The Department of
Water, Land and
Biodiversity
Conservation

Mt Lofty Ranges Groundwater Assessment, Upper Onkaparinga Catchment

Report DWLBC 2002/29

Onkaparinga Catchment Water Management Board

Government of South Australia

The Department of
Water, Land and
Biodiversity
Conservation

Mount Lofty Ranges Groundwater Assessment, Upper Onkaparinga Catchment

Dragana Zulfic, Steve R. Barnett and Jason van den Akker

Groundwater Assessment, Resource Assessment Division
Department of Water, Land and Biodiversity Conservation

February 2003

Report DWLBC 2002/29

Onkaparinga Catchment Water Management Board

Government
of South Australia

Groundwater Assessment Division
Department of Water, Land and Biodiversity Conservation
25 Grenfell Street, Adelaide
GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) 8463 6946
	International	+61 8 8463 6946
Fax	National	(08) 8463 6999
	International	+61 8 8463 6999
Website	www.dwlbc.sa.gov.au	

Disclaimer

Department of Water, Land and Biodiversity Conservation and its employees do not warrant or make any representation regarding the use, or results of the use, of the information contained herein as regards to its correctness, accuracy, reliability, currency or otherwise. The Department of Water, Land and Biodiversity Conservation and its employees expressly disclaims all liability or responsibility to any person using the information or advice.

Zulfic, D., Barnett, S.R., and van den Akker, J., 2002. Mount Lofty Ranges Groundwater Assessment, Upper Onkaparinga Catchment. *South Australia. Department of Water, Land and Biodiversity Conservation. Report,* DWLBC 2002/29.

Foreword

South Australia's natural resources are fundamental to South Australia's economic and social well being. One of the state's most precious natural resources, water, is a basic requirement of all living organisms and is one of the essential elements ensuring biological diversity of life at all levels. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of these resources changes the natural balance and may cause degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Understanding the cause and effect relationship between the various stresses imposed on the natural resources is paramount to developing effective management strategies. Reports of investigations into the availability and quality of water supplies throughout the state aim to build upon the existing knowledge base, enabling the community to make informed decisions concerning the future management of the natural resources thus ensuring conservation of biological diversity.

Bryan Harris
Director, Resource Assessment Division
Department of Water, Land and Biodiversity Conservation

CONTENTS

List of Tables

List of Figures

List of Appendices

ABSTRACT

The Upper Onkaparinga Catchment has nine sub-catchments where groundwater extraction from fractured rock aquifers is considered to be approaching the potential sustainable yield. This report presents a first-order assessment of the water balance and sustainable yield of these sub-catchments. Large spatial variability in groundwater quality and aquifer yield is observed across much of the study area.

Aquifer yields and salinities are more favourable for irrigated horticultural development in the western part of the Onkaparinga Catchment (Cock Creek, Western Branch, Upper Onkaparinga sub-catchments) compared to the eastern areas. Sub-catchments in the eastern portion of the Onkaparinga Catchment, including Charleston and Main Channel, are underlain by less permeable siltstones of the Saddleworth and Tapley Hill Formations and metasediments of the Kanmantoo Group.

Recharge rates also vary quite significantly within and across the sub-catchments investigated. Consequently, the recharge figures presented in this report are considered to be a preliminary estimation based on the best available information at the time the study was undertaken. The inherent limitations of the methods adopted to determine the water balance for these sub-catchments and the sustainable yield are well recognised but, in the absence of any other information, provide the best approximation concerning the availability of groundwater for broad-scale planning purposes. DWLBC is currently undertaking a number of more detailed groundwater investigations to better quantify the aquifer parameters and recharge rates across a number of ‘type’ catchments within the Mount Lofty Ranges. Results from these additional investigations will be progressively released as they become available over the next three to five years.

Whilst the more detailed investigations are underway, the water balances should be revised at regular intervals to take into account further changes in land use and irrigation practices, along with the additional information that will be available from the more detailed investigations. Regular water level and salinity monitoring networks should be established in areas of high groundwater use, and the metering of all irrigation and industrial supplies should be eventually carried out to allow accurate estimates of water use.

This Report concentrates primarily on the groundwater resources in the defined study area. A broadscale assessment of the surface water resources of the Mount Lofty Ranges is also being carried out by DWLBC (Teoh, 2002) in parallel with this groundwater assessment. Further studies are planned across selected catchments in the Mount Lofty Ranges in an attempt to better quantify the needs of water dependant ecosystems to ensure that any future management strategies allow adequate provision to meet this demand.

INTRODUCTION

The Mount Lofty Ranges (MLR) contain a significant groundwater resource. As this is coming under increasing pressure for development, it is imperative to gain an understanding of the extent of the groundwater resource and to develop appropriate management strategies in order to ensure that the future development is sustainable.

The Onkaparinga Catchment Water Management Board has primary responsibility for management of water resources within the area. This study commissioned by the Board aims to identify areas that may be under stress as a result of over development of groundwater as well as areas where future development of groundwater is possible.

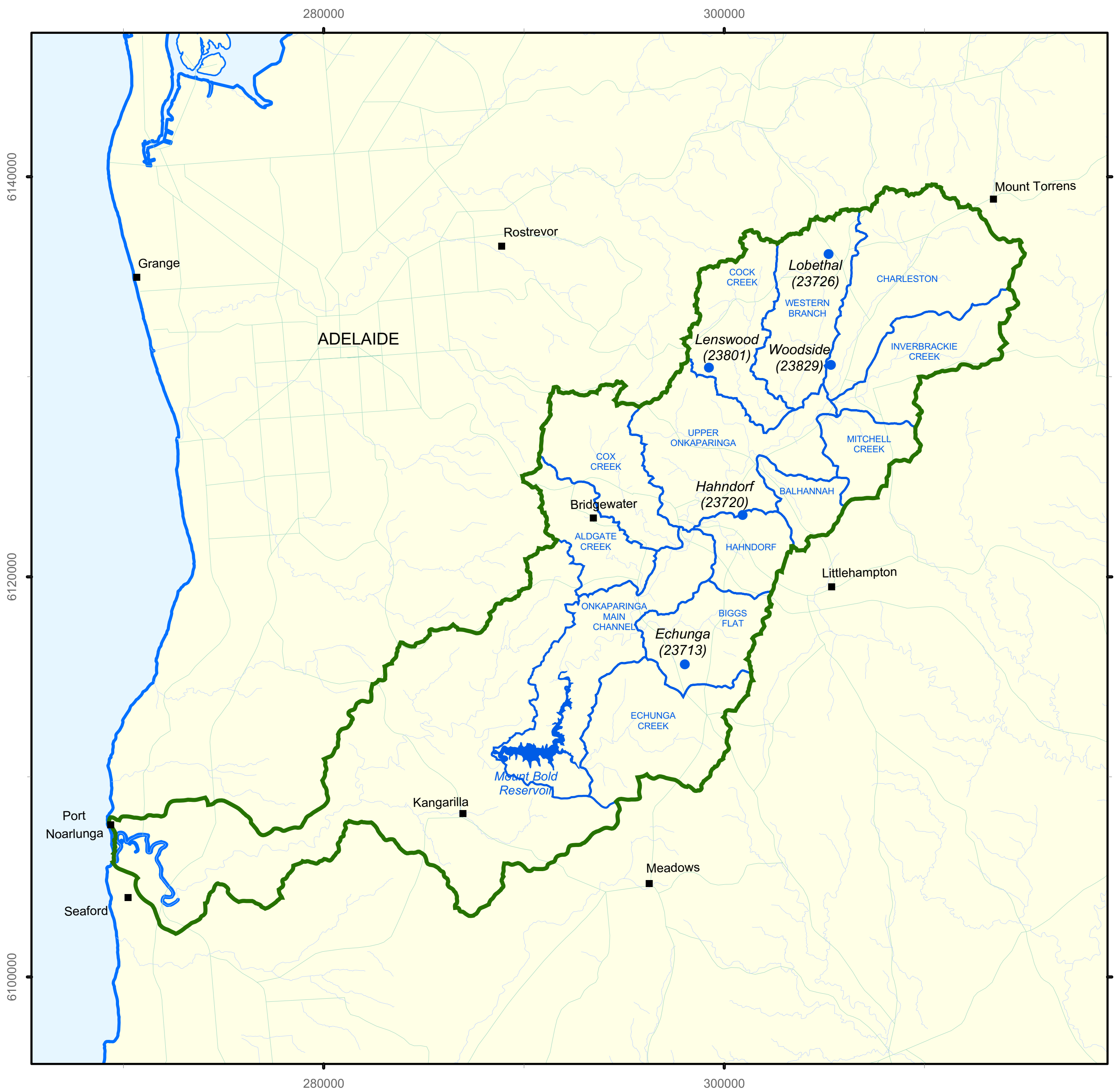
This report presents a first-order assessment of the water balances in the Upper Onkaparinga Catchment above Mount Bold Reservoir, which includes predominantly semi-rural hills area with townships of Lenswood, Oakbank, Lobethal, Woodside, Stirling, Hahndorf and Echunga (Fig. 1). This area is a significant part of the MLR Watershed that supplies up to 30% of metropolitan Adelaide's water supply. The area consists of 13 sub-catchments, identified in Table 1 and illustrated in Figure 1.

Table 1. Sub-catchments of the Upper Onkaparinga catchment

Sub-catchment	**Total area** (ha)
Charleston	5150
Western Branch	3297
Cock Creek	2840
Inverbrackie Creek	2674
Upper Onkaparinga	4711
Cox Creek	2889
Mitchell Creek	1450
Balhannah	1024
Aldgate Creek	1945
Hahndorf	1468
Biggs Flat	2362
Echunga Creek	3910
Onkaparinga Main Channel (above Mt Bold reservoir)	2451

This report reviews 11 of the 13 sub-catchments, those in which relatively high groundwater use has been identified. The Cock Creek sub-catchment has been excluded from this report because it was assessed earlier (Barnett and Zulfic, 1999). The Aldgate Creek sub-catchment was also not included because ~50% of the area is classified as rural living with virtually no irrigation.

This assessment draws on existing information, as well as a field survey carried out during the 2001–02 irrigation season to determine groundwater use. Shortfalls in data required for the efficient management of water resources are identified, together with recommendation for future monitoring.



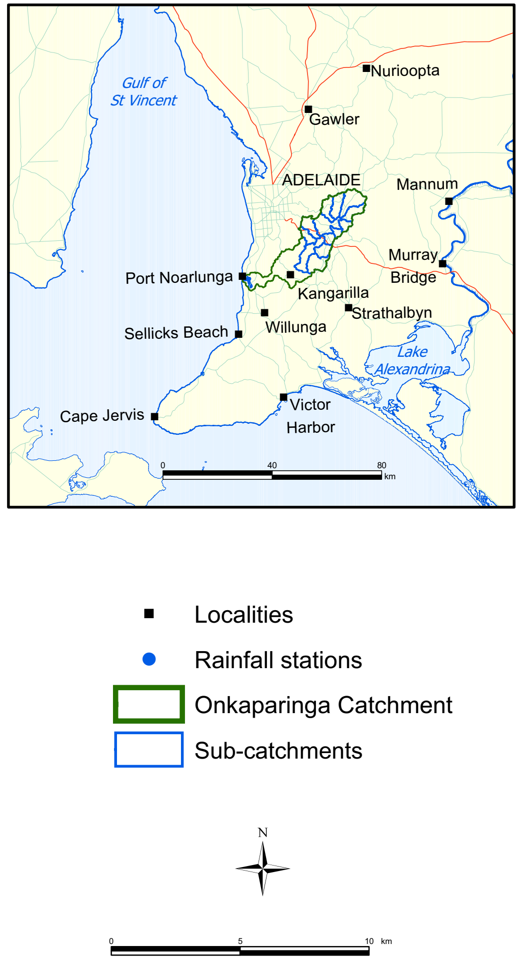


Figure 1

Onkaparinga Catchment Location Plan

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

The Department of Water, Land and Biodiversity Conservation

Government of South Australia

GEOLOGY

The Onkaparinga Catchment is underlain by consolidated basement rocks identified as the Barossa Complex, Adelaidean sediments and Kanmantoo Group (Fig. 2). Quaternary alluvium typically lines the valley floors and along drainage courses.

Barossa Complex — metamorphic rocks which form basement to the overlying Adelaidean sediments, comprising gneisses, schists and pegmatites which were metamorphosed at high temperature and pressure, and are thought to be 1600 million years old. They occur in the centre of large folds, and have been exposed by erosion as the Aldgate and Oakbank inliers. Only a very small portion of these inliers occurs in the high groundwater use area. The Aldgate inlier crops out in the western part of the Upper Onkaparinga Catchment; the Oakbank inlier occurs between Upper Onkaparinga, Mitchell Creek and Balhannah Catchments.

Adelaidean sediments — this belt of rocks, with minor volcanics in places, reaches a thickness of ~24 000 m. Although the rock units have been very strongly folded, they have been relatively unaffected by heat and therefore provide a record of depositional and climatic conditions that occurred ~1000 million years ago.

The Adelaidean rock units, which underlie most of the Onkaparinga Catchment, are dominated by the Burra Group (Aldgate Sandstone, Woolshed Flat Shale, Stonyfell Quartzite and Saddleworth Formation) which consists of siltstone, shale, slate, dolomite, sandstone and quartzite.

Kanmantoo Group — a large trough was formed during the Cambrian ~500 million years ago by rapid subsidence in a broad arc around the eastern side of the present MLR. The feldspathic sandstone that filled this trough was metamorphosed by heat and pressure into greywacke, schist and gneiss with an apparent thickness of ~21 000 m.

These metamorphic rocks are found only to the east of Charleston in the Onkaparinga Catchment.

Quaternary alluvium has been deposited at the lowest points in the catchment, along the Onkaparinga River and other drainage lines. It usually consists of dark grey silt, clay and gravel.

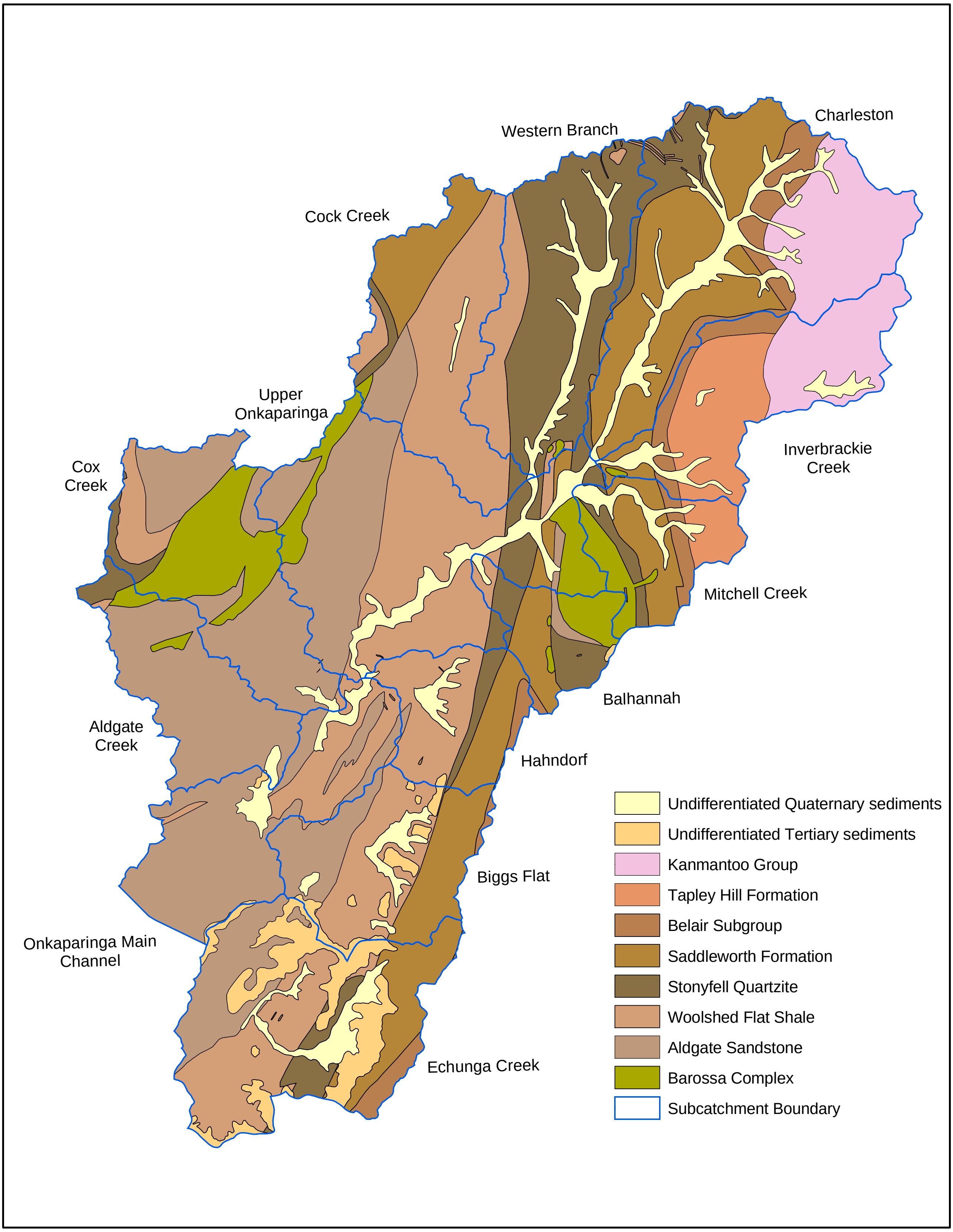
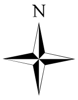


Figure 2

Onkaparinga catchment - Simplified geology



Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

REGIONAL HYDROGEOLOGY

Groundwater is stored in, and moves through, joints and fractures in the rocks underlying the Onkaparinga Catchment in what are typically referred to as fractured rock aquifer systems. Recharge to these aquifers occurs directly from that portion of rainfall which percolates down through the soil profile (much of the rainfall is lost to streams as overland flow or is used by plants). Groundwater moves from the higher points in the landscape to the lowest, where discharge occurs to the streams. Consequently, the streams act as drains for the fractured rock aquifer systems. This discharge constitutes the baseflow of the streams that dominates flow for most of the year, particularly over the summer and between rainfall events.

There are generally three groundwater flow systems operating within the fractured rock aquifer rock systems. A shallow groundwater flow which may manifest itself as seepage to drainage lines after a heavy rainfall event and movement of water through the ground is typically in the order of days. These systems are generally short lived and not considered sustainable for large pumping demands. An intermediate system may provide much of the baseflow to streams and other discharge points, and groundwater flow is typically in the order of weeks to decades through these systems. In the deeper regional systems, groundwater movement is typically in the order of several decades to centuries or more.

Development of groundwater resources may have an impact on any one of these systems to a lesser or greater degree. The primary mechanisms of groundwater movement and recharge must therefore be well understood to ensure that the appropriate resource management options are adopted.

The **Barossa Complex** is generally considered to be a poor aquifer, and from which irrigation supplies are usually not obtained. This is due to the fine grainsize and decomposition of some of the schistose and granitic rocks into clay, which can considerably reduce permeability.

For similar reasons, aquifers within the **Kanmantoo Group** metasediments are also generally considered to be poor, with higher salinities also evident due to the lower rainfall to the east. The lower rainfall and therefore recharge is considered to result in less flushing of the groundwater within this fractured rock aquifer system.

There is limited occurrence of these two rock groups within the sub-catchment area studied and no further assessment of groundwater availability from these systems is therefore made in this report.

The **Adelaidean sediments** comprise the Aldgate Sandstone and Woolshed Flat Shale in the northwestern part of the catchment. This area receives the highest rainfall and has very good quality groundwater. The southeastern part of the catchment is underlain by younger sequences: the Saddleworth Formation, Belair Subgroup and Tapley Hill Formation. This area is one of lower, rolling hills with lower rainfall and groundwater of poorer quality.

Yields throughout the area are variable, generally less than 5 L/s. Some higher yields occur in the Saddleworth Formation.

Although there is a network of 70 stream gauging stations throughout the MLR, only four are located to enable streamflow out of the sub-catchments to be measured.

CATCHMENT HYDROGEOLOGY

The hydrogeology of the assessed sub-catchments is discussed in more detail below.

Cock Creek

The Cock Creek sub-catchment is characterised by steep terrain and extends from Stringybark to Forest Range and Lenswood, with elevations varying from 550 m AHD at its northwestern divide to 360 m at the lowest point. Approximately 17% of the area is covered by native vegetation, with almost 40% given to orchards; there is some grazing in flatter areas (Fig. 3).

Rainfall is winter dominant, with the monthly averages for Lenswood shown in Table 2. The annual average rainfall is 1032 mm/y.

Table 2. Average monthly rainfall for Lenswood (mm)

J	F	M	A	M	J	J	A	S	O	N	D
33	29	42	78	115	133	160	149	119	83	45	43

The highest northwestern portion of the catchment is underlain by schist, siltstone and quartzite of the **Saddleworth Formation** and hosts large areas of grazing land and orchards. Due to high rainfall, salinities are generally between 500 and 1000 mg/L (Fig. 4). The groundwater supplies obtained from these sediments range from below 5 L/s to occasionally 10 L/s (Fig. 5). A small number of bores are developed in the **Aldgate Sandstone** (fine to coarse-grained sandstone and arkose) which wedges in between Saddleworth Formation and Woolshed Flat Shale on the southwestern margin of the catchment. Despite the limited extend of this geological unit in the catchment and a small number of bores, it shows excellent quality of groundwater, with recorded salinities of less than 500 mg/L and yields varying from less than 5 L/s to up to 20 L/s.

However, the main portion of this sub-catchment is underlain by the **Woolshed Flat Shale**, which consists of dark grey to black siltstone, slate and phyllite with some dolomitic lenses, and is sometimes pyritic. This aquifer is used for irrigation of orchards (mostly apple and pear), and small pockets of vineyards in the northern margins of the catchment. Groundwater obtained from these sediments is of a very good quality, ranging from less than 500 to 1000 mg/L. Although yields are chiefly below 5 L/s, a number of bores managed to develop yields up to 10 L/s, and few up to 20 L/s.

Western Branch

The Western Branch sub-catchment of the Onkaparinga River extends from Forest Range to the Oakbank Racecourse (Fig. 2), ranging in elevation from 350 to 500 m. The land use is dominated by vineyards, dairies and orchards, mainly scattered in the western and upper reaches of the sub-catchment (Fig. 3).

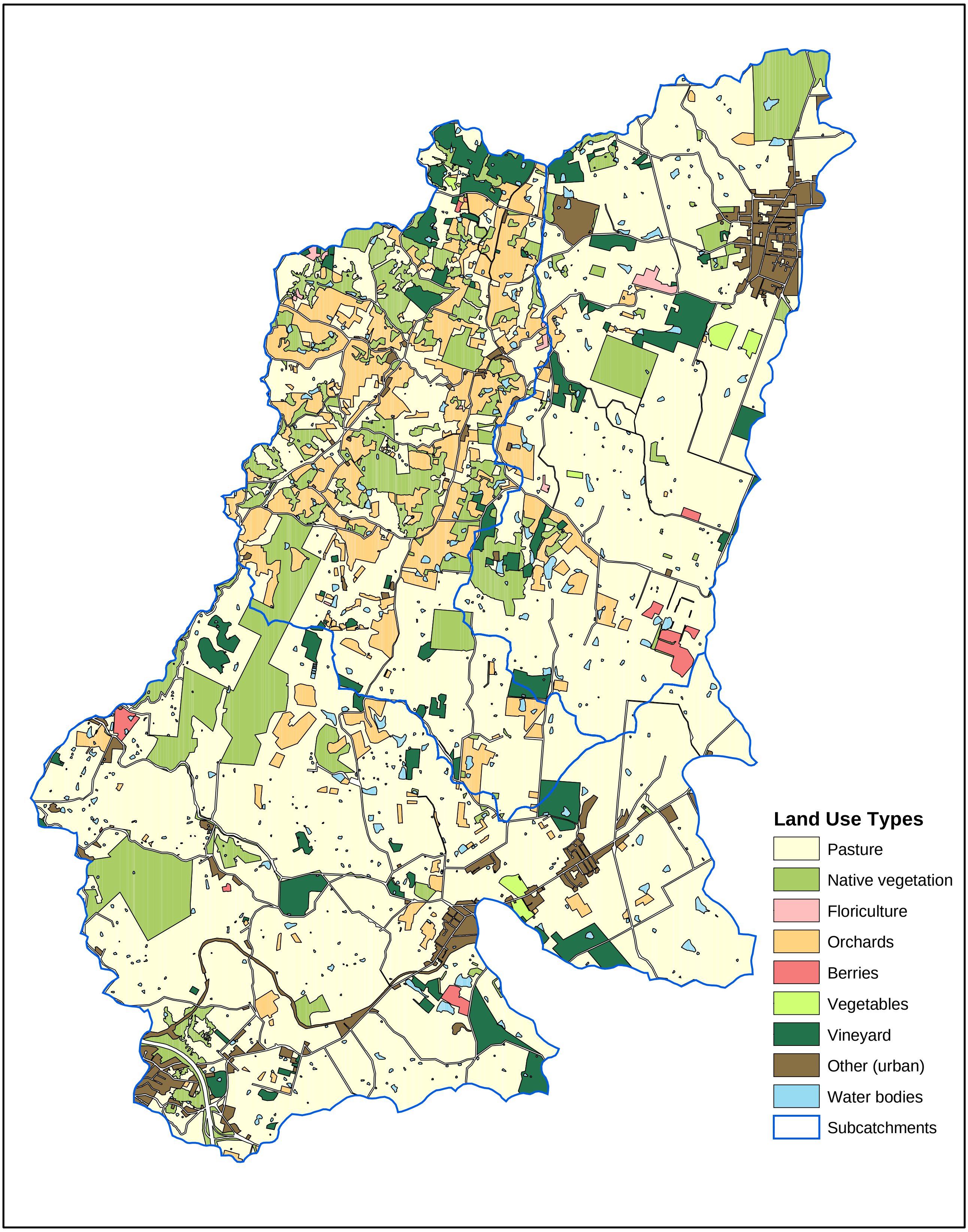


Figure 3

Cock Creek, Western Branch & Upper Onkaparinga Sub-catchments 2001 land use

0 2 4 km

N

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

Government of South Australia

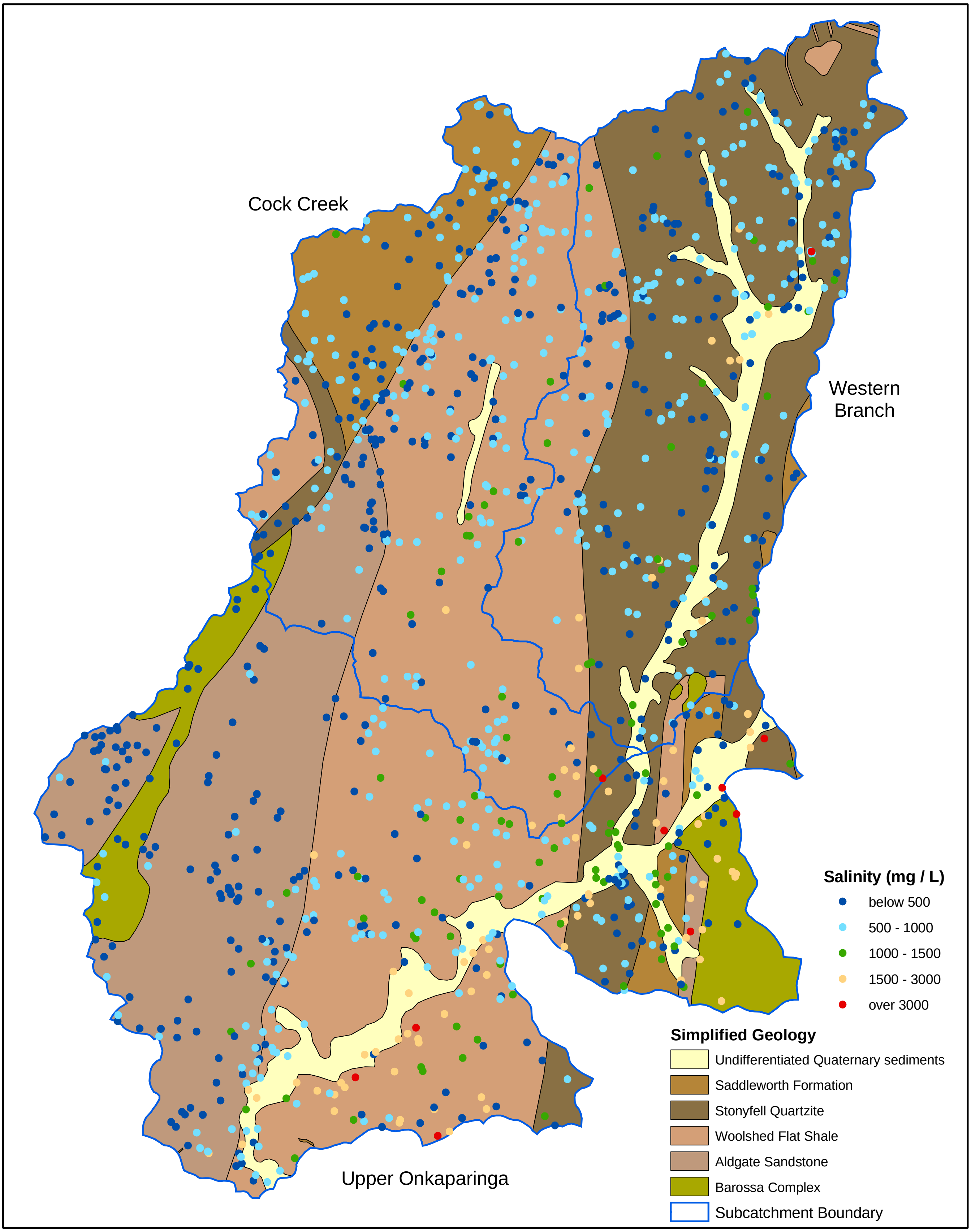


Figure 4

Cock Creek, Western Branch & Upper Onkaparinga Sub-catchments Geology and groundwater salinity

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

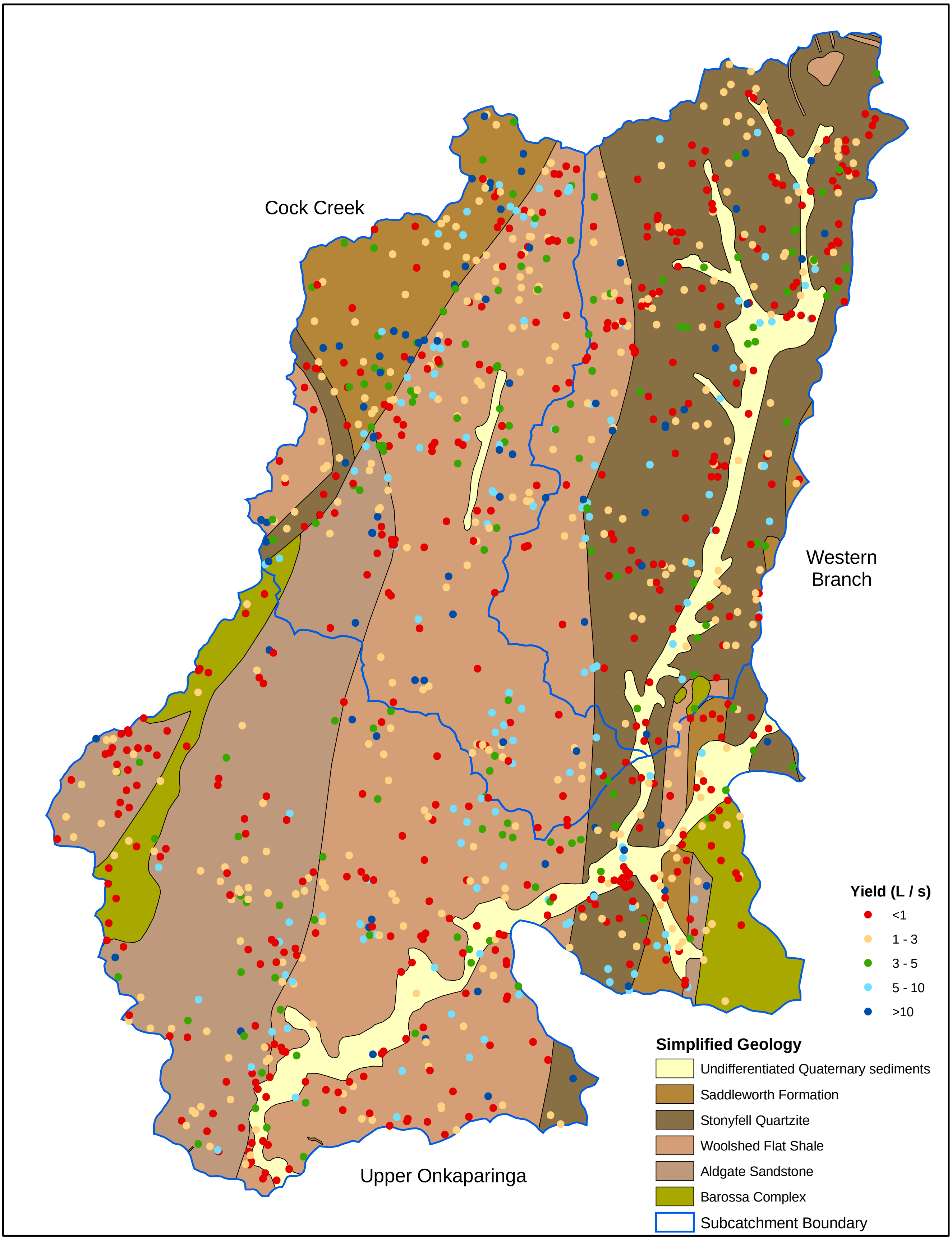
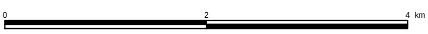


Figure 5

Cock Creek, Western Branch & Upper Onkaparinga Sub-catchments Geology and bore yields



Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

The annual average rainfall for Lobethal is 888 mm, with monthly rainfall distribution as shown in Table 3:

Table 3. Average monthly rainfall for Lobethal (mm)

J	F	M	A	M	J	J	A	S	O	N	D
27	27	31	65	101	126	128	127	100	74	43	36

The main aquifer developed for irrigation is the **Stonyfell Quartzite**, which consists of feldspathic quartzite, sandstone and siltstone, with yields falling below 5 L/s (Fig. 5). In the eastern portion of the sub-catchment, a number of bores developed yields up to 10 L/s. Salinities are generally between 500 and 1000 mg/L (Fig. 4), but there is a significant number of bores with salinities below 500 mg/L.

Upper Onkaparinga

This sub-catchment extends from the eastern side of the Onkaparinga Valley, with elevations of ~500 m AHD, to almost the western boundary of the catchment (Fig. 2). The lowest point is ~330 m AHD near Verdun. The Onkaparinga River here is quite wide and deep. Significant areas of native vegetation exist around the Carey Gully region. The land is predominantly used for grazing, although some orchards are scattered throughout. In recent years, considerable land-use change has occurred, with almost 200 ha of vineyards being established (groundwater survey 2001–02).

Although there are no rainfall stations in this sub-catchment, a 954 mm average annual rainfall was calculated using the isohyet map and the total area. The closest rainfall station is Lenswood, with an average annual rainfall of 1032 mm.

The main aquifers developed for irrigation in this sub-catchment are the **Aldgate Sandstone**, with groundwater salinities of less than 500 mg/L (Fig. 4), and Saddleworth Formation were groundwater salinities vary between 500 and 1000 mg/L. The western portion of the sub-catchment shows a sharp increase in groundwater salinity, rising from 1500 to 3000 mg/L. Groundwater yields again follow the observed trend for these aquifer systems, ranging from below 5 L/s up to 10 L/s (Fig. 5).

Charleston

This sub-catchment forms the headwaters of the Onkaparinga River, with its source located in the Spring Head area (just south of the town of Mount Torrens; Fig. 2). The catchment ranges in elevation from 550 and 500 m AHD (at the northwestern divide (Mt Torrens) and southeastern divide (Mt Charles), respectively) to 350 m AHD at its lowest point (gauging station at Woodside). The predominant land uses are dairying, grazing, vineyards and vegetable production. A relatively small area in the upper northern reaches is under orchard (Fig. 6).

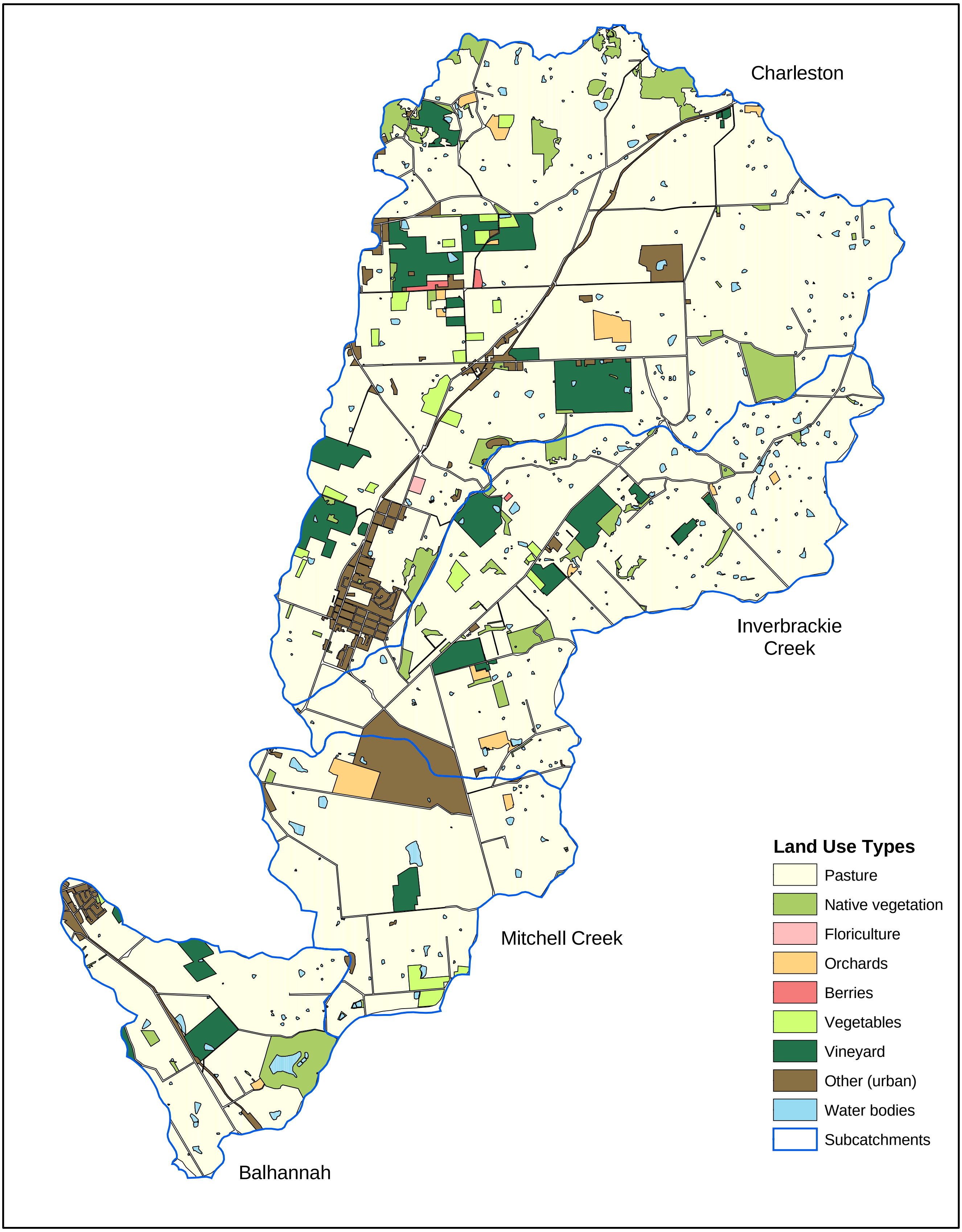


Figure 6

Charleston, Inverbrackie Creek, Mitchell Creek and Balhannah Sub-catchments 2001 Land Use

0 2.5 5 km

N

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

Government of South Australia

The average annual rainfall for Woodside is 804 mm. Rainfall is winter dominant with the monthly averages as shown in Table 4:

Table 4. Average monthly rainfall for Woodside (mm)

J	F	M	A	M	J	J	A	S	O	N	D
26	27	28	58	91	112	117	113	92	68	41	32

Figure 7 shows that the main aquifer developed for irrigation is in the **Saddleworth Formation**, with a very broad range of yields being generally below 5 L/s, but varying up to 20 L/s (Fig. 8). Salinities range between 500 and 1000 mg/L (Fig. 7), except for a number of bores with very high salinities of 1000–3000 mg/L located to the east of the Onkaparinga River and in the top northern part of the sub-catchment.

A number of bores that have been developed in the **Stonyfell Quartzite** have salinities less than 1000 mg/L and yields typically below 5 L/s. A very small number of bores that utilise groundwater from the **Belair Subgroup** (phyllite, schist and feldspathic quartzite) range in salinity from 500 to 1500 mg/L, while yields are below 5 L/s.

There is no irrigation development in the eastern part of the catchment from the **Kanmantoo Group** because of the very high salinities (up to 3000 mg/L) and unreliable supplies (mostly below 5 L/s). A considerable number of dams are present.

Inverbrackie Creek

The Inverbrackie Creek sub-catchment is characterised by a steep-sided stream channel and elevations between 400 and 500 m AHD. Land use is primarily dairying, grazing and, more recently, vineyard development (Fig. 6).

The average annual rainfall obtained from the isohyet map is 721 mm, with the closest rainfall station (Woodside) being in the Charleston sub-catchment where the annual average is 804 mm/y.

Almost half of this sub-catchment (eastern part) is underlain by the **Kanmantoo Group** (Figs 2, 5), which has been identified as a very poor aquifer and is not developed for irrigation. Younger geological sequences such as the **Tapley Hill Formation**, consisting of blue-grey laminated siltstone and slate, and the **Saddleworth Formation** (described earlier), are most prominent in the rest of the catchment. Groundwater drawn from these formations is generally 500–1000 mg/L (Fig. 7), with yields from below 5 L/s to mostly 10 L/s (Fig. 8). Occasionally, yields up to 20 L/s are obtained.

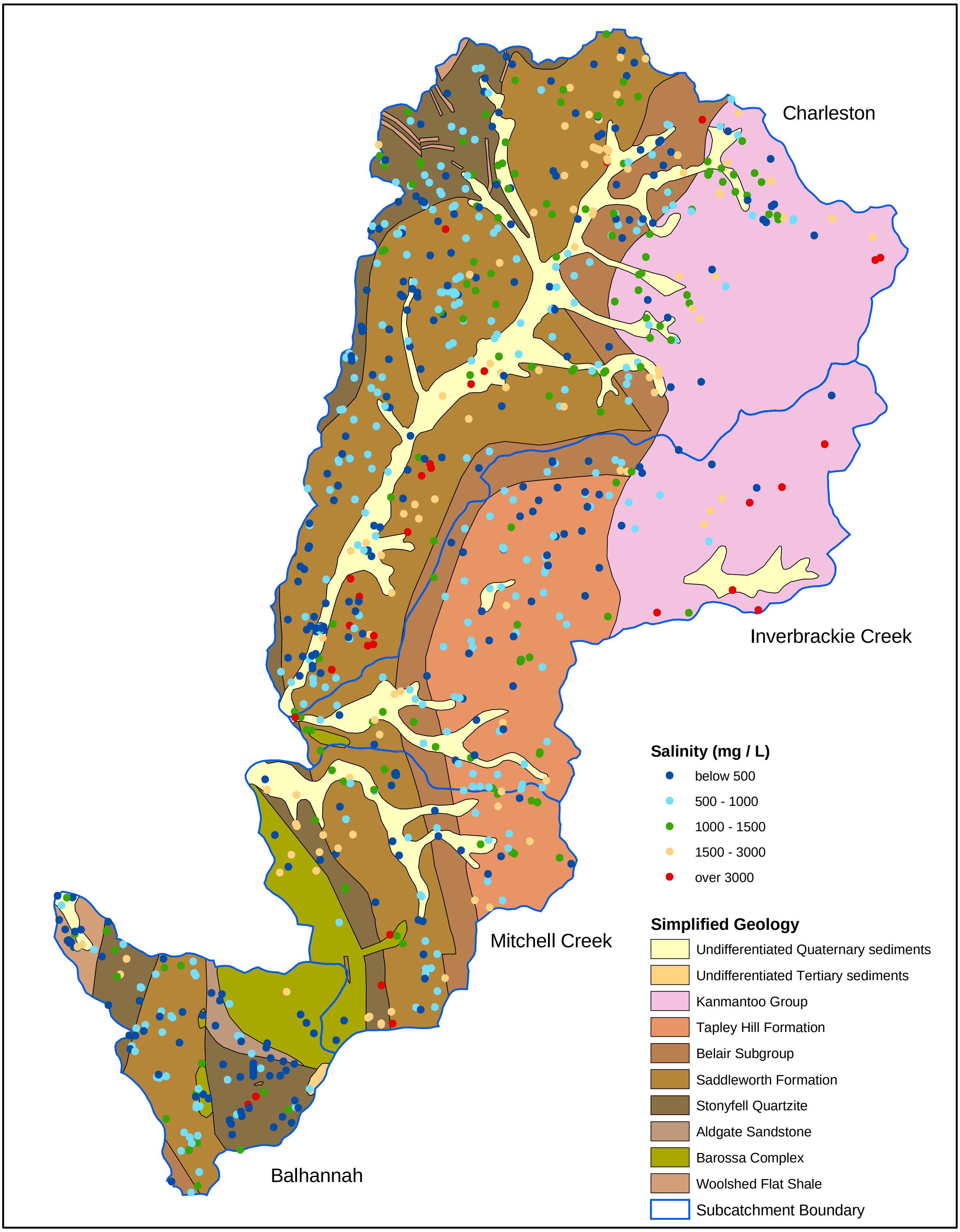


Figure 7

Charleston, Inverbrackie Creek, Mitchell Creek and Balhannah Sub-catchments Geology and groundwater salinity

0 2.5 5 km

N

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

Government of South Australia

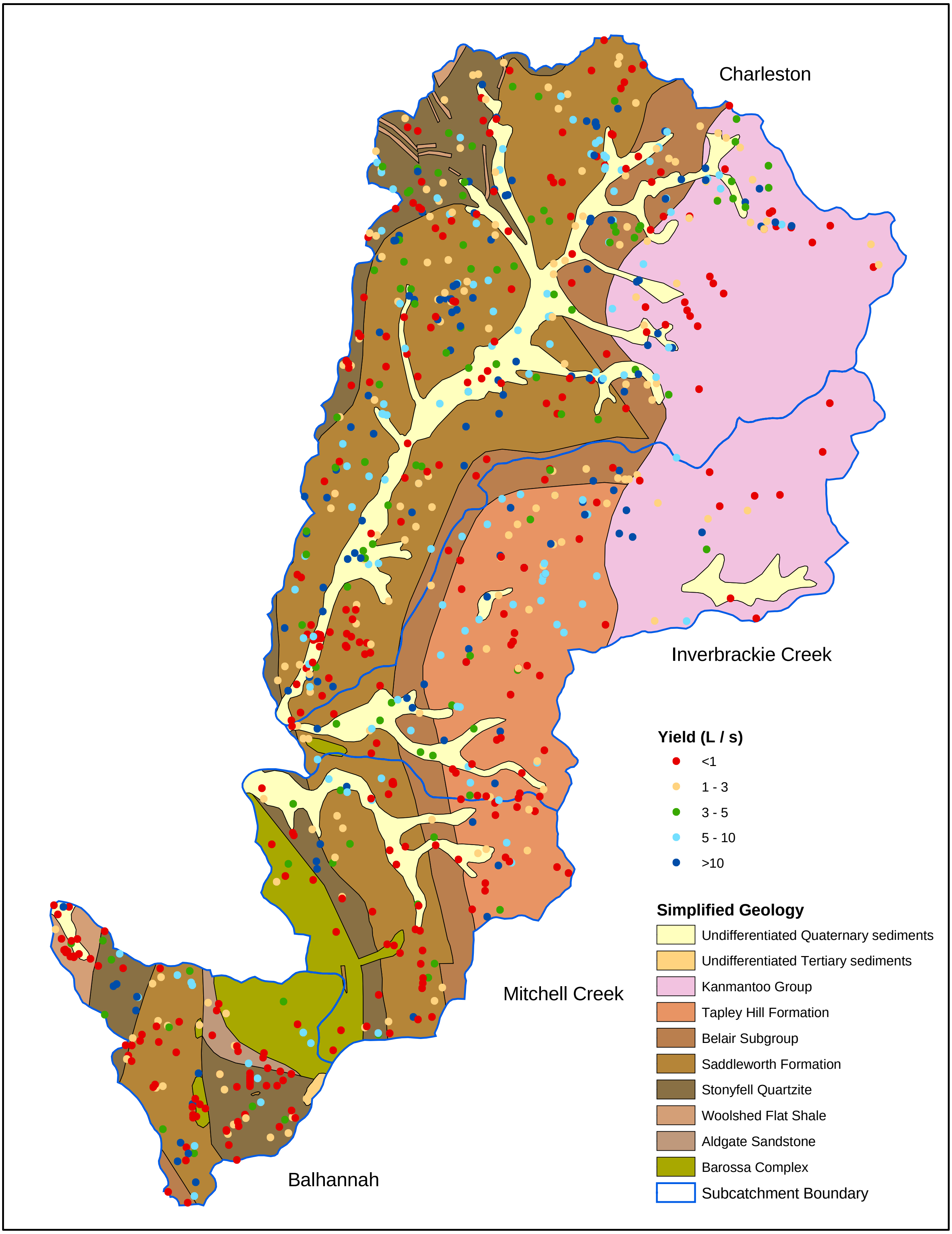


Figure 8

Charleston, Inverbrackie Creek, Mitchell Creek and Balhannah Sub-catchments Geology and bore yields

0 2.5 5 km

N

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

Mitchell Creek and Balhannah

The Mitchell Creek and Balhannah sub-catchments are broad, undulating valleys with elevations in the 400–450 m AHD range. Mitchell Creek has a narrow and shallow stream channel with a narrow floodplain. At one time this sub-catchment was the focus for the mining of alluvial gold and copper. In the Balhannah sub-catchment, urban living is an important land use. The most common rural land use in these catchments is grazing (Fig. 6). An increasing number of vineyards are being established in both catchments. The average annual rainfall is determined from the isohyet map and is 758 mm for Mitchell Creek and 807 mm for Balhannah, compared to the average annual rainfall of 860 mm for Hahndorf, the nearest rainfall station.

All major geological formations mentioned earlier are present in these two sub-catchments: the **Barossa Complex**, **Saddleworth Formation**, **Tapley Hill Formation** and **Kanmantoo Group**. However, there is no obvious correlation between geology and groundwater quality. Groundwater salinities are highly variable, ranging between 500 and 3000 mg/L (Fig. 7), and typical supplies obtained from all aquifers are below 5 L/s (Fig. 8). Some bores managed to develop supplies in the 5–10 L/s range.

Hahndorf

This area lies in the eastern part of the Onkaparinga Catchment where the landscape is gently undulating between 350 and 430 m AHD. The lowest point is 310 m AHD at the Hahndorf Creek gauging station. The area is mostly cleared of native vegetation, with grazing being the major land use (Fig. 9). The town of Hahndorf, which is the major built-up area, occupies ~15% of the land area, with pockets of vineyards, orchards and vegetables scattered throughout the area. This sub-catchment encompasses a watercourse which flows through Hahndorf and takes in the output from the Hahndorf Sewage Treatment Plant. The release of water from the plant creates an atypical flow regime in the section of Hahndorf Creek downstream of the plant.

Again, rainfall is winter dominant, with a decrease in rainfall in an easterly direction across the Onkaparinga Catchment evident due to the rain shadow effect. The monthly averages for Hahndorf are shown in Table 5. The annual average is 860 mm/y.

Table 5. Average monthly rainfall for Hahndorf (mm)

J	F	M	A	M	J	J	A	S	O	N	D
27	26	32	64	99	118	124	119	97	75	43	37

The **Adelaidean** rock units comprise the most productive fractured rock aquifers in the area, occurring in north–south-trending bands (Fig. 10). The **Woolshed Flat Shale** is the main rock type. A narrow band of **Stonyfell Quartzite** wedges out between the Woolshed Flat Shale and the **Saddleworth Formation**.

Groundwater supplies and salinities seem to have a different correlation with aquifer lithology compared to those in the western half of the catchments. Although the rock types vary from Woolshed Flat Shale and Stonyfell Quartzite through schist and siltstone of the Saddleworth Formation, the groundwater salinities, variable as they are (Fig. 10), decrease from west (1500–3000 mg/L) to east (below 1000 mg/L).

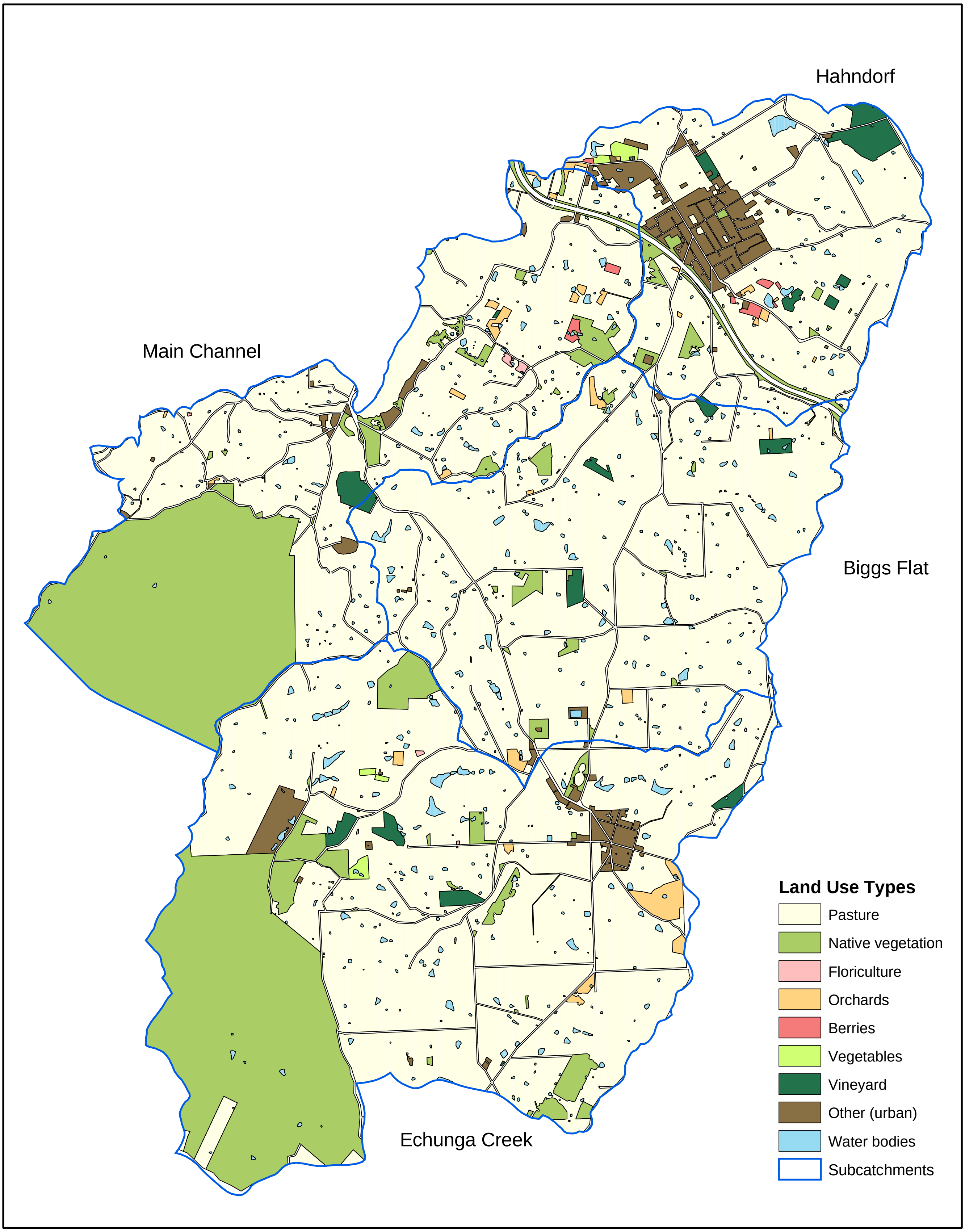


Figure 9

Hahndorf, Biggs Flat, Echunga Creek and Main Channel Sub-catchments 2001 Land Use

0 2 4 km

N

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

Government of South Australia

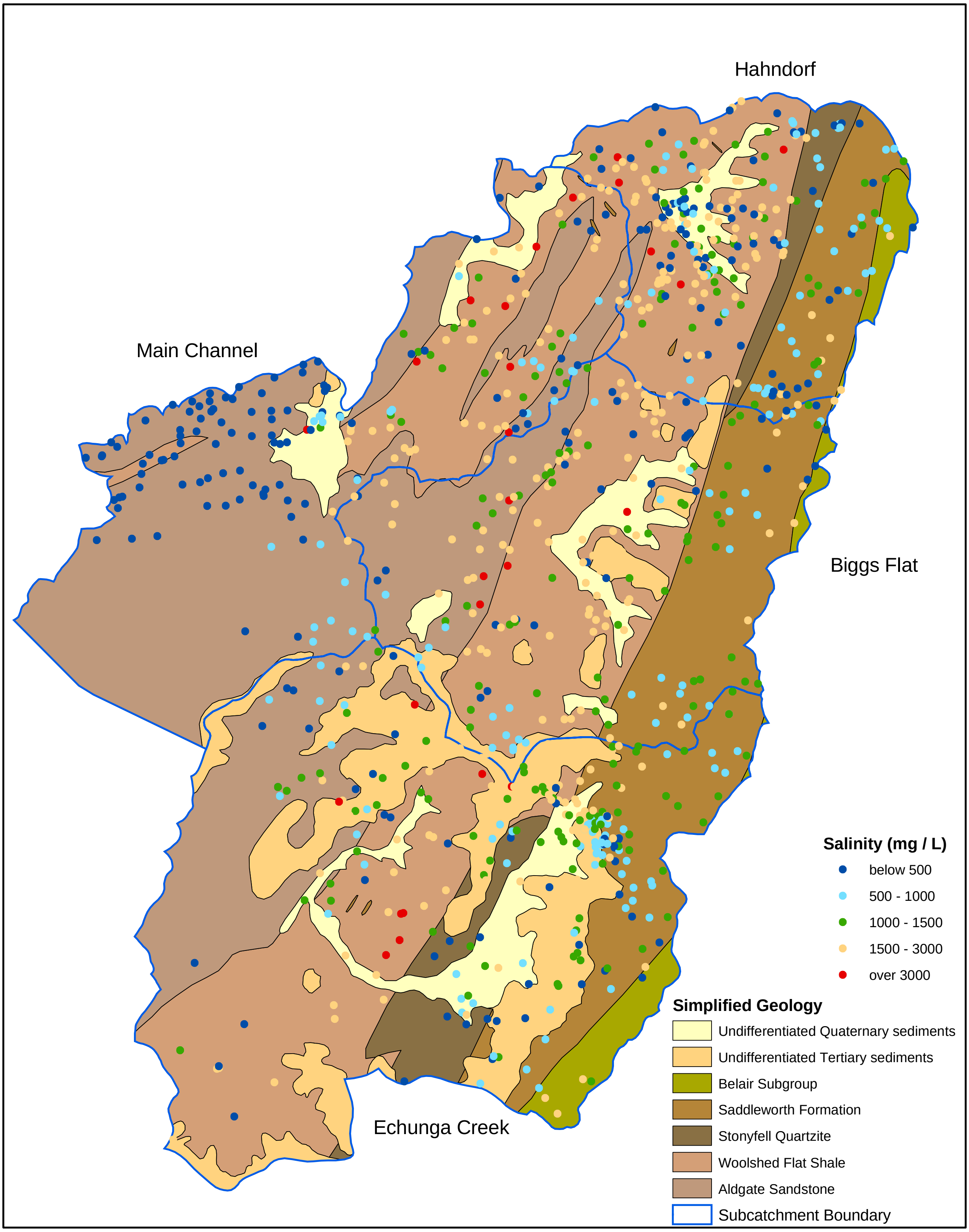


Figure 10

Hahndorf, Biggs Flat, Echunga Creek and Main Channel Sub-catchments Geology and groundwater salinity

0 2 4 km

N

Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

The Department of Water, Land and Biodiversity Conservation

Government of South Australia

Borehole yields similarly show a lack of correlation with rock type in this area (Fig. 11), with all rock types being generally below 5 L/s.

Biggs Flat and Echunga Creek

These two sub-catchments are located upstream of Mt Bold Reservoir. The upper reaches of Echunga Creek sub-catchment are reminiscent of the tea-tree swamps while the lower portion of the stream channel is incised with a relatively wide (15–200 m) floodplain. This catchment drains out into the Mt Bold Reservoir through Brady Gully. The elevations vary from ~400 m at the eastern boundary of both catchments to 250 m AHD at the lowest discharge point. The township of Echunga is on the divide between Echunga and Biggs Flat sub-catchments. The Biggs Flat stream channel is very narrow and shallow, with the bed width 1–2 m. Both dairy and beef cattle grazing are significant activities, especially in the upper sections of the sub-catchments. Large segments of the lower reaches of the Echunga sub-catchment are covered by either native vegetation or plantation forest (Fig. 9).

Similar to the Hahndorf sub-catchment, rainfall decreases in an easterly direction. It is still winter dominant, but average winter values are slightly lower than in the Hahndorf area. The annual average for Echunga is 808 mm, and the monthly averages are given in Table 6.

Table 6. Average monthly rainfall for Echunga (mm)

J	F	M	A	M	J	J	A	S	O	N	D
27	26	32	64	94	111	109	107	90	70	43	35

The surface geology (Fig. 10) is quite similar to that in the Hahndorf sub-catchment, with the **Aldgate Sandstone**, **Woolshed Flat Shale**, **Stonyfell Quartzite** and **Saddleworth Formation** occurring in north–south trending bands. Consequently, the salinity and yield patterns are similar too, showing a zone of poor-quality groundwater on the western margins of the sub-catchment. In this section, salinity is in the 1500–3000 mg/L range (Fig. 10), but better quality water is available in the eastern parts of catchment, ranging from 500 to 1500 mg/L. The correlation between groundwater quality and geological unit seems to be absent, while yields across the catchment are below 5 L/s (Fig. 11).

Onkaparinga Main Channel

The Onkaparinga Main Channel sub-catchment covers the area above Mt Bold Reservoir, where the Onkaparinga River is quite wide and deep. The elevations vary from ~330–350 m on the western and eastern boundaries of the sub-catchment to 258 m at the Houlgrave gauging station.

The area surrounding the Mt Bold Reservoir contains either native vegetation or plantation forest. The upper sections of the sub-catchment are mainly open grazing land (Fig. 9). The Onkaparinga River through the sub-catchment acts as an aqueduct channel for the transport of the River Murray water from the Murray Bridge – Onkaparinga pipeline.

The Onkaparinga Main Channel has an average annual rainfall of 895 mm. For the purpose of water balance calculation, only the upper portion of the catchment (above

Mt Bold Reservoir) was taken into account in this report. The surface geology and bore salinity distribution show that the groundwater quality is dependent on rock type. In the upper reaches of the sub-catchment, **Woolshed Flat Shale** is the dominant formation and salinity is highly variable and generally between 1500–3000 mg/L (Fig. 10), while yields are below 5 L/s (Fig. 11). In the lower parts of the sub-catchment, towards the western boundary, bores tapping the **Aldgate Sandstone** aquifer have salinities below 500 mg/L and yields from below 5 to 10 L/s.

A field survey carried out in January 2002 showed that no groundwater is used for irrigation in this sub-catchment.

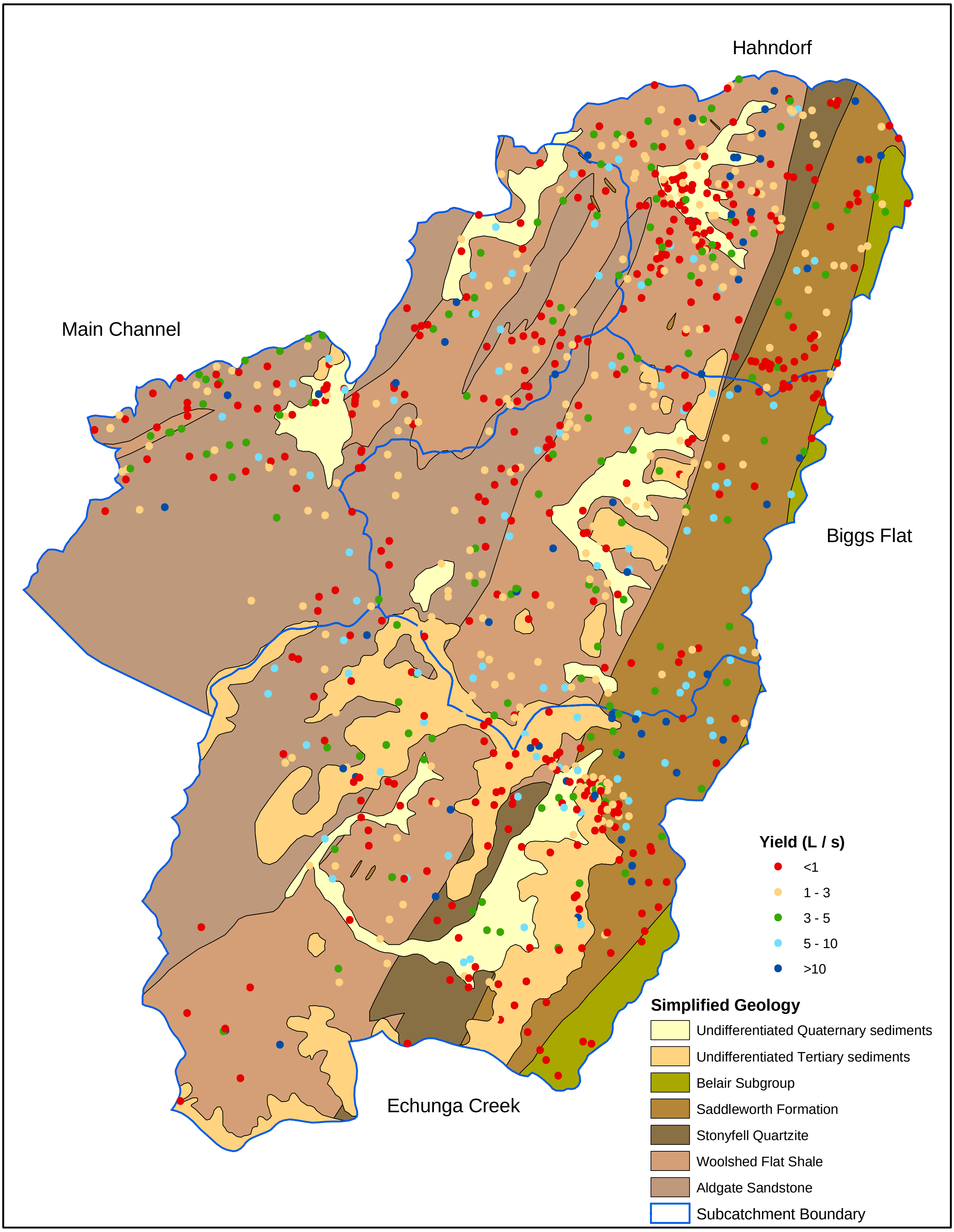
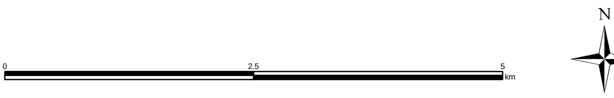


Figure 11

Hahndorf, Biggs Flat, Echunga Creek and Main Channel Sub-catchments Geology and bore yields



Produced : Resource Assessment Division
Department of Water, Land and Biodiversity Conservation
Projection: Map Grid of Australia 1994 (UTM) Zone 54
Datum: Geocentric Datum of Australia 1994
Date: January 2003

Government of South Australia

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 of relatively high groundwater use where each of the following components of the water balance (Fig. 12) 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 limitations of the methods adopted to determine the water balance for these sub-catchments and the sustainable yield are well recognised but, in the absence of any other information, provide the best approximation concerning the availability of groundwater for broad-scale planning purposes. DWLBC is currently undertaking a number of more detailed groundwater investigations to better quantify the parameters and recharge rates across a number of 'type' catchments within the MLR.

Rainfall

This is the main driving force of the hydrologic cycle and is the major water input to the catchment. Rainfall is winter dominant as discussed earlier. By combining a rainfall isohyet map with the areal extent of a catchment, the total average annual volume of rainfall falling on the catchment can be calculated. Because 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 7 lists the rainfall volumes in the selected sub-catchments.

Table 7. Sub-catchment rainfall volumes

Sub-catchment	Annual rainfall (ML)	Effective rainfall (ML)
Cock Creek	27 852	22 550
Western Branch	29 378	23 870
Upper Onkaparinga	44 948	36 361
Charleston	41 092	33 270
Inverbrackie Creek	19 270	15 376
Mitchell Creek	10 986	8 758
Balhannah	8 261	6 615
Hahndorf	12 262	9 836
Biggs Flat	18 997	15 222
Echunga Creek	32 032	25 570
Onkaparinga Main Channel	21 951	17 941

The amount of rainfall that may percolate past the root zone to the watertable as recharge is likely to be strongly related to antecedent climactic conditions, in particular, duration and intensity of rainfall events. Further work is being undertaken by DWLBC to better define recharge rates throughout the MLR catchments.

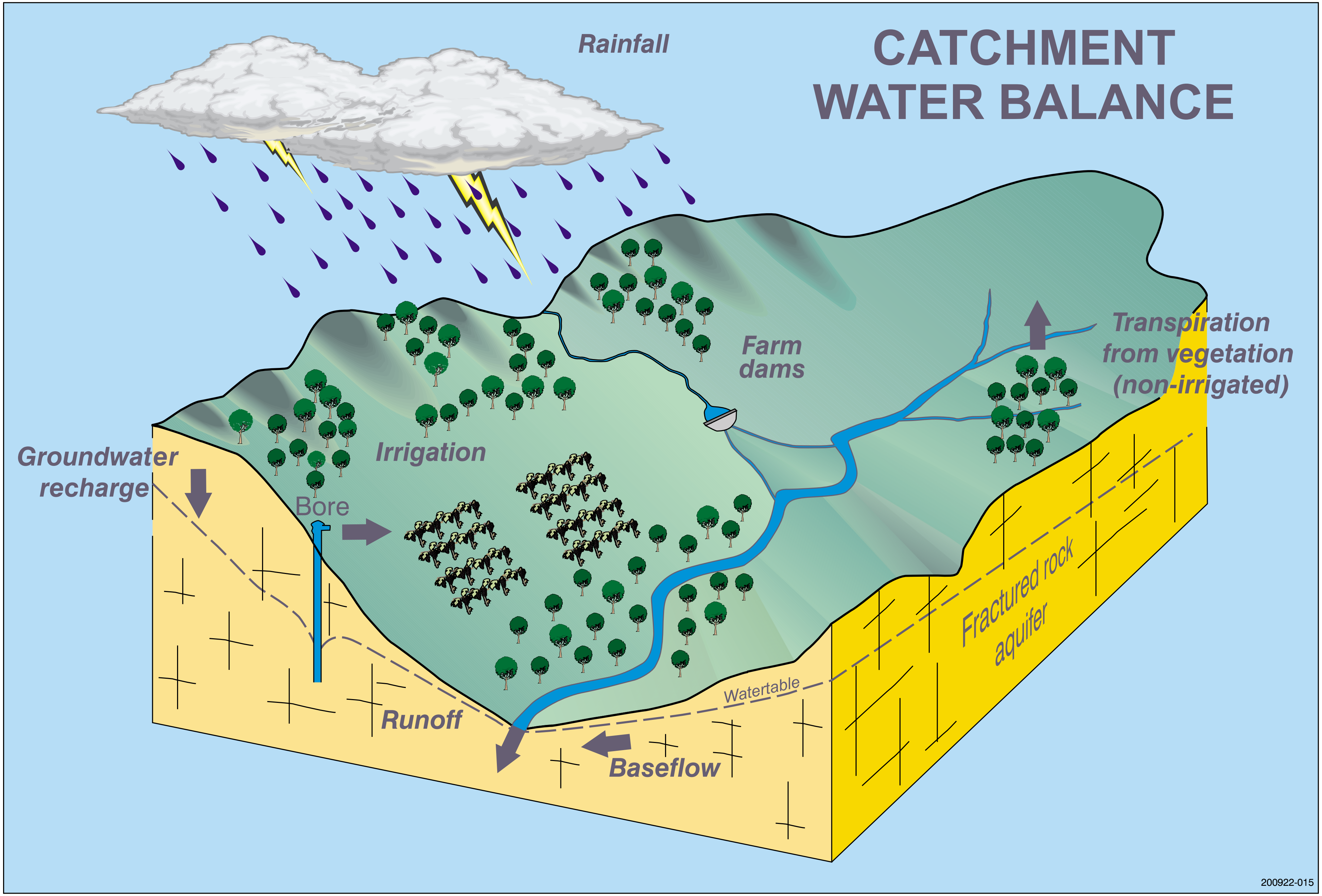


Figure 12 Catchment water balance components

Evapotranspiration

After rain has fallen, water is taken up by plants and trees through their roots. It is also evaporated from the topsoil and even from wet leaves in the tree canopy. Following recent research, reasonable estimates of plant water use by transpiration for various crops can be made. This is often the largest water use component in the catchment.

A geographic information system (GIS) coverage of land use in the MLR was constructed in 2001 using September 1999 1:20 000 ortho-rectified aerial photography. This coverage can provide areas of native vegetation, pasture, vineyards etc. and, hence, the volume of water transpired (from non-irrigated areas) can be estimated. This coverage can be updated using recent ground truthing. Maps of land use for the areas of interest are shown in Figures 3, 6 and 9, with details of water use presented in Appendix A.

Under native vegetation, it has been estimated that all but 30 mm/y of rainfall reaching the ground is transpired. It must be stressed that these estimates of plant water use are accurate to only ±10–15% and, consequently, estimates of evapotranspiration presented in Appendix A can at best have only a similar accuracy.

Streamflow

There is a network of ~70 continuous recording gauging stations throughout the MLR. Most of the data are stored at DWLBC on HYDSIS. Runoff and baseflow components can be separated from these records. Baseflow is the contribution to streamflow provided by groundwater discharge from the fractured rock aquifers.

Gauging stations are situated on the Onkaparinga River at Woodside and Houlgrave, Hahndorf Creek at Hahndorf (downstream of Sewerage Treatment Works), and Echunga Creek upstream of Mt Bold Reservoir (Table 8). The values given for Charleston and Hahndorf should be used with caution because there has been only short-term monitoring.

Table 8. Annual Catchment streamflow volumes (gauged)

Sub-catchment	**Runoff** (ML)	**Baseflow** (ML)
Charleston — 503538	2 800	885
Hahndorf — 503537	1 200	425
Echunga Creek — 503506	2 098	1 220
Onkaparinga (Houlgrave) — 503504	32 530	18 540

Estimates of the total streamflow for the ungauged Inverbrackie Creek, Mitchell Creek, Cock Creek, Balhannah, Upper Onkaparinga, Biggs Flat and Western Branch sub-catchments were made using catchment modelling carried out by the Surface Water Assessment Branch of DWLBC (Teoh, 2002). Runoff and baseflow estimates were again products of catchment modelling. The latest baseflow information supplied by Teoh was derived by Method 1, Chapman and Maxwell (Grayson, 1996) using the modelled flow outputs. All the current flow values, as shown in Table 9 are the median flows from 1900 to 1998. It appears that some of the modelled catchment runoffs (such as Charleston and Hahndorf) differ greatly from the measured values. This is because the periods of recorded flows vary from that of the model, and may be insufficient to produce accurate and representative figures. Therefore, for the catchment water balance calculations (Appendix A), modelled values were used for Charleston and Hahndorf.

Table 9. Annual Catchment streamflow volumes (modelled)

Sub-catchment	**Runoff** (ML)	**Baseflow** (ML)
Cock Creek	4667	2399
Western Branch	3798	998
Upper Onkaparinga	6097	1906
Charleston	3908	1687
Inverbrackie Creek	2175	874
Mitchell Creek	1070	155
Balhannah	811	220
Hahndorf	1870	355
Biggs Flat	1517	323
Echunga Creek	2603	1063
Onkaparinga Main Channel	3155	995

Surface storages

Some of the runoff is captured in farm dams. A recent study by DWLBC Surface Water Assessment Branch has calculated the volume of all farm dams in the MLR using infrared aerial photography and formula to calculate dam area and volume. In this assessment the following formula (McMurray, 1996) was used:

$V = 0.044\ S^{1.4}$ where S = surface area (m^2)

This coverage is also available on GIS. It is assumed that the dams are full at the end of winter–spring, and receive no more inflows during summer. Table 10 illustrates the calculated total volumes of water held in the respective catchments by farm dams based on 1999 data (Teoh, 2002).

Table 10. Catchment dam storage volumes

Sub-catchment	**Dam Volume** (ML)
Cock Creek	710
Western Branch	985
Upper Onkaparinga	1060
Charleston	1000
Inverbrackie Creek	540
Mitchell Creek	570
Balhannah	200
Hahndorf	560
Biggs Flat	660
Echunga Creek	1060
Onkaparinga Main Channel	315

Groundwater pumping

The main component of groundwater pumping is irrigation, but unfortunately very few of the bores have meters installed to measure their discharge.

The 2001 land-use coverage on GIS (Figs 3, 6, 9) can provide a reasonably accurate estimate of the area and crop type irrigated. Estimates of the various crop water application requirements (by PIRSA) for irrigation during summer can then allow an approximate calculation of the total volume extracted. This method works well in the smaller sub-catchments where properties are also small and dominated by one land use.

The first groundwater use survey was also carried out during the 2001–02 irrigation season in 11 sub-catchments: Charleston, Western Branch, Cock Creek, Inverbrackie Creek, Upper Onkaparinga, Mitchell Creek, Balhannah, Hahndorf, Biggs Flat, Echunga Creek and Onkaparinga Main Channel. Some irrigators have been contacted in person, by phone, or they have received the questionnaire through the mail. The majority of the contacts were successful, and a number of responses have been received. However, contact could not be made with some irrigators, and there was no response from any of the Mitchell Creek sub-catchment irrigators. The irrigators who did participate completed the questionnaire on groundwater and/or surface water use by estimating the number of hours they irrigate during the season and providing pumping rates. By multiplying the number of hours pumped by pumping rate, an estimation of the total extraction for the area was made (Appendix A).

Comparison of the two methods (GIS land use and field survey) showed similar values both in the total area irrigated and type of crop. Where they differed, the survey figures were used because it is considered that these data are more current and reflect changes in land use since the GIS survey was carried out.

The most uncertain results are those representing irrigated pasture. The 2001 land-use coverage divides total grazing area into two classes: broad-scale grazing and intensive grazing. The intensive grazing class includes all areas identified as dairy, horse, deer, alpacas, hens, ostrich and emu farming, and therefore does not delineate irrigated areas. A few assumptions had to be made to calculate pumping volumes for these areas. It is assumed that all areas of intensive grazing are irrigated. Again, comparison with the groundwater survey gives similar results. However, the results differ greatly for the Charleston and Inverbrackie sub-catchments, and the field survey findings were used for both of these.

In some sub-catchments, a large portion of irrigation water was supplied from surface water in farm dams. For the purpose of estimating irrigation or extraction volumes in Appendix A, an attempt was made to differentiate between surface and groundwater sources, with only the groundwater contribution being listed. The water requirements for Hahndorf are ~500 ML, but only 190 ML are estimated to be from groundwater. The Onkaparinga Main Channel (portion) irrigation requirements of over 300 ML are fully obtained from surface water. It is reasonable to assume that in the Mitchell Creek sub-catchment, surface water is mostly used for irrigation because of the large dam volume storage of 570 ML.

Irrigation efficiencies vary greatly throughout the MLR, with some crops being ‘under-irrigated’ as well as ‘over-irrigated’. Recirculation of excess irrigation water to the watertable may occur in areas where its depth is less than 10–15 m.

It must again be stressed that these estimates of return flows to the watertable from irrigation are accurate to only ±10–20%. Metering of irrigation and industrial users is strongly recommended to obtain accurate estimates of groundwater use.

The estimates for pumping from private wells for domestic use are based on the number of domestic wells on the state water well database (SA-GEODATA) and the average domestic consumption from SA Water reticulation in the area. The domestic consumption figures are likely to be an overestimate. There may be combined borehole and dam water supplies, and some field verification of actual use may be required.

Groundwater recharge

This is perhaps the most important component of the water balance 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 factors such as soil type and vegetation cover, together with rainfall intensity and duration. There are several methods available to estimate recharge.

A) WATER BALANCE

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

Recharge = Rainfall – (evapotranspiration + runoff + dam storage)

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

Recharge = Groundwater pumping + baseflow

The Charleston catchment data from Appendix A are used here as an example:

Recharge = Rainfall – (evapotranspiration + runoff + dam storage)

= 33 270 – (20 270 + 3908 + 1000)

= 8092 ML or 157 mm/y (~19% annual rainfall)

By using the groundwater balance only:

Recharge = Groundwater extraction + baseflow

= 1687 + 1687

= 3374 ML or 66 mm/y (8%).

B) 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 consequently concentrated in the reduced amount of water that eventually percolates down to recharge the groundwater. Recharge can be calculated by:

Recharge = (annual rainfall – runoff) x ($Cl_{rf} \div Cl_{gw}$)

where Cl_{rf} = chloride in rainfall (mg/L)

Cl_{gw} = chloride in groundwater (mg/L).

Care must be taken when using this method for several reasons. Pumped samples from private holes may obtain water from deep within 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 added by the recirculation of irrigation water and also 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 = distance from coast in km
Cl = chloride concentration in milliequivalents/litre

Kayaalp (1998)

$Cl = 1.1 + 2.98\ e^{-d/111}$ WET (in rainfall)
where: d = distance from coast in km
Cl = chloride concentration in mg/L
$Cl = 60 + 1043\ e^{-d/2.7}$ DRY (aerosol dust)
where d = distance from coast in km
Cl = chloride loading in kg/km^2/month

The total chloride accession, which consists of the sum of wet and dry chloride, can then be included in the recharge formula above. The chloride content of groundwater can be obtained from the Water Chemistry module of SA_GEODATA (Groundwater information database).

Table 11 shows the calculated recharge values for all sub-catchments using both equations above, both in mm/y and a percentage of annual rainfall. As expected, the two methods (Hutton and Kayaalp) show significantly different results. In the absence of any other supporting groundwater chemistry information such as stable isotopes, the Kayaalp method appears to under-estimate the potential recharge from rainfall. The Hutton values tend to approximate recharge rates calculated or observed in sedimentary aquifers throughout other parts of the state.

Estimations of recharge using the chloride mass balance approach within a fractured rock aquifer system do not often yield reliable results because of the significant spatial variability in groundwater salinity observed within these aquifer units. However, in the absence of other information, and provided that detailed screening of the base information is undertaken to ensure that only parameters determined from short open-hole intervals at the top of the watertable are used, the method can be applied to obtain first-order estimates of recharge for broad-scale planning purposes.

Table 11. Chloride recharge estimates

Sub-catchment	Cl_{gw} mg/L	Kayaalp Clrf mg/L	Hutton Clrf mg/L	Recharge (mm/y)		Recharge (%)		Recharge (ML)	
		(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Cock Creek	232	4.4	8.5	16	3 0	1.6	3.1	500	900
Western Branch	258	4.2	6.6	13	21	1.5	2.4	450	650
Upper Onkaparinga	310	4.24	7.3	12	20	1.2	2.1	600	1000
Charleston	252	4.3	7.1	13	19	1.6	2.4	700	1100
Inverbrackie Creek	214	4.27	6.2	13	19	1.8	2.6	350	510
Mitchell Creek	420	4.3	6.5	7	11	1	1.5	100	160
Balhannah	231	4.27	6.85	14	22	1.7	2.7	150	250
Hahndorf	600	4.4	7.55	6	10	0.7	1.2	100	150
Biggs Flat	670	4.4	7.55	5	9	0.6	1.1	120	210
Echunga Creek	450	4.4	7.55	8	13	1	1.6	350	500
Onkaparinga Main Channel	300	4.38	8.26	12	22	1.3	2.5	300	550

C) WATERTABLE RISE

This technique measures the direct effect of recharge during the winter season, which leads to an increase in water stored in the aquifer. This is a reasonably straightforward method, but uncertainties are introduced because the measured watertable rise must be multiplied by the specific yield to obtain the volume of recharge that has entered the aquifer. Specific yield values are difficult to measure and are highly variable, even within the same aquifer and more so in fractured rock aquifer systems.

The seasonal fluctuations in water levels within the fractured rock aquifer systems are often very pronounced (greater than 20 m in many cases) and, without knowing reliably the specific yield, make this method virtually impossible to apply to fractured rock aquifer systems.

D) DISCUSSION

The two different methods of estimating recharge provided different ranges of values in each catchment (summarised in Table 12).

As stated earlier, in other water balance studies, the values calculated by the chloride method also appear to be low when compared to the other methods of calculating recharge. This probably indicates that a new chloride equilibrium has not been reached since land clearing and that the values obtained could reflect pre-clearing recharge rates.

The water balance estimates should be considered as a broad approximation given many of the uncertainties in estimating the various inputs and outputs from the system. The estimates of groundwater pumping may be exaggerated because it is assumed that all

Table 12. Comparison of recharge estimates

Sub-catchment	Water balance (ML)	Chloride balance (ML)
Cock Creek	5800-5900	900
Western Branch	2400-6100	650
Upper Onkaparinga	3400-10 000	1000
Charleston	3400-8100	1100
Inverbrackie Creek	2000-2100	510
Mitchell Creek	900-1600	160
Balhannah	1150-1500	250
Hahndorf	600-2000	150
Biggs Flat	600-3500	210
Echunga Creek	2100-4300	500
Onkaparinga Main Channel	1000-2700	550

orchard and vineyard areas are fully irrigated. In the Inverbrackie, Mitchell Creek and Balhannah sub-catchments, because of the lack of response from irrigators, it is assumed that all irrigation water needs are obtained from groundwater. The huge dam storage volume indicates it is likely that half of the estimated irrigation requirements are obtained from surface water. The estimates of groundwater pumping and baseflow are therefore at best approximate to within ±25–30%.

For the purposes of this investigation and in the absence of any data to the contrary, the recharge values proposed for the various sub-catchments investigated are provided in Table 13. It should be noted that these figures are estimates only and are likely to have associated error margins of ±25–30%. Further work is currently being undertaken by DWLBC to try and refine these first order approximations.

Table 13. Adopted recharge values

Sub-catchment	ML	mm/y	% rainfall
Cock Creek	5000	175	18
Western Branch	3500	109	12
Upper Onkaparinga	6000	127	13
Charleston	5000	97	12
Inverbrackie Creek	2000	75	10
Mitchell Creek	1300	90	12
Balhannah	1300	126	15
Hahndorf	1500	102	12
Biggs Flat	2000	85	10
Echunga Creek	3000	77	9
Onkaparinga Main Channel	1700	70	8

Examining the figures presented in Table 13, it is apparent that the recharge rates decrease from west to east, corresponding with the decreasing rainfall pattern. The values derived using the water balance method appear to correlate with the empirical data and previous work. For example, the proposed rates for Cock Creek are very similar to the adjacent Cox Creek (Piccadilly Valley, 190 mm/y, 20% annual rainfall), which was determined by a similar method (Barnett and Zulfic, 1999).

Although Onkaparinga Main Channel has high rainfall, its recharge rate is the lowest in the whole study area. This is attributed to a very steep catchment and a much larger cover of native vegetation and plantation forests.

SUSTAINABLE YIELD

Normally, the concept of the sustainable yield of an aquifer is to ensure that the long-term rate of withdrawal should be equal to, or not exceed, the average annual recharge. This would result in no net change in the volume of groundwater stored in the aquifer, and consequently no net change in groundwater levels, apart from variations due to changes in annual rainfall.

In the fractured rock aquifers of the MLR, groundwater levels fluctuate seasonally. During summer, the watertable falls due to pumping, evapotranspiration and discharge to streams. In winter, recharge from rainfall occurs, with the watertable rising as the aquifer storage fills up. The excess groundwater 'overflows' and discharges to the streams as baseflow.

During years of drought or below-average rainfall, the reduced rate of recharge may not keep pace with the increased pumping and discharge to streams. Watertables may then fall several metres as groundwater is used from the huge amount of storage within the aquifer that contains groundwater in fractures down to depths of at least 100 m. A return to normal rainfall will rapidly fill the empty storage volume and return the watertable to its normal level.

A complicating factor in the sustainable yield concept outlined above is the increasing awareness of the requirement for maintaining flows in streams for environmental purposes. Even though groundwater withdrawals may be well below the sustainable yield, any increase in extraction of groundwater may reduce baseflow with a consequent reduction in streamflow. A recent study (Hatton and Evans, 1998) found a low level of understanding of these processes and concluded that the relationships between groundwater pumping, baseflow and the minimum streamflow required for environmental purposes are important questions to be resolved.

Therefore, for the purposes of this study, it is proposed that the sustainable yield should not exceed 75% of the estimated recharge. Estimates of sustainable yield for 50 and 75% of recharge are presented in Table 14. The values for the sustainable yield presented in Table 14 represent a first-order approximation and should be used with caution. Throughout this report, limitations concerning the reliability of the methods used to determine these values have been identified, and consequently it is recommended that for initial planning purposes as a precautionary approach the lower value of 50% of recharge be adopted as the potential sustainable yield for these sub-catchments. Further work is being undertaken by DWLBC to improve the understanding of recharge and discharge mechanisms and to develop new methods to better estimate parameters of the water budget required for sustainable management. Given the complexity of investigations required, these studies will be carried out over the next three to seven years.

In addition to the sustainable yield based on annual recharge, large volumes of groundwater are stored in joints and fractures down to at least 100 m below ground level. Assuming conservative values of 75 m for the thickness of the fractured rock aquifer, and 0.02 for the specific yield, the total volumes in storage are shown in Table 15, which are over 10 times the annual recharge. Despite the apparent large quantities of water in storage, not all of this can be extracted for use. In addition, salinities of groundwater within the fractured rock aquifer systems typically increase rapidly with depth.

Table 14. Estimates of sustainable yield (ML)

Sub-catchment	Current use	50% recharge	75% recharge
Cock Creek	3380	2500	3750
Western Branch	1400	1750	2625
Upper Onkaparinga	1450	3000	4500
Charleston	1700	2500	3750
Inverbrackie Creek	1140	1000	1500
Mitchell Creek	700	650	975
Balhannah	930	650	975
Hahndorf	200	750	1125
Biggs Flat	255	1000	1500
Echunga	1050	1500	2250
Onkaparinga Main Channel	0	850	1275

Table 15. Aquifer storage volumes

Sub-catchment	Volume in storage (ML)
Cock Creek	42 000
Western Branch	49 000
Upper Onkaparinga	70 000
Charleston	77 000
Inverbrackie Creek	40 000
Mitchell Creek	21 000
Balhannah	15 000
Hahndorf	22 000
Biggs Flat	35 000
Echunga	58 000
Onkaparinga Main Channel	36 000

There is obviously potential for further development of groundwater resources in Charleston, Western Branch, Upper Onkaparinga, Hahndorf, Biggs Flat, Echunga and the Main Channel sub-catchments. However, in smaller sub-catchments, significant withdrawals may have significant local impacts such as drawdowns in groundwater levels beneath neighbouring properties and a reduction in baseflow, which may have environmental consequences. Such impacts should be investigated on a case-by-case basis.

Extractions in the Cock, Inverbrackie, Mitchell and Balhannah sub-catchments appear to be approaching the estimated sustainable yield at 75% of recharge value, although the use of surface water from the large volume of dam storage may mean that actual groundwater pumping is well below 75% of recharge. Nevertheless, more accurate information on groundwater withdrawals is required, especially in areas of concentrated irrigation. Metering is strongly recommended to assist such assessments and to promote irrigation efficiency.

GROUNDWATER USE

It is important to examine the current groundwater status in any catchment in the context of its previous history. This means examining, where possible, the historical groundwater development and use. Inspection of aerial photographs has allowed such an estimate to be determined, as shown in Table 16.

The table shows an interesting trend of a decrease in groundwater extraction in the Charleston, Western Branch and Cock Creek sub-catchments by 15–20%, due to a change in land use from irrigated pastures and orchards to grazing and vineyards. This decrease reflects the lower water requirement of vines and the more efficient methods used to irrigate them.

Extraction in the Upper Onkaparinga sub-catchment has shown a significant increase of ~50% since 1987, largely due to the expansion of vineyards, berries and vegetable growing.

Significant land-use changes have occurred in the Mitchell, Balhannah and Hahndorf sub-catchments, mainly due to vineyard expansion. This has resulted in a significant increase in the water consumption by ~50%, but it is believed that the majority of water requirements are obtained from surface water. This is confirmed for Hahndorf, where only about one-third of supplies needed are obtained from groundwater.

Similar expansion in vine growing has been happening over recent years in other areas such as the Biggs Flat, Echunga and Main Channel sub-catchments. Large areas classified as dairies (irrigated pastures) have been subdivided into hobby farms or rural living, or replaced by viticulture. Again, replacing pasture with the lower water requirement crops has resulted in a decrease in groundwater consumption in these sub-catchments.

The water balances for all sub-catchments need to be revised at regular intervals to take into account such changes in land use and irrigation practices.

Groundwater monitoring

As well as examining historical land and water use, trends in groundwater levels and quality should also be examined where possible. Unfortunately, the only observation network in the Upper Onkaparinga Catchment exists in Piccadilly Valley and hence no analysis can be made for the whole catchment.

Concerns were expressed about falling water levels and reduced stream flows throughout the MLR during 1997–99 period. This was not caused by overpumping, but by the fact that the three years had very dry winters, well below average rainfall as shown in Figures 13 and 14 which depict graphs of the cumulative rainfall deviation for the Lenswood, Lobethal, Woodside, Hahndorf and Echunga rainfall stations. The graphs illustrate the difference between the actual measured rainfall and the average rainfall on an annual basis. An upward trend in this line indicates above average rainfall and, conversely, a downward trend indicates below average rainfall.

Figures 13 and 14 show that since 1976 there have been only 3–4 very wet years, with most below average.

Table 16. Historical land and water use

Crop	Area (ha)		
	1970	**1987**	**2001**
Charleston			
Improved pasture	375	385	70
Orchards			60
Vegetables			72
Vineyards			390
Berries			9
Floriculture			11
Use (ML)	**2250**	**2310**	**1700**
Western Branch			
Improved pasture	325	124	40
Orchards	126	78	116
Vegetables			21
Vineyards			186
Berries			28
Floriculture			12
Use (ML)	**2454**	**1056**	**1400**
Cock Creek			
Improved pasture	139	29	
Orchards	760	771	781
Vegetables			2
Vineyards			149
Berries			1.5
Floriculture			7.5
Use (ML)	**3874**	**3258**	**3380**
Upper Onkaparinga			
Pasture		58	70
Orchards	194*	140	136
Vegetables		5	15
Vineyards			194
Berries		2	20
Use (ML)	**864**	**952**	**1450**
Inverbrackie Creek			
Pasture	208	139	105
Orchards			10
Vegetables			17
Vineyards			203
Use (ML)	**1248**	**834**	**1140**

Crop	Area (ha)		
	1970	**1987**	**2001**
Mitchell Creek			
Pasture		70	47
Orchards			30
Vegetables			24
Vineyards			65
Use (ML)		**420**	**700**
Balhannah			
Pasture		70	120
Orchards			2.5
Vegetables			12
Vineyards			88
Use (ML)		**420**	**930**
Hahndorf			
Pasture		20	30
Orchards		15	7.5
Vegetables			21
Vineyards		14	95
Berries		8	2
Use (ML)		**253**	**190**
Biggs Flat			
Pasture	94	58	
Orchards			8
Vegetables			23.5
Vineyards			32
Use (ML)	**564**	**348**	**255**
Echunga			
Pastures	180	151	112
Orchard		4	46
Vegetables			10
Vineyards			65
Use (ML)	**1080**	**930**	**1050**
Onkaparinga Main Channel			
Pasture	55	29	32
Orchards	65	12	25
Vineyards			19
Berries			1
Use (ML)	**580**	**224**	**0**

* figure obtained from 1970 EWS digitised map *'Basic land use within the Onkaparinga Catchment'*

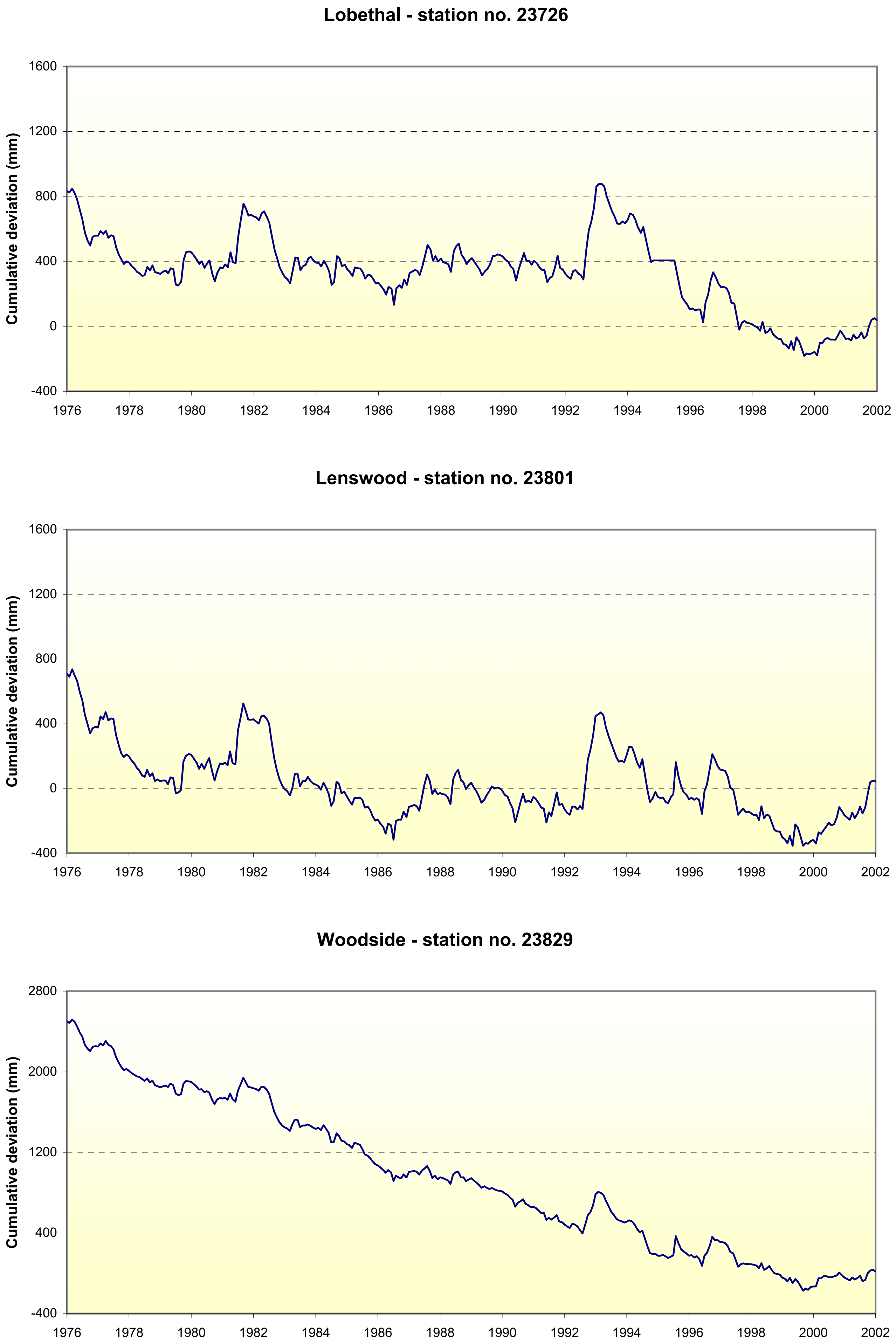
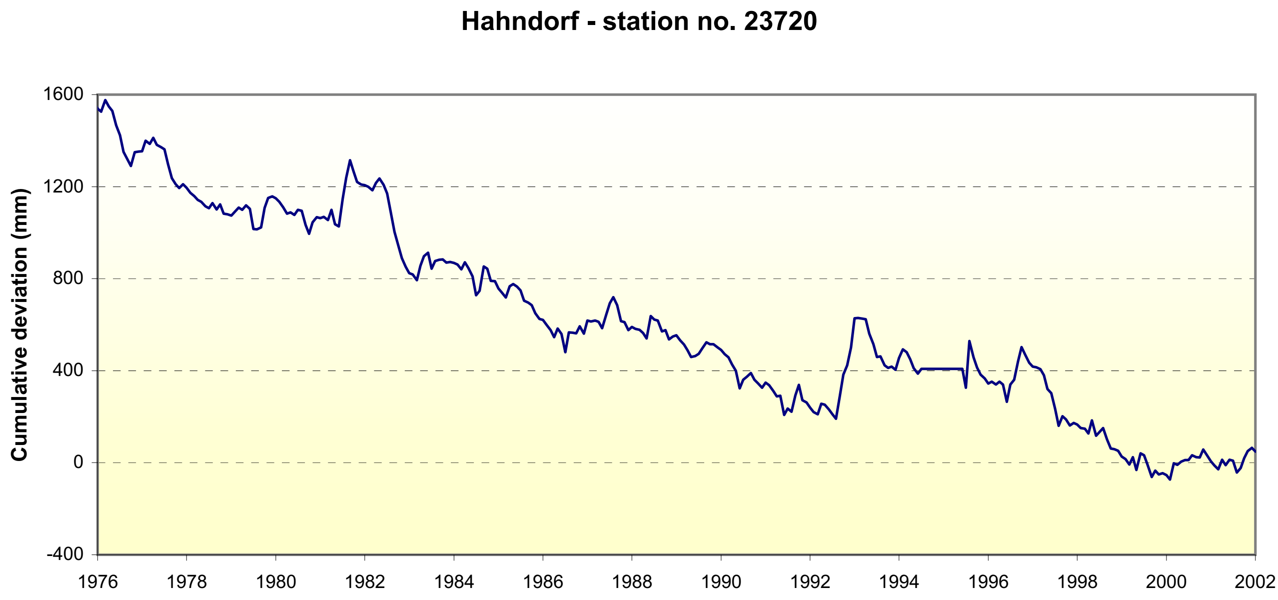


Figure 13 Lobethal, Lenswood and Woodside rainfall stations - cumulative deviation



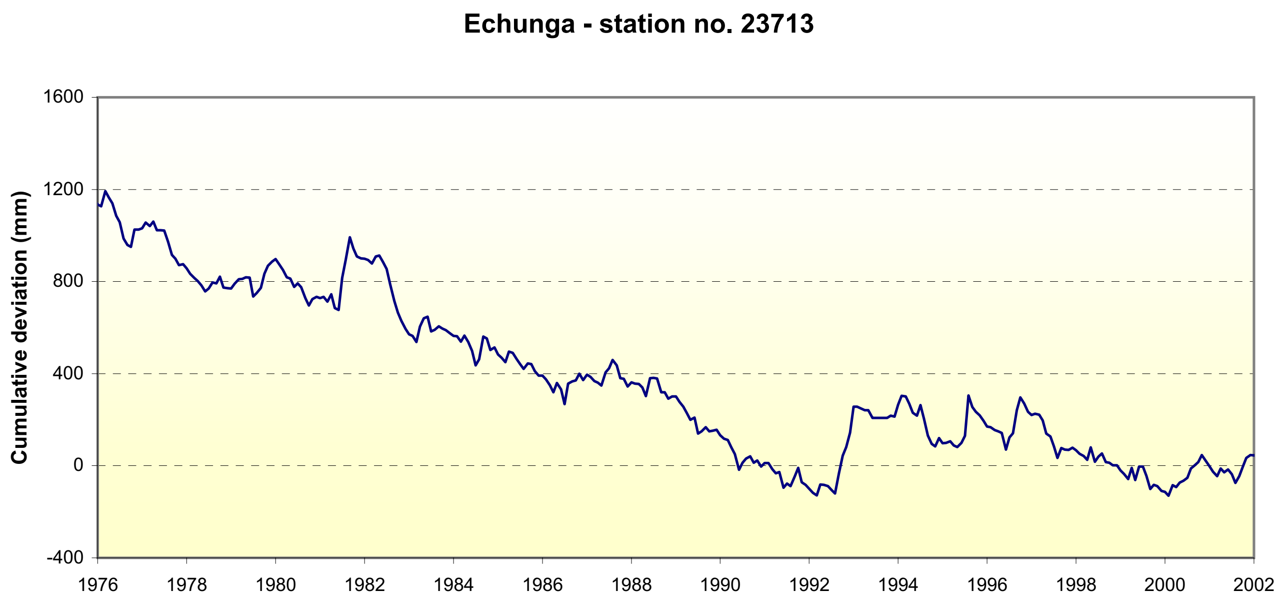


Figure 14 Hahndorf and Echunga rainfall stations - cumulative deviation

Little can be done to safeguard against such dry spells, except to deepen pumps, ensure that water is used efficiently and, in extreme cases, deepen wells. When average rainfall resumes, water levels would be expected to recover to normal levels.

A groundwater level monitoring network is being established throughout the catchments with high groundwater use to determine long-term trends. It is essential that the Onkaparinga CWMB be involved to ensure long-term and consistent monitoring which will underpin important management strategies for sustainable resource use, land degradation and surface water quality decline.

CONCLUSIONS AND RECOMMENDATIONS

In the Upper Onkaparinga Catchment, 11 sub-catchments where groundwater extraction is thought to be above the potential sustainable yield were the subject of this study. These areas are underlain by fractured rock aquifers that contain groundwater of varying quality and yields. Approximate water balances for these sub-catchments were calculated using existing information. The water balance figures presented in this report are considered to be a preliminary estimation based on the best available information 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 investigations currently being undertaken, it is anticipated that over the next three to seven years estimates of sustainable yields for these and other sub-catchments throughout the MLR will be reviewed and improved.

Aquifer yields and salinities are better in the western parts of the Onkaparinga Catchment — the Cock Creek, Western Branch and Upper Onkaparinga sub-catchments — rather then the eastern areas. This is due to the presence of the widely developed permeable Aldgate Sandstone, Woolshed Flat Shale and Stonyfell Quartzite which, together with the high rainfall, have resulted in higher recharge of 109–175 mm/y (12–18% rainfall).

Sub-catchments in the eastern portion of the Onkaparinga Catchment, including Charleston and Main Channel, are underlain by less permeable siltstone (Saddleworth and Tapley Hill Formations) and metasediments of the Kanmantoo Group. Recharge from rainfall in these areas is estimated at 70–100 mm (8–12% of rainfall). The lower transmissivity within these metasediments results in wells experiencing lower yields and higher salinities placing a greater reliance on dams for irrigation supplies.

The only exception is Balhannah sub-catchment where recharge appears to be higher than in other adjacent catchments and is 126 mm (15% rainfall).

There has been a decrease in the extraction of groundwater in the Cock Creek, Western Branch and Charleston sub-catchments by 15–20% since 1970 due to a change in land use from irrigated pastures and orchards to grazing and vineyards. Although there is potential for increased development in these catchments, the local effects of any large increases in groundwater pumping on groundwater levels and environmental flows in streams would need to be further investigated.

An increase in groundwater extraction occurred in the Upper Onkaparinga sub-catchment due to expansions of vineyard, berries and vegetable growing.

Significant land-use changes have occurred in the Mitchell, Balhannah and Hahndorf sub-catchments, mainly due to vineyard expansion. This may have resulted in a significant increase in the water consumption, and it appears that extractions may be approaching sustainable yield. It is, however, believed that the majority of water needs is obtained from surface water, which is confirmed for Hahndorf, where only about one-third of supplies needed is obtained from groundwater. More accurate information is required, especially in areas of concentrated irrigation.

The water balances need to be revised at regular intervals to take into account such changes in land use and irrigation practice. Regular water level and salinity monitoring networks should be established in areas of high groundwater use to determine long-term watertable trends. The metering of all irrigation and industrial supplies should be eventually carried out to allow accurate estimates of water use.

BIBLIOGRAPHY

Barnett, S.R. and Zulfic, D., 1999. Mount Lofty Ranges groundwater assessment — Piccadilly Valley. *South Australia. Department of Primary Industries and Resources. Report Book,* 99/001.

Barnett, S.R. and Zulfic, D., 1999. Mount Lofty Ranges groundwater assessment — Tookayerta Catchment. *South Australia. Department of Primary Industries and Resources. Report Book,* 99/018.

Barnett, S.R. and Zulfic, D., 2000. Mount Lofty Ranges groundwater assessment — portions of Torrens Rural Catchment. *South Australia. Department of Primary Industries and Resources. Report Book,* 99/019.

Bradley, J. and Billington, K., 2002. Land status data mapping for the Mount Lofty Ranges watershed. *South Australia. Department for Environment and Heritage. Report.*

Grayson, R.B, Argent, R.M., Nathan, R.J., McMahon, T.A. and Mein R.G., 1996. *Hydrological recipes — estimation techniques in Australian hydrology.* Cooperative Research Centre for Catchment Hydrology, Victoria.

McMurray, D., 1996. Farm dam storage assessment in the Mount Lofty Ranges of South Australia. Water Resource Group. *South Australia. Department of Environment and Natural Resources. Discussion Paper.*

PPK Environment and Infrastructure, 1999. *Onkaparinga Catchment Water Management Plan.*

Teoh, K.S., 2002. Estimating the impact of current farm dams development on the surface water resources of the Onkaparinga River Catchment. *Department of Water, Land & Biodiversity Conservation* (draft).

APPENDIX A SUB-CATCHMENT WATER BALANCES, UPPER ONKAPARINGA CATCHMENT

CATCHMENT WATER BALANCE, COCK CREEK

IRRIGATION / EXTRACTION

Crop Type/Use	**Area** (ha)	**Water Need** (mm)	**Water Use** (ML)
Orchard	781	400	3124
Vineyard	149	120	179
Vegetables	2	600	12
Berries	1.5	700	11
Floriculture	7.5	400	30
Domestic			20
		TOTAL	**3376**

EVAPOTRANSPIRATION

Land Use	**Area** (ha)	**Water Use** (mm)	**Water Loss** (ML)
Native vegetation	553	630	3484
Pasture	1164	425	4947
Orchard	781	300	2343
Vineyard	149	300	447
Vegetable	2	200	4
Berries/floriculture	9	230	21
Other (urban)	17.5	200	35
		TOTAL	**11281**

+

STREAMFLOW

Runoff (ML)	**4667**
Baseflow (ML)	**2399**
TOTAL	**7066**

+

RECHARGE

Method	**Comments**	**Estimate (ML)**
Deduction	Rainfall - (ET + runoff + dam vol)	**5892**
Deduction	Groundwater extractn + baseflow	**5775**
Chloride	Comparison rainfall & groundwater	**900**
	ADOPTED VALUE	**5000**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***710 ML*** ⇒ ***22 550 ML***

RAINFALL ***794 mm*** **X** AREA ***28.4 km²*** ⇒ ***22 550 ML***

INFLOW

CATCHMENT WATER BALANCE, WESTERN BRANCH

IRRIGATION / EXTRACTION

Crop Type/Use	Area (ha)	Water Need (mm)	Water Use (ML)
Orchard	116	400	464
Vineyard	186	120	223
Pasture	40	700	280
Vegetables	21	600	126
Berries	28	700	196
Floriculture	12	400	48
Domestic			20
		TOTAL	**1357**

EVAPOTRANSPIRATION

Land Use	Area (ha)	Water Use (mm)	Water Loss (ML)
Native vegetation	290	632	1833
Pasture	2312	420	9710
Orchard	116	300	348
Vineyard	186	300	558
Vegetable	21	200	42
Berries/floriculture	40	230	92
Other (urban)	220	200	440
		TOTAL	**13023**

+

STREAMFLOW

Runoff (ML)	**3798**
Baseflow (ML)	**998**
TOTAL	**4796**

+

RECHARGE

Method	Comments	Estimate (ML)
Deduction	Rainfall - (ET + runoff + dam vol)	**6064**
Deduction	Groundwater extractn + baseflow	**2355**
Chloride	Comparison rainfall & groundwater	**650**
	ADOPTED VALUE	**3500**

+

DAM STORAGE

TOTAL ***985 ML*** ⇒ ***TOTAL OUTFLOW*** ***23 870 ML***

RAINFALL ***724 mm*** **X** AREA ***32.97 km²*** ⇒ ***23 870 ML*** ***INFLOW***

CATCHMENT WATER BALANCE, UPPER ONKAPARINGA

IRRIGATION / EXTRACTION

Crop Type/Use	Area (ha)	Water Need (mm)	Water Use (ML)
Orchard	136	400	544
Vineyard	194	120	233
Pasture	70	600	420
Vegetables	15	600	90
Berries	20	700	140
Domestic			20
		TOTAL	**1477**

EVAPOTRANSPIRATION

Land Use	Area (ha)	Water Use (mm)	Water Loss (ML)
Native vegetation	474	630	2986
Pasture	3405	420	14301
Orchard	136	300	408
Vineyard	194	300	582
Vegetable	15	200	30
Berries	20	230	46
Other (urban)	271	200	542
		TOTAL	**18895**

+

STREAMFLOW

Runoff (ML)	**6097**
Baseflow (ML)	**1906**
TOTAL	**8003**

+

RECHARGE

Method	Comments	Estimate (ML)
Deduction	Rainfall - (ET + runoff + dam vol)	**10309**
Deduction	Groundwater extractn + baseflow	**3353**
Chloride	Comparison rainfall & groundwater	**1000**
	ADOPTED VALUE	**6000**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***1060 ML*** ⇒ ***36 361 ML***

RAINFALL ***772 mm*** **X** AREA ***47.1 km²*** ⇒ ***36 361 ML***

INFLOW

CATCHMENT WATER BALANCE, CHARLESTON

IRRIGATION / EXTRACTION

Crop Type/Use	**Area** (ha)	**Water Need** (mm)	**Water Use** (ML)
Orchard	60	400	240
Vineyard	390	120	468
Pasture	70	600	420
Vegetables	72	600	432
Berries	9	700	63
Floriculture	11	400	44
Domestic			20
		TOTAL	**1687**

EVAPOTRANSPIRATION

Land Use	**Area** (ha)	**Water Use** (mm)	**Water Loss** (ML)
Native vegetation	232	630	1462
Pasture	3980	420	16716
Orchard	60	300	180
Vineyard	390	300	1170
Vegetable	72	200	144
Berries/floriculture	14	230	32
Other (urban)	283	200	566
		TOTAL	**20270**

+

STREAMFLOW

Runoff (ML)	**3908**
Baseflow (ML)	**1687**
TOTAL	**5595**

+

RECHARGE

Method	**Comments**	**Estimate (ML)**
Deduction	Rainfall - (ET + runoff + dam vol)	**8092**
Deduction	Groundwater extractn + baseflow	**3374**
Chloride	Comparison rainfall & groundwater	**1100**
	ADOPTED VALUE	**5000**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***1000 ML*** ⇒ ***33 270 ML***

RAINFALL ***646 mm*** **X** AREA ***51.5 km²*** ⇒ ***33 270 ML***

INFLOW

CATCHMENT WATER BALANCE, INVERBRACKIE CREEK

IRRIGATION / EXTRACTION

Crop Type/Use	Area (ha)	Water Need (mm)	Water Use (ML)
Orchard	10	400	40
Vineyard	203	120	244
Pasture	105	700	735
Vegetables	17	600	102
Berries	1	700	7
Domestic			10
		TOTAL	**1138**

EVAPOTRANSPIRATION

Land Use	Area (ha)	Water Use (mm)	Water Loss (ML)
Native vegetation	110	632	695
Pasture	2140	420	8988
Orchard	10	300	30
Vineyard	203	300	609
Vegetable	17	200	34
Berries	1	230	2
Other (urban)	103	200	206
		TOTAL	**10564**

+

STREAMFLOW

Runoff (ML)	**2175**
Baseflow (ML)	**874**
TOTAL	**3049**

+

RECHARGE

Method	Comments	Estimate (ML)
Deduction	Rainfall - (ET + runoff + dam vol)	**2097**
Deduction	Groundwater extractn + baseflow	**2012**
Chloride	Comparison rainfall & groundwater	**510**
	ADOPTED VALUE	**2000**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***540 ML*** ⇒ ***15 376 ML***

RAINFALL ***575 mm*** **X** AREA ***26.74 km²*** ⇒ ***15 376 ML***

INFLOW

CATCHMENT WATER BALANCE, MITCHELL CREEK

IRRIGATION / EXTRACTION

Crop Type/Use	**Area** (ha)	**Water Need** (mm)	**Water Use** (ML)
Orchard	30	400	120
Vineyard	65	120	78
Pasture	47	700	329
Vegetables	24	600	144
Domestic			20
		TOTAL	**691**

EVAPOTRANSPIRATION

Land Use	**Area** (ha)	**Water Use** (mm)	**Water Loss** (ML)
Native vegetation	5	625	31
Pasture	1140	425	4845
Orchard	30	300	90
Vineyard	65	300	195
Vegetable	24	200	48
Other (urban)	160	200	320
		TOTAL	**5529**

+

STREAMFLOW

Runoff (ML)	**1070**
Baseflow (ML)	**155**
TOTAL	**1225**

+

RECHARGE

Method	**Comments**	**Estimate (ML)**
Deduction	Rainfall - (ET + runoff + dam vol)	**1589**
Deduction	Groundwater extractn + baseflow	**846**
Chloride	Comparison rainfall & groundwater	**160**
	ADOPTED VALUE	**1300**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***570 ML*** ⇒ ***8758 ML***

RAINFALL ***604 mm*** **X** AREA ***14.5 km²*** ⇒ ***8758 ML***

INFLOW

CATCHMENT WATER BALANCE, BALHANNAH

IRRIGATION / EXTRACTION

Crop Type/Use	**Area** (ha)	**Water Need** (mm)	**Water Use** (ML)
Orchard	2.5	400	10
Vineyard	88	120	106
Pasture	120	600	720
Vegetables	12	600	72
Domestic			20
		TOTAL	**928**

EVAPOTRANSPIRATION

Land Use	**Area** (ha)	**Water Use** (mm)	**Water Loss** (ML)
Native vegetation	80	630	504
Pasture	748	420	3142
Orchard	2.5	300	8
Vineyard	88	300	264
Vegetable	12	200	24
Other	69	200	138
		TOTAL	**4080**

+

STREAMFLOW

Runoff (ML)	**811**
Baseflow (ML)	**220**
TOTAL	**1031**

+

RECHARGE

Method	**Comments**	**Estimate (ML)**
Deduction	Rainfall - (ET + runoff + dam vol)	**1524**
Deduction	Groundwater extractn + baseflow	**1148**
Chloride	Comparison rainfall & groundwater	**250**
	ADOPTED VALUE	**1300**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***200 ML*** ⇒ ***6615 ML***

RAINFALL ***646 mm*** **X** AREA ***10.24 km²*** ⇒ ***6615 ML***

INFLOW

CATCHMENT WATER BALANCE, HAHNDORF

IRRIGATION / EXTRACTION

Crop Type/Use	**Area** (ha)	**Water Need** (mm)	**Water Use** (ML)
Orchard	7.5	400	30
Vineyard	56	120	68
Pasture	12	600	72
Domestic			20
		TOTAL	**189**

EVAPOTRANSPIRATION

Land Use	**Area** (ha)	**Water Use** (mm)	**Water Loss** (ML)
Native vegetation	50	630	315
Pasture	1040	420	4368
Orchard	7.5	300	23
Vineyard	95	300	285
Vegetable	10	200	20
Berries	7.5	230	17
Other	182	200	364
		TOTAL	**5392**

+

STREAMFLOW

Runoff (ML)	**1870**
Baseflow (ML)	**355**
TOTAL	**2225**

+

RECHARGE

Method	**Comments**	**Estimate (ML)**
Deduction	Rainfall - (ET + runoff + dam vol)	**2014**
Deduction	Groundwater extractn + baseflow	**544**
Chloride	Comparison rainfall & groundwater	**150**
	ADOPTED VALUE	**1500**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***560 ML*** ⇒ ***9836 ML***

RAINFALL ***670 mm*** **X** AREA ***14.68 km²*** ⇒ ***9836 ML***

INFLOW

CATCHMENT WATER BALANCE, BIGGS FLAT

IRRIGATION / EXTRACTION

Crop Type/Use	**Area** (ha)	**Water Need** (mm)	**Water Use** (ML)
Orchard/Olives	8	500	40
Vineyard	32	200	64
Vegetable	23.5	600	141
Domestic			10
		TOTAL	**255**

EVAPOTRANSPIRATION

Land Use	**Area** (ha)	**Water Use** (mm)	**Water Loss** (ML)
Native vegetation	40	630	252
Pasture	2127	420	8933
Orchard	8	300	24
Vineyard	32	300	96
Vegetable	23.5	200	47
Other	55	200	110
		TOTAL	**9462**

\+

STREAMFLOW

Runoff (ML)	**1517**
Baseflow (ML)	**323**
TOTAL	**1840**

\+

RECHARGE

Method	**Comments**	**Estimate (ML)**
Deduction	Rainfall - (ET + runoff + dam vol)	**3583**
Deduction	Groundwater extractn + baseflow	**578**
Chloride	Comparison rainfall & groundwater	**210**
	ADOPTED VALUE	**2000**

\+ ***TOTAL OUTFLOW***

DAM STORAGE

TOTAL ***660 ML*** ⇒ ***15 222 ML***

RAINFALL ***645 mm*** **X** AREA ***23.6 km²*** ⇒ ***15 222 ML***

INFLOW

CATCHMENT WATER BALANCE, ECHUNGA CREEK

IRRIGATION / EXTRACTION

Crop Type/Use	Area (ha)	Water Need (mm)	Water Use (ML)
Orchard	46	400	184
Vineyard	65	120	78
Pasture	97	600	582
Vegetables	10	600	60
Turf	15	600	90
Domestic			20
Stock			37
		TOTAL	**1051**

EVAPOTRANSPIRATION

Land Use	Area (ha)	Water Use (mm)	Water Loss (ML)
Native vegetation	1033	620	6405
Pasture	2498	420	10492
Orchard	46	300	138
Vineyard	65	300	195
Vegetable	10	200	20
Other	148	200	296
		TOTAL	**17546**

+

STREAMFLOW

Runoff (ML)	**2603**
Baseflow (ML)	**1063**
TOTAL	**3666**

+

RECHARGE

Method	Comments	Estimate (ML)
Deduction	Rainfall - (ET + runoff + dam vol)	**4361**
Deduction	Groundwater extractn + baseflow	**2114**
Chloride	Comparison rainfall & groundwater	**500**
	ADOPTED VALUE	**3000**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***1060 ML*** ⇒ ***25 570 ML***

RAINFALL ***654 mm*** **X** AREA ***39.1 km²*** ⇒ ***25 570 ML***

INFLOW

CATCHMENT WATER BALANCE, ONKAPARINGA MAIN CHANNEL

IRRIGATION / EXTRACTION

Crop Type/Use	**Area** (ha)	**Water Need** (mm)	**Water Use** (ML)
Orchard	25		
Vineyard	19		
Pasture	12		
Berries	1		
Domestic			
		TOTAL	**0**

EVAPOTRANSPIRATION

Land Use	**Area** (ha)	**Water Use** (mm)	**Water Loss** (ML)
Native vegetation	838	625	5238
Pasture	1512	420	6350
Orchard	25	300	75
Vineyard	19	300	57
Berries	1	230	2
Other	29	200	58
		TOTAL	**11780**

+

STREAMFLOW

Runoff (ML)	**3155**
Baseflow (ML)	**995**
TOTAL	**4150**

+

RECHARGE

Method	**Comments**	**Estimate (ML)**
Deduction	Rainfall - (ET + runoff + dam vol)	**2691**
Deduction	Groundwater extractn + baseflow	**995**
Chloride	Comparison rainfall & groundwater	**550**
	ADOPTED VALUE	**1700**

+ ***TOTAL***

DAM STORAGE ***OUTFLOW***

TOTAL ***315 ML*** ⇒ ***17 941 ML***

RAINFALL ***732 mm*** **X** AREA ***24.51 km²*** ⇒ ***17 941 ML***

INFLOW