Eastern Mount Lofty Ranges Groundwater Assessment

DRAGANA ZULFIC AND STEVE BARNETT

Report DWLBC 2003/25
Foreword

South Australia’s natural resources are fundamental to the economic and social well-being of the State. 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 the 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, Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
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## SI Units Commonly Used Within Text

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<td>Metre</td>
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<td>length</td>
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<tr>
<td>Milligram</td>
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<td>$10^{-3}$ g</td>
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<tr>
<td>Milligram/litre</td>
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## Abbreviations Commonly Used Within Text

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<td>Commonwealth Scientific and Industrial Research Organisation</td>
</tr>
<tr>
<td>DWLBC</td>
<td>Department of Water, Land and Biodiversity Conservation</td>
</tr>
<tr>
<td>EMLR</td>
<td>Eastern Mount Lofty Ranges</td>
</tr>
<tr>
<td>ET</td>
<td>Evapotranspiration</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic information system</td>
</tr>
<tr>
<td>HYDSIS</td>
<td>Database software</td>
</tr>
<tr>
<td>MLR</td>
<td>Mount Lofty Ranges</td>
</tr>
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ABSTRACT

Catchments in the EMLR are underlain by fractured rock and sedimentary aquifers that contain groundwater of varying quality and yields, with about 75% of the area underlain by poor aquifers with salinities too high for irrigation (greater than 3000 mg/L), and yields too low for irrigation (below 5 L/s), with no capability for increased development.

Aquifer yields and salinities are more favourable for development in the western and southern parts of the EMLR than in the east. This is due to the presence of the permeable Adelaideon fractured rocks and Permian Sands, together with the higher rainfall. Irrigation of vineyards, vegetables and dairy pastures has occurred in relatively localised areas. As many irrigation wells (356) have been drilled since 1995, as were drilled in the 20 years prior to 1995. Although monitoring has generally so far shown no adverse impacts on the groundwater resource, the main risks of further uncontrolled development in these areas are groundwater level declines and increasing salinities due to the lateral movement of more saline groundwater from surrounding areas.

In three subcatchments where sufficient information existed, approximate water balances were calculated. Groundwater usage in these subcatchments is well below estimates of sustainable yield. These figures are considered to be a preliminary estimation based on the best available information at the time this study was undertaken. DWLBC will be undertaking further work to improve estimates of recharge and the degree of connection between surface water and groundwater.

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 should be extended to other areas of high groundwater use.
1 INTRODUCTION

The Eastern Mount Lofty Ranges (EMLR) region extends from the Milendella Creek catchment in the north, to Currency Creek catchment in the south. Thirteen major catchments drain from the eastern side of the Mt Lofty Ranges to the River Murray and Lake Alexandrina, with Bremer, Angas and Finniss being some of the larger rivers (Fig. 1).

The water resources of the EMLR support agricultural and industrial activity but there are concerns that the increasing level of water resources development could have a detrimental impact on long-term water use and the environment.

Although there is no evidence of current over-extraction of groundwater within the EMLR, there are areas where extraction is increasing. The groundwater underlying most of the EMLR region is highly variable in quantity and quality. Groundwater developments are concentrated in areas of low salinity and good borehole yields. It is these areas that are at risk from potential problems associated with uncontrolled development, which could be experienced if stronger management controls were to be introduced for surface water systems only.

The Department of Water, Land and Biodiversity Conservation (DWLBC) has been undertaking an evaluation of the groundwater resources in areas of relatively high groundwater use within the Mt Lofty Ranges catchments using existing information only.

This report presents an overview of groundwater resources in the EMLR and the Murray Plains area between the Ranges and the River Murray. In areas of relatively high groundwater use where sufficient information could be obtained, namely parts of the Bremer, Angas and Finniss catchments (Fig. 1), a first-order assessment of water balances was carried out. Other areas of high groundwater use in the EMLR are the Tookayerta and Currency Creek catchments, which were the subject of earlier groundwater assessments (Barnett & Zulfic, 1999, 2002).

Shortfalls in data required for the efficient management of water resources are identified in this report, together with recommendations for future monitoring and management.

A broad-scale assessment of the surface water resources of the Eastern Mount Lofty Ranges is also being carried out by DWLBC (Savadamuthu, 2003), in parallel with this groundwater assessment. Further studies are planned across selected catchments in the area 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.
Figure 1

Locality Plan

Study areas
- Bremner River Catchment
- Upper Angas River Sub-catchment
- Finniss River Catchment

Legend:
- Catchment boundary
- Gauging stations
- Rainfall stations
- Monitoring networks

Datum GDA94
Map projection MGA Zone 54

GDA

EASTERN MOUNT LOFTY RANGES

Locality Plan

Study areas:
- Bremner River Catchment
- Upper Angas River Sub-catchment
- Finniss River Catchment

Legend:
- Catchment boundary
- Gauging stations
- Rainfall stations
- Monitoring networks

Datum GDA94
Map projection MGA Zone 54

GDA
2 GEOLOGY

The EMLR catchments are underlain by consolidated basement rocks beneath the hills, and unconsolidated sediments beneath the Murray Plains (Fig. 2):

2.1 Basement Rocks

Barossa Complex

Barossa Complex consists of gneisses, schists and pegmatites, which were metamorphosed at high temperature and pressure deep in the earth’s crust. They are the oldest rocks in the Mount Lofty Ranges and have been exposed by erosion as part of the Myponga inlier in the Tookayerta and Finniss catchments, which is also the highest topography reaching up to 440 m above sea level. The Barossa Complex is surrounded by younger Adelaidean sedimentary rocks.

Adelaidean sedimentary rocks

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 about 1000 million years ago. These rock units consist mainly of siltstone, shale and slate with minor interbeds of sandstone and quartzite.

Normanville Group

The Normanville Group consists of calcareous shale, phosphatic phyllite and marble. The Macclesfield Marble unit is a white coarsely crystallized marble that occurs in the Macclesfield area.

Kanmantoo Group

The Kanmantoo Group underlies the largest part of the eastern area. A large trough was formed by rapid subsidence in a broad arc around the eastern side of the present Mount Lofty Ranges during the Cambrian period about 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 about 21 km.

2.2 Sediments

Permian Sands

About 280 million years ago in the Permian era, large continental ice sheets moving from the southeast to the northwest, carved out several large U-shaped valleys from the older basement rocks (Tookayerta, Finniss catchments) which were later filled by glacial deposits (Fig. 2). These sediments consist of unconsolidated sands, silts and clays with occasional gravel beds, and are known as the Cape Jervis Formation.
Figure 2

EASTERN MOUNT LOFTY RANGES
Simplified Geology

Geology
- Quaternary
- Murray Group Limestone
- Permian Sands
- Kanmantoo Group
- Normanville Group
- Adelaidean Sediments
- Barossa Complex
- Catchment boundary

Datum GDA94
Map projection MGA Zone 54
**Murray Group Limestone**

The Murray Group consists of predominately shallow marine fossiliferous limestone with minor clays, silt and sands, that were deposited about 50 million years ago in the Murray Basin. It underlies most of the Murray Plains between the ranges and the River Murray.

**Quaternary sediments**

At the lowest points in the catchments adjacent to the drainage lines, Quaternary alluvium has been deposited. It usually consists of dark grey silts and clays with a high organic content and some reworked Permian sand. Significant thickness of peat occurs in some places. On the Plains, these sediments usually consist of red-brown clays and silts.
3 REGIONAL HYDROGEOLOGY

In the EMLR catchments, groundwater is sourced from two different types of aquifers. Fractured rock aquifers occur where groundwater is stored and moves through joints and fractures in the basement rocks. Sedimentary aquifers occur in the valleys and beneath the Murray Plains where groundwater flows through the pore spaces within the sediments.

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. 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

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.

Adelaidean sediments

Because the Adelaidean sediments have not been subject to 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. In addition, these sediments occur to the west of the region where the rainfall is higher, resulting in higher recharge and low salinities.

Normanville Group

Of particular interest in the Normanville Group aquifer is the occurrence of the Macclesfield Marble in the Macclesfield area. The unit has developed secondary porosity (fissures), which can provide greater yields, and allows greater recharge and hence lower salinities than surrounding rock units.

Kanmantoo Group

For similar reasons as Barossa Complex, the Kanmantoo Group aquifer is also 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. However, isolated instances of low salinity and high yields still occur.
3.2 Sedimentary aquifers

Permian Sand

The Permian Sand aquifer is widely developed for irrigation and town water supply use in the Tookayerta catchment (Barnett and Zulfic, 1999), and for irrigation in the Finniss River catchment, to the south of Ashbourne. The Permian Sand aquifer varies in productivity due to changes in the sedimentary deposition resulting in higher clay contents in some areas leading to low yields and high salinity. Correct bore construction in this environment is essential to ensure a sand free supply.

Murray Group Limestone

The Murray Group Limestone aquifer is an important source of water where it contains groundwater of good quality, and is confined by the overlying Quaternary sediments. It is the same aquifer utilized in the Angas – Bremer Prescribed Wells Area, but in the project area, only contains salinities below 3000 mg/L to the southwest of the township of Finniss. Irrigation supplies can be obtained in this area with moderate use currently for lucerne and vineyard irrigation.
4 CATCHMENT HYDROGEOLOGY

4.1 Bremer River

The Bremer River Catchment covers an area of ~ 590 km². It extends to the center of the Mt Lofty Ranges and ranges in height above sea level from around 400 m in the west to less than 50 m on the plains where the Bremer River flows before joining Lake Alexandrina. The area shown in pink in Figure 1 includes the Upper and Lower Bremer River and Dawesley, Upper and Lower Mount Barker Creek sub-catchments which cover ~ 473 km². This area will be the subject of a water balance study later in this report. Two sub-catchments in the southwest, Rodwell and Red Creeks, are excluded due to a lack of stream gauging stations.

The ranges have higher winter dominant rainfall, with the monthly averages for Mt Barker (Fig. 1) shown in Table 1. The long-term annual average (over 140 years) is 766 mm. The rainfall decreases to the southeast to only 383 mm on the plains at Hartley (Table 1) due to the rain shadow effect.

Table 1. Average monthly and annual rainfall – Bremer River Catchment

<table>
<thead>
<tr>
<th>Rainfall Station</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<th>Dec</th>
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<tr>
<td>Mt Barker 23733</td>
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</tr>
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</table>

The Adelaidean fractured rock aquifer in the northwest quarter of the catchment is the only rock type with reasonable yields (up to 5-10 L/s) and low salinities below 1500 mg/L as shown in Figure 3. The most favorable conditions occur in the Mt Barker – Littlehampton area where yields of over 10 L/s have been obtained for vegetable irrigation, although urban encroachment has reduced the area irrigated. The other significant land use is dairying, which uses groundwater to irrigate pasture (Fig. 4). Other land uses include livestock grazing and cropping.

The Kanmantoo Group aquifer underlies the rest of the catchment and is generally tight and impermeable with few open systems of fractures and joints resulting in yields mostly below 1 L/s and salinities greater than 3000 mg/L. The less favourable groundwater conditions are very apparent in Figure 3 and are reflected in the main land uses in this area which are livestock grazing and dry land cropping. The groundwater usage is low and it is not likely to increase in the future.

On the plains, the Angas Bremer PWA contains all suitable irrigation quality groundwater that occurs in the Murray Group Limestone aquifer.
Figure 3

EASTERN MOUNT LOFTY RANGES
Bremer Catchment Geology and Groundwater Salinity

Geology
- Quaternary
- Murray Group Limestone
- Kanmantoo Group
- Adelaidean Sediments
- Barossa Complex

Salinity (mg/L)
- < 500
- 500 - 1000
- 1000 - 1500
- 1500 - 3000
- 3000 - 7000
- 7000 - 14000
- > 14000

Datum GDA94
Map projection MGA Zone 54
EASTERN MOUNT LOFTY RANGES
Bremer Catchment Simplified Land Use

<table>
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<th>Land use</th>
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<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>Irrigated crop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved pasture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native vegetation</td>
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<tr>
<td>Orchard</td>
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<tr>
<td>Grazing</td>
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<td>Vegetables</td>
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<td>Vines</td>
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<tr>
<td>Sub-catchment boundary</td>
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</table>
4.2 Angas River

The Angas River Catchment covers an area of about 200 km², runs in a southeasterly direction and ranges in height from 450 m above sea level at the western boundary to about 50 m where it flows intermittently onto the plains. The Upper Angas River (shown in blue in Fig. 1) is a sub-catchment of 60 km² up-stream from the Angas River Weir (stream gauging station AW 426503) which will have a water balance carried out. Rainfall is winter dominant with the average monthly rainfall shown in Table 2. The long-term annual average (117 years) for Macclesfield (Fig. 1) is 733 mm.

Table 2. Average monthly and annual rainfall – Angas River Catchment

<table>
<thead>
<tr>
<th>Rainfall station</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<td>MACCLESFIELD 23728</td>
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<td>26</td>
<td>31</td>
<td>57</td>
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<td>84</td>
<td>64</td>
<td>42</td>
<td>34</td>
<td>733</td>
</tr>
</tbody>
</table>

The Adelaidean fractured rock aquifer underlying the northwestern part of the catchment can develop yields of 5-10 L/s and has low salinity groundwater below 1500 mg/L (Fig. 5). In the Macclesfield area, the Macclesfield Marble unit of the Normanville Group can provide greater yields (>10 L/s) and lower salinities (< than 1000 mg/L) than surrounding rock units. The favourable groundwater conditions have allowed development of vineyards in this area (Fig. 6). Other main land uses are dairying (with significant areas of pasture irrigated during summer) and livestock grazing.

In contrast, the basement rocks of the Kanmantoo Group underlie the remainder of the catchment in the hills. Consequently, yields are lower (<3 L/s), and salinities are higher than the Adelaidean rocks (>1 500 mg/L) as shown in Figure 5. On the plains, stock and domestic supplies are obtained from the Quaternary Sediments adjacent to the river channel. The Angas Bremer PWA contains all suitable irrigation quality groundwater in the Murray Group Limestone aquifer.
Figure 5

EASTERN MOUNT LOFTY RANGES
Angas River Catchment Geology and Groundwater Salinity

Geology
- Quaternary Sediments
- Murray Group Limestone
- Kanmantoo Group
- Normanville Group
- Adelaidean Sediments

Salinity (mg/L)
- < 500
- 500 - 1000
- 1000 - 1500
- 1500 - 3000
- 3000 - 7000
- 7000 - 14000
- > 14000

Datum GDA94
Map projection MGA Zone 54
Figure 6

EASTERN MOUNT LOFTY RANGES
Angas River Catchment Simplified Land Use

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<td>Crop</td>
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<tr>
<td>Grazing</td>
<td>1501 - 3000</td>
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<tr>
<td>Orchard</td>
<td>3001 - 7000</td>
</tr>
<tr>
<td>Native Vegetation</td>
<td>7001 - 14000</td>
</tr>
<tr>
<td>Irrigated Crops</td>
<td>&gt; 14000</td>
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<tr>
<td>Vines</td>
<td></td>
</tr>
</tbody>
</table>

Catchment boundary
Sub-catchment Boundary

Datum: GDA94
Map projection: MGA Zone 54

Figure 6: Map of Angas River Catchment Simplified Land Use in the Eastern Mount Lofty Ranges.
4.3 Finniss River

The Finniss Catchment extends across almost to the western margin of the MLR and covers an area of 375 km$^2$. The elevation ranges from 400 m at the western boundary down to 20 m at Finniss. A water balance assessment will be carried out on an area of about 192 km$^2$ which covers three sub-catchments shown in yellow in Figure 1: Meadows Creek, Blackfellow Creek and the Upper Finniss River up-stream from the stream gauging station near Yundi (AW 426504).

The Finniss Catchment is considered a comparatively wet catchment with winter dominant rainfall decreasing from the west due to the rain shadow effect, with an annual average of 877 mm (116 years) at Meadows, toward the east, with 674 mm at Ashbourne (114 years), and 488 mm at Finniss (104 years) on the plains. The monthly average rainfalls are shown in Table 3.

<table>
<thead>
<tr>
<th>Station</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEADOWS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>877</td>
</tr>
<tr>
<td>23730</td>
<td>28</td>
<td>28</td>
<td>37</td>
<td>69</td>
<td>99</td>
<td>119</td>
<td>121</td>
<td>114</td>
<td>99</td>
<td>75</td>
<td>48</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>ASHBOURNE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>674</td>
</tr>
<tr>
<td>23701</td>
<td>25</td>
<td>21</td>
<td>28</td>
<td>54</td>
<td>76</td>
<td>94</td>
<td>96</td>
<td>87</td>
<td>76</td>
<td>58</td>
<td>36</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>FINNISS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>488</td>
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<tr>
<td>23714</td>
<td>19</td>
<td>22</td>
<td>21</td>
<td>39</td>
<td>54</td>
<td>61</td>
<td>64</td>
<td>60</td>
<td>53</td>
<td>43</td>
<td>29</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

The Finniss Catchment encompasses a range of geological units. The most intensively used aquifers are the Adelaidean fractured rock aquifer to the west near Meadows, and Permian Sand aquifers in the Ashbourne and Yundi areas (Figs 1, 7). Although there is a considerable area shown as Quaternary near Meadows, these sediments are thin and do not contain groundwater. The bores in this area intersect the underlying Adelaidean fractured rock aquifer which is variable in salinity (from below 500 to 3000 mg/L) and yield (generally up to 5 L/s) with no obvious concentrations of irrigation.

The Barossa Complex bores have generally low yields, but salinities are low, probably due to high recharge associated with higher elevations around the catchment margins.

Yields obtained from the Permian Sand aquifer are in the range of 8-12 L/s for bores with appropriate sand-screens, and salinities are below 500 mg/L. Horticultural and vegetable irrigation occurs in the Ashbourne Valley, but as will be discussed later, monitoring shows no adverse impacts to date.

Elsewhere, the main land use activities are broad scale grazing and dairying (Fig. 8). Where salinities and yields are suitable for irrigation, vineyards have been established. Examples can be found adjacent to the Lower Finniss as it flows out onto the plains. About 21% of the total area is under native vegetation and plantation forest, the majority of which is Kuitpo Forest.
Figure 7

EASTERN MOUNT LOFTY RANGES
Finniss River Catchment Geology and Groundwater Salinity

<table>
<thead>
<tr>
<th>Geology</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>&lt; 500</td>
</tr>
<tr>
<td>Permian Sands</td>
<td>500 - 1000</td>
</tr>
<tr>
<td>Kanmantoo Group</td>
<td>1000 - 1500</td>
</tr>
<tr>
<td>Adelaean Sediments</td>
<td>1500 - 3000</td>
</tr>
<tr>
<td>Barossa Complex</td>
<td>3000 - 7000</td>
</tr>
<tr>
<td>Catchment boundary</td>
<td>7000 - 14000</td>
</tr>
<tr>
<td>Sub-catchment boundary</td>
<td>&gt; 14000</td>
</tr>
</tbody>
</table>

Datum GDA94
Map projection MGA Zone 54

Figure

<5000 0 0
<14000
500 - 1000
1000 - 1500
1500 - 3000
3000 - 7000
7000 - 14000
> 14000

Finniss River Catchment Geology and Groundwater Salinity

Geology
- Quaternary
- Permian Sands
- Kanmantoo Group
- Adelaean Sediments
- Barossa Complex
- Catchment boundary
- Sub-catchment boundary

Datum GDA94
Map projection MGA Zone 54
Figure 8

EASTERN MOUNT LOFTY RANGES
Finniss River Catchment Simplified Land Use

<table>
<thead>
<tr>
<th>Land use</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living (other)</td>
<td>&lt; 500</td>
</tr>
<tr>
<td>Improved Pasture</td>
<td>501 - 1000</td>
</tr>
<tr>
<td>Crop</td>
<td>1001 - 1500</td>
</tr>
<tr>
<td>Native Vegetation</td>
<td>1501 - 3000</td>
</tr>
<tr>
<td>Grazing</td>
<td>3001 - 7000</td>
</tr>
<tr>
<td>Orchard</td>
<td>7001 - 14000</td>
</tr>
<tr>
<td>Irrigated Crops</td>
<td>&gt; 14000</td>
</tr>
<tr>
<td>Vines</td>
<td></td>
</tr>
</tbody>
</table>

Sub-catchment boundary
Catchment boundary

Datum GDA94
Map projection MGA Zone 54
4.4 Tookayerta Catchment

The Tookayerta Catchment encompasses two glacially eroded valleys carved out of surrounding basement rocks that have been infilled by Permian Sands over 100 m in thickness. The Kanmantoo Group and Barossa Complex are generally considered to be poor aquifers and are not widely developed (Fig. 9). The Permian Sand aquifer is used for irrigation, town water supply, stock and domestic use because it contains excellent quality groundwater, mostly below 250 mg/L. From properly designed and constructed bores with appropriate sand-screens, yields of over 20 L/s can be obtained. The main irrigated land use is dairy pasture, with increasing areas of vineyards and berries (Fig. 10).

Barnett and Zulfic (1999) reported on the groundwater resources and carried out a preliminary water balance and found that although there was scope for further groundwater development, there may be local impacts and further investigations are needed to define the close relationship between groundwater and surface water.

4.5 Currency Creek Catchment

The Currency Creek catchment is dominated by basement rocks of the Kanmantoo Group which form resistant hills. The broader valleys near the western and eastern boundaries of the catchment are infilled with Permian Sands and Quaternary alluvium (Fig. 9).

Lower salinity groundwater below 1000 mg/L can be found in the western part of the catchment (where rainfall is higher), mostly from Permian sediments. Salinities are higher, in the 1000 – 2000 mg/L range, to the east of the catchment as a result of lower rainfall. Most of the bores in this area are in the NE-SW trending fault-controlled valley running past McFarlane Hill that has been infilled with Permian Sands.

Overall, borehole yields are relatively low in this catchment (mostly below 3 L/sec). However, there are several bores in the Permian Sands and Kanmantoo Group with recorded yields up to 15 L/sec. Consequently, a limited potential exists for further development. A water balance study (Barnett and Zulfic, 2002) found groundwater usage to be well below the sustainable yield.

4.6 Deep Creek Catchment

This catchment encompasses three aquifer systems (Fig. 9) – the Kanmantoo Group in the far west and highest part of the catchment with very little groundwater development, the Permian Sands on the eastern slopes of the Hills Zone with several wells obtaining irrigation supplies of about 10 L/s below 3000 mg/L, and the limestone aquifer beneath the Murray Plains. Here, a significant groundwater resource between 1000 and 1500 mg/L is being used to irrigate vineyards and lucerne. Limited monitoring has shown no adverse impacts, but is not conclusive. Higher salinity groundwater surrounds the developed area.
4.7 Sandergrove Plains

This area is not included in any existing catchment (Fig. 9). Apart from some low-yielding wells on the margin of the Hills Zone with salinities below 3000 mg/L, most of the area is underlain by the limestone aquifer with salinities in the range 3000 – 10 000 mg/L.

4.8 North Eastern EMLR Catchments

The remaining catchments in the EMLR include Ready, Salt, Preamimma, Rocky Gully, Long Gully and Milendella Creeks and Bees Knees (Fig. 1). They extend from the Hills to the River Murray and have broadly similar characteristics. Elevations at their western margin are at about 500 m, dropping to 50-100 m where streams flow intermittently onto the plains. The channels are often incised into the landscape as they approach the river. The main land use is broad scale grazing and dry land cropping, with very little irrigation development.

In the Hills Zone, all catchments are underlain by the Kanmnatoo Group which is a poor aquifer. As can be seen in Figure 11, groundwater salinities are high and yields low (usually <1 L/s). There are some exceptions, namely salinities below 3000 mg/L in the Harrogate area, which are probably the result of the higher rainfall. There are also isolated wells with yields over 5 L/s, but the combination of high yield and low salinity is rare.

The eastern parts of the catchments and the area extending to the River Murray are underlain by the Murray Group Limestone aquifer, which is overlain by Quaternary sediments, generally consisting of clay and silt. Immediately adjacent to the hills, these Quaternary sediments sometimes contain small stock and domestic supplies with salinities below 3000 mg/L. Elsewhere in the limestone aquifer, salinities vary from 3000 to over 7000 mg/L, with very little use.
Figure 9

EASTERN MOUNT LOFTY RANGES
South Western Catchments
Geology and Groundwater Salinity

<table>
<thead>
<tr>
<th>Geology</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary Sediments</td>
<td>&lt; 500</td>
</tr>
<tr>
<td>Murray Group Limestone</td>
<td>500 - 1000</td>
</tr>
<tr>
<td>Permian Sands</td>
<td>1000 - 1500</td>
</tr>
<tr>
<td>Kanmantoo Group</td>
<td>1500 - 3000</td>
</tr>
<tr>
<td>Normanville Group</td>
<td>3000 - 7000</td>
</tr>
<tr>
<td>Adelaidean Sediments</td>
<td>7000 - 14000</td>
</tr>
<tr>
<td>Barossa Complex</td>
<td>&gt; 14000</td>
</tr>
</tbody>
</table>

Datum GDA94
Map projection MGA Zone 54
Figure 10

EASTERN MOUNT LOFTY RANGES
South Western Catchments Simplified Land Use

Land use
- Crop
- Irrigated crop
- Improved pasture
- Native vegetation
- Orchard
- Living (other)
- Grazing
- Vegetables
- Vines
- Bremer Catchment boundary

Datum GDA94
Map projection MGA Zone 54
Figure 11

Geology
- Quaternary Sediments
- Murray Group Limestone
- Permian Sands
- Kanmantoo Group
- Barossa Complex
- North Eastern catchment boundary

Salinity (mg/L)
- < 500
- 501 - 1000
- 1001 - 1500
- 1501 - 3000
- 3001 - 7000
- 7001 - 14000
- > 14000

Figure 11

EASTERN MOUNT LOFTY RANGES
North Eastern Catchments Geology and Groundwater

Salinity (mg/L)
- < 500
- 501 - 1000
- 1001 - 1500
- 1501 - 3000
- 3001 - 7000
- 7001 - 14000
- > 14000

Geology
- Quaternary Sediments
- Murray Group Limestone
- Permian Sands
- Kanmantoo Group
- Barossa Complex
- North Eastern catchment boundary

Landuse
- Living (other)
- Grazing Pasture
- Crop
- Native Vegetation
- North-Eastern Catchment boundary
- Grazing
- Orchard
- Irrigated Crops
- Towns

Figure 11

EASTERN MOUNT LOFTY RANGES
North Eastern Catchments Geology and Groundwater

Salinity (mg/L)
- < 500
- 501 - 1000
- 1001 - 1500
- 1501 - 3000
- 3001 - 7000
- 7001 - 14000
- > 14000

Geology
- Quaternary Sediments
- Murray Group Limestone
- Permian Sands
- Kanmantoo Group
- Barossa Complex
- North Eastern catchment boundary

Landuse
- Living (other)
- Grazing Pasture
- Crop
- Native Vegetation
- North-Eastern Catchment boundary
- Grazing
- Orchard
- Irrigated Crops
- Towns

Figure 11

EASTERN MOUNT LOFTY RANGES
North Eastern Catchments Geology and Groundwater

Salinity (mg/L)
- < 500
- 501 - 1000
- 1001 - 1500
- 1501 - 3000
- 3001 - 7000
- 7001 - 14000
- > 14000

Geology
- Quaternary Sediments
- Murray Group Limestone
- Permian Sands
- Kanmantoo Group
- Barossa Complex
- North Eastern catchment boundary

Landuse
- Living (other)
- Grazing Pasture
- Crop
- Native Vegetation
- North-Eastern Catchment boundary
- Grazing
- Orchard
- Irrigated Crops
- Towns
5 DRILLING HISTORY

An analysis of the State drillhole database SA_GEODATA for the EMLR has provided data on the history of well drilling. The oldest recorded well was drilled in 1910, and since then, over 4000 wells have been drilled in the EMLR catchments. Before 1976, there was no requirement to report well details when drilling occurred. Consequently, about half the wells in the DWLBC corporate database have no original drilling date, nor the purpose for which the well was drilled.

In 1976, the passing of the Water Resources Act required a permit to be obtained for each new well drilled, and the submission of well construction details to the appropriate agency. In order to obtain information on wells drilled before 1976, a well location survey was carried out in the Hundred of Kuitpo between May 1976 and September 1977 and part of the Hundred of Macclesfield in 1991.

Since 1976, a total of 1500 wells were drilled in the south western catchments and about 250 in the north eastern catchments. In the south western catchments, 713 wells were drilled for irrigation (Table 4, Fig. 12) compared to 27 in the north eastern catchments. While some of these wells are likely to be replacements for older, less efficient or collapsed irrigation wells, it is still a significant increase in the south western catchments, especially since 1995 when 357 irrigation wells were drilled, compared to 356 in the 20 years before 1995. The data used to obtain number of bores for each category should be used with caution, because it originates from drilling permit applications and has not yet been validated or confirmed by any field surveys.

All observation, investigation, industrial, drainage and town water supply wells were grouped in one category (other wells). A significant number of wells fall into this category between 1976 and 1995, when most of them were drilled for dryland salinity monitoring and Brukunga Mine tailing seepage monitoring.

Table 4. History of groundwater development

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Number of wells drilled</th>
<th>Southern catchments</th>
<th>Northern catchments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>226</td>
<td>356</td>
<td>357</td>
</tr>
<tr>
<td>Domestic</td>
<td>197</td>
<td>252</td>
<td>170</td>
</tr>
<tr>
<td>Stock</td>
<td>242</td>
<td>84</td>
<td>46</td>
</tr>
<tr>
<td>Other</td>
<td>29</td>
<td>218</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>694</td>
<td>910</td>
<td>603</td>
</tr>
</tbody>
</table>
Figure 12. Drilling history – south western and north eastern catchments
6 GROUNDWATER INVESTIGATIONS

Although a comprehensive groundwater investigation has not been carried out for the whole region, a number of aquifer tests have been carried out at particular locations within the study area. These tests, summarised in Table 5, give an indication of the permeability (or transmissivity) of the various aquifers and the drawdown response to pumping rates.

A constant discharge pumping test was performed on the fractured rock aquifer (Adelaidean sediments) in 1987 at the Southern Hills Research Centre at Flaxley (Howles, 1988). The 24 hour test was conducted on an irrigation well 6627-5347. Drawdown was monitored on both production and observation (6627-7715) wells, with the recovery monitored for a period of three days. The discharge was conducted at a rate of 20 L/s and a drawdown of 32.9 m was observed. Results from the test allowed estimation of the long-term safe yield from the bore (15 L/s) and the determination of the aquifer parameters, such as the transmissivity and storage coefficient. The values obtained for the transmissivity (T) were 42-60 m²/d while the storage coefficient (S) was 0.1.

An irrigation well (6627-6050) drilled in fractured slate and sandstone of the Tapley Hill Formation (Adelaidean sediments) at Mount Barker High School was tested on the completion of drilling (Eberhard, 1980). A step drawdown test was conducted with discharge rates of 5.4, 7.3 and 9.5 L/s with a maximum drawdown during the test of 27.6 m. The transmissivity of the aquifer was calculated to be ~ 28 m²/d from the results of the main stage of the pump test.

A constant discharge pumping test was conducted at Ashbourne, in October 1997, on the confined Permian Sand aquifer (Morton, 1988). The estimates of the aquifer characteristics obtained from this test may be relevant for the same aquifer utilised in the western part of the Finniss catchment. The 48-hour test was undertaken using an irrigation well (6627-9119) and a disused well (6627-1062) situated 8 m from the pumping well, as an observation well. The discharge rate was 4.8 L/s and a drawdown of 22 m was observed. The drawdown in the observation well was 15.6 m. The transmissivity of 26 m²/d was calculated, resulting in a K value of 0.4 m/d. A storage coefficient value of 0.0007 was calculated which is generally attributed to a confined aquifer.

Several data loggers were installed in the Finniss River and wells adjacent to it in the Ashbourne area to help determine the groundwater / surface water interaction during high winter flows. The data will be analysed as part of the more detailed investigations into groundwater / surface water interactions to be carried out over the next few years.

Table 5. Aquifer test data in EMLR

<table>
<thead>
<tr>
<th>Location</th>
<th>Pumping rate (L/s)</th>
<th>Length of test (hrs)</th>
<th>Transmissivity (m²/d)</th>
<th>Storage coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flaxley</td>
<td>20</td>
<td>24</td>
<td>42 - 60</td>
<td>0.1</td>
</tr>
<tr>
<td>Mt Barker</td>
<td>9.5</td>
<td>12</td>
<td>28</td>
<td>-</td>
</tr>
<tr>
<td>Ashbourne</td>
<td>4.8</td>
<td>48</td>
<td>26</td>
<td>0.0007</td>
</tr>
</tbody>
</table>
7 GROUNDWATER MONITORING & TRENDS

Groundwater level and salinity monitoring in the EMLR has been carried out by DWLBC in three areas where groundwater extractions are concentrated: Mount Barker, Macclesfield and Ashbourne (Fig. 1). In the 1990s, two other monitoring networks were established in the Bremer Catchment: the Brukunga network in 1995 monitored by Primary Industries and Resources (PIRSA) and the Harrogate network in 1991, monitored by Harrogate Landcare Group (Fig. 1). Data from both networks have been incorporated in the DWLBC corporate database OBSWELL, which is accessible via the web at the following address; https://info.pir.sa.gov.au/obswell/new/obsWell/MainMenu/menu

7.1 Mount Barker network

In the Mount Barker – Littlehampton area of the Bremer Catchment, a network of 12 observations bores was established in 1986 for groundwater level and salinity monitoring (Figs. 13, 14). Since then, several bores became inaccessible due to housing developments. Currently, only seven bores are being monitored; six for water levels on a six-monthly basis and four bores are randomly sampled for salinity testing. All bores are completed in the Adelaidean sediments and monitor the fractured rock aquifer.

All observation wells show distinctive seasonal fluctuation of groundwater levels. During summer, the watertable falls due to pumping, evapotranspiration and recharge to streams, while in winter, recharge from rainfall occurs, with the watertable rising as the aquifer storage fills up. Long-term hydrographs for observation wells MCF 7, 8, 9 and 11 are presented in Figure 15 together with the cumulative deviation from the average winter rainfall. This graph measures the difference between the actual measured rainfall and the average rainfall during the winter months (May – Aug). An upward trend in this line indicates above average winter rainfall, and conversely, a downward trend indicates below average winter rainfall.

Long term water level trends show a lack of correlation with winter rainfall. A decreasing trend of 5 - 7 cm/year was observed from 1990-94 despite above average winter rainfall, suggesting that vegetable irrigation may have been responsible. A good correlation exists from 1995-99 where the lowest levels recorded coincided with three consecutive dry winters. However, despite continuing dry winters, a recovery trend was observed in all wells since 1999, which is probably a response to decreasing irrigation resulting from the urban expansion of Mt Barker.

All observation wells show an upward long-term salinity trend in order of ~20 to 50 mg/L/yr. The rising trend is the most obvious from MCF 9 (Fig. 16), which is rising at 50 mg/L/yr. It is however difficult to interpret these trends meaningfully because there has only been two samples since 1995, when reduction in funding and personnel took effect. Two of the wells seem to have stabilised, possibly as a result of reduced irrigation.
Figure 15. Mount Barker observation well hydrographs

Figure 16. Mount Barker observation well salinity graphs
7.2 Macclesfield network

Readings in the Macclesfield monitoring network in the Upper Angas River Catchment began in 1991 when 25 mainly private domestic bores were selected for water level and salinity monitoring. Initially, the network was established because groundwater from this area was used to augment Strathalbyn town water supplies (Figs 13, 14). Currently there are 18 bores which have been monitored for water levels twice a year since 1999. Salinity sampling has been conducted randomly during the past 12 years, unfortunately not often enough to be able to establish meaningful trends.

Long term water level monitoring shows that there has been virtually no change in water levels apart from seasonal changes. A slight correlation with rainfall may be apparent, although Macclesfield rainfall station records suspiciously show continual below average rainfall since 1993. The declines in level during 1994-95 were due to test pumping from the town water supply wells.

![Figure 17. Macclesfield observation well hydrographs](image)

7.3 Ashbourne network

In September 1996, after concerns were expressed because of expanding groundwater development in the Ashbourne area for market gardening, a groundwater level monitoring network was established (Fig. 13). Initially, 18 private wells were selected and since have been monitored twice a year, at the beginning of the irrigation season as well as at the
end. Most selected wells are completed in the confined Permian Sand aquifer; however, two wells are monitoring groundwater in the Kanmantoo Group fractured rock aquifer (KND 3, KND 11). One well is completed in both (KND 6).

The wells show a seasonal drawdown of up to 4 m due to irrigation pumping. Comparison with the cumulative monthly rainfall deviation for Meadows indicates a general correlation with rainfall, with slight falls in drier years and rises in wetter years. There seems to be no adverse trends at current levels of pumping.

![Figure 18. Ashbourne observation well hydrographs](image)

### 7.4 Harrogate network

In 1991, several agencies commenced investigations and monitoring of dryland salinity in several representative catchments in various geological provinces around the State, including the southern MLR. Monitoring of groundwater levels and quality was the responsibility of local landcare groups and CSIRO, with results periodically passed to DWLBC. The Harrogate site had a well-defined land salinisation problem and was chosen to be one of the representative catchments (Fig. 20). All monitoring wells were completed in the fractured rock aquifer of the Kanmantoo Group (Pugh, 1992). All wells showed decreasing water level trends in order of 0.01 to 0.22 m/yr for the period between 1991 and 1996 (Fig. 19).
Also plotted in Figure 19 is the cumulative rainfall deviation of the mean monthly rainfall, with the data obtained from the Harrogate rainfall station (23722, Fig.1) with the annual average rainfall of 557 mm. The groundwater levels rise and fall in a consistent manner with the trend of the cumulative deviation from the monthly rainfall.

In 1996, monitoring of these piezometers was discontinued due to lack of funding and insufficient agency resources to provide support.

![Figure 19. Harrogate observation well hydrographs](image)

### 7.5 Brukunga network

In 1995, 20 monitoring bores were established on the tailings dam of the disused Brukunga mine to ascertain depth to water within the tailings dam adjacent to the valley of Dawesley Creek. Monthly monitoring of the depth to groundwater is currently conducted in seven boreholes in the 22-hectare surface of the tailings dam (Fig. 20). Over the long term the water levels have declined indicating that a continual drying of the tailings has occurred (Cox and Randall, 2003). The hydrographs shown in Figure 21 together with the cumulative deviation of the mean monthly rainfall show that the decline observed in all bores is due to long-term below average rainfall. The rainfall data is obtained for the Nairne rainfall station (23739, Fig. 1) with the annual average rainfall of 682 mm. An observation bore located at the eastern edge of the tailings (KAN 45) shows typical seasonal fluctuations from summer to winter.
Figure 21. Brukunga observation well hydrographs
8 SUB-CATCHMENT WATER BALANCES

Determining the water balance of a catchment is a fundamental step in establishing the sustainable groundwater yield for development. If extractions are greater than estimates of recharge, adverse impacts on the resource and the environment can be expected. The water balance methodology is applied to sub-catchments in each of the Bremer, Angas and Finniss Catchments (Fig. 1) where components of the water balance can be measured or estimated to a reasonable degree of accuracy. These components are displayed in Figure 22.

Figure 22. Catchment water balance components

8.1 Rainfall

This is the main driving force of the hydrologic cycle and is the major water input to catchment. Rainfall in the EMLR is winter dominant. By combining a rainfall isohyet map with the aerial coverage 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 6 lists the rainfall in the selected catchments.
Table 6. Sub-catchment rainfall volumes

<table>
<thead>
<tr>
<th>Sub-catchment</th>
<th>Annual rainfall (ML)</th>
<th>Effective rainfall (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BREMER RIVER</td>
<td>281 310</td>
<td>216 112</td>
</tr>
<tr>
<td>ANGAS RIVER</td>
<td>44 980</td>
<td>35 287</td>
</tr>
<tr>
<td>FINNISS RIVER</td>
<td>159 160</td>
<td>127 815</td>
</tr>
</tbody>
</table>

8.2 Evapotranspiration

After rain has fallen, water is transpired by plants and trees through their roots. It is also evaporated from the topsoil and even from wet leaves in the tree canopy. Reasonable estimates of plant water use by transpiration for various crops can be made. Surprisingly, this is often the largest water use component in the catchment. A geographic information system (GIS) coverage of land use in the Mount Lofty Ranges was constructed in 1999 using current aerial photographs and ground truthing. For the eastern part of Bremer Catchment, a Lower Murray land use coverage (2000) was used.

These coverages can provide areas of native vegetation, pasture, vineyards etc. and hence, 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 can at best, only have a similar accuracy.

8.3 Streamflow

There is a network of about 70 continuous recording gauging stations throughout the Mount Lofty Ranges. Most of the 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 gauging stations are situated on the Bremer River at Hartley, on the Angas River at Angas Weir and on the Finniss River, 4 km east of Yundi (Fig. 1). The streamflow values consisting of runoff and baseflow components are presented in Table 7.

Table 7. Sub-catchment streamflow volumes

<table>
<thead>
<tr>
<th>Sub-catchments</th>
<th>Runoff (ML)</th>
<th>Baseflow (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bremer River AW 426533</td>
<td>10 040</td>
<td>7160</td>
</tr>
<tr>
<td>Angas River AW 426503</td>
<td>2785</td>
<td>1515</td>
</tr>
<tr>
<td>Finniss River AW 426504</td>
<td>14917</td>
<td>9563</td>
</tr>
</tbody>
</table>
8.4 Surface storages

Some of the runoff is captured in farm dams. A recent study by DWLBC has calculated the volume of all farm dams in the Mount Lofty Ranges using infra-red aerial photography (to determine the area of the dams), and the following formula:

\[ \text{Volume} = 0.0002 \times \text{area}^{1.2604} \]

where volume is in megalitres and the area in square metres (Pikusa, 1999).

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 8 shows the volumes calculated.

<table>
<thead>
<tr>
<th>Sub-catchments</th>
<th>Dam volumes (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bremer River</td>
<td>5560</td>
</tr>
<tr>
<td>Angas River</td>
<td>1950</td>
</tr>
<tr>
<td>Finniss River</td>
<td>5820</td>
</tr>
</tbody>
</table>

8.5 Groundwater pumping

The main component of groundwater pumping is irrigation. Unfortunately, very few of 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 1999 land use survey coverage on GIS to provide irrigated areas and crop types. This method works well in the smaller catchments where property sizes are also small and are dominated by one land use.

Unfortunately in the EMLR catchments, property sizes are larger and irrigation of dairy pasture is carried out on only part of the property. Regrettably, the 1999/2000 land use survey did not specifically delineate these irrigated areas and instead, classified the whole property as dairy which would give misleading results when calculating water use. To overcome this shortcoming, recent aerial photography on GIS (Inner Rural Series 2, 2002) was used to estimate irrigation water use. It was estimated that less than half of land classified as dairy and improved/irrigated pasture are, in fact irrigated.

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 and some field verification of actual use is essential to differentiate between groundwater and surface water sources.
It must also be pointed out that these estimates are accurate only to +/- 10–20%, but are nonetheless the best available. Metering of irrigation and industrial users is strongly recommended to obtain more accurate estimates of groundwater use.

### 8.6 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.

#### 8.6.1 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:

\[
\text{recharge} = \text{rainfall} - (\text{evapotranspiration} + \text{runoff} + \text{dam storage}).
\]

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

\[
\text{recharge} = \text{groundwater pumping} + \text{baseflow}.
\]

Data from the Bremer sub-catchment (Appendix A) is used here as an example:

\[
\begin{align*}
\text{recharge} & = \text{rainfall} - (\text{evapotranspiration} + \text{runoff} + \text{dam storage}) \\
& = 216,112 - (186,138 + 10,040 + 5,560) \\
& = 14,400 \text{ ML} \sim 31 \text{ mm/yr (5.5% annual rainfall)}. \\
\end{align*}
\]

By using the groundwater balance only:

\[
\begin{align*}
\text{recharge} & = \text{groundwater extraction} + \text{baseflow} \\
& = 5924 + 7160 \\
& = 13,100 \text{ ML or } \sim 28 \text{ mm/yr (5% annual rainfall)}. \\
\end{align*}
\]

#### 8.6.2 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, however uncertainties are introduced because the measured watertable rise must be multiplied by the specific yield to obtain the volume of recharge which has entered the aquifer. Specific yield values are difficult to measure and are highly variable, even within the same aquifer.
In all EMLR catchments, the only regular water level monitoring has been carried out in Mount Barker, Macclesfield, Tookayerta and Ashbourne. Because the annual fluctuations in water level in these areas are mainly caused by pumping and not natural discharge, the watertable rise method is not applicable.

### 8.6.3 DISCUSSION

The two different water balance methods of estimating recharge obtained generally values of the same order of magnitude, as shown in Table 9.

<table>
<thead>
<tr>
<th>Sub-catchments</th>
<th>Water balance 1 (ML)</th>
<th>Water balance 2 (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bremer River</td>
<td>13 100</td>
<td>14 400</td>
</tr>
<tr>
<td>Angas River</td>
<td>4000</td>
<td>7600</td>
</tr>
<tr>
<td>Finniss River</td>
<td>21 300</td>
<td>26 700</td>
</tr>
</tbody>
</table>

The water balance 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 at best approximate to within +/-25–30%. For the purposes of this report only, it is proposed to use the following initial recharge values for the sub-catchments (Table 10). Further detailed investigations may refine these recharge estimates.

<table>
<thead>
<tr>
<th>Sub-catchments</th>
<th>ML</th>
<th>mm/yr</th>
<th>% of annual rainfall</th>
<th>% of effective rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bremer River</td>
<td>13 500</td>
<td>30</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Angas River</td>
<td>5800</td>
<td>97</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Finniss River</td>
<td>24 000</td>
<td>125</td>
<td>15</td>
<td>19</td>
</tr>
</tbody>
</table>
9 SUSTAINABLE YIELD

The State Water Plan 2000 accepts the definition of sustainable yield proposed by the National Groundwater Committee of 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 also 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 to some extend dependent on groundwater, and which the community reasonably expects will be maintained or developed for a defined period. The task of determining and ranking the value of potential uses or demands for any aquifer is likely to be a subjective process that will require a combination of community input and expert opinion (Evans et al, 1998).

It should be noted that recharge is not mentioned in the definition of sustainable yield since, depending on the aquifer characteristics, other factors are more important.

Further work will investigate the relationship between surface and groundwater, and different approaches to determining sustainable yield of the resource for allocation purposes. Estimates for 50 and 75% of recharge are presented in Table 11.

**Table 11. Comparison of estimates of usage and recharge**

<table>
<thead>
<tr>
<th>Sub-catchments</th>
<th>Current use (ML)</th>
<th>50% recharge (ML)</th>
<th>75% recharge (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bremer</td>
<td>5924</td>
<td>6500</td>
<td>9750</td>
</tr>
<tr>
<td>Angas</td>
<td>2429</td>
<td>2800</td>
<td>4350</td>
</tr>
<tr>
<td>Finnis</td>
<td>11 714</td>
<td>12 000</td>
<td>18 000</td>
</tr>
</tbody>
</table>

It can be seen that current groundwater use in the three sub-catchments 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 for considerable distances 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 12. The total volumes calculated to be in storage are over ten 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 12. Aquifer storage volumes

<table>
<thead>
<tr>
<th>Sub-catchments</th>
<th>Storage (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bremer</td>
<td>700 000</td>
</tr>
<tr>
<td>Angas</td>
<td>89 000</td>
</tr>
<tr>
<td>Finniss</td>
<td>285 000</td>
</tr>
</tbody>
</table>

Although extractions of groundwater are approaching 50% of recharge, the use of surface water from the large volume of dam storage may mean that actual groundwater pumping is well below that level. Changes in land use to higher value irrigated crops may in fact, lead to a reduction in groundwater withdrawals due to more efficient irrigation methods and lower water requirements. For example, vines require about 1-2 ML/ha/yr applied by drip, whereas pasture requires 6-8 ML/ha/yr applied by sprinkler.

In smaller catchments, significant withdrawals may have significant local impacts such as drawdowns in groundwater levels beneath neighbouring properties and a reduction in baseflow to streams, which may have environmental consequences. 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, especially in areas of concentrated irrigation. Metering is strongly recommended to assist such assessments and to promote irrigation efficiency.
10 CONCLUSIONS AND RECOMMENDATIONS

Catchments in the EMLR are underlain by fractured rock and sedimentary aquifers that contain groundwater of varying quality and yields. The development of groundwater resources has been strongly related to geology. About 75% of the area is underlain by poor aquifers with salinities too high and yields too low for irrigation, with no capability for increased development.

Aquifer yields and salinities are more favourable in the western and southern parts of the EMLR than in the east. This is due to the presence of the permeable Adelaiaedan fractured rocks and Permian Sands, together with the higher rainfall. Irrigation of vineyards, vegetables and dairy pastures has occurred in relatively localised areas. As many irrigation wells (356) have been drilled since 1995, as were drilled in the 20 years prior to 1995. Although monitoring has so far shown no adverse impacts on the groundwater resource (apart from some salinity increases in the Mt Barker area), the main risks of further uncontrolled development in these areas are groundwater level declines and increasing salinities due to the lateral movement of more saline groundwater from surrounding areas.

In three sub-catchments where sufficient information existed, approximate water balances were calculated. This work indicated recharge rates varying from 100–125 mm/y (12–15% of annual rainfall) in the wetter areas to the west, to only 30 mm (5% of annual rainfall) to the east. These figures are considered to be a preliminary estimation based on the best available information at the time this study was undertaken. DWLBC will be undertaking further work to improve estimates of recharge and the degree of connection between surface water and groundwater.

The large dam storages present in all catchments indicate that surface water from dams supplies a significant amount of the irrigation water and some field verification of actual use is essential to differentiate between groundwater and surface water sources.

Although the current water level monitoring has shown no adverse impacts, regular monitoring should be extended to other areas of high groundwater use to determine long term watertable trends. Salinity monitoring networks should be established in those areas and the monitoring should be conducted on a regular basis.

The water balances need to be revised at regular intervals to take into account such changes in land use and irrigation practice. The metering of all irrigation and industrial supplies should be eventually carried out to allow accurate estimates of water use.
11 REFERENCES


12 APPENDIX A

SUB-CATCHMENT WATER BALANCES
## Sub-Catchment Water Balance

### BREMER RIVER

#### Irrigation/extraction

<table>
<thead>
<tr>
<th>Crop type/use</th>
<th>Area (ha)</th>
<th>Water need (mm)</th>
<th>Water use (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved pastures</td>
<td>700</td>
<td>500</td>
<td>3500</td>
</tr>
<tr>
<td>Vineyards</td>
<td>78</td>
<td>120</td>
<td>94</td>
</tr>
<tr>
<td>Vegetables</td>
<td>305</td>
<td>600</td>
<td>1830</td>
</tr>
<tr>
<td>Irrigated crop</td>
<td>45</td>
<td>300</td>
<td>135</td>
</tr>
<tr>
<td>Orchards</td>
<td>73</td>
<td>500</td>
<td>365</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5924</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Evapotranspiration

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (ha)</th>
<th>Water use (mm)</th>
<th>Water loss (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>35 080</td>
<td>419</td>
<td>146 985</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>971</td>
<td>500</td>
<td>4855</td>
</tr>
<tr>
<td>Vineyards</td>
<td>78</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Crops</td>
<td>5944</td>
<td>402</td>
<td>23895</td>
</tr>
<tr>
<td>Orchards</td>
<td>73</td>
<td>220</td>
<td>160</td>
</tr>
<tr>
<td>Vegetables</td>
<td>305</td>
<td>195</td>
<td>595</td>
</tr>
<tr>
<td>Living (other)</td>
<td>4818</td>
<td>200</td>
<td>9636</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>186 138</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Streamflow

| Runoff (ML) | 10 040 |
| Baseflow (ML) | 7160 |
| **Total** | **17 200** |

#### Recharge

<table>
<thead>
<tr>
<th>Method</th>
<th>Comments</th>
<th>Estimate (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deduction</td>
<td>Rainfall -(ET + runoff + damvol)</td>
<td>14 400</td>
</tr>
<tr>
<td>Deduction</td>
<td>Groundwater extraction + baseflow</td>
<td>13 100</td>
</tr>
<tr>
<td>Adopted initial value</td>
<td></td>
<td>13 500</td>
</tr>
</tbody>
</table>

#### Dam storage

<table>
<thead>
<tr>
<th>Total dam volume</th>
<th>5560 ML</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>⇒</strong> Total outflow</td>
<td><strong>216 112 ML</strong></td>
</tr>
</tbody>
</table>

| Rainfall (Effective) | 457 | Area | 472.75 km² | **⇒** 216 112 ML | **Total inflow** |

---

Eastern Mount Lofty Ranges Groundwater Assessment
## Sub-catchment Water Balance

### Irrigation/extraction

<table>
<thead>
<tr>
<th>Crop type/use</th>
<th>Area (ha)</th>
<th>Water need (mm)</th>
<th>Water use (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved pastures</td>
<td>410</td>
<td>500</td>
<td>2050</td>
</tr>
<tr>
<td>Vineyards</td>
<td>175</td>
<td>120</td>
<td>210</td>
</tr>
<tr>
<td>Orchard</td>
<td>20</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Irrigated crop</td>
<td>23</td>
<td>300</td>
<td>69</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2429</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Evapotranspiration

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (ha)</th>
<th>Water use (mm)</th>
<th>Water loss (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>4916</td>
<td>412</td>
<td>20253</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>185</td>
<td>620</td>
<td>1147</td>
</tr>
<tr>
<td>Vineyards</td>
<td>175</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td>Crop</td>
<td>53</td>
<td>395</td>
<td>209</td>
</tr>
<tr>
<td>Orchard</td>
<td>20</td>
<td>217</td>
<td>43</td>
</tr>
<tr>
<td>Living (other)</td>
<td>630</td>
<td>200</td>
<td>1260</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22938</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Streamflow

- Runoff (ML) 2785
- Baseflow (ML) 1515
- **Total** 4300

### Recharge

<table>
<thead>
<tr>
<th>Method</th>
<th>Comments</th>
<th>Estimate (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deduction</td>
<td>Rainfall -(ET + runoff + damvol)</td>
<td>7600</td>
</tr>
<tr>
<td>Deduction</td>
<td>Groundwater extraction + baseflow</td>
<td>4000</td>
</tr>
<tr>
<td><strong>Adopted initial value</strong></td>
<td></td>
<td>5800</td>
</tr>
</tbody>
</table>

### Dam storage

- **Total dam volume** 1950 ML

**Total outflow** 35287 ML

Rainfall 590 mm (Effective) X Area 59.8 km² = 35287 ML

**Total inflow**
### Sub-catchment Water Balance

#### Irrigation/extraction

<table>
<thead>
<tr>
<th>Crop type/use</th>
<th>Area (ha)</th>
<th>Water need (mm)</th>
<th>Water use (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved pastures</td>
<td>2108</td>
<td>500</td>
<td>10 540</td>
</tr>
<tr>
<td>Vineyards</td>
<td>771</td>
<td>110</td>
<td>848</td>
</tr>
<tr>
<td>Orchards</td>
<td>58</td>
<td>500</td>
<td>290</td>
</tr>
<tr>
<td>Irrigated crop</td>
<td>12</td>
<td>300</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11 714</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Evapotranspiration

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (ha)</th>
<th>Water use (mm)</th>
<th>Water loss (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>13 442</td>
<td>400</td>
<td>53 768</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>4077</td>
<td>604</td>
<td>24 625</td>
</tr>
<tr>
<td>Vineyards</td>
<td>771</td>
<td>15</td>
<td>115</td>
</tr>
<tr>
<td>Orchard</td>
<td>58</td>
<td>206</td>
<td>119</td>
</tr>
<tr>
<td>Crop</td>
<td>28</td>
<td>394</td>
<td>110</td>
</tr>
<tr>
<td>Living (other)</td>
<td>830</td>
<td>200</td>
<td>1660</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>80397</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Streamflow

<table>
<thead>
<tr>
<th>Component</th>
<th>Value (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff</td>
<td>14917</td>
</tr>
<tr>
<td>Baseflow</td>
<td>9563</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24480</strong></td>
</tr>
</tbody>
</table>

#### Recharge

<table>
<thead>
<tr>
<th>Method</th>
<th>Comments</th>
<th>Estimate (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deduction</td>
<td>Rainfall -(ET + runoff + damvol)</td>
<td>26 700</td>
</tr>
<tr>
<td>Deduction</td>
<td>Groundwater extraction + baseflow</td>
<td>21 300</td>
</tr>
<tr>
<td><strong>Adopted initial value</strong></td>
<td></td>
<td><strong>24 000</strong></td>
</tr>
</tbody>
</table>

#### Dam storage

<table>
<thead>
<tr>
<th>Component</th>
<th>Value (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dam volume</td>
<td>5820</td>
</tr>
<tr>
<td><strong>Total outflow</strong></td>
<td><strong>127 815 ML</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rainfall (Effective)</th>
<th>Area</th>
<th>Total inflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>665 mm</td>
<td>192.2 km²</td>
<td><strong>127 815 ML</strong></td>
</tr>
</tbody>
</table>