 6 GRG 10 WLR 7 WLR 5 WLR 6 WLR 13 WLR 15 PDA 1
Tertiary		WLR 12 WLR 18 WLR 24
Fractured Rock	GRG 12 GRG 13 GRG 18	APP 2 APP 3

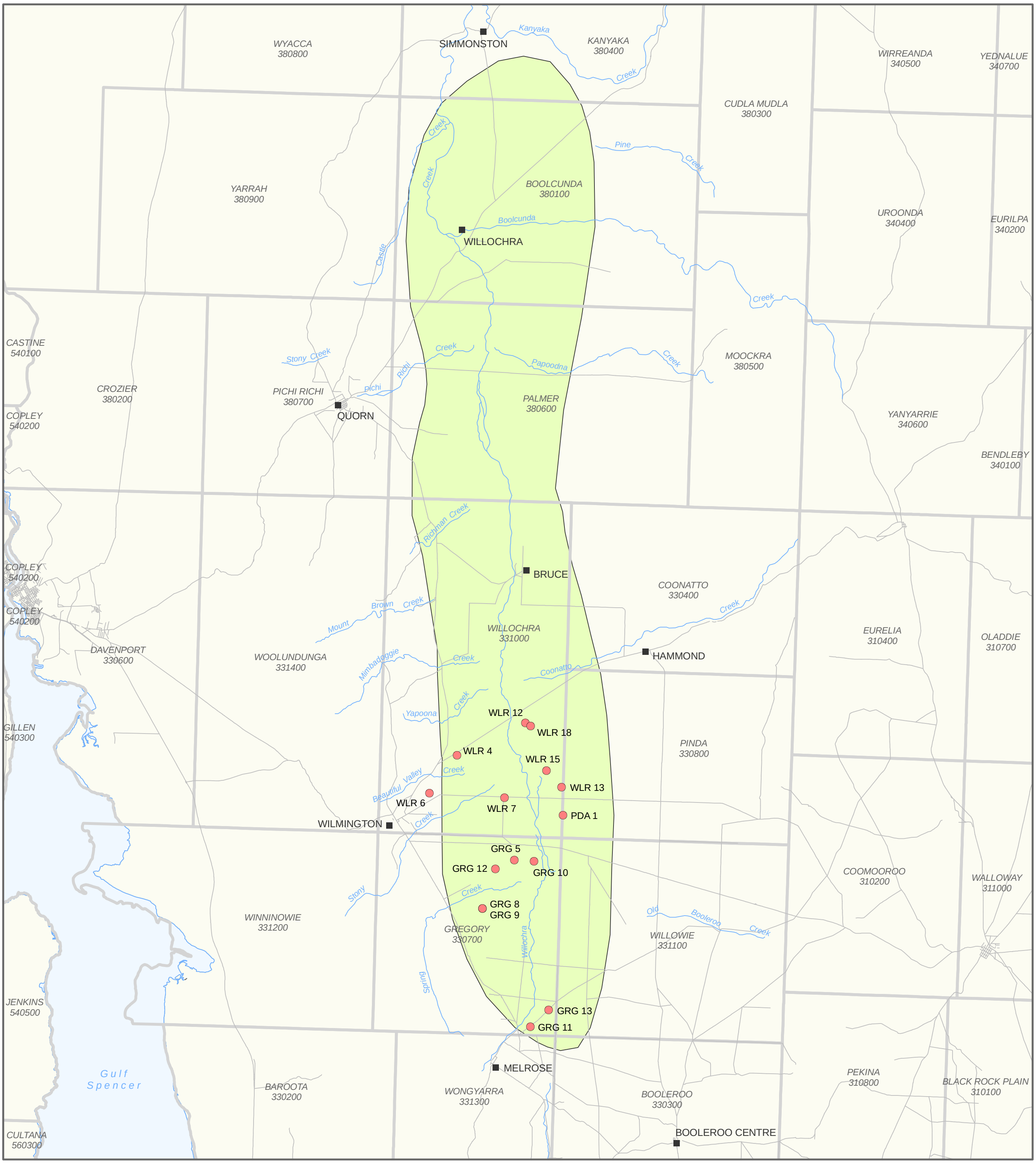


Figure 6.
Willochra Basin Standing Water Level Monitoring Wells

Town

Drainage

Road

Willochra Basin

Hundred Boundary

NYAD Boundary

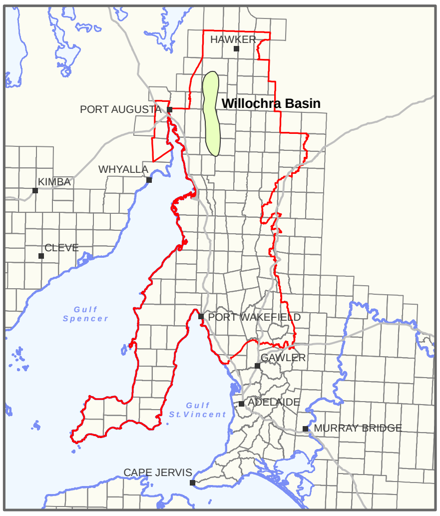
Monitoring Network

WLR 7 Obs.No

N

0 5 10 km

GDA Datum: Geocentric Datum of Australia 1994 South Australia Lambert
Projection: Lambert Conformal Conic



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Date: November 2005

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8. WATER LEVEL ANALYSIS

Hydrographs of for all aquifers are presented in Appendix B, C and D, of which records are available over the period 1985-2005. There are a total of 18 observation wells that monitor standing water level. Most of these are private wells with the exception of the town water supply well at Melrose (GRG 13) and an investigation well near Spring Creek (GRG 12).

The following is a summary of water levels observed in each of the respective aquifer systems.

Quaternary Aquifers

The Quaternary Aquifer system is monitored by 13 wells. Graphs show that groundwater levels in all Quaternary wells have fallen consistently since the last significant rainfall event of 1992/1993 (Appendix B).

It can be seen from the Figure 7 that the last major recharge event was in late 1992/early 1993, which resulted in the highest water levels seen at any point throughout the monitoring period. Since 1993, water levels have continued to fall. This fall cannot be explained by natural discharge, as the current water level is up to 2 m below that of pre-1992 conditions. It is likely that consecutive below average rainfall seasons has contributed to a decline in groundwater levels in this well.

Whether falls in groundwater level are considered significant depends on the depth of a well. Shallow wells GRG 5, GRG 10, WLR 7, WLR 13, WLR 15 and WLW 1 have depths of 10 m or less. Declines of up to two metres in these water levels can result in the well going dry, whereas declines of 2 m in wells with large depths of standing water level may not be significant. This is particularly important for landholders who utilise groundwaters from shallow hand dug wells and windmills, in which a number have expressed concerns with regard to salinisation* and lowering of water tables.

*In one instance salinisation was due to corroded well casing, in which seepage occurred from an overlying aquifer of poorer quality. However, salinisation can occur from over extraction, when groundwater is removed at a rate higher than what is being replenished, and water is drawn from adjacent groundwaters of poorer quality.

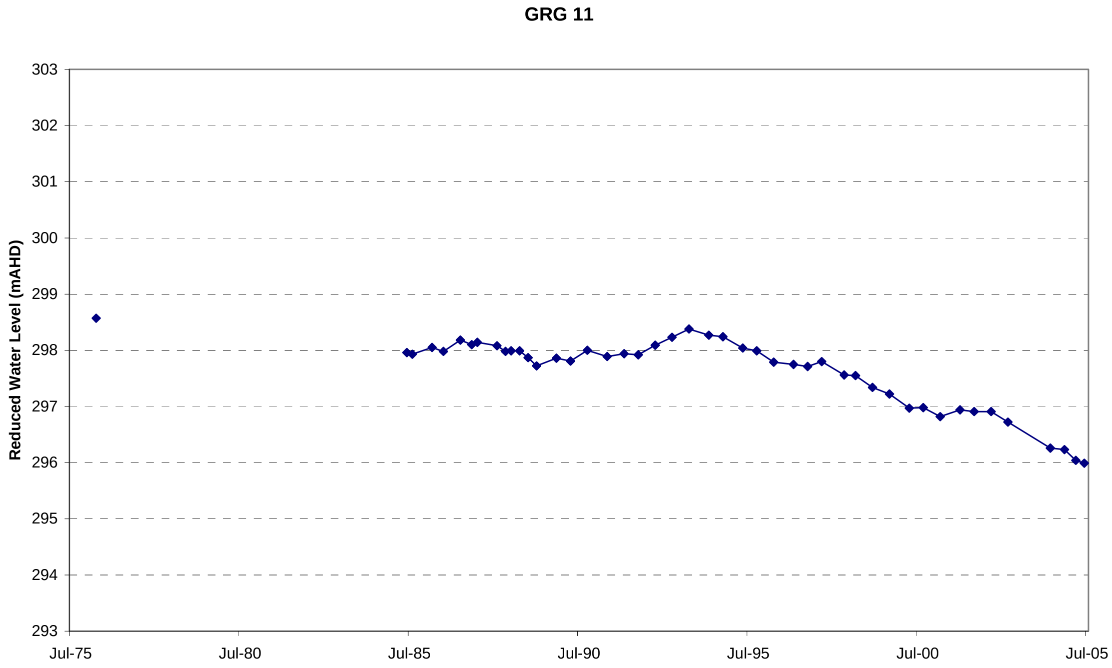


Figure 7. SWL hydrograph GRG11.

Tertiary Aquifers

The Confined Tertiary Aquifer obtains its recharge near the ranges in the south-western section of the Basin (O'Driscoll, 1956). Unlike Quaternary Aquifers reliant upon seasonal surface flow and upward leakage for recharge, the Tertiary Confined Aquifer has a larger storage and variations in water level are not as abrupt as those encountered in overlying Quaternary Aquifers.

There are two observation wells that monitor water levels in the Confined Tertiary Aquifer (see Figures 8 and 9). These are located in the central zone of the Willochra Plain, close to where irrigation for lucerne takes place. The 3 to 5 m annual water level variation is directly related to the summer irrigation demand from the Tertiary Aquifer.

There are no obvious trends for observation wells WLR 12 and WLR 18 (Figures 8 and 9), except that there has been a small decline in the summer water level at observation well WLR 12 from the year 2003-2005.

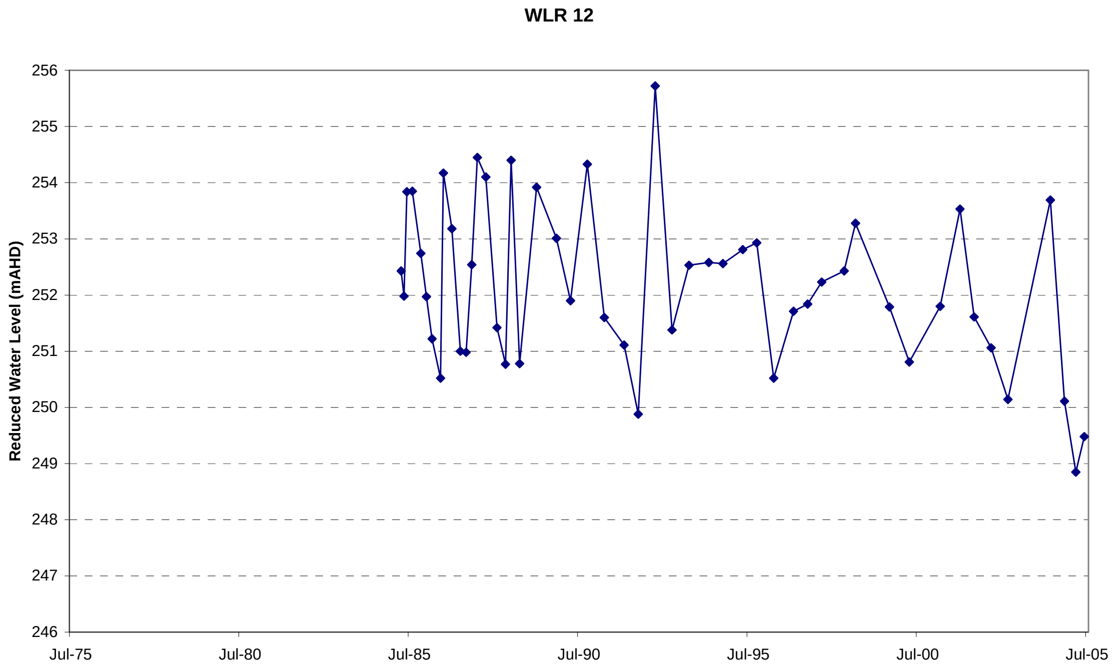


Figure 8. SWL hydrograph WLR 12

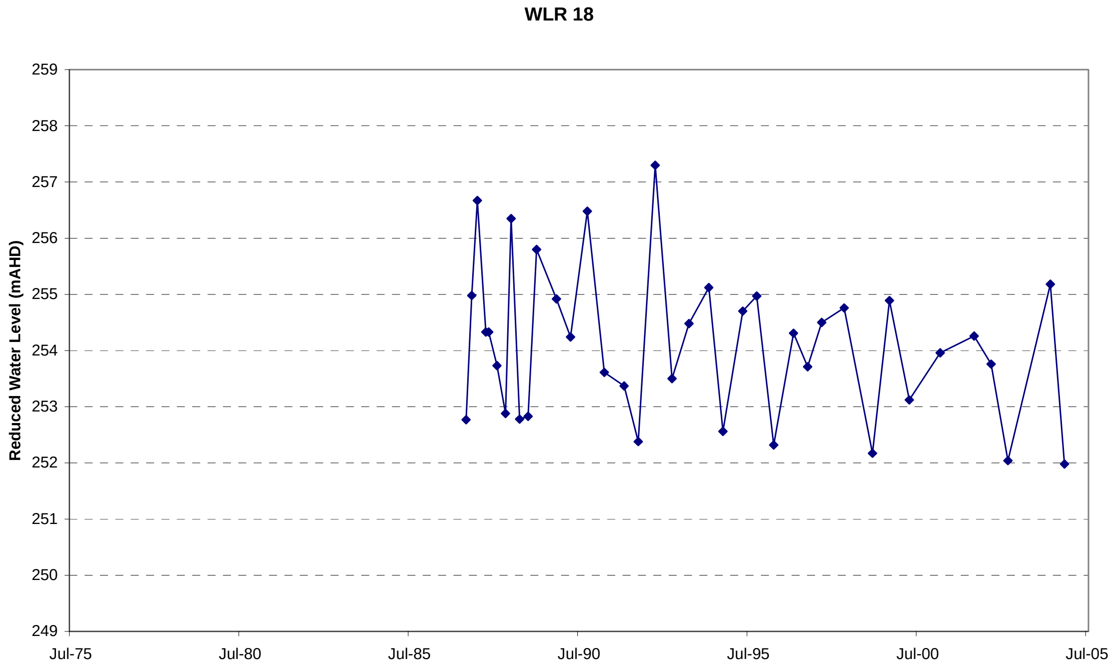


Figure 9. SWL hydrograph WLR 18.

Fractured Rock Aquifers

Two wells currently monitor fractured rock aquifers, GRG 12 and GRG 13. GRG 12 is located near Spring Creek and is constructed to a depth of 129 m, while GRG 13 is the current Melrose Town water supply extraction bore. Both wells show a consistent decline in water level since the last major recharge event in 1992. GRG 13 in particular shows a consistent drop without significant replenishment (Figure 10). This matches the cumulative deviation of rainfall (Figure 4) but is also likely to be associated with extraction for the Melrose TWS. GRG 12 shows consistent falls in groundwater level, except for a period in late 2001.

Both hydrographs can be seen in Appendix C.

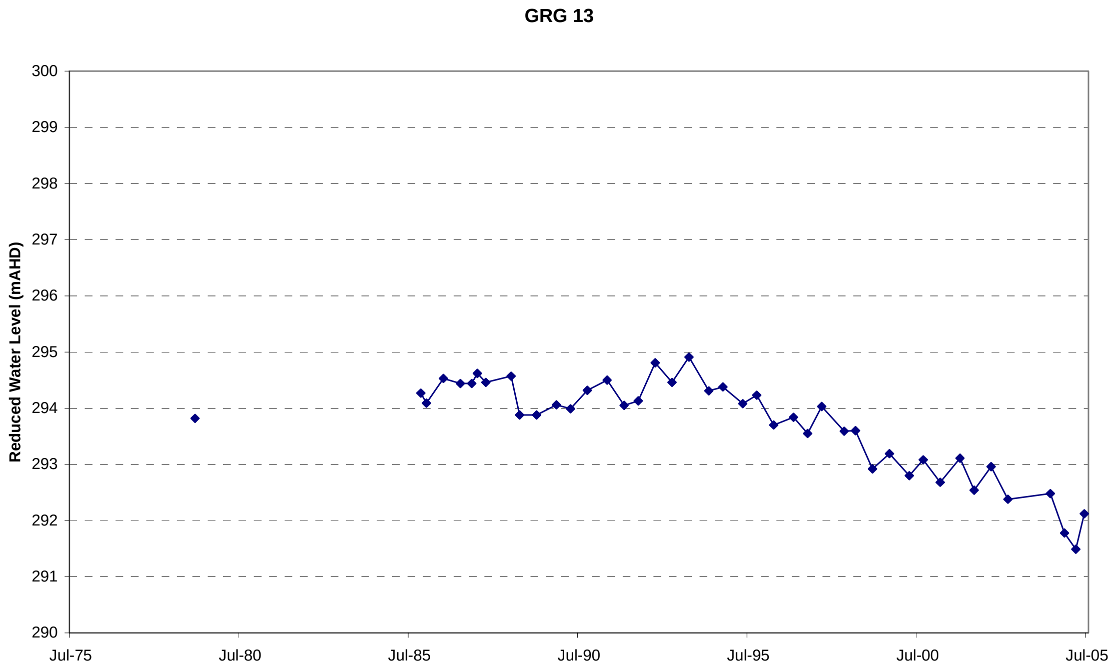


Figure 10. Hydrograph – observation well GRG 13.

Summary tables of all observation wells are presented in Tables 4, 5 and 6.

Table 4. Quaternary Aquifers: groundwater level trend.

Aquifer	Observation Well No	Unit Number	SWL Apr 1985 (m)	SWL Apr 1993 (m)	SWL Sep 2005 (m)	Comment
Quaternary	GRG 5	653200983	6.21	4.76	8.01	Decline of 3.25 m since 1993.
Quaternary	GRG 8	653201010	13.04	9.53	15.26	Decline of 5.73 m since 1993
Quaternary	GRG 9	653201011	20.9	19.68	22.86	Decline of 3.18 m
Quaternary	GRG 10	653208185	3.48	2.97	7.29	Decline of 4.32 m
Quaternary	GRG 11	653200571	22.98	22.71	24.95	Decline of 2.24 m
Quaternary	WLR 4	653201120	11.59	12.64	16.12	Decline of 3.48 m
Quaternary	WLR 6	653201150	7.47	7.46	9.57	Decline of 2.11 m
Quaternary	WLR 7*	653201165	3.89	3.20	5.35	Decline of 2.15 m
Quaternary	WLR 13	653201143	8.40	8.79	10.29	Decline of 1.5 m
Quaternary	WLR 15	653201128	5.71	4.44	6.84	Decline of 2.40 m
Quaternary	PDA 1^	653200931	13.20	13.07	13.37	Decline of 0.3 m since 1993.

*** Latest reading was October 2001.**

^ Latest reading March 2005.

Table 5. Tertiary Aquifers – groundwater level trend.

Aquifer	Observation Well No	Unit Number	SWL Apr 1985 (m)	SWL Apr 1993 (m)	SWL Sep 2005 (m)	Comment
Tertiary	WLR 12	653201296	2.57	3.34	2.66	Fall of 0.09 m since 1985.
Tertiary	WLR 18	653201346	2.23	3.50	3.06	Rise of 0.83 m since 1985.

Table 6. Fractured rock (basement) aquifers: Groundwater level trend.

Aquifer	Observation Well No	Unit Number	SWL Nov 1985 (m)	SWL Apr 1993 (m)	SWL Sep 2005 (m)	Comment
Fractured Rock	GRG 12	653201355	8.94*	8.74	13.49	Fall of 4.75 m since 1993.
Fractured Rock	GRG 13	653200570	11.73	11.54	14.60	Fall of 3.06 m since 1993

* First measurement taken May 1987.

9. SALINITY ANALYSIS

A network consisting of Quaternary, Tertiary and Basement monitoring wells was established in the late 1980s and early 1990s for salinity monitoring in the area. The network focuses on 3 regions; Spring Creek, Willochra Plain, and the Melrose TWS extraction bores. The salinity monitoring network is relatively small, and mostly targets those areas that currently experience extractive pressure. All of the wells monitored for salinity are either production wells or windmills. The salinity monitoring wells are seen in Figure 11.

Spring Creek

The groundwater that recharges aquifers around Spring Creek is of good quality and records show that groundwater has a salinity between 200 and 1000 mg/L TDS. Table 7 lists the current monitoring wells and their initial and latest salinities.

Table 7. Spring Creek salinity monitoring wells.

Observation Well no.	Unit number	Initial Salinity^ (mg/L TDS)	Latest Salinity (mg/L TDS)*	Change in Salinity (mg/L TDS)
GRG 5	653200983	431	438	+ 7
GRG 6	653201017	285	308	+ 23
GRG 8	653201010	308	512	+ 204
GRG 10	653208185	1140	2579	+ 1439

* Latest salinity refers to most recent salinity taken 29/09/2005.

^ Initial salinity refers to historical salinity level taken at commencement of monitoring.

Willochra Plain

Monitoring wells on the Willochra Plain include those constructed into Tertiary and Quaternary sediments and are located between Wilmington and a line approximately 13 km to the east-northeast.

WLR 12 monitors the Tertiary Aquifer on the Willochra Plain close to where irrigation of lucerne takes place. Readings recorded in the state drillhole database SA Geodata show that salinity has remained relatively constant since the commencement of monitoring in 1990. Other monitoring wells in the area (WLR 13, WLR 15) monitor shallow Quaternary Aquifers to depths less than 15 m. These have a much higher salinity (6500 mg/L TDS) and are suitable for stock watering purposes only. Records from Obswell show that there is no consistent trend with regard to rise or fall in salinity.

Table 8. Willochra Plain Salinity Monitoring Wells.

Observation Well no.	Unit number	Initial Salinity^ (mg/L TDS)	Latest Salinity (mg/L TDS)*	Change in Salinity (mg/L TDS)
WLR 12	653201296	558	603	+ 45
WLR 13	653201143	6460	6682	+ 222
WLR 15	653201128	7510	6378	- 1132

* Latest salinity refers to most recent salinity taken 29/09/2005.
^ Initial salinity refers to historical salinity level taken at commencement of monitoring.

The remaining monitoring wells on the Willochra Plain are wells WLR 4 and WLR 6. These are constructed into Quaternary sediments at depths less than 40 m (SA Geodata, 2005). WLR 4 has a current salinity of 1373 mg/L TDS, and has seen a rise of more than 200 mg/L since 1987. WLR 6 has a salinity of 5965 mg/L TDS, and has dropped in salinity by 2700 mg/L TDS since 1975.

Melrose Town Water Supply

The Melrose Town Water Supply is monitored from extraction well 653201383 (GRG 18) located approximately 4.5 km north east of the town. This well is constructed into basement rock of the Adelaide Geosyncline (Gilbert Range Quartzite) but is understood to be in connection with the main Tertiary Aquifer (Read, 1991). Its initial salinity taken in April 1992 gave a reading of 1317 mg/L TDS. The latest reading taken in March 2003 had a salinity of 1546 mg/L TDS corresponding to a rise of some 229 mg/L in 11 years.

Table 9. Melrose TWS salinity monitoring well.

Observation Well no.	Unit number	Initial Salinity^ (mg/L) TDS	Latest Salinity (mg/L)* TDS	Change in Salinity (mg/L) TDS
GRG 18	653201383	1317	1546	+ 229

* Latest salinity refers to most recent salinity taken 29/09/2005.
^ Initial salinity refers to historical salinity level taken at commencement of monitoring.

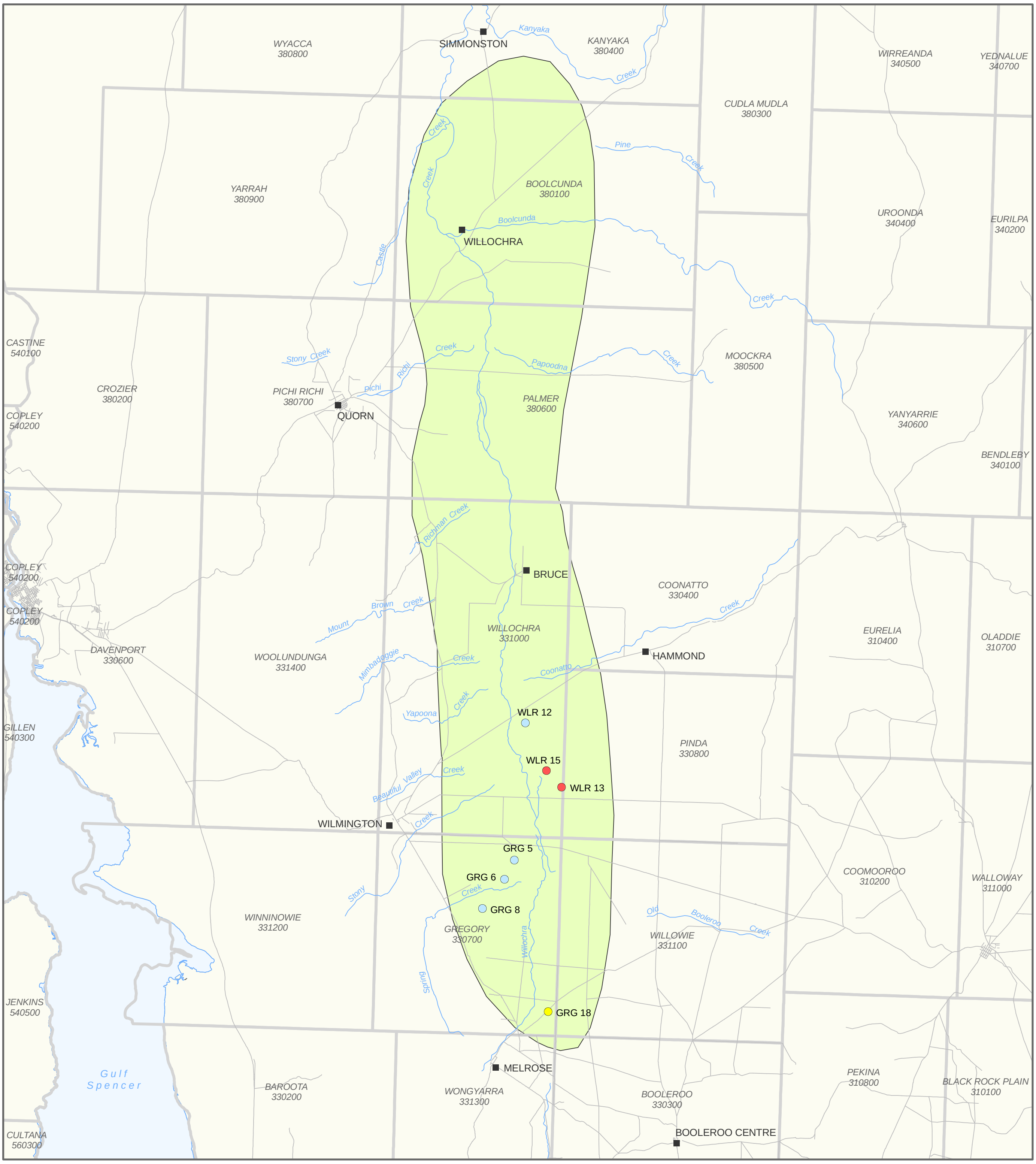


Figure 11.
Willochra Basin Salinity Monitoring Wells

Town

Drainage

Road

Willochra Basin

Hundred Boundary

NYAD Boundary

Monitoring Wells TDS

200 - 1000

1001 - 1500

1501 - 2000

> 2000

Obs. No

WLR 12

N

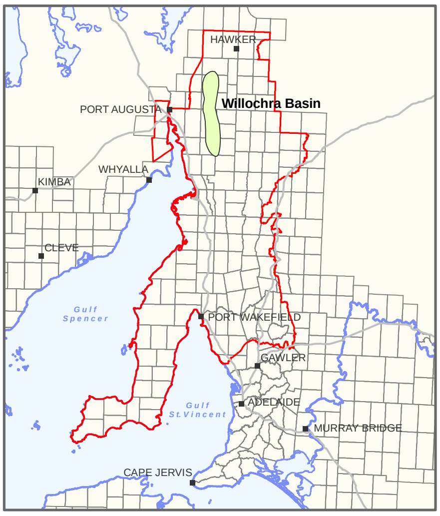
0 5 10 km

GDA

Datum: Geocentric Datum of Australia 1994 South Australia Lambert
Projection: Lambert Conformal Conic

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Produced by: Water Information Group
Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
Date: November 2005



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10. DISCUSSION

The capacity of the Plain/Basin to sustain highly intensive agriculture is limited by duplex and sodic soils in the north, which improve to the south and coupled with higher rainfalls give rise to cereal cropping and to some extent, irrigated horticulture. Irrigation currently takes place from a number of aquifers and includes pumping from Quaternary and fractured rock aquifers around Wilmington; Quaternary Aquifers at Spring Creek; Confined Tertiary Aquifer on the Willochra Plain and Fractured rock aquifers in the southern hills. Further extractions for TWS occur from basement rock (Melrose), fractured rock at Spring Creek Mine (Wilmington) and fractured rock in the eastern hills for Hammond/Willowie.

Basin wide, an estimated 1750 ML/yr is used which includes use for irrigation, reticulated supplies, domestic and stock.

Of interest to note is the water use for irrigation from the Tertiary Confined Aquifer (Chapter 5). Work done by O'Driscoll (1956) suggested a safe yield from this aquifer in the vicinity of 400 ML/yr. Current usage is estimated at 380 ML/yr for irrigation, with a conservative value for stock at 700 ML/yr, giving total use at 1000 ML/yr. Although there are only 2 wells that monitor this aquifer there appears to be no long term declines.

Climatic trends show that there has been below average rainfall between 2002-2005 and standing water levels in Quaternary Aquifers have fallen considerably. The deeper Tertiary Confined Aquifer has not shown significant declines, suggesting that this aquifer has a higher storage capacity. Saying this however, the Tertiary Aquifer is the most modified of all those in the area, in the fact that it receives the highest volume of extraction from irrigation, stock and the Melrose TWS*. It may be that extractions have kept potentiometric heads lower and stable over a longer period, and may return to a higher head if extractions were reduced.

The concerns for falling groundwater levels was noted during the public meeting. Most people believed that the current period has been the driest in recent memory, which has resulted in the drying of permanent springs and waterholes, salinisation of wells and general lowering of the watertable. Concerns were raised on the use of flood irrigation practises by the diversion of streamflow in the upper parts of the catchment, which reduce the volume of surface water flowing through the catchment. Anecdotal evidence suggests that loss of flow in the Willochra Creek is putting stress on dependent ecosystems/vegetation (Risby et al, 2003). During the meeting it was suggested that a water resource group be established to discuss this issue and develop strategy for sharing arrangement of surface and groundwater resources in the district.

*The Melrose TWS supply is constructed into basement rock. Quality and pressure is similar to that of the overlying Tertiary Sediments, and connection is presumed.

The State Water Plan makes allowances for environmental water requirements, but without prescription there is little weight to the plan that can enforce change to water use practise. The best way to protect all users (including environmental) is prescription.

The other issue raised during consultations was the salinisation of groundwater that may have been caused by either corrosion of steel casing or poor well construction. In one such example a well that was previously used for garden watering increased considerably in salinity over a short period. Given the age of the well it is assumed that this rise is attributed to mixing between aquifers caused by corrosion of the well casing (Hancock, pers. comm. 2005). Given the history of settlement of the Willochra Basin, the number of stock bores that have been drilled into the basin sediments, and poor construction techniques of bores drilled prior to 1976 (Read, 1979), a rehabilitation program isolating, repairing and backfilling disused wells may need to be considered in the future to ensure the integrity of groundwater resources is maintained.

Properly managed, the water resources in the Willochra Region has the potential to supply good quality groundwater in the years to come, but it is important that action is taken to ensure that all major users; social, economic and environmental receive their fair portion of use. At this stage the environmental benefits of surface and groundwater systems are being neglected the most.

11. RECOMMENDATIONS.

- Restrict further use of groundwater resources for high level water use particularly in the Wilmington area.
- Consider regulation of groundwater and surface water resources, in particular the development of policy on the use of surface flows for flood irrigation.
- Consider a rehabilitation assessment program for abandoned wells to identify old, abandoned and leaky wells that maybe causing detrimental impact to fresh groundwater resources.

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13. GLOSSARY

Alluvial Applied to the environments, actions and products of rivers or streams. Alluvial deposits (alluvium) are clastic, detrital materials transported by a stream or river and deposited as the river floodplain.

Alluvium *See alluvial

Anticline An arch shaped fold in rocks, closing upwards, with the oldest rocks found in the core.

Aquifer An underground layer of rock or sediment which holds and transmits economic quantities of water and allows water to percolate through.

Australian Height Datum (AHD) The datum used for the determination of elevations in Australia. The determination set mean sea level as zero elevation.

Bore (also called a 'well') (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water (groundwater).

Catchment A catchment is an area of land that is surrounded by high topographic features such as hills or ridges. An imaginary line that runs along the highest point through that high ground defines its boundary. All surface water within this bounded region has the potential to flow to the lowest point in the catchment.

Datum The reference point from which elevations are measured. Given the value of zero mAHD.

Depth to Water (DTW) The distance from the reference point to the water surface (that is not affected by pumping). Usually measured in metres.

Geographic Information System (GIS) Computer software that allows for the linking of geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis.

Ground Elevation The elevation of the ground surface above the datum. Units are in mAHD.

Groundwater Water occurring naturally below ground level or water pumped, diverted or released into a bore for storage underground.

Hydraulic Conductivity In general, the ability for a rock, sediment or soil to permit fluids to flow through it.

Hydrogeology The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. (See: hydrology)

Hydrology The study of the characteristics, occurrence, movement and utilisation of water on and below the earth's surface and within its atmosphere.(See: hydrogeology)

Neoproterozoic The most recent part of the Proterozoic, from about 1000-575 million years ago.

Piedmont The tract of country at the foot of a mountain range.

Pleistocene The first of two epochs of the Quaternary Period, conventionally thought to have lasted from 1.64 Ma to 10, 000 years ago at the beginning of the Holocene.

Potentiometric Surface A hypothetical surface defined by the level to which water in a confined aquifer rises in observation boreholes. In practise, the potentiometric surface is mapped by interpolation between borehole measurements.

Quaternary A sub era of the Cainozoic Era that covers the last 1.64 million years. The Quaternary comprises of the Pleistocene and Holocene Epochs.

Reduced Standing Water Level (RSWL) The elevation of the water level, typically measured in mAHD. It is calculated by subtracting the depth to water from the reference elevation.

Reference Elevation The elevation of the reference point above the datum measured in mAHD.

Reference Point The point at the surface from where the depth to water is measured. Sometimes called the 'stick up'.

Standing Water Level (SWL) The distance from the natural ground surface (natural surface) to the water surface. Usually measured in metres.

Transmissivity The rate at which groundwater is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

14. SI UNITS COMMONLY USED WITHIN TEXT

Name of unit	**Symbol**	**Definition in terms of other metric units**	
Millimetre	mm	10^{-3} m	length
Metre	m		length
Kilometre	km	10^{3} m	length
Hectare	ha	10^{4} m^{2}	area
Microlitre	µL	10^{-9} m^{3}	volume
Millilitre	mL	10^{-6} m^{3}	volume
Litre	L	10^{-3} m^{3}	volume
Kilolitre	kL	1 m^{3}	volume
Megalitre	ML	10^{3} m^{3}	volume
Gigalitres	GL	10^{6} m^{3}	volume
Microgram	µg	10^{-6} g	mass
Milligram	mg	10^{-3} g	mass
Gram	g		mass
Kilogram	kg	10^{3} g	Mass

Abbreviations Commonly Used Within Text

Abbreviation		**Name**	**Units of measure**
TDS	=	Total Dissolved Solids *(milligrams per litre)*	mg/L
EC	=	Electrical Conductivity *(micro Siemens per centimetre)*	µS/cm
PH	=	Acidity	
δD	=	Hydrogen isotope composition	$^{o}/_{oo}$
CFC	=	Chlorofluorocarbon *(parts per trillion volume)*	pptv
$\delta^{18}O$	=	Oxygen isotope composition	$^{o}/_{oo}$
^{14}C	=	Carbon-14 isotope *(percent modern Carbon)*	pmC
Ppm	=	Parts per million	
Ppb	=	Parts per billion	

APPENDIX A. SURVEY FORM – WATER USE

Department of Water, Land and Biodiversity Conservation

Northern and Yorke Agricultural District INRM Committee

Water Use Survey

Catchment (please circle)	Willochra Ck; Broughton River; Booborowie Valley, Mambray Coast.	Other	

Owner(s) Name(s)				Address		
Postcode		**Phone**		**Fax**		
Alternative Contact				Preferred contact method		

Source of Water used (for more than one source, additional tables at end of survey)

Source Type	Dam:		Watercourse Diversion:		Underground:		Source ID:				
Underground Only	Well Unit number (if known)		Casing/Outlet Size				Salinity				
Dam Only	Type		Surveyed Capacity		Wall Height		Surface Area (m²)				
Pump Type/Power			Pump Pipe Size		Pump Flow Rate		Photo				
Easting		Northing		Interim Source		Destination					
Comments :											

Do you have any disused/abandoned wells

Location (parcel)		Year last used	
Comments (eg rusted out, collapsed, too saline):			

1.1.1 IRRIGATION WATER USE QUESTIONNAIRE

Crop	Period of Irrigation		Hours per Irrigation	Number of Irrigations	Amount Applied	Emitter Type/Output	Irrigated Every Year (Y/N)
	From	To					

Report Nu 9

Predominant Soil Type		**Method of Irrigation**	

Further Comments

Local history and knowledge of resource use is valuable information. Please feel free to record any recollections you have regarding changes to resource condition or the levels of water-use that have occurred during your time in the region. Additional information relating to climate, such as unusually dry or wet periods is also of interest. (Attach further pages if required)

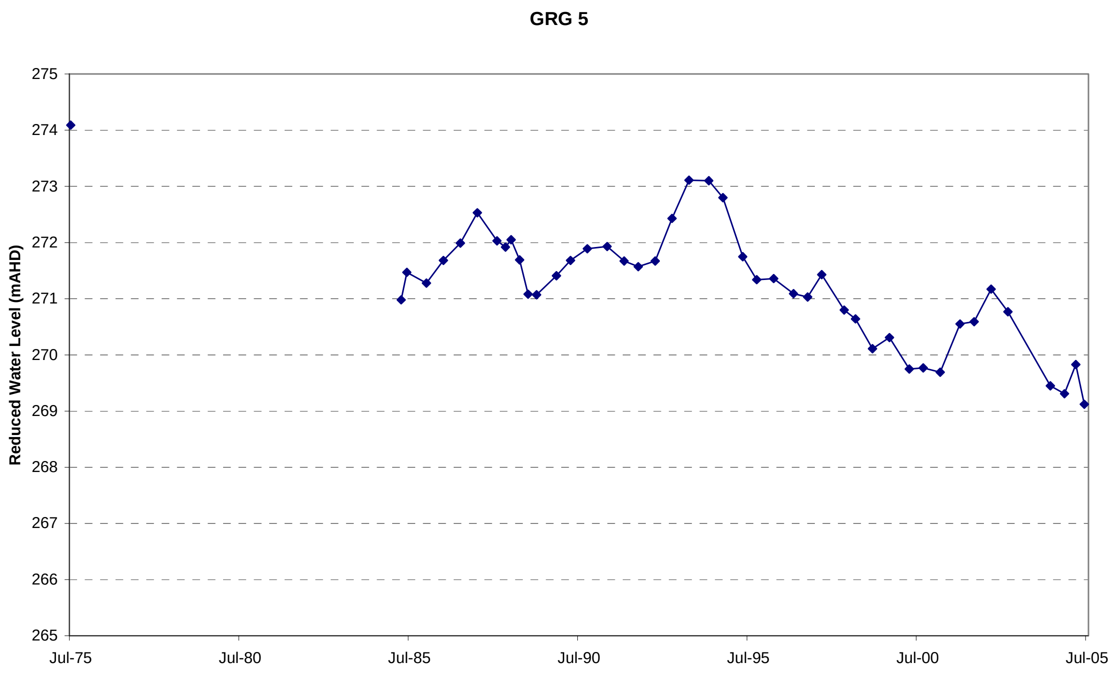
Resource condition – please record any concerns you have regarding the resource that should be considered for future management

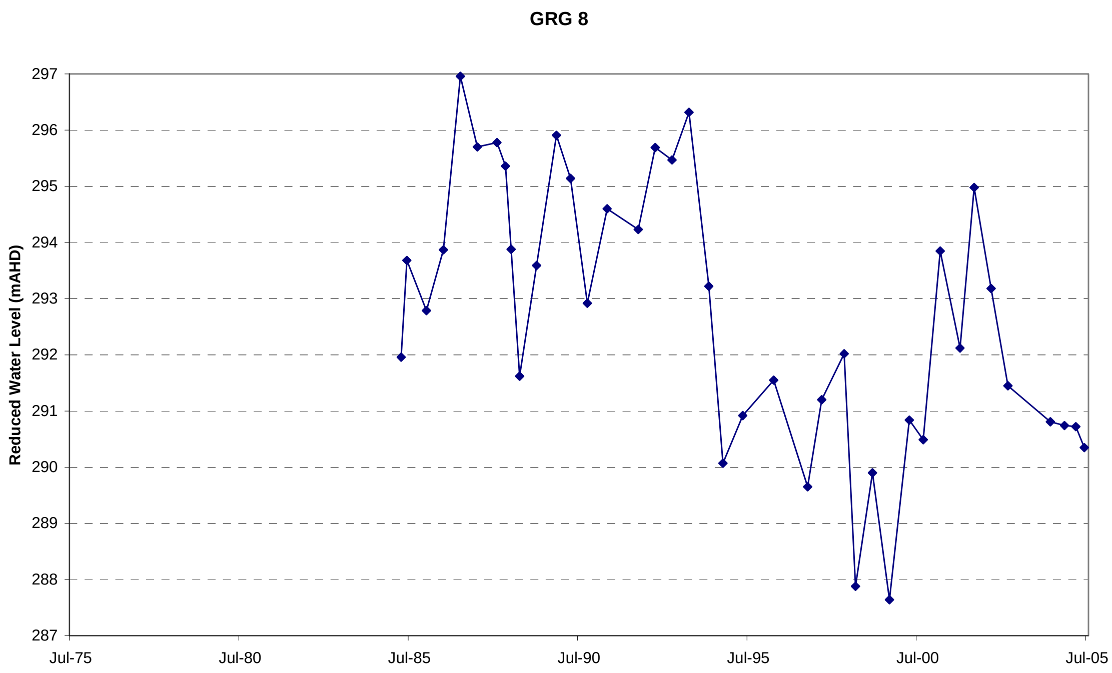
Name of person completing survey: ………………………………………….. Contact Telephone……………………..…………..

Date : …………..

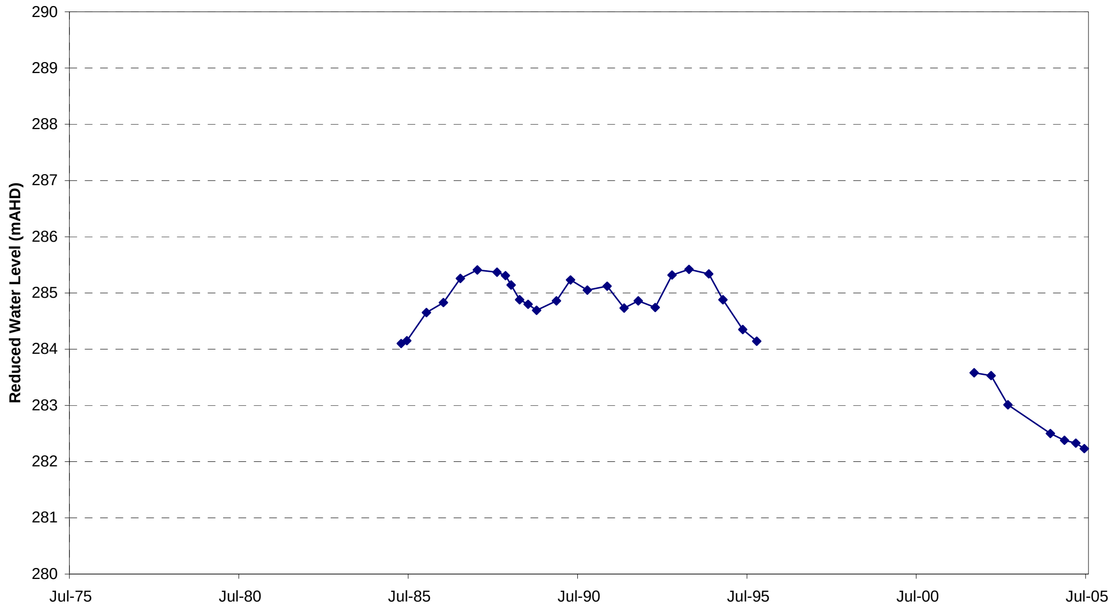
**** Thank you for your assistance ****

APPENDIX B. SWL OBSERVATION WELLS – QUATERNARY AQUIFERS





GRG 9



Reduced Water Level (mAHD)
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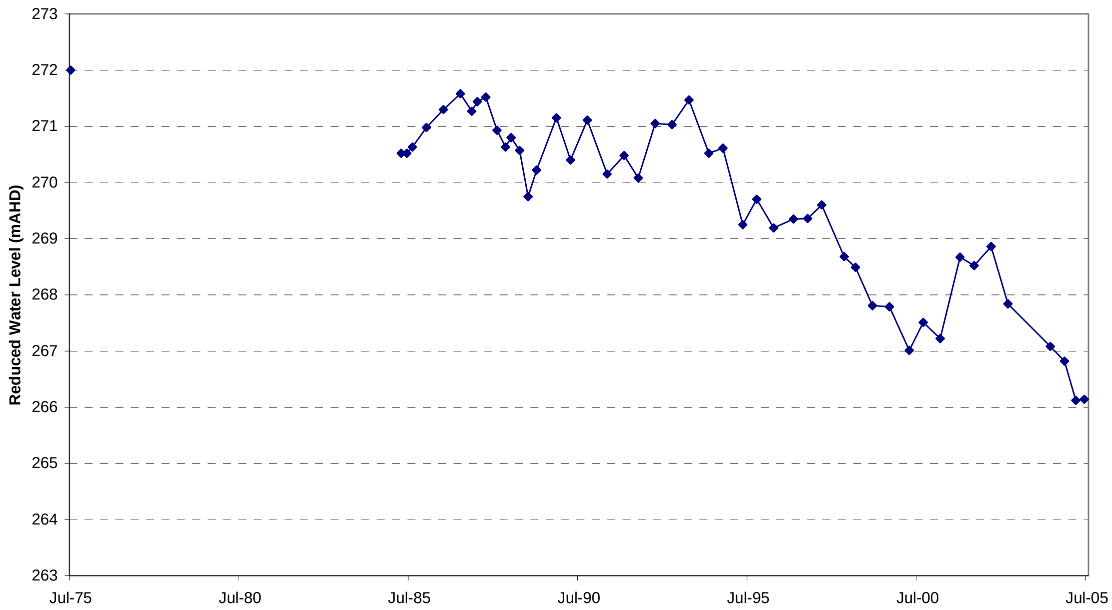
Jul-00
Jul-05

GRG 10



Reduced Water Level (mAHD)
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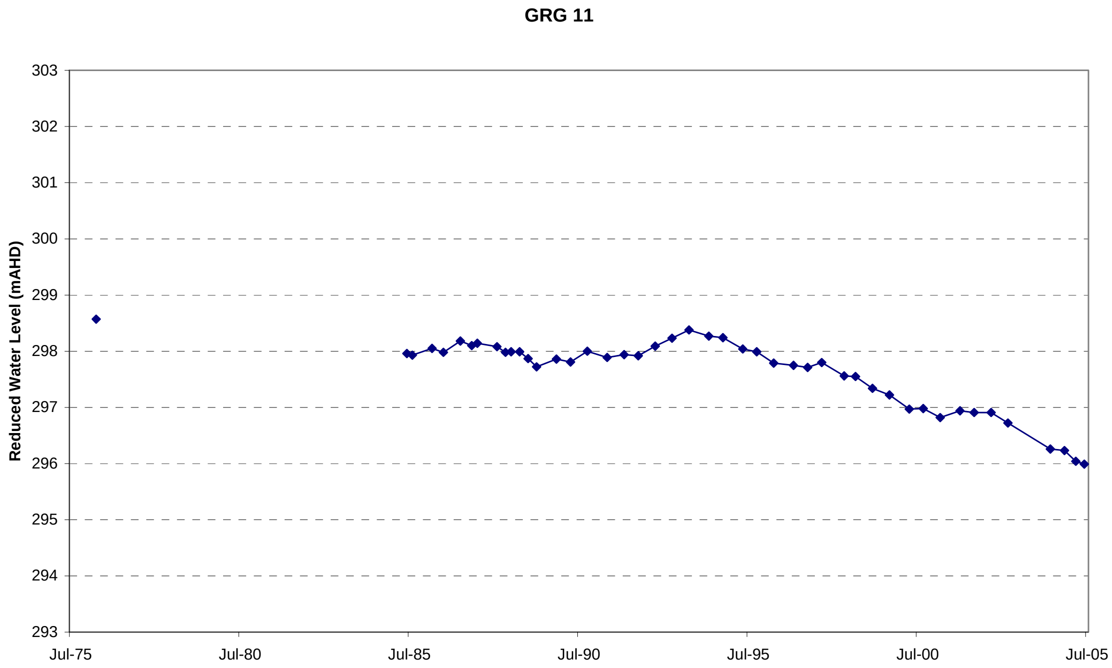
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Reduced Water Level (mAHD)
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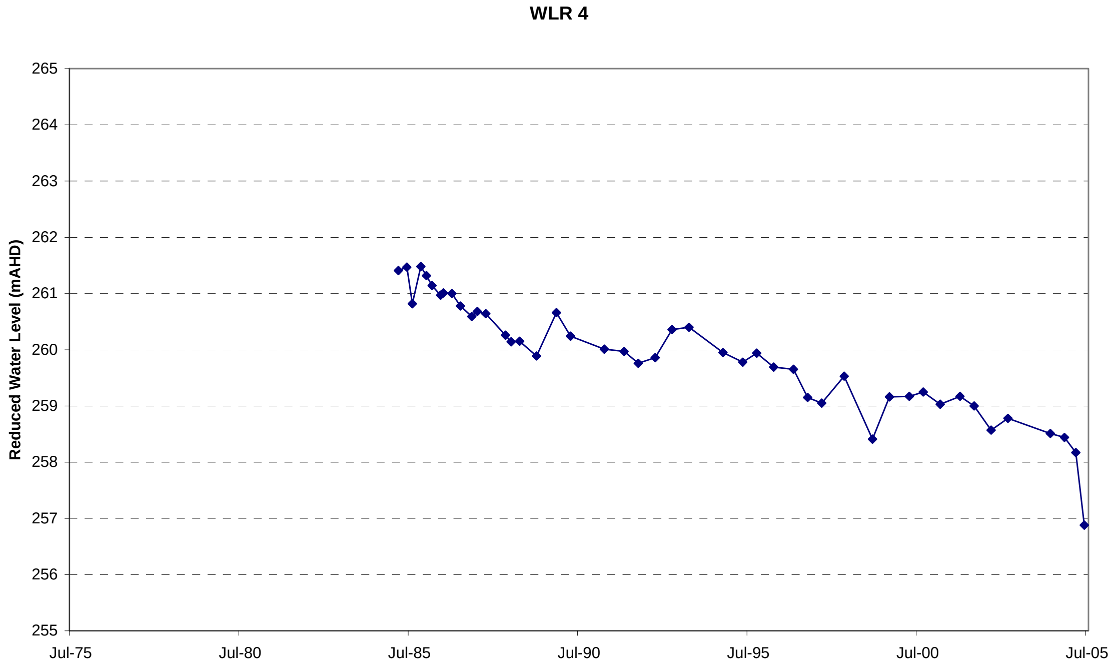
WLR 4
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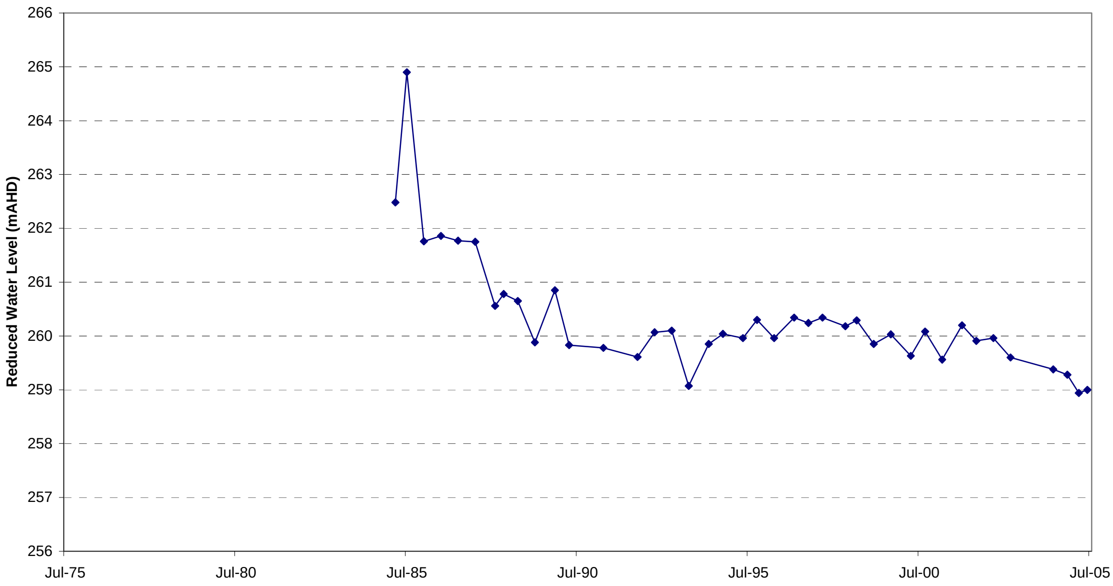
WLR 5


Reduced Water Level (mAHD)
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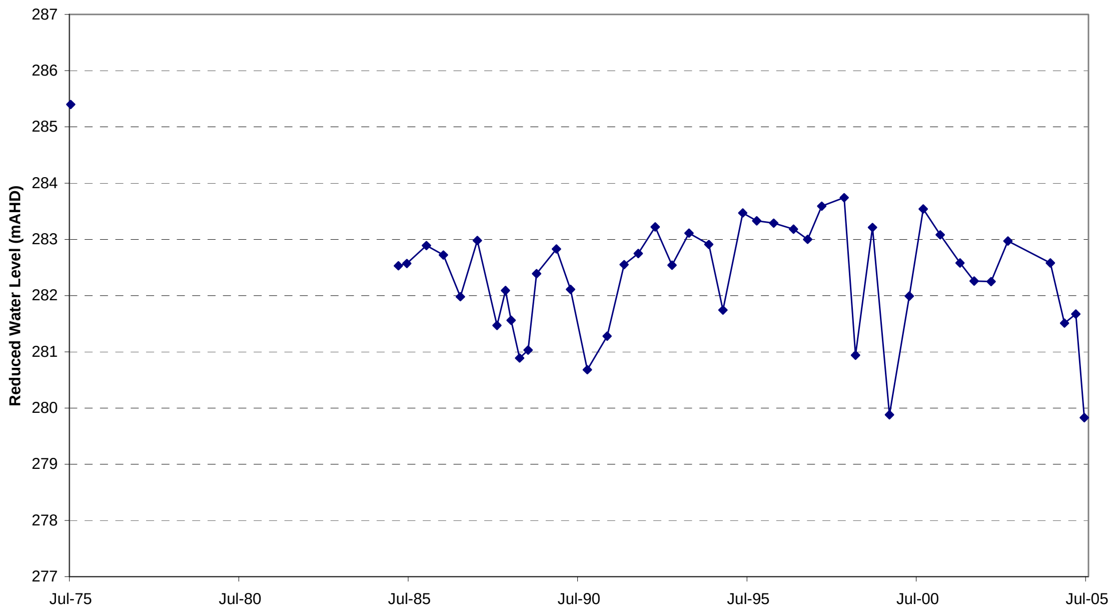
WLR 6


Reduced Water Level (mAHD)
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Jul-05


WLR 7
Reduced Water Level (mAHD)
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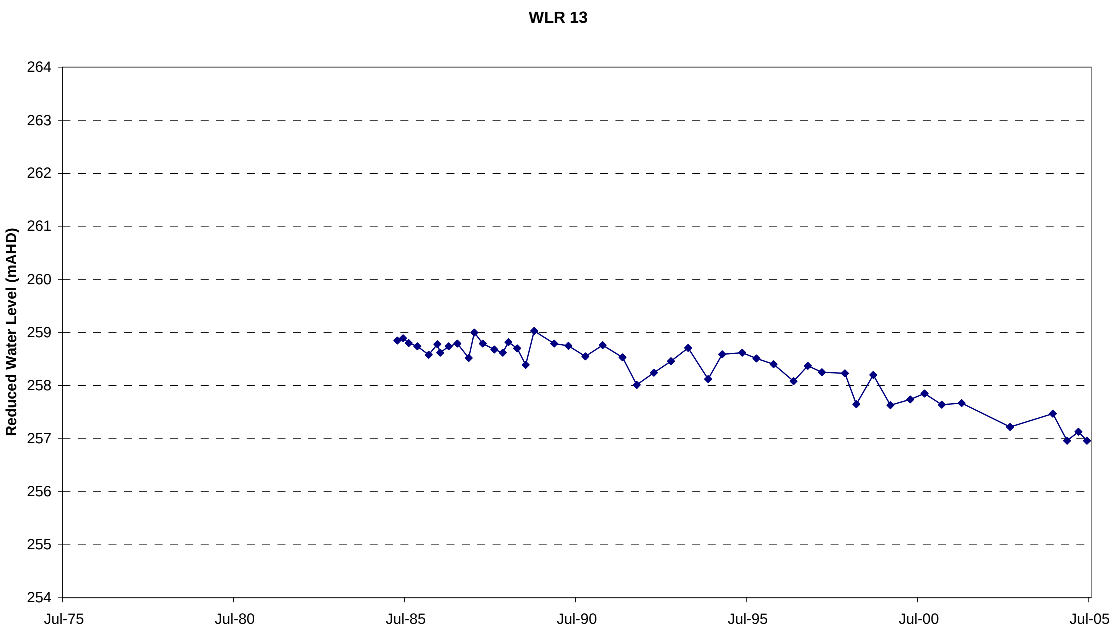
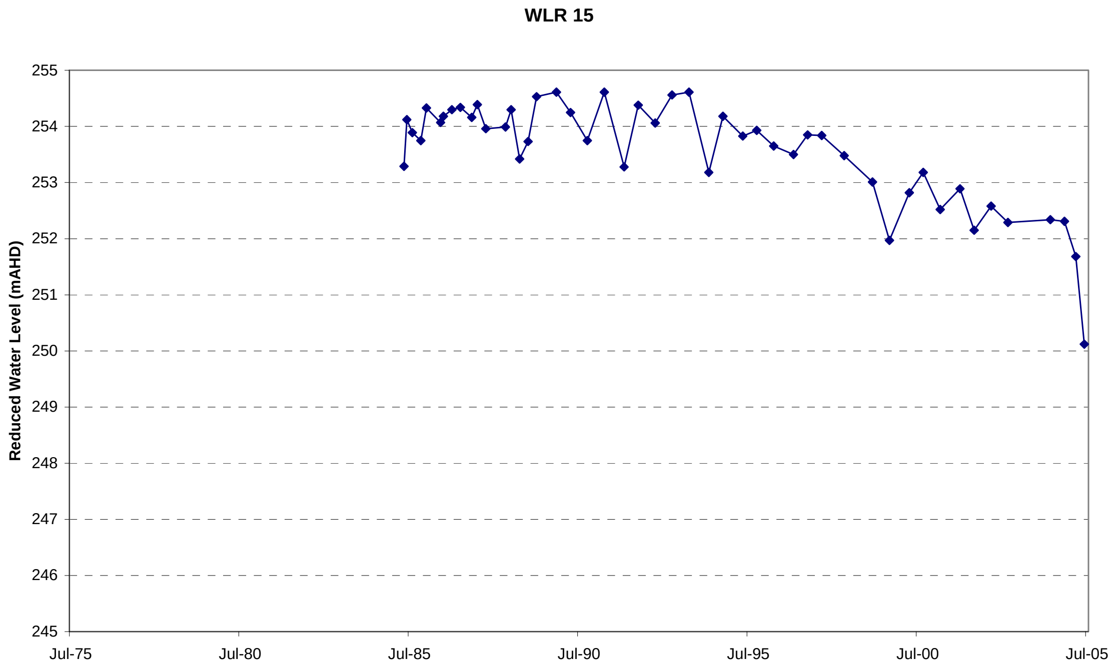
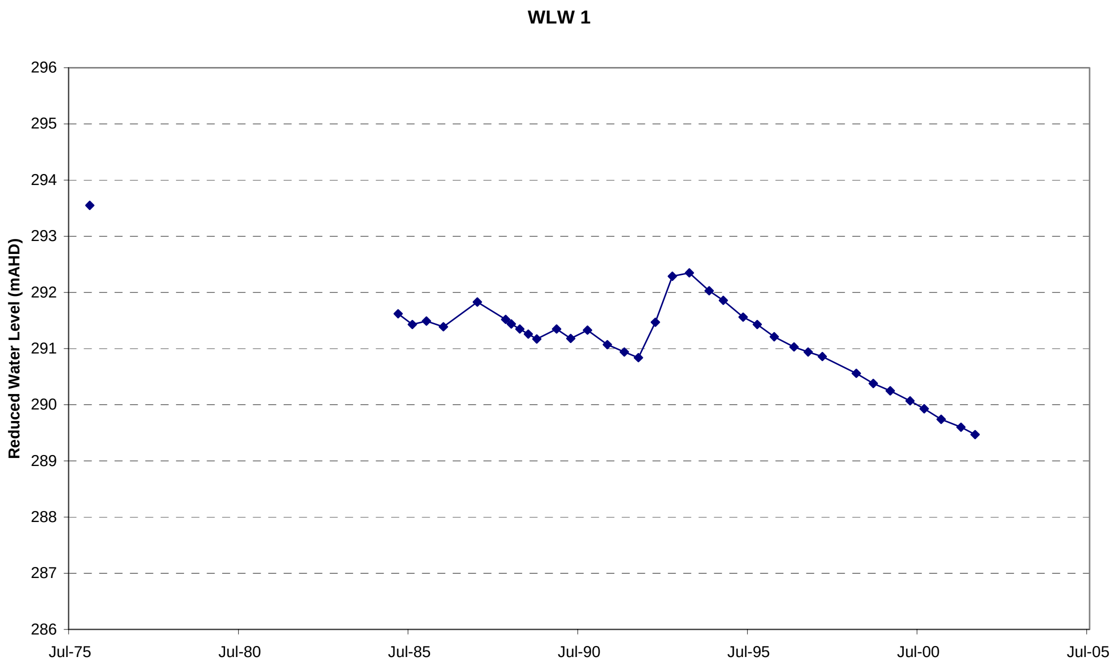
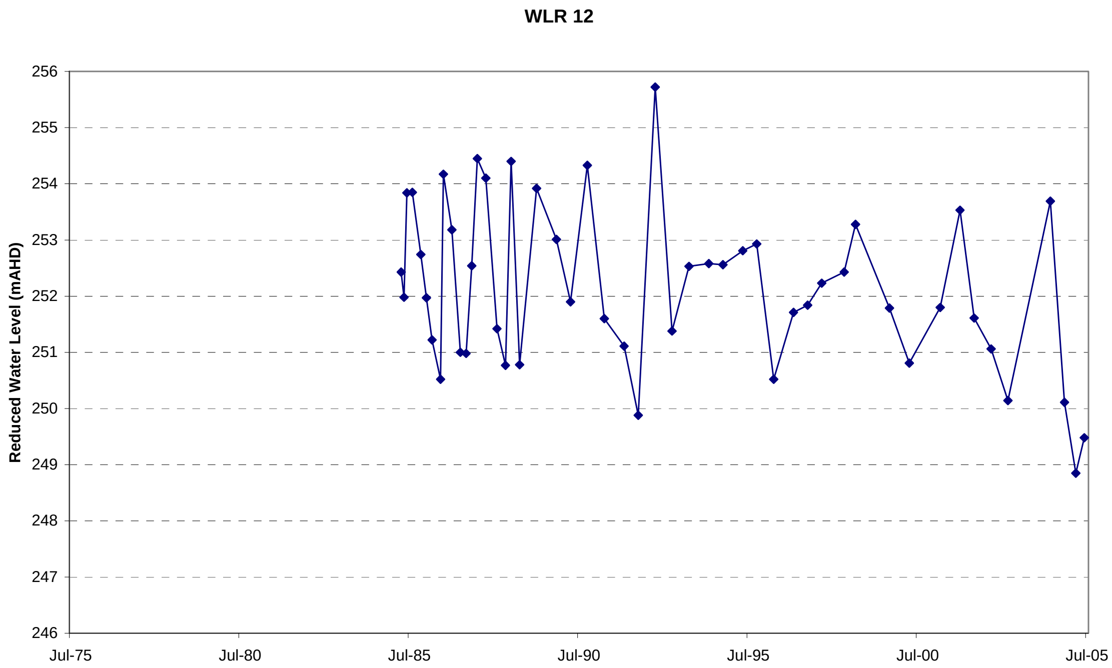
259
258
257
256
255
Jul-75
Jul-80
Jul-85
Jul-90
Jul-95
Jul-00
Jul-05

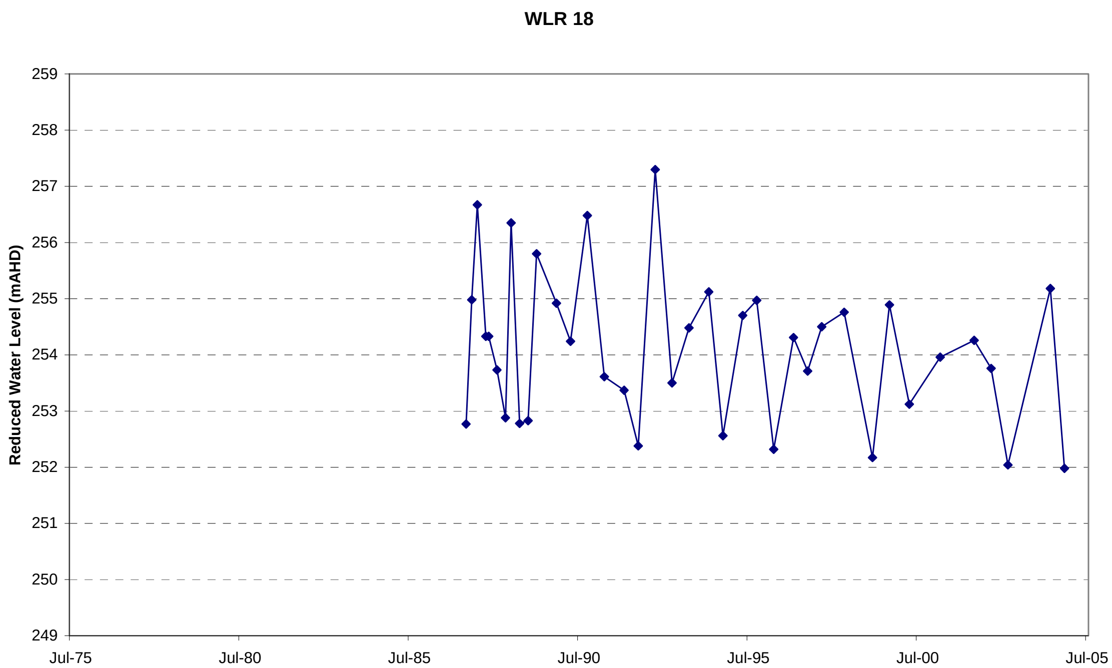

WLR 13
Reduced Water Level (mAHD)
264
263
262
261
260
259
258
257
256
255
254
Jul-75
Jul-80
Jul-85
Jul-90
Jul-95
Jul-00
Jul-05


WLR 15
Reduced Water Level (mAHD)
255
254
253
252
251
250
249
248
247
246
245
Jul-75
Jul-80
Jul-85
Jul-90
Jul-95
Jul-00
Jul-05


WLW 1
Reduced Water Level (mAHD)
296
295
294
293
292
291
290
289
288
287
286
Jul-75
Jul-80
Jul-85
Jul-90
Jul-95
Jul-00
Jul-05

APPENDIX C. SWL OBSERVATION WELLS – TERTIARY AQUIFER





APPENDIX D. SWL OBSERVATION WELLS – FRACTURED ROCK AQUIFER