DWLBC REPORT

Mount Lofty Ranges Groundwater Assessment - South Para River Catchment

2005/41

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

Mount Lofty Ranges Groundwater Assessment — South Para River Catchment

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

March 2006

Report DWLBC 2005/41

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

Knowledge and Information Division

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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

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EXECUTIVE SUMMARY

The South Para River Catchment is underlain by fractured rock aquifers which contain groundwater of varying salinity and yield. The availability of groundwater data is very limited for this catchment.

Since 1993, irrigated areas across the South Para River Catchment increased from 300–746 ha, mainly due to the expansion of vineyards in the Upper and Middle Catchments. However, these irrigated areas represent only ~2% of the total catchment area.

The current irrigation water use is estimated to be ~1555 ML, half of which is thought to be obtained from groundwater (~800 ML). The remainder of irrigation water needs are assumed to be met from the large dam storage of almost 3000 ML.

Recharge rates are estimated to vary between 13 mm/y (Upper Catchment) and 46 mm/y (Middle Catchment) or 2.5–8% of the effective rainfall. The low recharge rates estimated in the Upper Catchment are due to extensive plantation forests, native vegetation, and the underlying Kanmantoo Group rocks which generally demonstrate lower recharge rates. The highest recharge rates are estimated in the Middle Catchment where deep-rooted vegetation covers a smaller area and where highly permeable Adelaidean rocks are extensive. The rainfall is also relatively high in this area.

The estimated groundwater extraction of 800 ML/y is a relatively small compared to the estimated annual recharge of 9500 ML.

The water balances should be revised at regular intervals to take into account further changes in land use and irrigation practices, together with any additional information that will be available from more detailed investigations in the future.

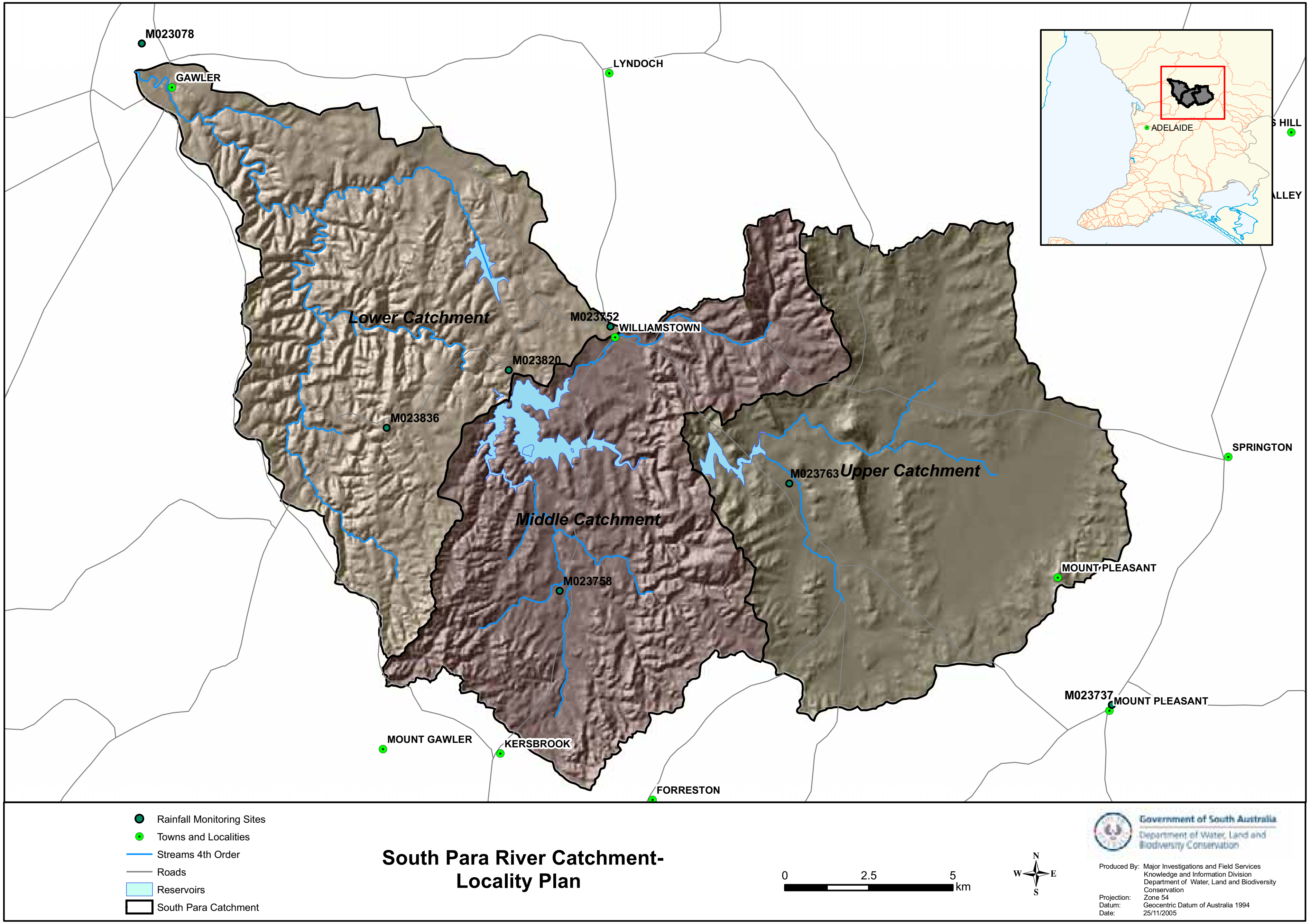
1. INTRODUCTION

The South Para River Catchment is located ~60 km northeast of Adelaide (Fig. 1). This catchment provides the major source of water for the Metropolitan Adelaide, Warren and Northern Water Supply Systems, as well as for domestic, stock and minor irrigation needs.

This report evaluates the groundwater resources in the South Para River Catchment using only existing information. It is a first-order assessment of the water balances in the South Para River Catchment, which covers a total area of 337 km^2 and consists of three sub-catchments: Upper, Middle and Lower. A broad-scale assessment of surface water data resources of the South Para River Catchment has already been carried out by DWLBC (Teoh 2003), and the streamflow modelling results were used for this study in the absence of stream gauging information and observed data.

The combined reservoir and farm dam storage in the catchment is 57.6 GL. The recent expansion of viticulture has increased demand for irrigation and increased pressure for more farm dam development and has the potential to increase demands for groundwater. Although there is no evidence of current over-extraction of groundwater in this catchment, it is important to gain an understanding of the extent and quality of the groundwater resources to assist in future management.

Shortfalls in data required for the efficient management of the water resources are identified, together with a recommendation for future management.


M023078
GAWLER
LYNDOCH
Lower Catchment
M023752
WILLIAMSTOWN
M023820
M023836
Middle Catchment
M023763
Upper Catchment
M023758
SPRINGTON
MOUNT PLEASANT
M023737
MOUNT PLEASANT
MOUNT GAWLER
KERSBROOK
FORRESTON
ADELAIDE
Rainfall Monitoring Sites
Towns and Localities
Streams 4th Order
Roads
Reservoirs
South Para Catchment
South Para River Catchment-
Locality Plan
0
2.5
5
km
N
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Government of South Australia
Department of Water, Land and Biodiversity Conservation
Produced By: Major Investigations and Field Services
Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
Projection: Zone 54
Datum: Geocentric Datum of Australia 1994
Date: 25/11/2005

Figure 1

2. GEOLOGY

The South Para River Catchment is underlain by consolidated basement rocks. At the lowest points in the catchment adjacent to the drainage lines, alluvial sediments have been deposited.

2.1 BASEMENT ROCKS

2.1.1 Barossa Complex

The Barossa Complex consists of gneiss, schist and pegmatite, which were subject to metamorphism at high temperatures and pressures deep in the earth's crust (Fig. 2). They are the oldest rocks in the Mount Lofty Ranges (MLR), occurring in the centre of large folds, and have been exposed by erosion to form the Houghton Inlier. The Barossa Complex forms the basement to the overlying Adelaidean sedimentary rocks.

The Houghton Inlier is located to the south and southwest of the South Para Reservoir in the Middle and Lower Catchments. Another less extensive outcrop surrounds the Warren Reservoir between the Upper and Middle Catchments.

Adelaidean sedimentary rocks, although strongly folded, have been relatively unaffected by heat and pressure and therefore provide a record of depositional and climatic conditions that occurred ~1000 million years ago. The Adelaidean rock units are dominated by the Burra Group (Stonyfell Quartzite, Saddleworth Formation, Woolshed Flat Shale and Aldgate Sandstone) which consists mainly of siltstone, shale, and slate with minor interbeds of sandstone, quartzite and dolomite.

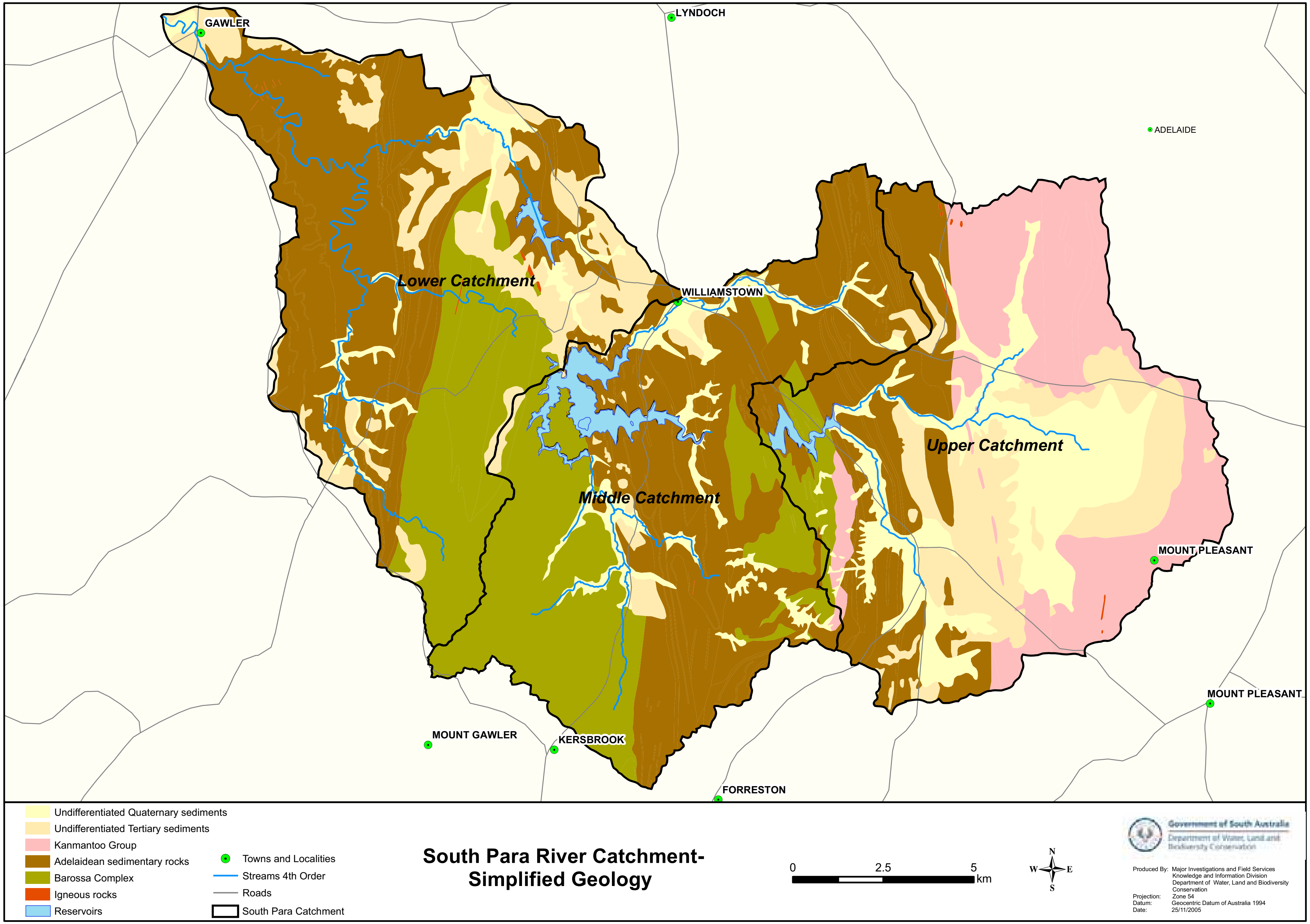
2.1.2 Kanmantoo Group

The Kanmantoo Group underlies the eastern part of the Upper Catchment area. A large trough was formed by rapid subsidence in a broad arc around the eastern side of the present MLR during the Cambrian period, ~500 million years ago. The feldspathic sandstone that infilled this trough was later metamorphosed by heat and pressure into greywacke, schist and gneiss with a thickness of ~21 km.

2.2 SEDIMENTS

Tertiary sediments consist of laterised deposits and ferruginised sands and gravels in the uplifted plateau areas.

Quaternary sediments consist of dark grey silt, clay and gravel that have been deposited along the South and Little Para rivers and other drainage lines, at the lowest points in the catchments.



GAWLER
LYNDOCH
ADELAIDE
Lower Catchment
WILLIAMSTOWN
Middle Catchment
Upper Catchment
MOUNT PLEASANT
MOUNT PLEASANT
MOUNT GAWLER
KERSBROOK
FORRESTON
Undifferentiated Quaternary sediments
Undifferentiated Tertiary sediments
Kanmantoo Group
Adelaidean sedimentary rocks
Barossa Complex
Igneous rocks
Reservoirs
Towns and Localities
Streams 4th Order
Roads
South Para Catchment
South Para River Catchment-
Simplified Geology
0
2.5
5
km
N
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S
Government of South Australia
Department of Water, Land and Biodiversity Conservation
Produced By: Major Investigations and Field Services
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Figure 2

3. REGIONAL HYDROGEOLOGY

In the South Para River Catchment, groundwater is mainly sourced from the fractured rock aquifer system, where groundwater is stored and moves through joints and fractures in the basement rocks. Groundwater moves from the higher points in the landscape (which are usually basement rocks around the catchment boundaries), towards the lowest areas where discharge normally occurs through the sedimentary aquifers in the valleys to the streams. This discharge constitutes the baseflow of the streams, which dominates flow for most of the year, particularly over the summer and between rainfall events (Barnett & Zulfic, 2000). Recharge to both these aquifers occurs directly from part of the rainfall, which percolates down to the watertable through the soil profile. Most of the rainfall runs off straight to the streams or is used by vegetation.

3.1 FRACTURED ROCK AQUIFERS

3.1.1 Barossa Complex

The Barossa Complex is generally considered to be a poor aquifer from which irrigation supplies are usually not obtained. These basement rocks are, in general, tight and impermeable with few open systems of fractures and joints in which groundwater is stored and transmitted. Clayey weathered materials have infilled joints and fractures. Soluble components of these materials can dissolve and raise the salinity of the groundwater. The clays can also restrict the infiltration of rainwater.

3.1.2 Adelaidean Sedimentary Rocks

The Adelaidean sediments have been relatively unaffected by the heat and pressure of metamorphism. They are considered good aquifers because the joints and fractures are open and permeable resulting in relatively high yields. Groundwater prospects are generally better in quartzite, sandstone and limestone units, while slates, shales and siltstones are more clayey and less permeable.

3.1.3 Kanmantoo Group

For similar reasons to the Barossa Complex the Kanmantoo Group aquifer is generally considered to be poor, with higher salinities also evident due to the lower rainfall to the east resulting in reduced flushing and recharge to this aquifer. Very few bores, mainly for stock supplies, are developed in this aquifer.

3.2 SEDIMENTARY AQUIFERS

The Quaternary sediments consist of alluvial deposits of river and creek channels, which have minor groundwater development for stock and domestic use.

4. CATCHMENT HYDROGEOLOGY

The South Para River Catchment is characterised by steep terrain and extends from Mount Pleasant in the east to Gawler in the west. Elevations range from 630 m at the northeast boundary to only 50 m on the western plain. Rainfall distribution is reflected in a similar manner, varying from 775 mm on the northern boundary to 475 mm on the western boundary. Three major reservoirs, with a combined storage of 54 600 ML, supply water to the Metropolitan Adelaide, Warren and Northern Water Supply Systems.

Based on the stream orders, the catchment is subdivided into three catchments: Upper, Middle and Lower (Teoh 2003).

4.1 UPPER CATCHMENT

The Upper Catchment covers an area of 119 km^2, with elevations varying from ~600 m AHD at the northeast boundary to ~400 m AHD at the lowest point of the catchment. The Warren Reservoir lies within the Upper Catchment storing 5100 ML of water.

Approximately 47% of the catchment is under plantation forests and native vegetation (mainly in the south), with an equal area of the catchment, generally to the north, being used for grazing. Only ~2% of the catchment is irrigated with the main crop being vines (Fig. 3).

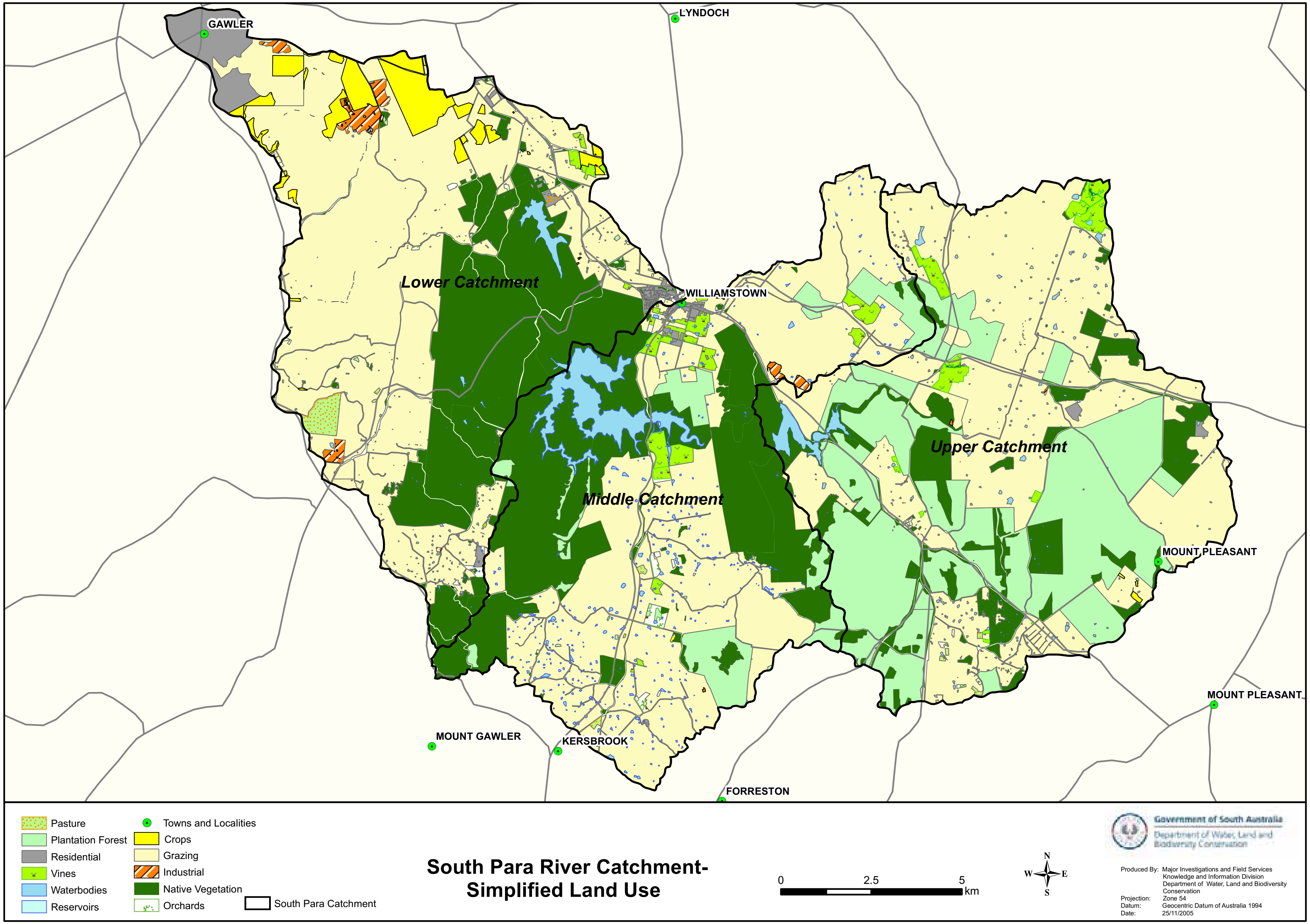
The rainfall is winter dominant with 70% of the annual rainfall occurring between May and October. Monthly and annual average rainfall data are shown in Table 1.

Table 1. Upper Catchment average monthly and annual rainfall (mm)

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann.	Period (y)
Mount Pleasant 23737	24	24	25	49	74	90	93	91	77	59	35	29	675	120
Williamstown Mt Crawford 23763	25	24	28	53	89	98	115	103	83	65	37	35	757	42

Most of the eastern portion of the catchment is underlain by metasediments of the Kanmantoo Group, with salinities generally between 3000–7000 mg/L (Fig. 4) and yields up to 1 L/s (Fig. 5).

The Adelaidean sediments comprise quartzite and shale in the western part of the catchment. These are the only rock types with low salinities, generally up to 1500 mg/L, and yields up to 5 L/s.


LYNDOCH
GAWLER
WILLIAMSTOWN
Lower Catchment
Middle Catchment
Upper Catchment
MOUNT PLEASANT
MOUNT PLEASANT
MOUNT GAWLER
KERSBROOK
FORRESTON
Pasture
Plantation Forest
Residential
Vines
Waterbodies
Reservoirs
Towns and Localities
Crops
Grazing
Industrial
Native Vegetation
Orchards
South Para Catchment
South Para River Catchment-
Simplified Land Use
0
2.5
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Government of South Australia
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Produced By: Major Investigations and Field Services
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Figure 3

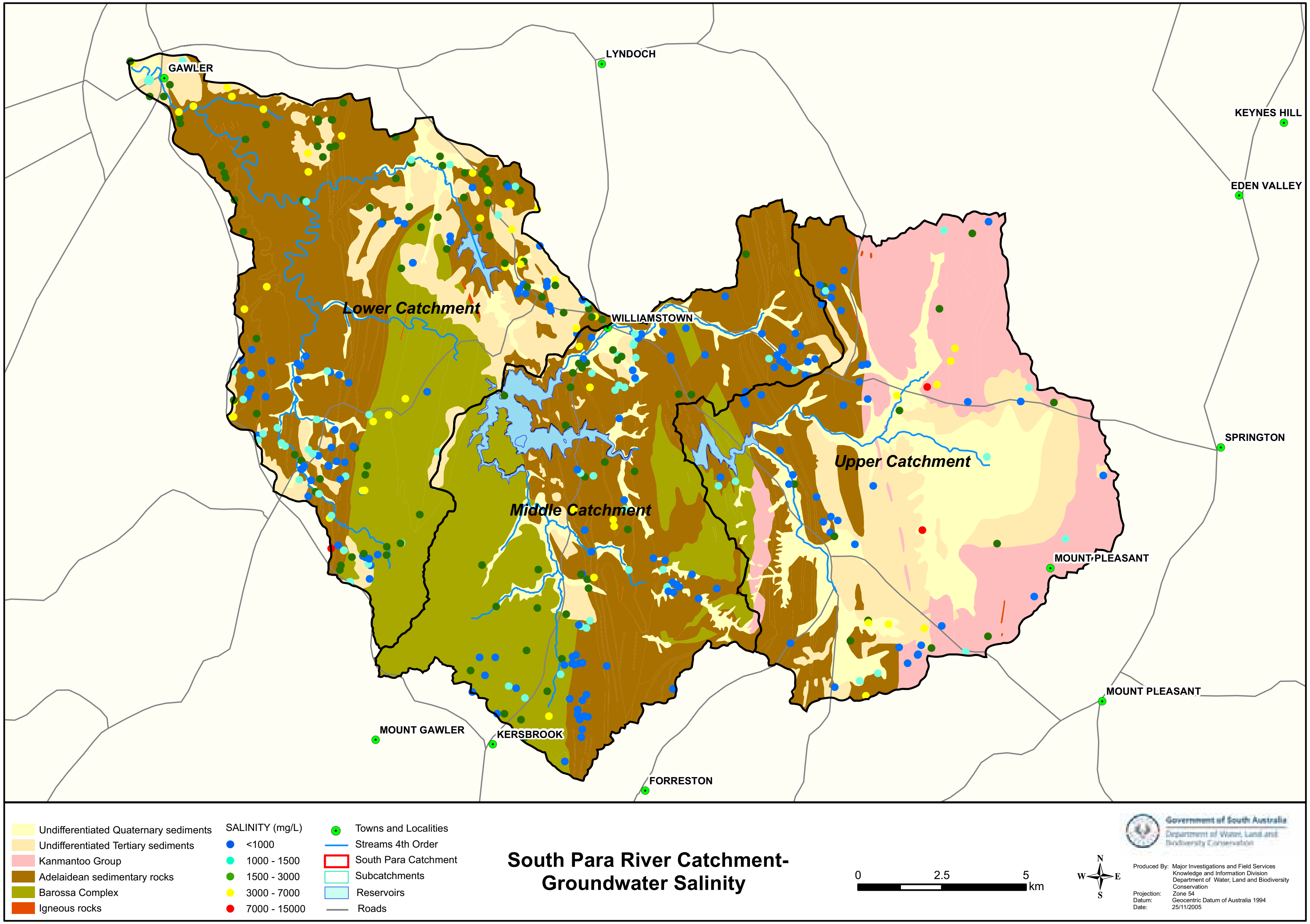
GAWLER
LYNDOCH
KEYNES HILL
EDEN VALLEY
WILLIAMSTOWN
Lower Catchment
Middle Catchment
Upper Catchment
SPRINGTON
MOUNT PLEASANT
MOUNT PLEASANT
MOUNT GAWLER
KERSBROOK
FORRESTON
Undifferentiated Quaternary sediments
Undifferentiated Tertiary sediments
Kanmantoo Group
Adelaidean sedimentary rocks
Barossa Complex
Igneous rocks
SALINITY (mg/L)
<1000
1000 - 1500
1500 - 3000
3000 - 7000
7000 - 15000
Towns and Localities
Streams 4th Order
South Para Catchment
Subcatchments
Reservoirs
Roads
South Para River Catchment-
Groundwater Salinity
0
2.5
5
km
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Figure 4

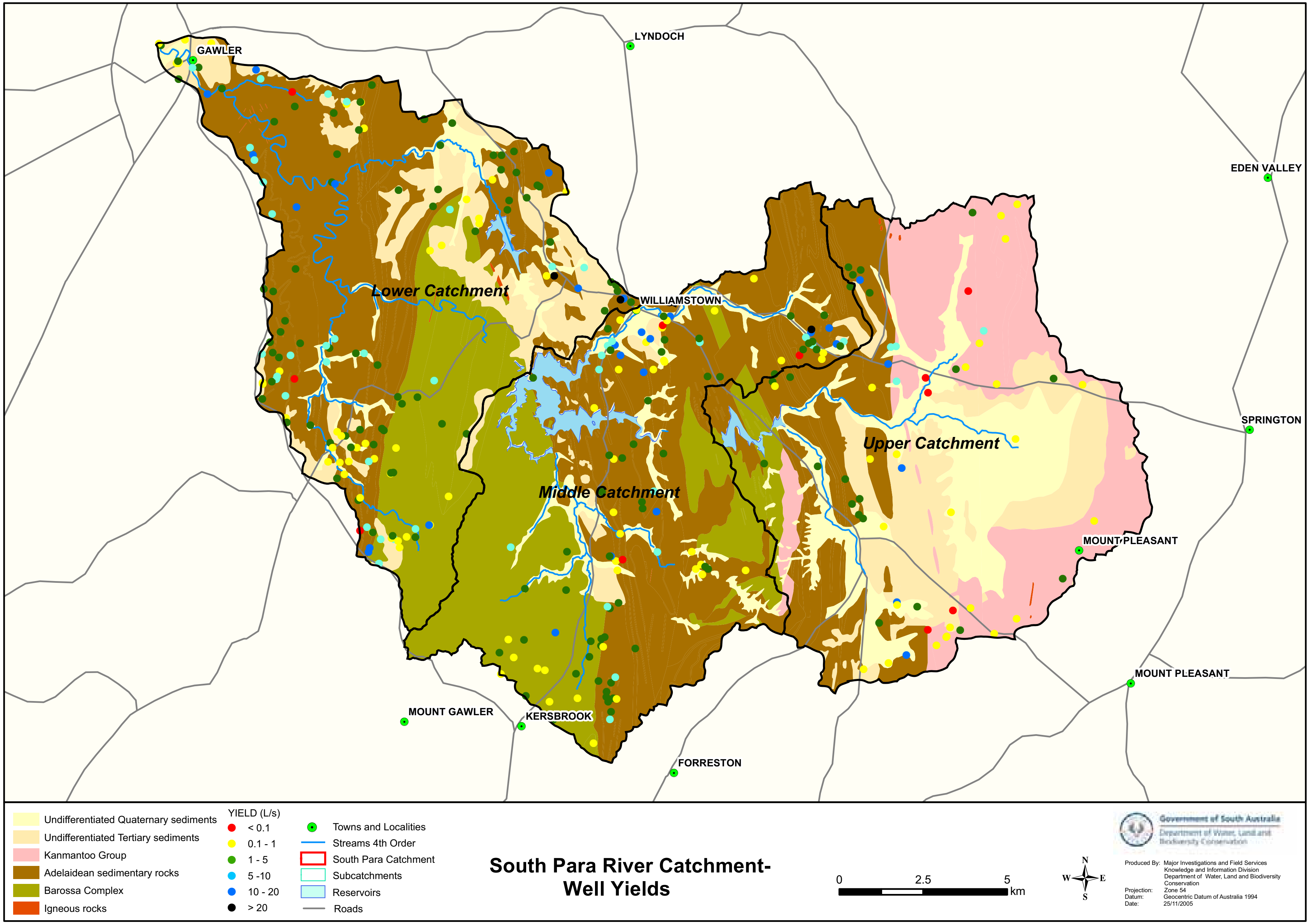
GAWLER
LYNDOCH
EDEN VALLEY
WILLIAMSTOWN
Lower Catchment
Middle Catchment
Upper Catchment
SPRINGTON
MOUNT PLEASANT
MOUNT PLEASANT
MOUNT GAWLER
KERSBROOK
FORRESTON
Undifferentiated Quaternary sediments
Undifferentiated Tertiary sediments
Kanmantoo Group
Adelaidean sedimentary rocks
Barossa Complex
Igneous rocks
YIELD (L/s)
< 0.1
0.1 - 1
1 - 5
5 -10
10 - 20
> 20
Towns and Localities
Streams 4th Order
South Para Catchment
Subcatchments
Reservoirs
Roads
South Para River Catchment-
Well Yields
0
2.5
5
km
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Figure 5

4.2 MIDDLE CATCHMENT

The Middle Catchment covers an area of 108 km^2, with elevations ranging from ~450 m AHD at Mount Crawford Forest, south of Kersbrook, to ~230 m AHD near Williamstown. The South Para Reservoir is within the Middle Catchment storing 45 000 ML.

The main land use in the catchment is grazing which occupies ~52% of the total area, with ~38% being covered by native vegetation and plantation forests. Only ~3% of land is under vineyards and orchards, mainly in the north near the township of Williamstown (Fig. 3).

Rainfall is winter dominant with monthly and annual average rainfall data shown in Table 2.

Table 2. Middle Catchment average monthly and annual rainfall

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann.	Period (y)
Kersbrook 23758	22	22	23	51	90	98	112	99	85	67	37	31	736	50

The Adelaidean sediments—quartzite and sandstone—have good quality groundwater, generally up to 1500 mg/L, and reasonable yields varying between 5 to 10 L/s (Figs 4, 5). Occasionally, bores completed in the Barossa Complex can have salinities of ~1500 mg/L but very low yields, usually up to 1 L/s and not greater than 5 L/s.

4.3 LOWER CATCHMENT

The Lower Catchment covers an area of 110 km^2 and extends from Williamstown to Gawler. Elevations vary between 350 and 50 m AHD. The Barossa Reservoir is within the lower catchment storing 4500 ML. The main land use activity is broad-scale grazing (55%), with native vegetation covering ~30%. Just over 1% of the catchment is irrigated land, chiefly for dairy farming (Fig. 3).

Rainfall is winter dominant with monthly and annual average rainfall data shown in Table 3.

Table 3. Lower Catchment average monthly and annual rainfall

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann.	Period (y)
Gawler 23078	18	17	24	39	55	62	56	56	52	43	27	22	472	100
Williamstown 23752	23	21	24	52	78	100	94	92	74	61	37	28	683	120

The Adelaidean sediments—quartzite, shale and dolomite—have better quality groundwater of ~1500 mg/L in the southwestern parts of the Lower Catchment, while salinities in the northwest are generally 1500–3000 mg/L, with yields varying between 1 to 5 L/s (Figs 4, 5). The lowest points in the catchment (South Para sub-catchment) display salinities of up to 7000 mg/L.

Very few bores are completed in the Barossa Complex and salinities can vary greatly, from ~1500–7000 mg/L, with low yields, usually up to 1 L/s and not greater than 5 L/s.

5. DRILLING HISTORY

An analysis of the state drillhole database (SA_Geodata) for the South Para River Catchment has provided data on the history of well drilling. The oldest recorded well was drilled in 1933 and since then, over 500 wells have been drilled in the catchment. Before 1976, there was no requirement to report well details when drilling occurred. Consequently, almost half the wells in the database have no original drilling date, nor the purpose for which the well was drilled.

The passing of the *Water Resource Act 1976* required a permit to be obtained for each new well drilled and well construction details to be submitted to the appropriate agency. Since then a total of 245 wells have been drilled in the South Para River Catchment, 97 for irrigation purposes (Table 4, Fig. 6).

Table 4. History of groundwater development

South Para River	<1976	1976–95	>1995
Irrigation	9	43	54
Domestic	13	42	22
Stock	8	13	11
Other wells	30	53	7
TOTAL	**60**	**151**	**94**

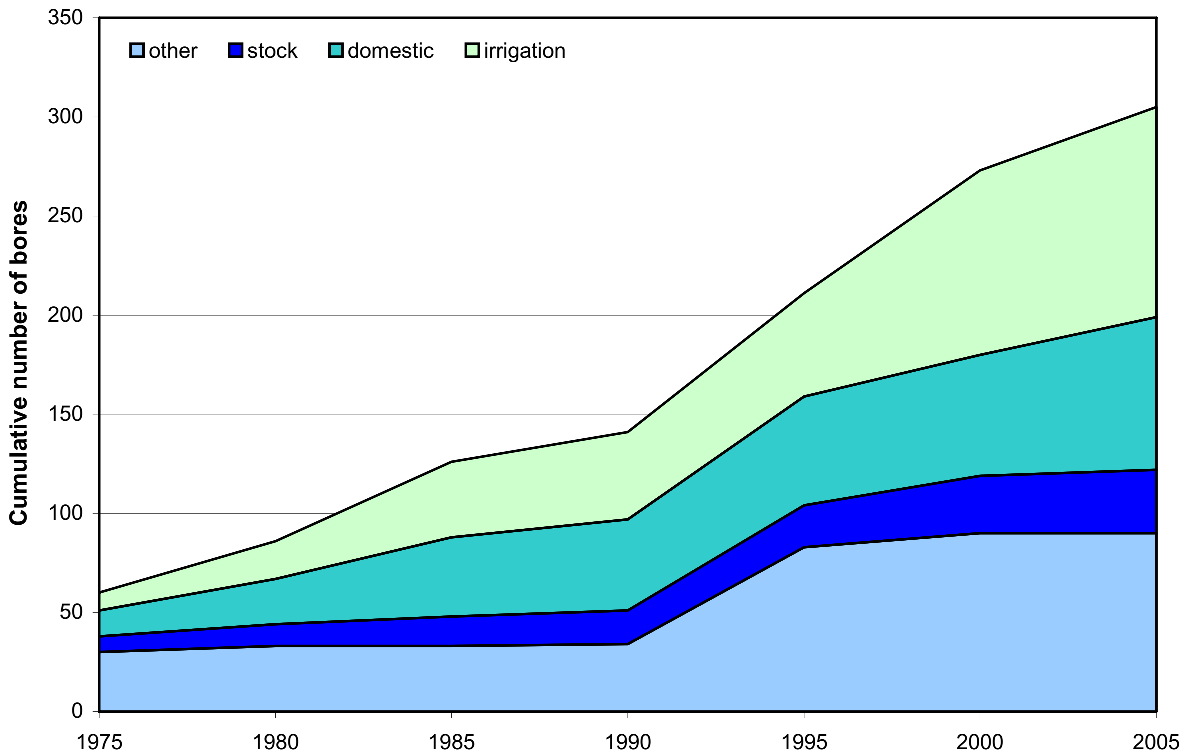

Figure 6. History of groundwater development, South Para River Catchment

All observation, industrial, drainage and investigation wells were grouped in one category (other wells). A significant number of wells in this category are observation wells drilled in the early 1990s for dryland salinity monitoring.

The data used to obtain the number of bores for each category should be used with caution, as it was extracted from drilling permit applications and has not been validated or confirmed by any field surveys. The current purpose may significantly differ from that on the original permit application.

6. GROUNDWATER USE

It is important to examine the current groundwater status in any catchment in the context of its previous history, examining where possible the historical groundwater development and use.

Sinclair Knight Merz (2001) reported that only 300 ha were irrigated in 1993 across the whole South Para River Catchment, based on the 1993 land use survey (Table 5). A more recent land use survey was conducted in 2001–02 showing an increase to 674 ha, due mainly to the expansion of vineyards in Upper and Middle Catchments. Since 2003, the irrigated area has increased further to 746 ha (based on 2005 aerial photography), mainly in the Middle Catchment and slightly in the Lower. However overall, only ~2% of the South Para River Catchment area is under irrigation.

The 2001–02 land survey did not determine whether irrigation needs are obtained from groundwater or surface water. The large dam volume storage in all catchments indicates that surface water from dams supplies a significant amount of the irrigation water. There may also be combined borehole and dam water supplies. Some field verification of actual use is essential to differentiate between groundwater and surface water sources.

Table 5. Historical land and water use

	Area (ha)		
	1993	**2002**	**2005**
	Upper Catchment		
Pasture		9	9
Vines	100	210	210
Orchards	2	9	9
Flowers		6	6
Berries		1	1
USE (ML)	20	361	361
	Middle Catchment		
Pasture	6	9	9
Vines	84	247	300
Orchards	53	53	53
Flowers	2	2	2.5
Berries	36		
USE (ML)	510	561	625
	Lower Catchment		
Pasture		91	91
Vines	17	18	38
Orchards		17	17
Flowers		1.5	
USE (ML)	20	550	569
TOTAL USE	**550**	**1472**	**1555**

7. WATER BALANCE

Determining the water balance of a catchment is a fundamental step in establishing the sustainable groundwater yield for development.

The water balance methodology is applied to the areas where each of the components of the water balance shown in Figure 7 can be measured or estimated to a reasonable degree of certainty. The water balance figures presented in this report are considered to be a preliminary estimation based on the best available information at the time of this study. The inherent limitation of the methods adopted to determine water balances for these catchments are well recognised but, in the absence of any other information, provide the best approximation concerning the availability of groundwater for broad-scale purposes. DWLBC is currently undertaking a number of detailed groundwater investigations to better quantify the parameters and recharge rates across a number of catchments within the MLR.

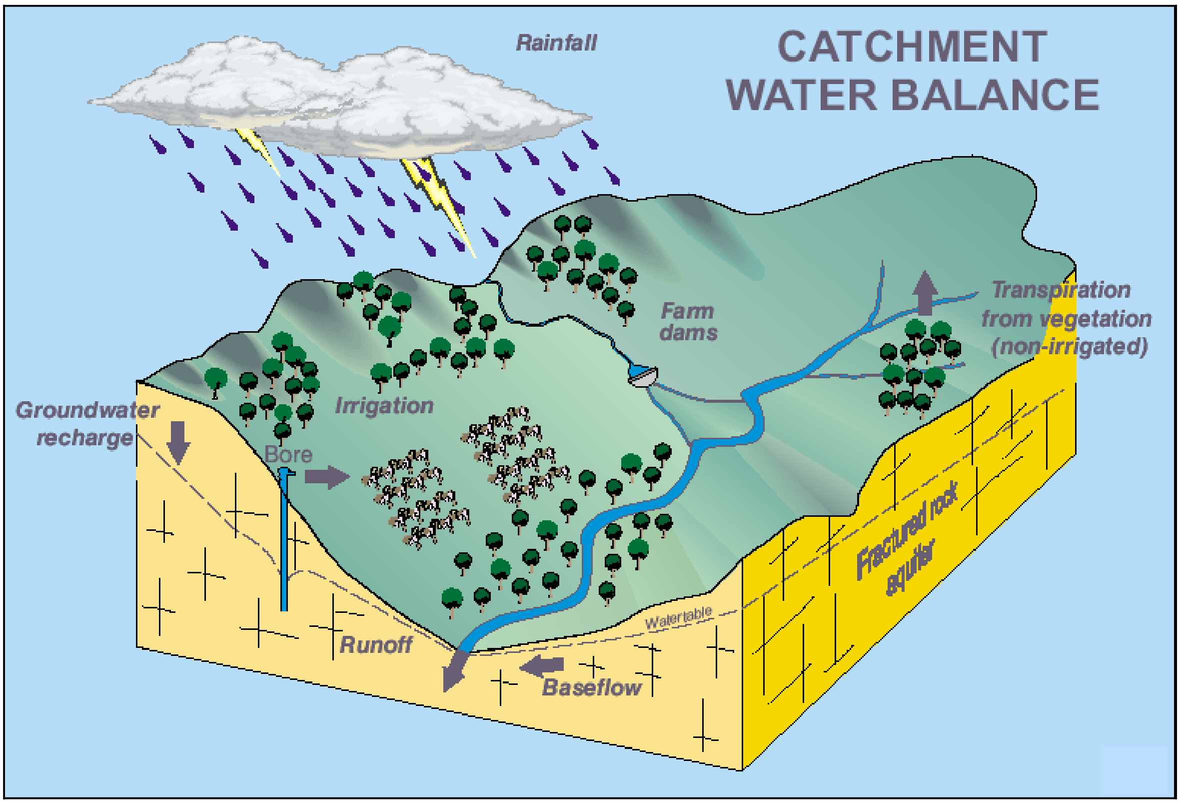

Figure 7. Water balance components

7.1 RAINFALL

Rainfall in the MLR is winter dominant and this is the main driving force of the hydrologic cycle. By combining a rainfall isohyet map with the areal coverage of a catchment, the total average annual volume of rainfall falling on the catchment can be calculated.

As most of the summer rainfall is lost by evaporation before it has a chance to percolate down to the plant root zone or the watertable, only winter rainfall (April–October) is considered to be effective in contributing to the water balance. Table 6 lists the average rainfalls and rainfall volumes in the South Para River Catchments.

Table 6. Catchment rainfall volumes

Catchment	Annual rainfall (ML)	Effective rainfall (ML)	Annual rainfall (mm)	Effective rainfall (mm)
Upper	86 275	68 544	725	576
Middle	77 112	61 884	714	573
Lower	64 350	50 160	585	456

From over one hundred years of rainfall records from 14 rainfall stations, the mean annual rainfall for the South Para River Catchment was calculated to be 683 mm (Teoh 2003).

7.2 EVAPOTRANSPIRATION

After rain has fallen water is transpired by plants and trees through their roots and evaporated from the topsoil and wet leaves in the tree canopy. This is often the largest water use component in the catchment. Reasonable estimates of plant water use by transpiration for various crops can be made. A geographic information system (GIS) coverage of land use in the MLR was obtained from data developed by the Environment Protection Agency MLR Watershed Protection Office and the Northern Adelaide and Barossa Catchment Water Management Board. Between June 2001 and March 2002 a land use survey was conducted and the information has been incorporated in the coverage.

These coverages can provide areas of native vegetation, pasture and vineyards and therefore the volume of water transpired can be calculated. It must be stressed that these calculations of plant water use are estimated to be accurate only to ±10–15% and consequently water use figures presented in Appendix A may only have a similar accuracy.

7.3 STREAMFLOW

There is a network of ~70 continuous recording gauging stations throughout the MLR and data is stored at the DWLBC on the HYDSIS database. Runoff and baseflow components can be extracted from these records. Baseflow, the contribution to streamflow provided by groundwater discharge, is obtained from HYDSIS using separation value method. The AW 505503 gauging station, situated on the South Para River (2.6 km southeast from the Gawler Post Office in the Lower Catchment), is the only current streamflow station with long-term records. There are no streamflow gauging stations in the Middle (except Victoria Creek sub-catchment) and Upper Catchments.

Estimates of the total streamflow for the ungauged Upper and Middle Catchments were made using catchment modelling (Teoh 2003). Both runoff and baseflow estimates were products of catchment modelling and are presented in Table 7. The baseflow information was derived by Method 3 – Lyne and Hollick filter (Nathan and McMahon *in* Grayson et al. 1996), using the modelled daily flow outputs. Reservoir storage and spillway discharge are recorded on the Barossa Diversion Weir, Warren and South Para Reservoirs.

Table 7. Annual catchment streamflow volumes

Catchment	Streamflow (ML)		Runoff (ML)		Baseflow (ML)	
	With farm dams	*Without farm dams*	*With farm dams*	*Without farm dams*	*With farm dams*	*Without farm dams*
Upper	14 670	15 500	13 033	13 365	1 637	2 135
Middle	13 970	14 700	10 023	9 788	3 947	4 912
Lower	5 024	5 340	3 684	3 762	1 340	1 578

7.4 SURFACE STORAGES

A quantity of runoff is captured in farm dams. A recent study by DWLBC (Pikusa1999).has calculated the volume of all farm dams in the MLR using infrared aerial photographs surveyed in 1999 (to determine the area of the dams) and the following formula:

Volume = 0.0002 x area $^{1.2604}$

where volume is in mega litres and the area in square metres.

This coverage is also available on GIS. It is assumed that the dams are full at the end of winter and spring, and receive no more inflows during summer. Table 8 shows the volumes calculated for each catchment.

Table 8. Catchment dam storage volumes

Catchment	Number of dams	Dam volumes (ML)
Upper	357	1431
Middle	356	1033
Lower	266	497

The total number of dams across the entire South Para River Catchment in 1999 was 979, with an estimated storage capacity of 2960 ML.

The three major reservoirs—Warren, South Para and Barossa, with combined storage of 54 000 ML—capture a significant portion of the catchment runoff. The Warren and South Para are on-stream reservoirs, while the Barossa is an off-stream dam which draws water from the Barossa Diversion Weir downstream of the South Para Reservoir.

Environmental releases from the reservoirs, particularly the South Para Reservoir, have been proposed but not yet carried out (URS 2002). These releases would allow a period of flow, help flush built up sediments and provide a link between water holes, allowing for species migration and the increase of aquatic habitats.

7.5 GROUNDWATER PUMPING

The main component of groundwater pumping is irrigation. Very few of the irrigation bores have meters installed to measure their discharge. However, if a reasonably accurate estimate of the area and crop type irrigated can be obtained, estimates of the various crop water application requirements for irrigation during summer can then allow an approximate calculation of the total volume extracted. Previous water balance studies used the 2001–02 land use survey coverage on GIS to provide irrigated areas and crop types (Teoh 2003). This method works well in the smaller catchments where property sizes are also small and are dominated by one land use.

As the 2001–02 land survey did not determine whether irrigation needs are obtained from groundwater or surface water, for the purpose of this study it is assumed that 50% of the irrigation needs across the whole catchment is derived from groundwater. This agrees with McMurray (2003), where usage rates of 20–30% of aggregated farm dam volume were found. On sub-catchment level, the surface water usage is 13%, 28% and 55% of the total farm dam volume in the Upper, Middle and Lower Catchments respectively (Teoh 2003). The groundwater and surface water use estimated volumes are presented in Table 9.

Table 9. Groundwater and surface water use

Catchment	Dam volume (ML)	Surface water use (% dam vol)	Surface water use (ML)	Groundwater use (ML)
Upper	1430	13	186	175
Middle	1033	28	289	336
Lower	497	55	273	296
TOTAL			**748**	**807**

These estimates are the best available and accurate only to ±10–20%.

Pumping from private wells for domestic, stock and industrial use was not taken into account because of the marginal number of bores drilled for these purposes. Once metering of irrigation and industrial users is carried out and the sources of irrigation water are confirmed through a field survey, the irrigation water estimates will be revised.

7.6 GROUNDWATER RECHARGE

This is perhaps the most important component and the most difficult to estimate. It can generally only be measured indirectly, and is variable over any given catchment because of its dependence on other variable factors such as soil type and vegetation cover. There are several methods available to estimate recharge: water balance and chloride balance methods are described below.

7.6.1 Water Balance

Using the method of calculating all other components of the water balance with the outstanding quantity attributed to recharge averages the recharge over the whole catchment. Examination of hydrographs has shown little change in storage in average rainfall years and, consequently, recharge can be calculated:

recharge = rainfall – (evapotranspiration + runoff + dam storage).

Another possible method of calculation is to consider only the groundwater component of the water balance:

recharge = groundwater pumping + baseflow.

Data from the Upper Catchment (App. A) is used here as an example:

recharge = rainfall – (evapotranspiration + runoff + dam storage)

= 68 544 – (52 674 + 13 033 + 1430)

= 1400 ML ~12 mm/y (2% annual rainfall).

By using the groundwater balance only:

recharge = groundwater extraction + baseflow

= 1637 +175

= 1818 ML or ~15 mm/y (2% annual rainfall).

7.6.2 Chloride Balance

The chloride ion can be used to estimate recharge provided that it is not dissolved from rocks and minerals. After rain falls evapotranspiration processes remove water from the soil. The conservative chloride ion remains and is concentrated in the reduced amount of water that percolates down to recharge the groundwater. Recharge can be calculated by:

$R = (\text{annual rainfall} - \text{runoff}) \times (Cl_{rf} \div Cl_{gw})$

where: R is the recharge (mm/y)

Cl_{rf} is the chloride concentration of rainfall (mg/L) and

Cl_{gw} is the constant chloride concentration of groundwater (mg/L).

The chloride mass balance method (Eriksson & Khunakasem 1969) developed a relation between precipitation and recharge:

$P_{eff} \times Cl_{rf} = R \times Cl_{gw}$

Where: P_{eff} is the effective rainfall (mm/y).

Recharge can therefore be calculated:

$R = (P_{eff} \times Cl_{rf}) \div Cl_{gw}$

Care must be taken when using this method. Pumped samples from private boreholes may obtain water from deep parts of the aquifer rather than just below the watertable, which is the preferred location. Therefore, only wells that have been completed over very short intervals and across the top few metres of the watertable aquifer are suitable for sampling. In areas of intensive agriculture, chloride may be increased by the recirculation of irrigation water and by the application of fertilisers.

The chloride content of rainfall decreases with distance from the coast, and several equations have been derived to quantify this relationship.

Hutton (1976)

$$Cl = \frac{0.99}{\sqrt[4]{d}} - 0.23$$

where: d is the distance from coast in km

Cl is the chloride concentration in meq/L.

Kayaalp (2001)

$Cl_w = 1.1 + 2.98\, e^{-d/111}$ WET (in rainfall)

$Cl_{dry} = 60 + 1043\, e^{-d/2.7}$ DRY (aerosol dust)

where: d is the distance from the coast in km

Cl_w is the chloride concentration in mg/L

Cl_{dry} is the chloride loading in kg/km^2/month

The total chloride accession consisting of the sum of wet and dry chloride can then be included in the recharge formulae above. The chloride content of groundwater can be obtained from the water chemistry module of SA_Geodata.

Table 10 shows the calculated chloride recharge values for all sub-catchments using both equations above, both in mm and a percentage of annual rainfall. The two methods (Hutton and Kayaalp) show significantly different results. The Hutton values give long term average recharge rates, based on observations from sedimentary aquifers in other parts of the state. In the absence of any other supporting groundwater chemistry information such as stable isotopes, the Kayaalp method may under-estimate the potential recharge from rainfall.

Table 10. Chloride recharge estimates

Catchment	Cl_{gw} (mg/L)	Cl_{rf} (mg/L)		Recharge (mm/y)		Recharge (%)		Recharge (ML)	
		Hutton	*Kayaalp*	*Hutton*	*Kayaalp*	*Hutton*	*Kayaalp*	*Hutton*	*Kayaalp*
Upper	278	4.4	4.2	11.5	11	1.6	1.5	1370	1310
Middle	617*	6.8	4.1	7.9	19	1.1	2.7	850	515
	257**			4.8	11.4	0.7	1.6	2050	1230
Lower	559	7.1	4.6	7.4	4.8	1.3	0.8	815	530

* Groundwater salinity – Barossa Complex

** Groundwater salinity – Aldgate Sandstone

Estimations of recharge using the chloride mass balance within fractured rock aquifer systems do not often yield reliable results because of the significant spatial variability in groundwater salinity observed within different aquifer units. However, in the absence of other information the method can be applied to obtain first-order estimates of recharge for broad-scale planning purposes.

7.6.3 Discussion

The two different water balance methods of estimating recharge produced values of the same order of magnitude, as shown in Table 11.

These estimates could also be considered conservative because of the assumption that the November–March rainfall does not contribute to the water balance. The estimates of groundwater pumping and baseflow are approximate to within ±25–30%. For the purposes of this report only it is proposed to adopt the following initial recharge values for the catchments (Table 12). Further detailed investigations may refine these recharge estimates.

Table 11. Recharge estimates

Catchment	Water balance 1 ML	Water balance 2 ML
Upper	1400	1800
Middle	8200	4300
Lower	4450	1625

Table 12. Adopted initial recharge values

Catchment	ML	mm/year (ML)	% of annual rainfall	% of effective rainfall
Upper	1500	13	2.0	2.5
Middle	5000	46	6.5	8.0
Lower	3000	27	5.0	6.0

8. SUSTAINABLE YIELD

The State Water Plan 2000 accepts the definition of sustainable yield proposed by the National Groundwater Committee of Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), which defines sustainable yield as:

> the groundwater extraction regime, measured over a specified planning timeframe, that allows acceptable levels of stress and protects the higher value uses associated with the total resource.

The State Water Plan states that the timeframe must take into account delayed ecological impacts, and that the sustainable yield may not necessarily be a fixed annual volume. A precautionary approach must be taken with lower sustainable yields in areas with little information and areas of high use.

The higher value uses may be agriculture, ecosystem, infrastructure, industry or other activities which are dependent on groundwater and which the community reasonably expects will be maintained or developed for a defined period.

Further work will investigate the relationship between surface water and groundwater and different approaches to determining sustainable yield of the resource for allocation purposes. Estimates for 50% and 75% of the total catchment recharge are presented in Table 13.

Table 13. Estimates of sustainable yield

Catchment	Current use (ML)	50% recharge (ML)	75% recharge (ML)
Upper	361–180	750	1125
Middle	625–313	2500	3750
Lower	569–285	1500	2250

Current groundwater use in the Upper Catchment appears to be approaching the level equivalent to 50% of recharge, but is well below the 75% value.

In addition to annual recharge, there are large volumes of groundwater stored in joints, fractures and pore spaces far below ground level. The total volumes in storage can be over ten times the annual recharge, however not all of this can be extracted for use. In addition, salinities of groundwater within the fractured rock aquifer systems typically increase with depth.

Changes in land use to higher value irrigated crops may also lead to a reduction in groundwater withdrawals due to more efficient irrigation methods and lower water requirements. For example, vines require ~1–2 ML/ha/y applied by drip irrigation, whereas pasture requires 6–8 ML/ha/y applied by sprinkler.

In catchments where property sizes are small, large withdrawals may have significant local impacts. This may include drawdowns in groundwater levels beneath neighbouring properties, and a reduction in baseflow to streams resulting in environmental degradation. Heavy localised pumping may also result in increasing salinities due to the lateral movement of more saline groundwater from surrounding areas. More accurate information on groundwater withdrawals is required, particularly in areas of concentrated irrigation.

9. CONCLUSIONS AND RECOMMENDATIONS

The South Para River Catchment is underlain by fractured rock aquifers which contain groundwater of varying salinity and yield. The availability of groundwater data is limited for this catchment. Approximate water balances have been calculated using existing information and are considered to be preliminary estimations based on the best available data at the time this study was undertaken. The inherent limitations of the methods adopted to determine the water balance and the sustainable yield are well recognised but, in the absence of any other information, provide the best assessment concerning the availability of groundwater for broad-scale planning purposes. DWLBC is continuing to undertake further work to improve methodologies associated with determining the water balance inputs and outputs. Based on the investigation currently undertaken, it is anticipated that over the next several years estimates of sustainable yields for all sub-catchments through the MLR will be reviewed and improved.

Since 1993, the irrigated area across the South Para River Catchment increased from 300–746 ha, mainly due to the expansion of vineyards in the Upper and Middle Catchments. However, these irrigated areas represent only ~2% of the total catchment area.

The current irrigation water use is estimated to be ~1555 ML, half of which is thought to be obtained from groundwater (~800 ML). The large dam storage of almost 3000 ML is assumed to supply the remainder of irrigation needs.

Recharge rates are estimated to vary between 13 mm/y (Upper Catchment) and 46 mm/y (Middle Catchment) or 2.5–8% of the effective rainfall. The low recharge rates estimated in the Upper Catchment are due to extensive plantation forests and native vegetation land cover, with a greater portion of this catchment underlain by the Kanmantoo Group rocks, which generally demonstrate lower recharge rates. The highest recharge rates occur in the Middle Catchment where deep-rooted vegetation covers a smaller area, highly permeable Adelaidean rocks are widely developed and the rainfall is relatively high.

The estimated groundwater extraction of 800 ML/y is a relatively small compared to the estimated annual recharge of 9500 ML.

The water balances need to be revised at regular intervals to take into account changes in land use and irrigation practices. The eventual metering of all irrigation and industrial supplies as part of the prescription process will allow accurate recording of water use.

At this stage, regular water level and salinity monitoring is not a high priority, however, if viticulture expansion continues in concentrated areas, it may be necessary to establish monitoring to ensure localised aquifer stress does not occur.

APPENDIX A

CATCHMENT WATER BALANCES

CATCHMENT WATER BALANCE—UPPER CATCHMENT

Irrigation/extraction

Crop type/use	Area (ha)	Water need (mm)	Water use (ML)
Pastures	9	500	45
Vines	210	120	252
Orchards	9	400	36
Native flower	6	400	24
Berries	1	400	4
		Total	**361**

Evapotranspiration

Land use	Area (ha)	Water use (mm)	Water loss (ML)
Plantation forests	4299	600	25 794
Native vegetation	1505	550	8 278
Grazing	5466	335	18 310
Vines	210	30	63
Orchards	9	180	16
Other	213	100	213
		Total	**52 674**

Streamflow

Runoff (ML)	13 033
Baseflow (ML)	1 637
Total	**14 670**

Recharge

Method	Comments	Estimate (ML)
Deduction	Rainfall – (ET + runoff + damvol)	1400
Deduction	Groundwater extraction + baseflow	1800
Cl		1370
	Adopted initial value	**1500**

Dam storage

Total outflow

Total dam volume	**1430 ML**	⇒	**ML**

Rainfall (Effective) **576 mm** **X** Area **119 km²** ⇒ **68 544 ML**

Total inflow

CATCHMENT WATER BALANCE—MIDDLE CATCHMENT

Irrigation/extraction

Crop type/use	Area (ha)	Water need (mm)	Water use (ML)
Pastures	9.5	500	45
Vines	300	120	360
Orchards	53	400	212
Native flower	2	400	8
		Total	**625**

Evapotranspiration

Land use	Area (ha)	Water use (mm)	Water loss (ML)
Plantation forests	886	600	5 316
Native vegetation	3204	550	17 620
Grazing	5640	335	18 894
Vines	300	50	150
Orchards	53	150	80
Other	559	100	559
		Total	**42 619**

Streamflow

Runoff (ML)	10 023
Baseflow (ML)	3 947
Total	**13 970**

Recharge

Method	Comments	Estimate (ML)
Deduction	Rainfall – (ET + runoff + damvol)	8200
Deduction	Groundwater extraction + baseflow	4300
Cl		1450
	Adopted initial value	**5000**

Dam storage

Total outflow

Total dam volume	1033 ML	⇒			ML
Rainfall (Effective)	**573 mm**	**X** Area	**108 km²**	⇒	**61 884 ML**

Total inflow

CATCHMENT WATER BALANCE—LOWER CATCHMENT

Irrigation/extraction

Crop type/use	Area (ha)	Water need (mm)	Water use (ML)
Pastures	91	500	46
Vines	38	120	455
Orchards	17	400	68
		Total	**569**

Evapotranspiration

Land use	Area (ha)	Water use (mm)	Water loss (ML)
Plantation forests	16	500	80
Native vegetation	3 195	450	14 377
Grazing	6 107	330	20 153
Crops	589	320	1 885
Vines	38	32	12
Orchards	17	150	26
Other	720	100	720
		Total	**37 253**

Streamflow

Runoff (ML)	3684
Baseflow (ML)	1340
Total	**5024**

Recharge

Method	Comments	Estimate (ML)
Deduction	Rainfall – (ET + runoff + damvol)	4450
Deduction	Groundwater extraction + baseflow	1625
Cl		815
	Adopted initial value	**3000**

Dam storage

Total outflow

Total dam volume	**497 ML**			⇒	**ML**
Rainfall (Effective)	**456 mm**	**X** Area	**100.6 km²**	⇒	**45 875 ML**

Total inflow

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	356 or 366 days	time interval

Shortened Forms

Shortened form	Name
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
DWLBC	Department of Water, Land and Biodiversity Conservation
ET	Evapotranspiration
GIS	Geographic information system
HYDSIS	Database software
MLR	Mount Lofty Ranges
SA_Geodata	State-wide geoscientific database

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