Aquifer Storage and Recovery Potential of Fractured Rock Aquifers in the Golden Grove Embayment

Todd Hodgkin

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

June 2006

Report DWLBC 2006/03
FOREWORD

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

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

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

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

**FOREWORD** ....................................................................................................................... i

**EXECUTIVE SUMMARY** ................................................................................................. 1

1. **INTRODUCTION** ............................................................................................................. 3

2. **OBJECTIVES AND SCOPE** ........................................................................................... 4

3. **BACKGROUND** ............................................................................................................. 5

   3.1 **PREVIOUS GEOLOGICAL AND HYDROGEOLOGICAL REPORTS** ................. 5
   3.2 **FRA ASR OPERATIONS AND INVESTIGATIONS** ........................................... 5

4. **METHODOLOGY** ............................................................................................................ 7

5. **BASEMENT GEOLOGY** ................................................................................................. 8

   5.1 **LITHOSTRATIGRAPHY** .......................................................................................... 8

      5.1.1 **CASTAMBUL FORMATION** ............................................................................. 8
      5.1.2 **MONTACUTE DOLOMITE** ................................................................................ 8
      5.1.3 **WOOLSHED FLAT SHALE** .............................................................................. 8
      5.1.4 **STONYFELL QUARTZITE** ............................................................................. 8
      5.1.5 **SADDLEWORTH FORMATION** ...................................................................... 9
      5.1.6 **BEAUMONT DOLOMITE** ............................................................................... 9
      5.1.7 **GLEN OSMOND SLATE** .................................................................................. 9
      5.1.8 **BELAIR SUBGROUP** ...................................................................................... 9
      5.1.9 **STURT TILLITE** .............................................................................................. 9
      5.1.10 **TAPLEY HILL FORMATION** ......................................................................... 10

   5.2 **SUBCROP** .................................................................................................................. 10

   5.3 **FAULTS** ................................................................................................................... 10

   5.4 **BASE OF SEDIMENTS** ........................................................................................... 11

   5.5 **TOP OF FRESH BEDROCK** .................................................................................... 12

6. **HYDROGEOLOGY** .......................................................................................................... 14

   6.1 **FRACTURED ROCK AQUIFER TYPES** ................................................................. 14

      6.1.1 **Type 1 — Base of Weathering** ....................................................................... 14
      6.1.2 **Type 2 — Fracture Zones** ............................................................................. 14
      6.1.3 **Type 3 — Karstic Aquifers** ........................................................................... 15

   6.2 **GROUNDWATER LEVELS** .................................................................................... 15

   6.3 **GROUNDWATER SALINITY** ............................................................................... 16

   6.4 **GROUNDWATER YIELDS** .................................................................................... 16
CONTENTS

7. FRA ASR POTENTIAL.................................................................................................................. 18

7.1 FRA ASR SUSTAINIBILITY AND SUITABILITY WITHIN THE STUDY AREA...... 18

7.1.1 Impacts on Existing Groundwater Users ........................................................................... 18

7.1.2 Increased Water-Table Levels............................................................................................... 19

7.1.3 Size of FRA ASR Projects .................................................................................................. 19

7.1.4 Well Completion................................................................................................................... 19

7.1.5 Native Groundwater Salinity.............................................................................................. 20

7.1.6 Depth To Aquifer.................................................................................................................. 20

7.1.7 Depth To Groundwater......................................................................................................... 20

7.1.8 Structural Geology.............................................................................................................. 21

7.1.9 Investigation Techniques..................................................................................................... 21

7.2 FRA ASR ZONES .............................................................................................................. 22

7.3 SITES AND EXISTING WELLS RECOMMENDED FOR FURTHER
INVESTIGATION .............................................................................................................. 23

7.3.1 Existing Water Wells......................................................................................................... 23

7.3.2 Potential FRA ASR Sites .................................................................................................. 24

8. CONCLUSIONS AND RECOMMENDATIONS ................................................................. 26

APPENDICES ............................................................................................................................ 41

A. 1982–83 AND 1983–84 AVERAGE ANNUAL GROUNDWATER ABSTRACTIONS
(AFTER EDWARDS ET AL, 1987) .......................................................................................... 41

B. EXISTING WELLS SUITABLE FOR FRA ASR AQUIFER TESTING .......................... 42

C. POTENTIAL FRA ASR INVESTIGATION SITES ............................................................. 43

UNITS AND MEASUREMENTS .............................................................................................. 45

GLOSSARY ............................................................................................................................... 46

REFERENCES.......................................................................................................................... 54
LIST OF FIGURES

Figure 1. Fractured rock aquifer study area ................................................................. 28
Figure 2. Burra Group stratigraphy of the Adelaide Geosyncline, after Priess 1987 ...... 29
Figure 3. Bedrock geology plan .................................................................................. 30
Figure 4a. Base of Quaternary and Tertiary sediments (mAHD) ................................. 31
Figure 4b. Base of Quaternary and Tertiary sediments (mbgl) ..................................... 32
Figure 5a. Top of fresh bedrock (mAHD) .................................................................... 33
Figure 5b. Top of fresh bedrock (mbgl) ....................................................................... 34
Figure 6. Weathered rock isopachs ............................................................................ 35
Figure 7a. Fractured rock aquifer groundwater levels (mAHD) ................................. 36
Figure 7b. Fractured rock aquifer groundwater levels (mAHD) ................................. 37
Figure 8. Fractured rock aquifer salinity ..................................................................... 38
Figure 9. Fractured rock aquifer yields ....................................................................... 39
Figure 10. FRA ASR zones and potential investigation sites ................................. 40

LIST OF TABLES

Table 1. Operating FRA ASR projects within the study area ........................................ 6
Table 2. FRA ASR Zones ............................................................................................ 22
Table 3. Existing FRA Wells Recommended for Possible Aquifer Testing .................. 24
Table 4. Potential FRA ASR sites ............................................................................... 25
EXECUTIVE SUMMARY

This study has assessed the hydrogeological potential of the Fractured Rock Aquifer (FRA) for Aquifer Storage and Recovery (ASR) projects within a 147 km² Adelaide metropolitan area bounded by Dry Creek, Brown Hill Creek, Para Fault and the Hills Face Zone (HFZ). Within this area there are currently four operational ASR projects (Northgate, Regent Gardens, Torrens Valley Sportsfield and Scotch College) injecting a combined 135–250 ML/y. Other sites under recent or current investigation by, or with the assistance of, the Adelaide and Mount Lofty Ranges Natural Resource Management (NRM) Board include St Ignatius Senior School, Victoria Park Racecourse and the Botanic Gardens.

The study has been undertaken on a broad level as a desktop evaluation using the results of past geological, geophysical and hydrogeological investigations, and extensive review of the state drillhole and water well databases and archives. Over 4200 drillholes and wells occur in the study area; all those considered likely to intersect bedrock were identified and reviewed to establish and contour the:

- depth of overlying sediments
- thickness of weathered bedrock
- bedrock aquifer intervals, yields, salinities and groundwater levels.

Bedrock within the study area is largely concealed beneath a veneer of Quaternary and Tertiary sediments of the Golden Grove Embayment (GGE). Areas of outcropping bedrock are limited to the eastern margin of the study area and within the upper reaches of the Torrens River Valley (TRV). Drilling data indicate that the concealed basement is dominated by fine-grained metasiltstone, shale and slate of the Saddleworth Formation, Belair Subgroup and Tapley Hill Formation. The basement rocks have a variable palaeo-surface and are structurally complex as a result of extensive folding and faulting during the Delamerian Orogeny, which makes the identification of suitable aquifer zones difficult. The hydrogeology of the basement is quite variable, but can be summarised by:

- groundwater levels are often very shallow or artesian along the HFZ and TRV, but can be deeper than 30 m west of the Hope Valley Fault
- the depth to bedrock is controlled by current drainage patterns and the overall southeasterly dipping floor of the GGE; unfavourably high depths to bedrock in excess of 150 m occur in the southern and southeastern parts of the study area
- groundwater salinity is relatively good, being lowest (typically <3000 mg/L Total Dissolved Solids [TDS]) in eastern and northern parts of the study area, and highest (>5000 mg/L TDS) in the western and southwestern parts
- aquifer yields are highly variable as expected; of ~180 drillholes and water wells within the study area with yield information, ~50 have relatively high yields (>4 L/s).

Conceptually, the main aquifer targets are relatively high transmissivity, low storage fracture zone aquifers associated with discrete bedrock structures which, if developed for ASR, may be limited in size to below ~50 ML/y. The identification and quantification of such aquifer zones will rely on relatively high-risk site drilling investigations. The size and hydrogeological sustainability of ASR operations within such FRAs will be strongly influenced by the depth to
EXECUTIVE SUMMARY

(native) groundwater, aquifer transmissivity, storage, depth and orientation, and the proximity to existing users of the same FRA. In general terms, the study area has significant areas with favourable hydrogeologic conditions that include:

- ability to complete wells with open-hole production intervals
- ~60% of the study area has native groundwater salinities <3000 mg/L TDS
- much of area has <100 m of sedimentary cover above bedrock
- presence of at least three major fault and/or structural corridors.

The FRA ASR potential of the study area has been spatially mapped by definition and application of eight different zones based on native groundwater salinity, proximity to major structure zones, depth to bedrock and ground surface slope. Some of the less favourable categories (Type 5 and 6) are based on the assumption that the aquifer zone is relatively shallow but, if deeper confined aquifer zones occur in these areas, then conditions for FRA ASR may be more favourable.

Twenty-eight sites were identified as having high potential for FRA ASR development by qualitatively considering all landholdings within Type 1 zones that:

- are close to potential water supplies from creeks, drains or stormwater pipes of >0.5 m diameter
- have at least ~1 ha of open space for water capture and pre-treatment
- have a potential water demand based mainly on the presence of sports grounds or grassed public spaces.

Twelve existing FRA water wells with yields >4 L/s were identified that are considered suitable for further ASR investigation by undertaking aquifer tests. Seven of these wells coincide with, or are very close to, the 29 investigation sites and should be considered as priorities for testing.

Recommendations for furthering the development of new FRA ASR projects in the study area are:

1. Undertake a census of current groundwater use from the sedimentary T1 aquifer and FRA to identify potential FRA ASR proponents and determine the potential for adverse impacts from specific FRA ASR projects upon existing groundwater users.

2. Integrate the findings of the above with the potential ASR sites and existing water well shortlist from this study to define and prioritise the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR NRM) Board’s future directions in promoting and supporting development of new FRA ASR operations within the study area.
1. INTRODUCTION

A study to evaluate the potential storage capacities of the major aquifers of the Adelaide region for ASR was recently concluded by the Department of Water, Land and Biodiversity Conservation (DWLBC; Hodgkin 2004). The study focused on the sedimentary aquifers as they have reasonably continuous extents that allow quantification of storage capacity. The storage capacities of the FRA were not estimated in the 2005 study as the bedrock aquifers are typically highly anisotropic and of variable extent. However, in many parts of the metropolitan area, the FRA forms the only significant aquifer for either groundwater supply or ASR projects.

The FRA is a significant aquifer within the northeastern, eastern and southern suburbs of the metropolitan area below the Adelaide Hills Face Zone (HFZ). The Torrens and Patawalonga Catchment Water Management Boards (now part of the AMLR NRM Board) commissioned DWLBC in late 2004 to investigate the potential for FRA ASR within this area. The study area is ~147 km² in size and forms a rectangular area bounded approximately by Dry Creek in the north, the Para Fault to the west, Brown Hill Creek to the south and the HFZ to the east (Fig. 1). The investigation was undertaken during 2005 as a desktop-based study using existing information. This report presents the results of the study and outlines favourable areas and existing well sites recommended for drilling and/or aquifer testing to establish potentially sustainable FRA ASR projects.
2. OBJECTIVES AND SCOPE

The objectives of the study comprise:

- Identify preferred areas and well sites for further (field) investigation of FRA ASR potential.

- Determine hydrogeological criteria for defining the potential sustainability of FRA ASR operations within the study area.

- Undertake aquifer testing at up to five existing favourable well sites to assist quantification of the potential ASR injection volumes.

The scope of work completed is:

- Review of previous relevant geological and hydrogeological reports.

- Review of past and current FRA ASR investigations within the study area.

- Collation and validation of existing drillhole and water well data.

- Interpretive mapping of various geological and hydrogeological surfaces and parameters.

- Establishment of hydrogeological criteria that can be spatially applied to delineate areas and sites where the potential for significantly sized operations (>10 ML/y) and sustainable FRA ASR operations is relatively high.

- Application of the above criteria to the developed datasets to delineate hydrogeologically favourable areas for FRA ASR.

- Preliminary mapping of potential ASR demand and source water availability to provide refined delineation of preferred areas and well sites for further FRA ASR investigation.

Aquifer testing of any preferred well sites is yet to be undertaken. The 12 wells listed in Section 7 should be considered by the AMLR NRM Board for aquifer testing.
3. BACKGROUND

3.1 PREVIOUS GEOLOGICAL AND HYDROGEOLOGICAL REPORTS

Most hydrogeological investigations to date within the study area have focused on the Quaternary and Tertiary-aged sediments that overlie Proterozoic bedrock within the GGE. Geological investigations of bedrock have been mainly by mapping of outcrop within drainage lines and areas east of the HFZ. Several geophysical surveys have been undertaken to delineate the location of major faults that form the eastern boundary of the GGE.

Previous reports used for this study comprise:
- Selby and Lindsay (1982)—a synthesis of the geology and hydrogeology of the Adelaide Central Business District area.
- Hough (1986)—gravity surveys to locate the Eden–Burnside Fault in the Clapham and Panorama areas.
- Woods (1987)—a University of Adelaide Honours Degree project to locate possible fault structures in eastern suburban areas.
- Gerges (1997)—overview of the hydrogeology of the Adelaide area.
- Fairburn (2004)—a review of the shallow Cainozoic fluvial history of the GGE.
- Hodgkin (2004)—evaluation of the (sedimentary) aquifer storage capacities of the Adelaide region.

3.2 FRA ASR OPERATIONS AND INVESTIGATIONS

ASR investigations of the FRA to date within the study area have culminated in the establishment of four operating ASR projects that inject a combined volume of up to 250 ML/y. Summary details of these operations are presented in Table 1, and their location shown on Figure 1.
### Table 1. Operating FRA ASR projects within the study area

<table>
<thead>
<tr>
<th>Project</th>
<th>Year commenced operating</th>
<th>Typical injection volumes (ML/y)</th>
<th>Water source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotch College</td>
<td>1989</td>
<td>40</td>
<td>Brownhill Creek</td>
</tr>
<tr>
<td>Regent Gardens</td>
<td>1995</td>
<td>40–60</td>
<td>Urban runoff</td>
</tr>
<tr>
<td>Northgate</td>
<td>2001</td>
<td>40–110</td>
<td>Urban runoff</td>
</tr>
<tr>
<td>Torrens Valley Sportsfield</td>
<td>2003</td>
<td>15–40</td>
<td>Fifth Creek</td>
</tr>
</tbody>
</table>

Other past and current ASR investigations (Fig. 1) that have considered FRA targets within the study area include:

- Evaluation of ASR potential of the Tea Tree Gully Council area by Australian Groundwater Technologies (AGT) in 2001. This council area is largely to the north of the study area but does extend down within the study area in the vicinity of the Hope Valley Reservoir. The AGT study delineated three sites for further investigation:
  - Torrens River
  - Lyons Road Oval
  - Barracks Rd Hope Valley
- Preliminary investigations by St Ignatius Senior School for oval irrigation.
- FRA ASR potential of the Adelaide City Parkland areas by the AMLR NRM Board. Three sites (Victoria Park Racecourse, Botanic Gardens and North Parklands) were drilled during 2005 under the direction of AGT.
4. METHODOLOGY

The methodologies used for this study, in approximate order of completion, are:

- Capture of all drillhole and water well records within the study area held on the DWLBC-maintained SA_Geodata database. Approximately 4200 drillholes and wells, as at August 2005, are recorded within the study area, but most of these do not intersect bedrock.

- Analysis and review of the drillhole and well dataset using microfiche records and previous reports to establish data subsets of holes and wells that contain information on:
  - depth of sedimentary cover above bedrock
  - thickness of weathered bedrock
  - bedrock lithology
  - groundwater salinity of bedrock intervals
  - groundwater yield of bedrock intervals measured during drilling or pumping
  - groundwater levels of bedrock intervals measured during drilling or post-well construction.

For each of these data subsets, each record was assigned a qualitative confidence level rating (as a number between 1 to 3 or 1 to 4) to reflect the degree of uncertainty in the assigned value (1 being high-confidence data, a 3 or 4 being lower confidence data based on interpretation).

- Review of available pumping test information.

- Collation and review of known and interpreted fault locations from previous workers.

- Contouring and digitising of the base-of-sediments and top-of-fresh-bedrock surfaces (in absolute datum mAHD), groundwater salinity and groundwater level surfaces using the data subsets described above.

- Calculation, using Surfer 8 contouring software, of the following surfaces:
  - depth to base of sediments as metres below ground (mbgl)
  - depth to top of fresh bedrock (mbgl)
  - weathered rock isopach (thickness)
  - depth to groundwater (mbgl).

This work effectively involved the re-contouring of the hand-drawn contours by using a kriging interpolator on a 50x50 m cell size over a grid area between 275000 and 294000mE, and 6122000 to 6144000mN, and subsequent subtractions from a ground surface grid previously generated by Hodgkin (2004).

- Application of hydrogeological criteria to map the ASR aquifer potential of different zones within the study area.

- Refinement of hydrogeologically favourable areas by application of preliminary ASR demand and source water criteria.

- Delineation of potential FRA ASR sites by qualitatively considering potential water sources, water demand and open area within the most favourable ASR aquifer potential zones.

- Identification of high-yielding existing water wells within favourable ASR zones for possible aquifer testing.
5. BASEMENT GEOLOGY

5.1 LITHOSTRATIGRAPHY

The study area is underlain and bounded by various Proterozoic sedimentary rocks of the Adelaide Geosyncline, but predominantly by shale, slate, siltstone and quartzite of the Burra Group. A lithostratigraphic column of the Burra Group is shown in Figure 2. Figure 3 shows an outcrop plan of the major lithostratigraphic units of the study area and the main lithologies intersected near the base of ~200 drillholes and water wells.

A brief lithological description of the major stratigraphic rock units within and immediately surrounding the study area is provided below. More detailed descriptions are given in Preiss (1987).

5.1.1 CASTAMBUL FORMATION

Within the Torrens Gorge (near to the study area), this formation comprises a pale grey to white, finely crystalline, massive dolomite which occurs as a 50–100 m thick interbed within a dark grey and greenish, silty and phyllitic sequence overlying the Aldgate Sandstone (Preiss 1987). The dolomite is also sandy in the upper sections and grades up into ~30 m of coarse-grained quartzite (Preiss 1987).

5.1.2 MONTACUTE DOLOMITE

This unit comprises dominantly blue-grey fine-grained dolomite with interbeds of dolomitic sandstone, quartzite, magnesite conglomerate and minor dolomitic phyllite (Preiss 1987). It is ~130 m thick in the type section at Castambul, ~3 km east of Athelstone.

5.1.3 WOOLSHED FLAT SHALE

In the Montacute – Tea Tree Gully area, the Woolshed Flat Shale typically comprises an upper unit of laminated sandy or silty shale and phyllite, and a lower unit of dolomitic phyllite with thin dolomite lenses (Preiss 1987).

In the Mount Lofty – Lenswood – Balhannah area, the Burra Group is represented almost entirely by the Balhannah Shale Member, a carbonaceous black slate within the Woolshed Flat Shale (Preiss 1987).

5.1.4 STONYFELL QUARTZITE

This unit is responsible for much of the prominent relief of the Adelaide HFZ, especially north of the Black Hill – Athelstone area, where it is the main lithostratigraphic unit occurring immediately to the east of the major Eden–Burnside Fault (Fig. 3). Close to the study area, the Stonyfell Quartzite is ~250 m thick and comprised predominantly of feldspathic quartzite; it has been subdivided into three informal members (Preiss 1987):
The basal Wattle Park Member is predominantly feldspathic quartzite with thin laminations of shale that transitions upwards into medium to coarse feldspathic sandstone, and then hard pink to white quartzite with minor thin shale laminations.

The Slapes Gully Member is a feldspathic silty sandstone with shaly interbeds and thin quartzite bands. It is commonly schistose and calcareous.

The uppermost Greenhill Member, which is a relatively clean, well-sorted quartzite and sandstone sequence.

5.1.5 SADDLEWORTH FORMATION

This unit is a relatively thick, fine-grained sequence that occurs as outcrop in Dry Creek and prominently within the HFZ between Black Hill and Glen Osmond (Fig. 3). Within and near the study area, the formation typically comprises dark green to grey dolomitic phyllite, slate and minor quartzite and dolomite (Preiss 1987). In the type section near Riverton, laminated shale is common.

5.1.6 BEAUMONT DOLOMITE

The Beaumont Dolomite is 110–140 m thick and consists of dark to medium grey, flaggy, laminated to medium-bedded dolomicrite with occasional black chert blebs (Preiss 1987).

5.1.7 GLEN OSMOND SLATE

This unit has some lithological similarities to the underlying Saddleworth Formation and has been mapped as outcrop within the Torrens Valley near Highbury. It characteristically occurs as laminated and fine sandy siltstone ~200 m thick at its type locality along the Mt Barker Road at Glen Osmond. Minor, very thin, fine dolomite lenses and slumped siltstone beds occur locally (Preiss 1987).

5.1.8 BELAIR SUBGROUP

This uppermost sequence of the Burra Group is known to crop out in the Torrens Valley near Highbury and immediately east of the Eden–Burnside Fault along the HFZ south of Glen Osmond (Fig. 3). The sequence comprises ~270 m of unnamed alternating laminated siltstone and fine sandstone above the 30 m thick, coarse to medium-grained highly feldspathic, cross-bedded Mitcham Quartzite (Preiss 1987).

5.1.9 STURT TILLITE

This unit occurs as part of the Umberatana Group, a major Neoproterozoic sequence that unconformably overlies the Burra Group. It consists of up to 360 m of boulder tillite with several 3–6 m thick interbeds of pale green and dark grey, carbonaceous, finely laminated shale and siltstone (Preiss 1987). It has not been definitively identified beneath the sediments of the GGE by this study but does crop out in the western Mount Lofty Ranges near the southern boundary of the study area.
5.1.10 TAPLEY HILL FORMATION

The dominant lithology of the thick (>1500 m) Tapley Hill Formation is a well-sorted, dark bluish grey, slightly calcareous or dolomitic, often pyritic siltstone, with grain size and carbonate content elevated in the upper parts of the unit (Preiss 1987). Very fine alternating pale and darker laminations are characteristic of the formation. It crops out in the HFZ to the south of the study area (below the Sturt River) and has been intersected by the Victoria Park Racecourse ASR investigation well and several other wells in the city area.

5.2 SUBCROP

Figure 3 displays the main rock types present at or near the base of over 200 drillholes and wells. Most of these intersections occur in the northern half of the study area where basement rocks are typically shallow and FRA have been historically utilised for such applications as market gardening in the River Torrens Valley upstream of Third Creek.

The dominant rock type recorded in the upper basement is slate with lesser occurrences of siltstone, shale, sandstone, quartzite and dolomite. Many of the slate intersections are based on field inspections of drill cuttings by drilling contractors — it is possible that a significant number of these intersections are actually fine-grained siltstone and shale.

Regardless of the slate definition, it is clear that the study area is underlain predominantly by fine-grained clastic sequences of the Burra Group, consistent with the outcropping basement sequences to the north and east of the study area. Slate and siltstone of the Tapley Hill Formation (Umberatana group) have been identified in several wells near the city of Adelaide, such as recent wells Adelaide University No.1 and N117b Botanic Gardens.

5.3 FAULTS

Post-orogenic faulting provided a strong control to initial development of the GGE. The Eden–Burnside Fault (Fig. 3) represents the eastern limit of Tertiary sedimentation, whilst the Para Fault is an Adelaidean fault that was reactivated in the Tertiary, causing post-depositional displacement of Tertiary sediments and which forms the boundary between the GGE and the Adelaide Plains Sub-basin.

The major fault zones are complex, probably occurring as a series of close-spaced faults, and individual locations are not always well known, especially when they occur beneath sedimentary cover. Some of this complexity and uncertainty is displayed in Figure 3, which plots the major fault traces of Gerges (1999), Forbes (1980), and from the current DWLBC GIS dataset.

Given the inherently low permeability of the fine-grained bedrock beneath the GGE, fault zones are known to form significant structurally controlled aquifer zones within the Adelaidean basement. Their location and nature is therefore considered to be of great significance to the establishment of potential FRA ASR sites within the study area.

Major fault positions have been previously mapped by a combination of field mapping, aerial photography interpretation and drilling. Locally, land-based gravity surveys have been used, such as Hough (1986), who located a portion of the Eden–Burnside Fault zone in the Clapham–Panorama area, which occurs near the southern edge of the study area. Other geophysical surveys, such as more expansive land gravity surveys (Woods 1987) and the
state-wide airborne gravity and magnetics datasets held by PIRSA, are not considered to be of sufficient resolution to delineate individual faults.

Smaller scale faults than those shown in Figure 3, that may suitable for development of small ASR projects (<10 ML), are likely to be present throughout the study area. Locating and mapping of such faults would rely on close-spaced drilling.

### 5.4 BASE OF SEDIMENTS

The most comprehensive work completed to date that defines the base of Quaternary and Tertiary sediments (or top of bedrock) in the GGE is that of Gerges (1999). This dataset and contouring was updated using drillholes and wells installed since the mid-1990s as well as a few older sites from microfiche records.

About 240 drillholes and wells were used to hand-contour the approximate base of sediments surface (mAHD) shown in Figure 4a. Confidence levels were assigned to each record based on the certainty and accuracy of the flagged sediment–bedrock boundary; low-confidence ratings were assigned to such situations where fine-grained sediments were considered to overly strongly weathered sedimentary rocks or where only inconclusive drilling logs were available. High-confidence flags were assigned to drillholes and wells where there were sharp contrasts between the sediment and bedrock mineralogies, or if detailed lithological logs by geologists were available. Many, but not all, of the low-confidence records were used for contouring, especially in areas where there was little or no other data.

Given the complexity of the major Eden–Burnside Fault zone and some uncertainties regarding exact fault locations, a singular fault trace considered to represent the westernmost position of the fault complex was chosen to simplify the contouring. The inferred position of this contouring constraint is shown as a dashed green line in Figure 4a. Conceptually, bedrock to the west of this line represents the down-thrown block of Adelaidean strata whilst, to the east of the line, bedrock occurs close to the ground surface, blanketed by relatively shallow alluvial and colluvial sediments.

The base of sediment contours are not considered highly accurate due to a lack of data in the southern and western parts of the study area, and because the Tertiary and Quaternary sediments were deposited unconformably over an undulating palaeotopography. They do, however, display the same southwesterly trending palaeosurface mapped by Gerges (1999).

The hand-drawn (mAHD) contours were re-gridded using Surfer and then subtracted from a Surfer grid of the current-day ground surface to generate a plot of the depth to weathered bedrock (Fig. 4b). These contours are shown over the top of several other datasets that have relevance to the thickness of sedimentary cover over bedrock:
- the state-wide airborne gravity dataset held by PIRSA
- inferred fault positions from the land-based gravity survey of Woods (1987)
- the approximate trace of the Golden Grove palaeochannel within the study area as mapped by Rowett (1997).

Key features of the depth of sediment contours (Fig. 4b) include:
- shallow depths to weathered bedrock within the Adelaide HFZ, along Dry Creek and along the upper reaches of the TRV
relatively thick sequence of sedimentary cover south of the River Torrens and Fifth Creek that dips and thickens to the southeast towards the bounding Eden–Burnside Fault zone

a southwest-trending palaeochannel beneath the Hope Valley Reservoir that shows a reasonable correlation between the contoured point data, the inferred fault position of Woods (1987) and the palaeochannel mapped by Rowett (1997)

relatively shallow sedimentary cover in the northwestern parts of the study area.

The state-wide gravity dataset shows a subtle southwest-trending lineation along the TRV that extends from near the Hope Valley Reservoir down to the Adelaide Central Business District. Discussions with PIRSA geologists indicate that the reason(s) for the subtle lineation is unclear, but may reflect some form of structural control within the Adelaidean basement.

5.5 **TOP OF FRESH BEDROCK**

A similar process was followed for contouring the top of fresh bedrock; hand-drawn contours were developed using ~210 drillholes and wells, each assigned a confidence level, with some low-confidence records ignored during the contouring process. Figure 5a shows the top of fresh bedrock surface as an absolute datum (mAHD) whilst Figure 5b shows the surface as depth below ground that was calculated using Surfer software.

The top of fresh bedrock contours are not considered highly accurate due to:
- a lack of data in the southern and western parts of the study area
- the typically variable shape of the true base of weathering profile in structurally controlled sedimentary rock environments
- identification of the base of weathering in individual drillholes or exposures can be highly subjective, based on the visual assessment of a subtle boundary between slightly weathered and fresh rock.

Similar trends are noted for the top of fresh bedrock as for the base of sediments plots; the contoured surface is reasonably consistent with earlier contours of Gerges (1999).

An isopach map for the weathered rock interval (Fig. 6) was calculated by using Surfer to subtract the re-gridded base of sediment contours from the top of fresh bedrock contours. The weathered rock contours are considered less accurate than the two individual surfaces used to create it, as the accuracy errors are cumulative. The weathered rock isopachs are only considered representative of regional trends or accurate within localised areas where there are numerous close-spaced drillholes and wells.

Consideration of the weathered rock isopach map highlights some trends and observations consistent with what one would expect from the other contour maps and the general conceptualisation of the sediment–bedrock environment. These include:
- thin weathered rock intervals (typically <10 m) in the Adelaide HFZ, along the upper sections of the TRV and along Dry Creek, where bedrock crops out or is overlain by a relatively thin veneer of sediments
- relatively thin, weathered rock intervals (typically 5–20 m) in the area between the Hope Valley and Eden–Burnside Fault zones
BASEMENT GEOLOGY

- some elongation and thickening of the weathered rock interval in the Hope Valley Reservoir area, possibly as a result of enhanced weathering beneath a Tertiary palaeochannel
- large variations in weathered rock thickness (5–60 m) in the general vicinity of the River Torrens between Third and Fifth Creeks.
6. HYDROGEOLOGY

6.1 FRACTURED ROCK AQUIFER TYPES

In general terms, FRA can be subdivided into three types that reflect the process(es) responsible for development of enhanced aquifer storage and transmissivity.

6.1.1 TYPE 1 — BASE OF WEATHERING

In areas where significant weathering of bedrock has occurred, a considerable enhancement of aquifer properties can occur, particularly in the lower sections of the weathering profile. The upper portions of a highly weathered alumino-silicate rock profile may be dominated by clay minerals, which tends to development of aquitard zones. However, the lower zones that display only slight or moderate weathering often contain less clay minerals and have enhanced permeability as a result of weathering through primary porosity or along secondary features such as joint sets and other fracture sets. The lithology and texture of the bedrock is important to the development of significant permeability. The fine-grained base of Quaternary and Tertiary sediments, such as the shale, siltstone and slate present beneath much of the GGE, has limited primary permeability and would rely on extensively jointed and fractured zones within the weathering profile or weathering enhanced permeability for such to develop. Coarser grained rocks with higher silica contents, such as granite, quartz sandstone and calcarenite, can develop significantly enhanced permeability and porosity by weathering processes.

Base of weathering aquifer zones tend to be subhorizontal and have lateral extents that greatly exceed their vertical extent. Such zones typically exhibit low to moderate storativity and transmissivity. Given the high proportion of fine-grained alumino-silicate rocks beneath the study area and the degree of weathering observed, the base of weathering aquifer zones are considered overall to have relatively poor storativity and transmissivity, thus limiting their potential for ASR.

6.1.2 TYPE 2 — FRACTURE ZONES

This setting applies to bedrock where relatively narrow structural features such as faults, shear zones and close-spaced joint sets form a semi-planar aquifer. The aquifer geometry is typically limited in the direction perpendicular to the controlling structure(s) and relatively extensive along strike and down-dip of the controlling structure(s), with a highly variable orientation possible.

High-permeability zones associated with fracture sets can occur within the weathering profile or at great depths within fresh bedrock. Whilst only a generalisation, many FRA become less permeable or transmissive with increasing depth as the vertical and horizontal stresses associated with the increasing weight of the rock ‘column’ reduces the aperture of the individual fractures. Significant fracture zone aquifers below depths of the order of 150–200 m are relatively rare.
Within the fresh bedrock profile, there is a general tendency for fracture zone aquifers to display relatively high transmissivity (a result of very high permeability along individual fractures) but low storage as there is often very limited primary porosity and only the fracture porosity itself to store water.

6.1.3 TYPE 3 — KARSTIC AQUIFERS

Karstic aquifers represent a special version of Type 1 aquifers in which dissolution of significant portions of matrix material during weathering by percolating fluids results in the creation of significant (and often large in size) secondary porosity. Typical examples are karstic features formed by dissolution of carbonate within calcarenite or massive limestone, or the development of vuggy silcrete during extreme weathering of ultramafic igneous rocks.

Karstic aquifers can have very high transmissivities and storage, but often have limited extent and irregular distribution.

The three aquifer types outlined above do not always occur in isolation; two or more aquifer types are often well developed together. A common example of this is where near-vertical structures form preferential flow paths for weathering fluids, often resulting in deeper weathering and enhanced aquifer properties above the limit of weathering.

Within the study area, review of the individual drillhole and water well records and the overall regional geological setting indicates that FRA occurrences are dominated by the Type 2 (structural) aquifers with lesser occurrences of Type 1 and no obvious evidence of Type 3 aquifers.

6.2 GROUNDWATER LEVELS

There are relatively few FRA wells currently monitored with the study area as part of the DWLBC Obswell network, which prevents an accurate current-day potentiometric surface from being compiled. Instead, an approximation of the potentiometric surface has been created using current, recent and historic data (Fig. 7a). Consistent with earlier surfaces calculated by Gerges (1999) and with overlying aquifers, the regional groundwater flow direction is southwesterly to westerly. Current-day abstraction from the FRA is considered relatively minor, such that the contours drawn should be a reasonable representation of the natural groundwater flow regime.

Groundwater levels would be dominated by ground surface levels and drainage lines where the FRA is unconfined or semi-confined along the HFZ and northern parts of the study area. Elsewhere, under confined conditions, groundwater levels would be partly controlled by the orientation and extent of major structures and the connections these features have with overlying and adjoining (laterally) sedimentary aquifers.

The FRA potentiometric surface as depth below ground contours has been generated with Surfer 8 by subtracting the groundwater surface grid from a ground surface grid (previously developed by Hodgkin (2004) using the DWLBC 5 m contour GIS dataset). These contours (Fig. 7b) show that:

- Relatively shallow groundwater levels occur along elevated parts of the HFZ where the FRA is conceptually unconfined.
HYDROGEOLOGY

- The deepest groundwater levels occur between the Hope Valley and Eden–Burnside Faults where the ground surface gradually rises from the Adelaide Plains up to the HFZ.
- Relatively deep groundwater levels occur in the topographically high northwestern and northeastern parts of the study area.
- Shallower groundwater levels occur along the TRV and Dry Creek, which forms the northern boundary of the study area.
- Artesian groundwater levels have been observed in parts of the TRV and in parts of the HFZ, such as those observed recently in the ASR investigation well at the North Parklands site and at the University of Adelaide.
- An apparent discord between groundwater levels near the inferred western limit of the Eden–Burnside Fault system. Some of these differences may be artificial as groundwater levels were contoured as separate areas to the east and west of the Eden–Burnside Fault. To the west of the inferred fault line shown in Figure 7, groundwater levels represent the potentiometric surface of a confined aquifer system, while to the east, the groundwater contours conceptually represent water-table levels of an unconfined aquifer system.

The depth to groundwater is an important variable to ASR projects as shallow groundwater levels may limit the ultimate level of storage possible and also trigger the need to inject water under pressure at the well head instead of drainage by gravity. These and other hydrogeological criteria important to ASR development are discussed further in Section 7.

**6.3 GROUNDWATER SALINITY**

As with groundwater levels, there is a general lack of current DWLBC Obswells that monitor basic water-quality parameters such as Electrical Conductivity (EC), salinity (mg/L TDS) and pH. Within the study area there are eight Obswells monitored infrequently (ADE 126, 168, 170, 184, and YAT 77, 106, 109, 110).

A recent monitoring program by the Torrens and Patawalonga Catchment Water Management Boards has undertaken detailed water-quality analyses from an additional 12 FRA wells within the study area. Salinity results from this program, and past results for other wells, have been used to generate the salinity contours displayed in Figure 8. The results are colour coded according to the confidence levels assigned to the salinity results. Recent salinity values from wells definitely screened and isolated within fractured rock intervals were assigned the highest confidence levels, while those drillholes or wells with old records, anomalous levels or with doubtful aquifer intervals were assigned the lowest confidence.

The contours were hand drawn and are both approximate and interpretive, although they are consistent with earlier work by Gerges (1999). Figure 8 shows that the freshest groundwater occurs in the eastern and northern parts of the study area, consistent with the conceptualisation of significant recharge of the FRA by rainfall and runoff from the western Mount Lofty Ranges. Salinity increases to >5000 mg/L TDS in the western and southwestern parts of the study area, partly as a result of reduced aquifer transmissivities.

**6.4 GROUNDWATER YIELDS**

About 220 drillholes and wells within and immediately adjacent to the study area were assigned yields after detailed review of the SA_Geodata database and microfiche records.
These yields (L/s) are plotted in Figure 9, with colour coding according to confidence levels. Highest confidence levels were assigned to those wells or drillholes with pumping values definitely recorded from fractured rock intervals, while lowest confidence levels were assigned to airlift yield data from uncertain aquifer intervals.

Yields were not contoured for several reasons:
- the lack of data over large portions of the study area
- limited accuracy and consistency of data, as many estimates may have been derived by visual estimation of airlift flows whereas some values are based on pumping rates from aquifer tests.
- the spatial distribution of yields would have a strong structural control with relatively discrete and limited continuity.

Wells with yields >4 L/s are highlighted in Figure 8. These were reviewed in detail to identify a preferred subset of wells that may potentially be aquifer-tested (see Section 7.3.1).
7. FRA ASR POTENTIAL

This section presents a broad discussion of the key issues likely to affect the development and sustainability of FRA ASR projects within the study area from a hydrogeological perspective (Section 7.1). Hydrogeological criteria are then applied to subdivide the study area into zones of differing ASR potential (Section 7.2). Within the hydrogeologically most favourable areas, potential FRA ASR sites for further investigation have been identified based on a qualitative assessment of existing high-yield wells, proximity of source water, open land availability and potential water demand (Section 7.3).

7.1 FRA ASR SUSTAINABILITY AND SUITABILITY WITHIN THE STUDY AREA

Licensing and permitting issues associated with ASR establishment and operation are not discussed here, but are presented by Hodgkin (2004). Rather, issues that would influence the development and sustainability of FRA ASR operations in the study area from a hydrogeological perspective are presented below.

7.1.1 IMPACTS ON EXISTING GROUNDWATER USERS

Whilst the study area is not part of a Prescribed Well Area (PWA), which has Water Allocation Plans (WAPs) that provide documented guidelines and policies for abstraction and injection of groundwater, DWLBC would give consideration to the potential impacts of a proposed ASR project before issuing well and drainage permits.

The location of current groundwater users within the study area is not well known; the last detailed census was conducted in the mid-1980s (Edwards, Earl & Mathews 1987). The results of this census are summarily shown in Figure 10 and in detail as Appendix A. Both the T1 sedimentary aquifer and the FRA are shown, as the two aquifers may be in direct hydraulic connection (and hence injection into the FRA may impact upon the T1 aquifer) and because a T1 aquifer user may potentially be a future FRA ASR proponent.

The potential impacts of any FRA ASR in the study area on surrounding groundwater users could be highly variable if the aquifer displays a strong structural control with relatively high transmissivity and limited storage. If another FRA groundwater user is relatively close (say even tens of metres) to the proposed new ASR site, but is actually located on a separate structure system, then there may be little or no impacts. However, if another groundwater user exists on the same structure for which the new ASR is proposed, then groundwater level changes impacts may be noticed at considerable distance from the ASR well (many hundreds of metres). Such cyclic groundwater level rises may not be adverse unless artesian groundwater levels are induced in a confined aquifer setting, which is probably only possible in wells located very close to the ASR project (tens of metres).

Exclusion zones of 500 m radius have been nominated in Figure 10 around existing FRA ASR operation wells. These zones would provide a buffer against possibly adverse interference of groundwater levels between two nearby ASR projects. The actual shape and size of any such buffer zone in FRAs could only be realistically defined by field investigations.
7.1.2 INCREASED WATER-TABLE LEVELS

As outlined by Hodgkin (2004) and earlier workers, ASR injection into unconfined aquifers with shallow water tables presents a risk of potential adverse impacts that include:

- water logging and salinisation of the shallow subsurface profile
- unwanted discharge of water at the ground surface
- damage to built infrastructure due to water-table rise affecting foundations and footings.

Unconfined, or semi-confined conditions for the FRA within the study area occur in several areas, notably along the HFZ, the upper reaches of the TRV, and northern parts of the study area where the overlying sediments are unsaturated, thin or absent. These areas are not automatically unsuitable for FRA ASR as it depends on the depth of the actual aquifer interval and the degree of confinement. Shallow aquifer intervals in these parts of the study area should be evaluated with a strong degree of caution to establish the nature of the aquifer and the true potential for adverse impacts from any significant rises induced upon a shallow water table. Deeper aquifer intervals in these parts of the study area will probably not be of a concern as they may be isolated from the shallow water table aquifer and be of a strongly confined nature.

7.1.3 SIZE OF FRA ASR PROJECTS

The potential size of individual FRA ASR projects in the study area may be relatively limited compared to other ASR projects in sedimentary aquifers within the Adelaide region. The four existing FRA ASR projects in the study area inject between 15 and 110 ML/y, typically of the order of 40–60 ML/y, compared to the typical injection volumes of 600–750 ML/y associated with some of the larger T1 and T2 ASR projects at Morphettville Racecourse and Edinburgh Park.

New FRA ASR projects within the study area are expected to be of a similar order of magnitude to the current FRA ASR operations, certainly not much larger. This expectation is based on the conceptualisation of most FRAs being of the fracture-zone subtype with relatively high transmissivity and low storativity. Such sites may permit relatively high injection rates but the effective injection volume may be limited by the low storage potential, causing large groundwater level rises within short timeframes. The combination of high transmissivity and low storativity may also enable significant migration of the injected freshwater plume during the dormant phase between injection and recovery, which would adversely impact the recovery efficiency of the project, especially if the required end-use water quality is high and the site has relatively high native salinities.

7.1.4 WELL COMPLETION

Open-hole well completions in the aquifer interval are expected to be possible in virtually all potential FRA ASR projects in the study area as a result of the consolidated and competent nature of the bedrock types. Such well completions are preferred in general terms for ASR as it maximises the well efficiency, removes the potential for clogging of slotted casing or wire-wound screens, and reduces the potential time required for back-pumping or redevelopment of the injection well.
FRAs in the study area may also be suitable for enhancement of injection well efficiency by hydro-fracturing or acidification (if the bedrock has any significant carbonate content associated with the fracture zones). Such enhancements may reduce the amount of pre-treatment of source water needed, in turn potentially saving costs or land area.

7.1.5 NATIVE GROUNDWATER SALINITY

Much of the study area is suitable for ASR projects with low TDS requirements, as the native groundwater salinities are fresh or brackish. About 61% of the area is <3000 mg/L TDS, while only ~22% of the area is >5000 mg/L TDS. Much of the potentially unsuitable +5000 mg/L TDS groundwater occurs in an area of relatively thick sedimentary cover, which is itself a potential ASR negative.

Sub-3000 mg/L TDS is considered an important level (Hodgkin 2004), as it represents the approximate limit at which recovered water remains below 1000 mg/L TDS assuming that:

- injected water is required within the same irrigation season, with no significant build up of a freshwater plume to act as a buffer zone in subsequent recovery periods
- injected water salinity of ~300 mg/L TDS
- recovery efficiency of 75%
- the end uses for recovered water require potable TDS levels, such as turf irrigation or horticulture.

7.1.6 DEPTH TO AQUIFER

The depth of sedimentary cover above bedrock is only significantly high in the southern parts of the study area to the west of the Eden–Burnside Fault system, where it increases in a southeasterly direction to up to ~280 m near Torrens Park and Clapham (Fig. 4b).

Areas where the depth to bedrock exceeds ~150–200 m are considered to have reduced potential for FRA ASR in terms of aquifer transmissivity, storativity and salinity. In addition, deep wells may reduce the ASR potential as result of the increased cost of drilling and constructing injection and monitoring wells.

7.1.7 DEPTH TO GROUNDWATER

As outlined in Section 6.2, the depth to groundwater is quite variable throughout the study area, which would influence the effective injection volumes and choice of injection method (gravity or pressure injection).

In areas where the depth to the water table (unconfined aquifer) or potentiometric surface (confined aquifer) is high, the project may attain the required injection volume by gravity drainage of source water into the well alone (with the option of pressure injection also still available). Where groundwater levels are very shallow, the only option for attaining sufficient injection volumes will be by pressure injection.
7.1.8 STRUCTURAL GEOLOGY

The greatest potential for establishing FRA ASR projects in the study area is within the Fracture Zone aquifer types, predominantly below the limit of weathering. However, the accurate delineation of all such bedrock structures beneath sedimentary cover is not possible with the datasets available. That said, the major Eden–Burnside and Hope Valley Fault systems represent high-priority areas for further investigations, as does the potential structural corridor associated with the present-day TRV and the Tertiary Golden Grove palaeochannel.

The favourable structural corridors shown in Figure 10 are acknowledged as gross simplifications of what is expected to be a complex structural geological setting that would be influenced by the competency contrast between interbedded sedimentary rocks and pre-Tertiary folding and faulting associated with the Delamerian Orogeny. The complex distribution of rock types and fault structures within the western Mount Lofty Ranges is shown in Figure 3. A similar level of complex distribution is expected beneath sedimentary cover of the GGE.

7.1.9 INVESTIGATION TECHNIQUES

The identification of unmapped structures beneath sedimentary cover within the study area represents a costly challenge. The commitment to drill and construct water wells at sites where there is little or no supporting information is relatively high risk and high cost. However this approach may be preferred if the ASR proponent has a relatively limited land holding or search area available. If a large search area is involved, or if multiple potential ASR sites are to be investigated, then broader scale subsurface mapping should be considered prior to committing to installation of water wells.

Geophysical survey techniques may be useful in estimating the location and depth of buried geological structures. Advice should be sought from PIRSA staff to establish if any high-resolution land-based gravity or magnetic surveys may be useful. Another potential geophysical application is Controlled Source Audio-Frequency Magnetotellurics (CSAMT), which DWLBC is about to trial in a buried FRA water supply project at Nepabunna in the Northern Aboriginal Lands of South Australia in partnership with Zonge Engineering on behalf of SA Water. This technique has found application in the delineation of geological structures at depths ranging from 20–2000 m, largely for the mineral exploration industry. The technique uses large transmitter and receiver arrays which, along with the presence of significant electromagnetic sources in the urban environment, may not prevent or limit its application in the study area. However, it is recommended that the AMLR NRM Board keep in contact with DWLBC regarding the results of the Nepabunna project.

Reconnaissance drilling, either in conjunction with the results of geophysical surveys or as a stand-alone option before installation of water wells, should also be considered. The cheapest form of reconnaissance drilling is narrow-diameter (75–100 mm) air core or rotary-air-blast (RAB) holes. However, this drilling is generally confined to small drilling rigs that may not be able to drill much below 100 m, and have limited ability to penetrate significant hard bedrock intervals. RAB drilling by hammer is preferable for aquifer yield measurements and bedrock penetration but may not be feasible in areas where sedimentary cover is thick and/or unconsolidated. Such areas occur in large parts of the study area, in which the conventional drilling approach often involves use of a water well rig to drill and case the
sedimentary cover using mud-rotary drilling, and then undertake RAB drilling below the casing, usually at a minimum of 150 mm hole diameter. This is relatively expensive and is basically the full cost of a water well. A compromised reconnaissance drilling method may be use of conventional mineral industry reverse circulation (RC) rigs, which would use rotary air drilling by hammer to produce representative drill cuttings from hole diameters of ~100–125 mm to depths beyond 200 m if required. Aquifer yields during drilling by this method are suppressed and often misleading; the identification of FRA intervals requires close consideration of the drill cuttings, drilling penetration rates and other drilling indicators.

7.2 FRA ASR ZONES

The study area has been subdivided into eight categories or zones of FRA ASR potential based on key hydrogeological criteria as outlined in Table 2. The spatial distribution of the ASR zones is shown in Figure 10.

Table 2. FRA ASR Zones

<table>
<thead>
<tr>
<th>ASR potential</th>
<th>Zone number</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher</td>
<td>1</td>
<td>Native groundwater salinity &lt;3000 mg/L TDS and area within 500 m of major structure zone(s)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Native groundwater salinity &lt;3000 mg/L TDS and area beyond 500 m of major structure zone(s)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Native groundwater salinity 3000–5000 mg/L TDS and area within 500 m of major structure zone(s)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Native groundwater salinity 3000–5000 mg/L TDS and area beyond 500 m of major structure zone(s)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>&lt;10 m of sedimentary cover and groundwater level &lt;10 m below ground</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>&lt;10 m of sedimentary cover and ground surface slope steeper than 1:10</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Sedimentary cover &gt;150 m</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Native groundwater salinity &gt;5000 mg/L TDS</td>
</tr>
</tbody>
</table>

The ASR zones are relatively self-explanatory but require the following points of clarification if the spatial patterns are to be used further in future FRA ASR on-ground investigations:

- Not all possible combinations of the different hydrogeological criteria are used in defining the eight categories. For example, within the +5000 mg/L TDS area, there would be parts considered less suitable than others, i.e. those sub-areas where sedimentary cover is <150 m and within 500 m of a structure corridor would be preferable to those remaining areas where depths to sediment is >150 m and distance to a structure corridor >500 m where the potential for adverse impacts from ASR development in shallow FRAs are greater.

- Native groundwater salinity would not be as significant a variable to ASR projects that do not have low TDS end-use requirements.

- Structure corridors — an arbitrary 500 m buffer from a known or inferred fault zone trace has been used to define favourable target areas, which would have a variable accuracy. An example of this is the southern parts of the Eden–Burnside Fault system, where the ‘displacement’ of bedrock to the west of the true fault is significant. Thus, drilling in part of a favourable Type 1 zone may not intersect bedrock at the interpreted FRA depth. Selection of any future drilling targets should also consider the individual well and structural datasets shown in Figures 3–9.
The Type 5 and 6 zones do not reflect areas that should be avoided from further consideration. Rather, they are intended to highlight areas where the potential for adverse impacts from ASR development in shallow FRAs are greater. However, these areas may also host deep confined aquifer intervals that may prove to be suitable ASR sites without risk of detrimental near-surface effects such as waterlogging and discharge, soil salinisation and damage to infrastructure.

The boundaries of each zone are strongly influenced by the accuracy of the contouring of the individual datasets. As highlighted earlier, each contoured surface is only approximate so the zone boundaries shown in Figure 10 cannot be regarded as highly accurate.

### 7.3 SITES AND EXISTING WELLS RECOMMENDED FOR FURTHER INVESTIGATION

#### 7.3.1 EXISTING WATER WELLS

Initially, all sites with yields >4 L/s were extracted from the dataset displayed in Figure 9. This produced 50 records within the study area, which were refined by eliminating sites that:

- occurred outside of Type 1 or 2 ASR zones
- have casing diameters <100 mm
- appear in SA_Geodata as abandoned or backfilled
- occur within 500 m of existing FRA ASR injection wells
- appear to be private or domestic wells based on visual examination of the recorded well position well against GIS coverages of aerial photography and land ownership.

As a result of applying the above criteria, 12 wells have been short-listed for possible aquifer testing; these are displayed in Figure 10. Summary details are presented in Table 3, and full details, including land ownership as indicated from a 2005 GIS coverage provided by the AMLR NRM Board, are included as Appendix B.

Well number 662812311, although listed with a yield of only 3 L/s, has been included, as it has other favourable ASR potential criteria. This well is part of the Cadbury Schweppes operations in Payneham, and occurs in a favourable ASR Zone (Type 2) very close to Third Creek. In the 1982–84 period, the average annual abstraction was ~160 000 kL, which suggests that the well may be capable of a yield higher than 3 L/s.

Well 662809072 was listed as a T1 well by Edwards, Earl and Mathews (1987). The original drilling log from 1972 could not be found; however, the well was deepened in 1994 from 64–73 m and intersected slate in this interval with an airlift yield at 73 m of 6 L/s. Cased below 21 m, the well is expected to be fully producing from the FRA.

The selection of any of these wells for aquifer testing should consider the ASR sites recommended in Section 7.3.2, as seven of the existing wells are within several hundred metres of sites considered suitable from the perspective of proximity to source water, land availability and potential water demand.

The SA_Geodata database indicates that none of these wells have previously been aquifer tested.
Table 3. Existing FRA Wells Recommended for Possible Aquifer Testing

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>Land owner</th>
<th>Date drilled</th>
<th>Production interval (mbgl)</th>
<th>Minimum casing diameter (mm)</th>
<th>Yield (L/s)</th>
<th>Approximate groundwater level (mbgl)</th>
<th>Salinity (mg/L TDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>662809702</td>
<td>Corp. of the City of Campbelltown</td>
<td>12/14/72</td>
<td>21.3–73</td>
<td>127</td>
<td>8.8</td>
<td>12</td>
<td>1384</td>
</tr>
<tr>
<td>662810005</td>
<td>Christian Brothers Inc.</td>
<td>10/23/76</td>
<td>75.2–111</td>
<td>150</td>
<td>5.0</td>
<td>20</td>
<td>1468</td>
</tr>
<tr>
<td>662810007</td>
<td>Minister for Human Services</td>
<td>2/24/70</td>
<td>36.3–64</td>
<td>152</td>
<td>10.1</td>
<td>15</td>
<td>835</td>
</tr>
<tr>
<td>662812058</td>
<td>St Peters Collegiate Girls School</td>
<td>10/27/82</td>
<td>276.9–287</td>
<td>152</td>
<td>9.0</td>
<td>105</td>
<td>973</td>
</tr>
<tr>
<td>662812311</td>
<td>Cadbury Schweppes Pty Ltd</td>
<td>6/17/83</td>
<td>103–152</td>
<td>150</td>
<td>3.0</td>
<td>17</td>
<td>792</td>
</tr>
<tr>
<td>662813651</td>
<td>P &amp; HJ Martino</td>
<td>4/30/86</td>
<td>54.8–98?</td>
<td>152</td>
<td>8.8</td>
<td>16</td>
<td>2409</td>
</tr>
<tr>
<td>662813652</td>
<td>SA Water Corp.</td>
<td>5/2/86</td>
<td>25.7–154</td>
<td>203</td>
<td>4.0</td>
<td>0</td>
<td>2278</td>
</tr>
<tr>
<td>662815256</td>
<td>CSR Ltd</td>
<td>11/16/90</td>
<td>39.1–146</td>
<td>155</td>
<td>10.0</td>
<td>31</td>
<td>3609</td>
</tr>
<tr>
<td>662815439</td>
<td>Corp. of the Town of Walkerville</td>
<td>11/15/90</td>
<td>60–90</td>
<td>203</td>
<td>25.0</td>
<td>11</td>
<td>860</td>
</tr>
<tr>
<td>662821610</td>
<td>Manresa Soc Inc.</td>
<td>1/28/04</td>
<td>52–140</td>
<td>158</td>
<td>12.5</td>
<td>38</td>
<td>2631</td>
</tr>
<tr>
<td>662822151</td>
<td>Corp. of the City of Adelaide</td>
<td>3/10/05</td>
<td>174–192</td>
<td>155</td>
<td>8.0</td>
<td>18</td>
<td>3110</td>
</tr>
<tr>
<td>662822152</td>
<td>Governors of the Botanic Garden</td>
<td>3/8/05</td>
<td>115–186</td>
<td>100</td>
<td>9.0</td>
<td>3</td>
<td>2700</td>
</tr>
</tbody>
</table>

Note: mbgl = metres below ground level

mm = millimetres

well unit numbers in italics correspond to known groundwater uses from the 1982–84 census.

7.3.2 POTENTIAL FRA ASR SITES

A qualitative assessment of all landholdings within Type 1 ASR zones was undertaken to generate a listing of sites where the potential for development of FRA ASR operations is considered relatively high.

Only Type 1 zones were assessed to maximise the hydrogeological suitability of derived targets. The landholdings or sites selected were all those considered to have the combined criteria of:

- proximity to a water source, as defined by a natural or modified water course or a stormwater pipe >0.5 m in diameter
- an open-land area of at least ~1 ha
- a potential irrigation water demand based mainly on the nearby presence of sports grounds and public reserves.

Twenty-eight sites were defined and are shown in Figure 10. Summary details are presented in Table 4 and additional details in Appendix C. The 28 sites are considered as a first-pass screening and not a rigid listing of all potential FRA ASR projects within the study area. Much of the development of future FRA ASR projects is expected be driven by the physical locations of the individual proponents, that may well be outside of the Type 1 ASR zones.
### Table 4. Potential FRA ASR sites

<table>
<thead>
<tr>
<th>Site number</th>
<th>Site name</th>
<th>Water source</th>
<th>Land owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mitcham Reserve</td>
<td>Stream</td>
<td>Unknown</td>
</tr>
<tr>
<td>2</td>
<td>Urrbrae Agricultural High School</td>
<td>Pipe</td>
<td>Minister for Education and Childrens Services</td>
</tr>
<tr>
<td>3</td>
<td>Waite Arboretum</td>
<td>Pipe</td>
<td>Distribution Lessor Corp.</td>
</tr>
<tr>
<td>4</td>
<td>Ridge Park Reserve</td>
<td>Stream or pipe</td>
<td>Corp. of the City of Unley</td>
</tr>
<tr>
<td>5</td>
<td>Langman Reserve</td>
<td>Stream</td>
<td>City of Burnside</td>
</tr>
<tr>
<td>6</td>
<td>Hazelwood Park</td>
<td>Stream</td>
<td>City of Burnside</td>
</tr>
<tr>
<td>7</td>
<td>Ferguson Park</td>
<td>Stream</td>
<td>Minister for Environment and Conservation</td>
</tr>
<tr>
<td>8</td>
<td>Penfolds Winery</td>
<td>Pipe</td>
<td>Southcorp Wines Pty Ltd</td>
</tr>
<tr>
<td>9</td>
<td>UniSA Magill Campus</td>
<td>Stream or pipe</td>
<td>Distribution Lessor Corp.</td>
</tr>
<tr>
<td>10</td>
<td>Gums Recreation Ground</td>
<td>Stream</td>
<td>Corp. of the City of Campelltown</td>
</tr>
<tr>
<td>11</td>
<td>Kensington Oval</td>
<td>Pipe</td>
<td>City of Burnside</td>
</tr>
<tr>
<td>12</td>
<td>Rostrevor College</td>
<td>Stream</td>
<td>Christian Brothers Inc.</td>
</tr>
<tr>
<td>13</td>
<td>Leabrook Drive Reserve</td>
<td>Stream</td>
<td>Corp. of the City of Campelltown</td>
</tr>
<tr>
<td>14</td>
<td>Market Garden</td>
<td>Pipe</td>
<td>Borriolo</td>
</tr>
<tr>
<td>15</td>
<td>Wadmore Park</td>
<td>Stream</td>
<td>Corp. of the City of Campelltown</td>
</tr>
<tr>
<td>16</td>
<td>River Torrens # 1</td>
<td>Stream</td>
<td>Minister for Transport and Urban Planning</td>
</tr>
<tr>
<td>17</td>
<td>CSR Quarry</td>
<td>Stream</td>
<td>CSR Ltd</td>
</tr>
<tr>
<td>18</td>
<td>Thorndon Park Reserve</td>
<td>Reservoir or pipe</td>
<td>Corp. of the City of Campelltown</td>
</tr>
<tr>
<td>19</td>
<td>River Torrens # 2</td>
<td>Stream</td>
<td>Unknown</td>
</tr>
<tr>
<td>20</td>
<td>River Torrens # 3</td>
<td>Stream</td>
<td>Corp. of the City of Campelltown</td>
</tr>
<tr>
<td>21</td>
<td>Botanic Gardens</td>
<td>Stream</td>
<td>Governors of the Botanic Garden</td>
</tr>
<tr>
<td>22</td>
<td>St Peters River Park</td>
<td>Stream</td>
<td>Corp. of the City of Norwood Payneham and St Peters</td>
</tr>
<tr>
<td>23</td>
<td>River Torrens # 4</td>
<td>Stream</td>
<td>Minister for Infrastructure</td>
</tr>
<tr>
<td>24</td>
<td>Felixstow Reserve</td>
<td>Stream</td>
<td>Corp. of the City of Norwood Payneham and St Peters</td>
</tr>
<tr>
<td>25</td>
<td>Lochiel Park</td>
<td>Stream</td>
<td>SA Water Corp.</td>
</tr>
<tr>
<td>26</td>
<td>Campbell Memorial Oval</td>
<td>Stream</td>
<td>Corp. of the City of Campelltown</td>
</tr>
<tr>
<td>27</td>
<td>Lyons Road Reserve</td>
<td>Stream</td>
<td>City of Tea Tree Gully</td>
</tr>
<tr>
<td>28</td>
<td>Hope Valley Reservoir</td>
<td>Reservoir</td>
<td>SA Water Corp.</td>
</tr>
</tbody>
</table>

Land ownership at most of the 28 sites appears to be held by government agencies or private business, which may be preferable for ASR development.
8. CONCLUSIONS AND RECOMMENDATIONS

Key findings and conclusions from the desktop evaluation of the FRA ASR potential of the study comprise:

1. Currently there are four ASR operations within the study area (Northgate, Regent Gardens, Torrens Valley Sportsfield and Scotch College) injecting a combined volume of 135–250 ML/y into FRA.

2. The study area is underlain and adjoined by predominantly fine-grained metasedimentary rocks of the Adelaidean Burra and Umberatana Groups, notably shale, siltstone and slate of the Saddleworth Formation, Belair Subgroup and Tapley Hill Formation.

3. The structural geology of the Adelaidean basement beneath the GGE is likely to be quite complex, no less so than the outcropping areas in the western Mount Lofty Ranges, and cannot be highly resolved by this study.

4. Review of existing drillhole and water well records indicates that the most significant FRA settings in the study area are related to structurally discrete fracture zones, often within unweathered and quartz-veined slate. Such zones are considered most likely to occur within three major south-southwest-trending structural corridors; the Eden–Burnside and Hope Valley Fault systems and a corridor aligned with both the present-day TRV and the older Golden Grove palaeochannel.

5. The main FRA targets are considered likely to display relatively high aquifer transmissivities and low storativities, which may limit the ultimate injection volumes of individual projects to typically below 100 ML/y.

6. The potential impacts of developing FRA ASR schemes are quite variable and depend strongly on the orientation and continuity of the fracture zone(s), depth of the aquifer interval and depth to groundwater. Other groundwater users, even if close by, may not be affected if they are not ‘co-located’ on the same fracture zone(s). The knowledge of current groundwater use, from FRA or sedimentary aquifers, is poor — the last significant census of groundwater use concluded in 1984.

7. Caution should be applied in target areas where the aquifer interval and groundwater levels are shallow and the land surface is steep. Such combinations may result in soil salinisation, water discharge at surface or damage to the foundations of built infrastructure.

8. Much of the basement in the study area exhibits positive hydrogeological criteria for the development of FRA ASR, namely native groundwater salinities <3000 mg/L TDS, sediment cover of <150 m and depths to groundwater >10 m.

9. Eight categories of FRA ASR potential have been defined and spatially applied to the study area. The highest potential zone (Type 1) is defined as those areas located within 500 m of known or inferred major fracture zones that have groundwater salinities <3000 mg/L TDS.

10. Within Type 1 and 2 ASR zones, a detailed review of relatively high-yielding (>4 L/s) water wells has produced a shortlist of 12 wells considered suitable for further investigation and possible aquifer testing.
11. A qualitative assessment of all landholdings within Type 1 ASR Zones has identified 28 sites considered to have significant FRA ASR potential, based on proximity to source water (from natural streams, stormwater pipes and drains), presence of at least 1 ha of open land, and a likely irrigation water demand (principally based on the presence of sports grounds and public reserves).

12. Seven of the existing wells considered suitable for ASR aquifer testing are located within several hundred metres of the 28 potential ASR sites and could be integrated into any individual site evaluation.

Recommendations for furthering the development of new FRA ASR projects in the study area are:

1. Undertake a census of current groundwater use from the sedimentary T1 aquifer and FRA to identify potential FRA ASR proponents and determine the potential for adverse impacts from specific FRA ASR projects upon existing groundwater users.

2. Integrate the findings of the above with the potential ASR sites and existing water well shortlist from this study to define and prioritise the AMLR NRM Boards future directions in promoting and supporting development of new FRA ASR operations within the study area.
DISCLAIMER
The Department of Water, Land and Biodiversity Conservation, its employees and servants do not warrant or make any representation regarding the use, or results of use of the information contained herein as to its correctness, accuracy, currency or otherwise. The Department of Water, Land and Biodiversity Conservation, its employees and servants expressly disclaim all liability or responsibility to any person using the information or advice contained herein.

M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_1.mxd. T. Hodgkin. October 2005

Study Area
- Key Localities
- Main Roads
- Rivers / Creeks
- Catchment Water Management Board Boundary
- Reservoirs
- Bedrock Outcrop
- FRA ASR Operation
- FRA ASR Investigation

ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT

Figure 1
Figure 2. Burra Group stratigraphy of the Adelaide Geosyncline, after Priess 1987
DISCLAIMER
The Department of Water, Land and Biodiversity Conservation, its employees and servants do not warrant or make any representation regarding the use, or results of use of the information contained herein as to its correctness, accuracy, currency or otherwise. The Department of Water, Land and Biodiversity Conservation, its employees and servants expressly disclaim all liability or responsibility to any person using the information or advice contained herein.
DISCLAIMER
The Department of Water, Land and Biodiversity Conservation, its employees and servants do not warrant or make any representation regarding the use, or results of use of the information contained herein as to its correctness, accuracy, currency or otherwise. The Department of Water, Land and Biodiversity Conservation, its employees and servants expressly disclaim all liability or responsibility to any person using the information or advice contained herein.

ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Base of Quaternary and Tertiary Sediments (mbgl)

Fault Traces used to Constrain Contouring
- DWLBC GIS dataset
- 1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
- Inferred fault position

Basemap is statewide gravimetric image from PIRSA

Approximate Trace of Golden Grove Tertiary Palaeodrainage (after Rowett, 1997)
Inferred fault positions from Wood’s 1987 Gravity Survey

ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Base of Quaternary and Tertiary Sediments (mbgl)
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT

Top of Fresh Bedrock (mAHD)

Reservoir
Main Roads
Rivers / Creeks
Study Area

Well / Drillhole Data
- 17900 / -45
- Top of fresh bedrock elevation (mAHD)

Fault Traces used to Constrain Contouring
- DWLBC GIS dataset
- 1:55,000 "Adelaide" Geology Map
- By Geol. Surv. SA. 1980
- Inferred fault position

Increasing Confidence in Data

Figure 5a
Figure 6

Weathered Rock Isopachs

Weathered Rock Isopachs (metres)

Fault Traces used to Constrain Contouring

Well / Drillhole Data

Approximate Trace of Golden Grove Tertiary Palaeodrainage (after Rivelin, 1997)

Inferred Fault Positions from Wood’s 1987 Gravity Survey
DISCLAIMER
The Department of Water, Land and Biodiversity Conservation, its employees and servants do not warrant or make any representation regarding the use, or results of use of the information contained herein as to its correctness, accuracy, currency or otherwise. The Department of Water, Land and Biodiversity Conservation, its employees and servants expressly disclaim all liability or responsibility to any person using the information or advice contained herein.
Figure 8

Fractured Rock Aquifer Salinity

Approximate Salinity Contours (mg/L TDS)

Fault Traces used to Constrain Contouring

Note 1: DWLBC Obsoletely currently monitored for groundwater quality are labelled (eg YAT110)

Note 2: FRA wells analysed by T & P (with GVRB) in 2003 indicated by symbol

Inferred fault position

Constrain Contouring

Fault Traces used to

Approximate Salinity Contours (mg/L TDS)

Asper Potential of Fractured Rock Aquifers in the Golden Grove Embayment

The Department of Water, Land and Biodiversity Conservation, its employees and servants expressly disclaim all liability or responsibility for any person using the information or advice contained herein.
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT

Fractured Rock Aquifer Yields

Note 1: Yields >= 4 L/sec highlighted by larger symbol and font size
Note 2: Yields = 0 L/sec indicate dry drillholes or insignificant yields
Figure 10

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


<table>
<thead>
<tr>
<th>ID</th>
<th>Well Unit Number</th>
<th>MGA Easting</th>
<th>MGA Northing</th>
<th>Aquifer</th>
<th>Well Depth (m)</th>
<th>Average Annual Abstraction (kL)</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>662809817</td>
<td>284748</td>
<td>613748</td>
<td>Fractured rock</td>
<td>73.2</td>
<td>730</td>
<td>Mr L Heading, Klemzig (agricultural)</td>
</tr>
<tr>
<td>2</td>
<td>662811721</td>
<td>289137</td>
<td>6139813</td>
<td>Fractured rock</td>
<td>31.6</td>
<td>2180</td>
<td>NV Emergy, Athelstone (agricultural)</td>
</tr>
<tr>
<td>3</td>
<td>662811989</td>
<td>290207</td>
<td>6137376</td>
<td>Fractured rock</td>
<td>114.0</td>
<td>2270</td>
<td>Black Hill Conservation Park</td>
</tr>
<tr>
<td>4</td>
<td>662810025</td>
<td>286938</td>
<td>6130422</td>
<td>Fractured rock</td>
<td>22.0</td>
<td>2270</td>
<td>RG Pank, Burnside</td>
</tr>
<tr>
<td>5</td>
<td>662811722</td>
<td>286399</td>
<td>6129971</td>
<td>Fractured rock</td>
<td>90.0</td>
<td>5455</td>
<td>Beaumont House (National Trust)</td>
</tr>
<tr>
<td>6</td>
<td>662809762</td>
<td>289104</td>
<td>6139764</td>
<td>Fractured rock</td>
<td>93.0</td>
<td>5455</td>
<td>P Mercorella, Athelstone (agricultural)</td>
</tr>
<tr>
<td>7</td>
<td>662812020</td>
<td>284259</td>
<td>6128027</td>
<td>Fractured rock</td>
<td>62.0</td>
<td>6240</td>
<td>Waite Research Unit</td>
</tr>
<tr>
<td>8</td>
<td>662809756</td>
<td>289419</td>
<td>6140114</td>
<td>Fractured rock</td>
<td>24.4</td>
<td>6545</td>
<td>Mr Fry (agricultural)</td>
</tr>
<tr>
<td>9</td>
<td>662811643</td>
<td>284828</td>
<td>6128548</td>
<td>Fractured rock</td>
<td>21.3</td>
<td>8180</td>
<td>Carmelite Cement</td>
</tr>
<tr>
<td>10</td>
<td>662812058</td>
<td>287201</td>
<td>6132297</td>
<td>Fractured rock</td>
<td>287.0</td>
<td>11 820</td>
<td>St Peters Girl School, Wattle Park</td>
</tr>
<tr>
<td>11</td>
<td>662805471</td>
<td>290588</td>
<td>6141454</td>
<td>Fractured rock</td>
<td>75.6</td>
<td>15 840</td>
<td>Highbury Primary School PBD</td>
</tr>
<tr>
<td>12</td>
<td>662809786</td>
<td>289775</td>
<td>6138101</td>
<td>Fractured rock</td>
<td>140.0</td>
<td>50 455</td>
<td>St Ignatius College</td>
</tr>
<tr>
<td>13</td>
<td>662807267</td>
<td>285705</td>
<td>6128861</td>
<td>Fractured rock</td>
<td>121.9</td>
<td>98 180</td>
<td>Mt Osmond Golf Club, total from 27 wells</td>
</tr>
<tr>
<td>14</td>
<td>662812311</td>
<td>284691</td>
<td>6136068</td>
<td>Fractured rock</td>
<td>152.0</td>
<td>159 105</td>
<td>Cadbury Schweppes Pty Ltd</td>
</tr>
<tr>
<td>15</td>
<td>662811758</td>
<td>283586</td>
<td>6130473</td>
<td>T1</td>
<td>250.0</td>
<td>301</td>
<td>Glenside Hospital</td>
</tr>
<tr>
<td>16</td>
<td>662800104</td>
<td>282475</td>
<td>6134025</td>
<td>T1</td>
<td>47.5</td>
<td>590</td>
<td>St Peters Boys College, Hackney</td>
</tr>
<tr>
<td>17</td>
<td>662807759</td>
<td>278635</td>
<td>6131316</td>
<td>T1</td>
<td>103.0</td>
<td>680</td>
<td>SA Cold Stores</td>
</tr>
<tr>
<td>18</td>
<td>662809723</td>
<td>287268</td>
<td>6138258</td>
<td>T1</td>
<td>90.8</td>
<td>7000</td>
<td>Campbelltown Primary School</td>
</tr>
<tr>
<td>19</td>
<td>662809915</td>
<td>286756</td>
<td>6136681</td>
<td>T1</td>
<td>89.9</td>
<td>10 780</td>
<td>Newton Primary School PBD</td>
</tr>
<tr>
<td>20</td>
<td>662809874</td>
<td>285869</td>
<td>6137263</td>
<td>T1</td>
<td>48.0</td>
<td>10 910</td>
<td>St Bernards Recreation Centre</td>
</tr>
<tr>
<td>21</td>
<td>662809872</td>
<td>285573</td>
<td>6137436</td>
<td>T1</td>
<td>45.7</td>
<td>13 370</td>
<td>East Marden Primary School PBD</td>
</tr>
<tr>
<td>22</td>
<td>662811160</td>
<td>285847</td>
<td>6131529</td>
<td>T1</td>
<td>133.3</td>
<td>13 640</td>
<td>Hazelwood Park Reserve</td>
</tr>
<tr>
<td>23</td>
<td>662808010</td>
<td>279832</td>
<td>6127798</td>
<td>T1</td>
<td>61.0</td>
<td>21 820</td>
<td>Cabra Convent</td>
</tr>
<tr>
<td>24</td>
<td>662809702</td>
<td>286985</td>
<td>6138766</td>
<td>T1</td>
<td>63.1</td>
<td>22 730</td>
<td>Campbelltown Oval, Daly Rd</td>
</tr>
<tr>
<td>25</td>
<td>662800555</td>
<td>280973</td>
<td>6131351</td>
<td>T1</td>
<td>29.3</td>
<td>36 000</td>
<td>Pulteney Grammar School</td>
</tr>
<tr>
<td>26</td>
<td>662809570</td>
<td>283684</td>
<td>6136448</td>
<td>T1</td>
<td>50.3</td>
<td>39 900</td>
<td>Marden High School PBD</td>
</tr>
</tbody>
</table>
B. EXISTING WELLS SUITABLE FOR FRA ASR AQUIFER TESTING

<table>
<thead>
<tr>
<th>Well Unit Number</th>
<th>Date completed</th>
<th>MGA Easting</th>
<th>MGA Northing</th>
<th>Approximate ground level</th>
<th>Obswell</th>
<th>Production interval (mbgl)</th>
<th>Minimum casing diameter (mm)</th>
<th>Assigned yield (L/s)</th>
<th>Approximate groundwater level (mbgl)</th>
<th>Salinity (mg/L TDS)</th>
<th>Depth To weathered bedrock (mbgl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>662809702</td>
<td>14/12/1972</td>
<td>286984</td>
<td>6138766</td>
<td>63</td>
<td>-</td>
<td>21.3–73</td>
<td>127</td>
<td>8.8</td>
<td>12</td>
<td>1384</td>
<td>78</td>
</tr>
<tr>
<td>662810005</td>
<td>23/10/1976</td>
<td>288788</td>
<td>6135280</td>
<td>168</td>
<td>ADE64</td>
<td>75.2–111 ?</td>
<td>150</td>
<td>5.0</td>
<td>20</td>
<td>1468</td>
<td></td>
</tr>
<tr>
<td>662810007</td>
<td>24/02/1970</td>
<td>288901</td>
<td>6134846</td>
<td>186</td>
<td>-</td>
<td>36.3–64</td>
<td>152</td>
<td>10.1</td>
<td>15</td>
<td>835</td>
<td>0.0</td>
</tr>
<tr>
<td>662812058</td>
<td>27/10/1982</td>
<td>287200</td>
<td>6132297</td>
<td>158</td>
<td>ADE138</td>
<td>276.9–287</td>
<td>152</td>
<td>9.0</td>
<td>105</td>
<td>973</td>
<td></td>
</tr>
<tr>
<td>662812311</td>
<td>17/06/1983</td>
<td>284691</td>
<td>6136068</td>
<td>51</td>
<td>-</td>
<td>103–152</td>
<td>150</td>
<td>3.0</td>
<td>17</td>
<td>792</td>
<td>62</td>
</tr>
<tr>
<td>662813651</td>
<td>30/04/1986</td>
<td>284792</td>
<td>6138235</td>
<td>53</td>
<td>-</td>
<td>54.8–98?</td>
<td>152</td>
<td>8.8</td>
<td>16</td>
<td>2409</td>
<td>0.0</td>
</tr>
<tr>
<td>662813652</td>
<td>02/05/1986</td>
<td>285687</td>
<td>6139011</td>
<td>53</td>
<td>-</td>
<td>25.7–154</td>
<td>203</td>
<td>4.0</td>
<td>0</td>
<td>2278</td>
<td>17.0</td>
</tr>
<tr>
<td>662815256</td>
<td>16/11/1990</td>
<td>291879</td>
<td>6141299</td>
<td>149</td>
<td>-</td>
<td>39.1–146</td>
<td>155</td>
<td>10.0</td>
<td>31</td>
<td>3609</td>
<td>36</td>
</tr>
<tr>
<td>662815439</td>
<td>15/11/1990</td>
<td>283823</td>
<td>6136911</td>
<td>40</td>
<td>-</td>
<td>60–90</td>
<td>203</td>
<td>25.0</td>
<td>11</td>
<td>860</td>
<td>51.0</td>
</tr>
<tr>
<td>662821610</td>
<td>28/01/2004</td>
<td>289688</td>
<td>6138228</td>
<td>109</td>
<td>-</td>
<td>52–140</td>
<td>158</td>
<td>12.5</td>
<td>38</td>
<td>2631</td>
<td>42</td>
</tr>
<tr>
<td>662822151</td>
<td>10/03/2005</td>
<td>282785</td>
<td>6131298</td>
<td>55</td>
<td>-</td>
<td>174–192</td>
<td>155</td>
<td>5.0</td>
<td>18</td>
<td>3110</td>
<td>166</td>
</tr>
<tr>
<td>662822152</td>
<td>08/03/2005</td>
<td>281897</td>
<td>6133460</td>
<td>35</td>
<td>-</td>
<td>115–186</td>
<td>100</td>
<td>9.0</td>
<td>3</td>
<td>2700</td>
<td>88.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Well Unit Number</th>
<th>Depth to fresh bedrock</th>
<th>DCDB_ID</th>
<th>TITLE_ID</th>
<th>Owner</th>
<th>Owner address</th>
</tr>
</thead>
<tbody>
<tr>
<td>662809702</td>
<td>42</td>
<td>F126935 A1</td>
<td>CT5878/611</td>
<td>Corp. of the City of Campbelltown</td>
<td>PO Box 1 CAMPBELTTOWN 5074</td>
</tr>
<tr>
<td>662810005</td>
<td></td>
<td>F134182 A31</td>
<td>CT5506/173</td>
<td>Christian Brothers Inc.</td>
<td>214 Wakefield St ADELAIDE 5000</td>
</tr>
<tr>
<td>662810007</td>
<td>27.0</td>
<td>D47275 A501</td>
<td>CT5440/636</td>
<td>Minister for Human Services</td>
<td>GPO Box 2555 ADELAIDE 5001</td>
</tr>
<tr>
<td>662812058</td>
<td></td>
<td>F141797 A36</td>
<td>CT5803/930</td>
<td>St Peters Collegiate Girls School Inc.</td>
<td>Stonyfell Rd STONYFELL 5066</td>
</tr>
<tr>
<td>662812311</td>
<td>92</td>
<td>F135526 A75</td>
<td>CT5791/806</td>
<td>Cadbury Schweppes Pty Ltd</td>
<td>323 - 351 Canterbury Rd RINGWOOD VIC 3134</td>
</tr>
<tr>
<td>662813651</td>
<td>70.0</td>
<td>D6708 A15</td>
<td>CT5633/272</td>
<td>Martino</td>
<td>42 Fourth Ave KLEMZIG 5087</td>
</tr>
<tr>
<td>662813652</td>
<td>32.0</td>
<td>F131993 A3</td>
<td>CT5870/424</td>
<td>SA Water Corp.</td>
<td>Attn F.Alexander Level 15/77 Grenfell St ADELAIDE 5000</td>
</tr>
<tr>
<td>662815256</td>
<td>39.0</td>
<td>D55490 A55</td>
<td>CT5890/10</td>
<td>CSR Ltd</td>
<td>Level 1/9 Help St CHATSWOOD N S W 2067</td>
</tr>
<tr>
<td>662815439</td>
<td>51.0</td>
<td>F127638 A4</td>
<td>CT5749/386</td>
<td>Corp. of the Town of Walkerville</td>
<td>PO Box 55 WALKERVILLE 5081</td>
</tr>
<tr>
<td>662821610</td>
<td>52</td>
<td>F146367 A4</td>
<td>CT5565/126</td>
<td>Manresa Soc. Inc.</td>
<td>&quot;MANRESA&quot; 137 William St NORWOOD 5067</td>
</tr>
<tr>
<td>662822151</td>
<td>176</td>
<td>H105100 S6016</td>
<td>CR5707/712</td>
<td>Corp. of the City of Adelaide</td>
<td>PO Box 43 NORTH ADELAIDE 5006</td>
</tr>
<tr>
<td>662822152</td>
<td>118.0</td>
<td>H105100 S571</td>
<td>CR5715/226</td>
<td>Governors of the Botanic Garden</td>
<td>Goodman Building Hackney Rd ADELAIDE 5000</td>
</tr>
</tbody>
</table>
### C. POTENTIAL FRA ASR INVESTIGATION SITES

<table>
<thead>
<tr>
<th>Site no.</th>
<th>Approx. MGA Easting</th>
<th>Approx. MGA Northing</th>
<th>Site name</th>
<th>Water source</th>
<th>DCDB ID</th>
<th>PLAN ID</th>
<th>PARCEL ID</th>
<th>TITLE ID</th>
<th>Land owner</th>
<th>Land Owners Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>283000</td>
<td>6126550</td>
<td>Mitcham Reserve</td>
<td>Stream</td>
<td>D15858</td>
<td>A52</td>
<td>A10</td>
<td>CT5540/952</td>
<td>Minister for Education and Children's Services</td>
<td>C/- PROPERTY MANAGER LEVEL 7/31 FLINDERS ST ADELAIDE 5000</td>
</tr>
<tr>
<td>2</td>
<td>283200</td>
<td>6127700</td>
<td>Unbrea Agricultural High School</td>
<td>Pipe</td>
<td>D39536</td>
<td>A10</td>
<td>D39536</td>
<td>A10</td>
<td>Distribution Lessor Corp.</td>
<td>GPO BOX 1045 ADELAIDE 5001</td>
</tr>
<tr>
<td>3</td>
<td>283750</td>
<td>6128000</td>
<td>Waite Arboretum</td>
<td>Pipe</td>
<td>F16164</td>
<td>A101</td>
<td>F16164</td>
<td>A101</td>
<td>Distribution Lessor Corp.</td>
<td>GPO BOX 1045 ADELAIDE 5001</td>
</tr>
<tr>
<td>4</td>
<td>284600</td>
<td>6128750</td>
<td>Ridge Park Reserve</td>
<td>Stream or pipe</td>
<td>F15596</td>
<td>A128</td>
<td>F15596</td>
<td>A128</td>
<td>Corp. of the City of Unley</td>
<td>PO BOX 1 UNLEY 5061</td>
</tr>
<tr>
<td>5</td>
<td>286750</td>
<td>6130800</td>
<td>Langman Reserve</td>
<td>Stream</td>
<td>F18762</td>
<td>A354</td>
<td>F18762</td>
<td>A354</td>
<td>City of Burnside</td>
<td>PO BOX 9 GLENSIDE 5065</td>
</tr>
<tr>
<td>6</td>
<td>285950</td>
<td>6131550</td>
<td>Hazelwood Park</td>
<td>Stream</td>
<td>F138218</td>
<td>A38</td>
<td>F138218</td>
<td>A38</td>
<td>City of Burnside</td>
<td>PO BOX 9 GLENSIDE 5065</td>
</tr>
<tr>
<td>7</td>
<td>287400</td>
<td>6132150</td>
<td>Ferguson Park</td>
<td>Stream</td>
<td>H105100</td>
<td>S687</td>
<td>H105100</td>
<td>S687</td>
<td>City of Burnside</td>
<td>ADELAIDE 5000</td>
</tr>
<tr>
<td>8</td>
<td>287900</td>
<td>6133300</td>
<td>Penfolds Winery</td>
<td>Pipe</td>
<td>F20538</td>
<td>A1</td>
<td>F20538</td>
<td>A1</td>
<td>Southcorp Wines Pty Ltd</td>
<td>403 PACIFIC HIGHWAY ARTARMON N S W 2064</td>
</tr>
<tr>
<td>9</td>
<td>287600</td>
<td>6134400</td>
<td>UniSA Magill Campus</td>
<td>Stream or pipe</td>
<td>F146354</td>
<td>A11</td>
<td>F146354</td>
<td>A11</td>
<td>Distribution Lessor Corp.</td>
<td>GPO BOX 1045 ADELAIDE 5001</td>
</tr>
<tr>
<td>10</td>
<td>286600</td>
<td>6134800</td>
<td>Gums Recreation Ground</td>
<td>Stream</td>
<td>F133886</td>
<td>A35</td>
<td>F133886</td>
<td>A35</td>
<td>City of Burnside</td>
<td>PO BOX 9 GLENSIDE 5065</td>
</tr>
<tr>
<td>11</td>
<td>285600</td>
<td>6133100</td>
<td>Kensington Oval</td>
<td>Pipe</td>
<td>F141164</td>
<td>A4</td>
<td>F141164</td>
<td>A4</td>
<td>City of Burnside</td>
<td>PO BOX 9 GLENSIDE 5065</td>
</tr>
<tr>
<td>12</td>
<td>288550</td>
<td>6135100</td>
<td>Rostrevor College</td>
<td>Stream</td>
<td>D47275</td>
<td>A500</td>
<td>D47275</td>
<td>A500</td>
<td>Christian Brothers Inc.</td>
<td>PO BOX 1129 BENTLEY DC WA 6983</td>
</tr>
<tr>
<td>13</td>
<td>287750</td>
<td>6136700</td>
<td>Leabrook Drive Reserve</td>
<td>Stream</td>
<td>F133131</td>
<td>A41</td>
<td>F133131</td>
<td>A41</td>
<td>City of Burnside</td>
<td>PO BOX 1 CAMPBELTTOWN 5074</td>
</tr>
<tr>
<td>14</td>
<td>288850</td>
<td>6137600</td>
<td>Market Garden</td>
<td>Pipe</td>
<td>F9233</td>
<td>A19</td>
<td>F9233</td>
<td>A19</td>
<td>City of Burnside</td>
<td>PO BOX 1 CAMPBELTTOWN 5074</td>
</tr>
<tr>
<td>15</td>
<td>289900</td>
<td>6137950</td>
<td>Wadmore Park</td>
<td>Stream</td>
<td>D35275</td>
<td>A2</td>
<td>D35275</td>
<td>A2</td>
<td>City of Burnside</td>
<td>PO BOX 1 CAMPBELTTOWN 5074</td>
</tr>
<tr>
<td>16</td>
<td>291350</td>
<td>6139900</td>
<td>River Torrens # 1</td>
<td>Stream</td>
<td>D55138</td>
<td>A2312</td>
<td>D55138</td>
<td>A2312</td>
<td>City of Burnside</td>
<td>PO BOX 1 CAMPBELTTOWN 5074</td>
</tr>
</tbody>
</table>
### APPENDICES

**Report DWLBC 2006/03**

Aquifer Storage and Recovery Potential of Fractured Rock Aquifers in the Golden Grove Embayment

<table>
<thead>
<tr>
<th>Site no.</th>
<th>Approx. MGA Easting</th>
<th>Approx. MGA Northing</th>
<th>Site name</th>
<th>Water source</th>
<th>DCDB ID</th>
<th>PLAN ID</th>
<th>PARCEL ID</th>
<th>TITLE ID</th>
<th>Land owner</th>
<th>Land Owners Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>291750</td>
<td>6141300</td>
<td>CSR Quarry</td>
<td>Stream</td>
<td>D55490 A55</td>
<td>D55490 A55</td>
<td>CT5809/10</td>
<td>CSR Ltd</td>
<td></td>
<td>LEVEL 1/9 HELP STREET CHATSWOOD N S W 2067</td>
</tr>
<tr>
<td>18</td>
<td>288450</td>
<td>6138450</td>
<td>Thorndon Park Reserve</td>
<td>Reservoir or pipe</td>
<td>H105100 S726</td>
<td>H105100 S726</td>
<td>CR5759/864</td>
<td>Corp. of the City of Campbelltown</td>
<td></td>
<td>PO BOX 1 CAMPBELLTOWN 5074</td>
</tr>
<tr>
<td>19</td>
<td>289250</td>
<td>6139800</td>
<td>River Torrens # 2</td>
<td>Stream</td>
<td>D9801 A46</td>
<td>D9801 A46</td>
<td></td>
<td></td>
<td></td>
<td>PO BOX 1 CAMPBELLTOWN 5074</td>
</tr>
<tr>
<td>20</td>
<td>288350</td>
<td>6139301</td>
<td>River Torrens # 3</td>
<td>Stream</td>
<td>F11032 A2</td>
<td>F11032 A2</td>
<td>A2 CT5528/955</td>
<td>Corp. of the City of Campbelltown</td>
<td></td>
<td>PO BOX 1 CAMPBELLTOWN 5074</td>
</tr>
<tr>
<td>21</td>
<td>281850</td>
<td>6134200</td>
<td>Botanic Gardens</td>
<td>Stream</td>
<td>H105100 S574</td>
<td>H105100 S574</td>
<td>CR5756/651</td>
<td>Govens of the Botanic Garden</td>
<td></td>
<td>PO BOX 204 KENT TOWN 5071</td>
</tr>
<tr>
<td>22</td>
<td>282300</td>
<td>6134900</td>
<td>St Peters River Park</td>
<td>Stream</td>
<td>F136682 A31</td>
<td>F136682 A31</td>
<td>A31 CT5853/87</td>
<td>Corp of the City of Norwood Paynham and St Peters</td>
<td></td>
<td>PO BOX 204 KENT TOWN 5071</td>
</tr>
<tr>
<td>23</td>
<td>283550</td>
<td>6136600</td>
<td>River Torrens # 4</td>
<td>Stream</td>
<td>D19035 A24</td>
<td>D19035 A24</td>
<td>A24 CT5471/360</td>
<td>Minister for Infrastructure</td>
<td></td>
<td>LEVEL 11 TERRACE TOWERS 178 NORTH TCE ADELAIDE 5000</td>
</tr>
<tr>
<td>24</td>
<td>285050</td>
<td>6137200</td>
<td>Felixstow Reserve</td>
<td>Stream</td>
<td>F128129 A95</td>
<td>F128129 A95</td>
<td>A95 CT5805/49</td>
<td>Corp. of the City of Norwood Paynham and St Peters</td>
<td></td>
<td>PO BOX 204 KENT TOWN 5071</td>
</tr>
<tr>
<td>25</td>
<td>285100</td>
<td>6138200</td>
<td>Lochiel Park</td>
<td>Stream</td>
<td>D57618 A302</td>
<td>D57618 A302</td>
<td>A302 CT5873/761</td>
<td>SA Water Corp.</td>
<td></td>
<td>ATTN F.ALEXANDER LEVEL 15/77 GRENFELL ST ADELAIDE 5000</td>
</tr>
<tr>
<td>26</td>
<td>286975</td>
<td>6139000</td>
<td>Campbell Memorial Oval</td>
<td>Stream</td>
<td>F126935 A1</td>
<td>F126935 A1</td>
<td>A1 CT5878/611</td>
<td>Corp. of the City of Campbelltown</td>
<td></td>
<td>PO BOX 1 CAMPBELLTOWN 5074</td>
</tr>
<tr>
<td>27</td>
<td>287700</td>
<td>6140450</td>
<td>Lyons Road Reserve</td>
<td>Stream</td>
<td>D28047 A611</td>
<td>D28047 A611</td>
<td>A611 CT5408/478</td>
<td>City of Tea Tree Gully</td>
<td></td>
<td>PO BOX 571 MODBURY 5092</td>
</tr>
<tr>
<td>28</td>
<td>289070</td>
<td>6141480</td>
<td>Hope Valley Reservoir</td>
<td>Reservoir</td>
<td>D33371 A1</td>
<td>D33371 A1</td>
<td>A1 CT5066/56</td>
<td>SA Water Corp.</td>
<td></td>
<td>ATTN F.ALEXANDER LEVEL 15/77 GRENFELL ST ADELAIDE 5000</td>
</tr>
</tbody>
</table>

Report DWLBC 2006/03

Aquifer Storage and Recovery Potential of Fractured Rock Aquifers in the Golden Grove Embayment
### UNITS AND MEASUREMENTS

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

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

- $\delta^D$ hydrogen isotope composition
- $\delta^{18}O$ oxygen isotope composition
- $^{14}C$ carbon-14 isotope (percent modern carbon)
- CFC chlorofluorocarbon (parts per trillion volume)
- EC electrical conductivity (μS/cm)
- pH acidity
- ppm parts per million
- ppb parts per billion
- TDS total dissolved solids (mg/L)
GLOSSARY

**Act (the).** In this document, refers to The *Natural Resources Management Act* (South Australia) 2004.

**Adaptive management.** A management approach, often used in natural resource management, where there is little information and/or a lot of complexity and there is a need to implement some management changes sooner rather than later. The approach is to use the best available information for the first actions, implement the changes, monitor the outcomes, investigate the assumptions and regularly evaluate and review the actions required. Consideration must be given to the temporal and spatial scale of monitoring and the evaluation processes appropriate to the ecosystem being managed.

**Algal bloom.** A rapid accumulation of algal biomass (living organic matter) which can result in deterioration in water quality when the algae die and break down consuming the dissolved oxygen and releasing toxins.

**Ambient.** The background level of an environmental parameter (e.g. a background water quality like salinity).

**Anabranch.** A branch of a river that leaves the main stream.

**Annual adjusted catchment yield.** Annual catchment yield with the impact of dams removed.

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

**Aquifer, confined.** Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure. Water in a penetrating well will rise above the surface of the aquifer.

**Aquifer, storage and recovery (ASR).** The process of recharging water into an aquifer for the purpose of storage and subsequent withdrawal.

**Aquifer test.** A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well.

**Aquifer, unconfined.** Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

**Aquitard.** A layer in the geological profile that separates two aquifers and restricts the flow between them.

**Arid lands.** In South Australia arid lands are usually considered to be areas with an average rainfall of less than 250 mm and support pastoral activities instead of broad acre cropping.

**Artesian.** Under pressure such that when wells penetrate the aquifer water will rise to the ground surface without the need for pumping.

**Artificial recharge.** The process of artificially diverting water from the surface to an aquifer. Artificial recharge can reduce evaporation losses and increase aquifer yield. (See recharge, natural recharge, aquifer.)

**Barrage.** Specifically any of the five low weirs at the mouth of the River Murray constructed to exclude seawater from the Lower Lakes.

**Baseflow.** The water in a stream that results from groundwater discharge to the stream. (This discharge often maintains flows during seasonal dry periods and has important ecological functions.)

**Basin.** The area drained by a major river and its tributaries.

**Benchmark condition.** Points of reference from which change can be measured.

**Biological diversity (biodiversity).** The variety of life forms: the different life forms including plants, animals and micro-organisms, the genes they contain and the *ecosystems (see below)* they form. It is usually considered at three levels — genetic diversity, species diversity and ecosystem diversity.
**Biota.** All of the organisms at a particular locality.

**Bore.** See well.

**Buffer zone.** A neutral area that separates and minimises interactions between zones whose management objectives are significantly different or in conflict (e.g. a vegetated riparian zone can act as a buffer to protect the water quality and streams from adjacent land uses).

**Catchment.** A catchment is that area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

**Catchment water management board.** A statutory body established under Part 6, Division 3, s. 53 of the Act whose prime function under Division 2, s. 61 is to implement a catchment water management plan for its area.

**Catchment water management plan.** The plan prepared by a CWMB and adopted by the Minister in accordance with Part 7, Division 2 of the Water Resources Act 1997.

**Codes of practice.** Standards of management developed by industry and government, promoting techniques or methods of environmental management by which environmental objectives may be achieved.

**Cone of depression.** An inverted cone-shaped space within an aquifer caused by a rate of groundwater extraction which exceeds the rate of recharge. Continuing extraction of water can extend the area and may affect the viability of adjacent wells, due to declining water levels or water quality.

**Conjunctive use.** The utilisation of more than one source of water to satisfy a single demand.

**Council of Australian Governments (COAG).** A council of the Prime Minister, State Premiers, Territory Chief Ministers and the President of the Australian Local Government Association which exists to set national policy directions for Australia.

**CWMB.** Catchment Water Management Board.

**Dams, off-stream dam.** A dam, wall or other structure that is not constructed across a watercourse or drainage path and is designed to hold water diverted, or pumped, from a watercourse, a drainage path, an aquifer or from another source. Off-stream dams may capture a limited volume of surface water from the catchment above the dam.

**Dams, on-stream dam.** A dam, wall or other structure placed or constructed on, in or across a watercourse or drainage path for the purpose of holding and storing the natural flow of that watercourse or the surface water.

**Dams, turkey nest dam.** An off-stream dam that does not capture any surface water from the catchment above the dam.

**Diffuse source pollution.** Pollution from sources such as an eroding paddock, urban or suburban lands and forests; spread out, and often not easily identified or managed.

**District Plan.** (District Soil Conservation Plan) An approved soil conservation plan under the repealed Soil Conservation Act 1989. These plans are taken to form part of the relevant regional NRM plans under the transitional provisions of the Natural Resources Management Act 2004 (Schedule 4 – subclause 53[4]) until regional NRM plans are prepared under Chapter 4, Part 2 of the Act.

**Domestic purpose.** The taking of water for ordinary household purposes and includes the watering of land in conjunction with a dwelling not exceeding 0.4 hectares.

**Domestic wastewater.** Water used in the disposal of human waste, for personal washing, washing clothes or dishes, and swimming pools.

**DSS (decision support system).** A system of logic or a set of rules derived from experts, to assist decision making. Typically they are constructed as computer programs.

**DSS.** Dissolved suspended solids.

**DWLBC.** Department of Water, Land and Biodiversity Conservation. Government of South Australia.

**EC.** Abbreviation for electrical conductivity. 1 EC unit = 1 micro-Siemen per centimetre (μS/cm) measured at 25 degrees Celsius. Commonly used to indicate the salinity of water.
GLOSSARY

Ecological processes. All biological, physical or chemical processes that maintain an ecosystem.

Ecological values. The habitats, the natural ecological processes and the biodiversity of ecosystems.

Ecologically sustainable development (ESD). Using, conserving and enhancing the community’s resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.

Ecology. The study of the relationships between living organisms and their environment.

Ecosystem. Any system in which there is an interdependence upon and interaction between living organisms and their immediate physical, chemical and biological environment.

Ecosystem Services. All biological, physical or chemical processes that maintain ecosystems and biodiversity and provide inputs and waste treatment services that support human activities.

Effluent. Domestic wastewater and industrial wastewater.

EIP. Environment improvement program.

EMLR. Eastern Mount Lofty Ranges.


Environmental values. The uses of the environment that are recognised as of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy, which recognises five environmental values — protection of aquatic ecosystems, recreational water use and aesthetics, potable (drinking water) use, agricultural and aquaculture use, and industrial use. It is not the same as ecological values, which are about the elements and functions of ecosystems.

Environmental water provisions. Those parts of environmental water requirements that can be met, at any given time. This is what can be provided at that time with consideration of existing users’ rights, social and economic impacts.

Environmental water requirements. The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.

EP. Eyre Peninsula.

EPA. Environment Protection Agency.

Ephemeral streams / wetlands. Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

Erosion. Natural breakdown and movement of soil and rock by water, wind or ice. The process may be accelerated by human activities.

ESD. Ecologically sustainable development (see above for definition).

Estuaries. Semi-enclosed waterbodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences and experience periodic fluctuations and gradients in salinity.

Eutrophication. Degradation of water quality due to enrichment by nutrients (primarily nitrogen and phosphorus), causing excessive plant growth and decay. (See algal bloom).

Evapotranspiration. The total loss of water as a result of transpiration from plants and evaporation from land, and surface waterbodies.

Fishway. A generic term describing all mechanisms that allow the passage of fish along a waterway. Specific structures include fish ladders (gentle sloping channels with baffles that reduce the velocity of water and provide resting places for fish as they ‘climb’ over a weir) and fishlifts (chambers, rather like lift-wells, that are flooded and emptied to enable fish to move across a barrier).

Floodplain. Of a watercourse means: (a) the floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under Part 7 of the Water Resources Act 1997; or (b) where paragraph (a) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the Development Act 1993, or (c) where neither
paragraph (a) nor paragraph (b) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse.

**Flow bands.** Flows of different frequency, volume and duration.

**GAB.** Great Artesian Basin.

**Gigalitre (GL).** One thousand million litres (1 000 000 000).

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

**GL.** See gigalitre.

**Greenhouse effect.** The balance of incoming and outgoing solar radiation which regulates our climate. Changes to the composition of the atmosphere such as the addition of carbon dioxide through human activities, have the potential to alter the radiation balance and to effect changes to the climate. Scientists suggest that changes would include global warming, a rise in sea level and shifts in rainfall patterns.

**Geological features.** Include geological monuments, landscape amenity and the substrate of land systems and ecosystems.

**Greywater.** Household wastewater excluding sewage effluent. Wastewater from kitchen, laundry and bathroom.

**Groundwater.** See underground water.

**Habitat.** The natural place or type of site in which an animal or plant, or communities of plants and animals, lives.

**Heavy metal.** Any metal with a high atomic weight (usually, although not exclusively, greater than 100), for example mercury, lead and chromium. Heavy metals have a widespread industrial use, and many are released into the biosphere via air, water and solids pollution. Usually these metals are toxic at low concentrations to most plant and animal life.

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

**Hydrography.** The discipline related to the measurement and recording of parameters associated with the hydrological cycle, both historic and real time.

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

**Hyporheic zone.** The wetted zone among sediments below and alongside rivers. It is a refuge for some aquatic fauna.

**Indigenous species.** A species that occurs naturally in a region.

**Industrial wastewater.** Water (not being domestic wastewater) that has been used in the course of carrying on a business (including water used in the watering of irrigation of plants) that has been allowed to run to waste or has been disposed of or has been collected for disposal.

**Infrastructure.** Artificial lakes; or dams or reservoirs; or embankments, walls, channels or other works; or buildings or structures; or pipes, machinery or other equipment.

**Integrated catchment management.** Natural resources management that considers in an integrated manner the total long-term effect of land and water management practices on a catchment basis, from production and environmental viewpoints.

**Intensive farming.** A method of keeping animals in the course of carrying on the business of primary production in which the animals are confined to a small space or area and are usually fed by hand or by mechanical means.

**Irrigation.** Watering land by any means for the purpose of growing plants.

**Irrigation season.** The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May.
**Lake.** A natural lake, pond, lagoon, wetland or spring (whether modified or not) and includes: part of a lake; and a body of water declared by regulation to be a lake; a reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

**Land.** Whether under water or not and includes an interest in land and any building or structure fixed to the land.

**Land capability.** The ability of the land to accept a type and intensity of use without sustaining long-term damage.

**Leaching.** Removal of material in solution such as minerals, nutrients and salts through soil.

**Licence.** A licence to take water in accordance with the Water Resources Act 1997. (See water licence.)

**Licensee.** A person who holds a water licence.

**Local water management plan.** A plan prepared by a council and adopted by the Minister in accordance with Part 7, Division 4 of the Act.

**Macro-invertebrates.** Animals without backbones that are typically of a size that is visible to the naked eye. They are a major component of aquatic ecosystem biodiversity and fundamental in food webs.

**MDBC.** Murray-Darling Basin Commission.

**Megalitre (ML).** One million litres (1 000 000).

**ML.** See megalitre.

**MLR.** Mount Lofty Ranges.

**Model.** A conceptual or mathematical means of understanding elements of the real world which allows for predictions of outcomes given certain conditions. Examples include estimating storm runoff, assessing the impacts of dams or predicting ecological response to environmental change.

**Mount Lofty Ranges Watershed.** The area prescribed by Schedule 1 of the regulations.

**Natural recharge.** The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.) (See recharge area, artificial recharge.)

**NHMRC.** National Health and Medical Research Council.

**NHT.** Natural Heritage Trust.

**Natural Resources.** Soil; water resources; geological features and landscapes; native vegetation, native animals and other native organisms; ecosystems.

**Natural Resources Management (NRM).** All activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

**Occupier of land.** A person who has, or is entitled to, possession or control of the land.

**Owner of land.** In relation to land alienated from the Crown by grant in fee simple — the holder of the fee simple; in relation to dedicated land within the meaning of the Crown Lands Act 1929 that has not been granted in fee simple but which is under the care, control and management of a Minister, body or other person — the Minister, body or other person; in relation to land held under Crown lease or licence — the lessee or licensee; in relation to land held under an agreement to purchase from the Crown — the person entitled to the benefit of the agreement; in relation to any other land — the Minister who is responsible for the care, control and management of the land or, if no Minister is responsible for the land, the Minister for Environment and Heritage.

**Palaeochannels.** Ancient buried river channels in arid areas of the state. Aquifers in palaeochannels can yield useful quantities of groundwater or be suitable for ASR.

**Pasture.** Grassland used for the production of grazing animals such as sheep and cattle.
Percentile. A way of describing sets of data by ranking the data set and establishing the value for each percentage of the total number of data records. The 90th percentile of the distribution is the value such that 90% of the observations fall at or below it.

Permeability. A measure of the ease with which water flows through an aquifer or aquitard.

Personal property. All forms of property other than real property. For example, shares or a water licence.

Phreaphytic vegetation. Vegetation that exists in a climate more arid than its normal range by virtue of its access to groundwater.

Phytoplankton. The plant constituent of organisms inhabiting the surface layer of a lake; mainly single-cell algae.

PIRSA. (Department of) Primary Industries and Resources South Australia.

Pollution, diffuse source. Pollution from sources that are spread out and not easily identified or managed (e.g. an eroding paddock, urban or suburban lands and forests).

Pollution, point source. A localised source of pollution.

Potable water. Water suitable for human consumption.

Potentiometric head. The potentiometric head or surface is the level to which water rises in a well due to water pressure in the aquifer.

Precautionary principle. Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

Prescribed area, surface water. Part of the State declared to be a surface water prescribed area under the Water Resources Act 1997.

Prescribed lake. A lake declared to be a prescribed lake under the Water Resources Act 1997.

Prescribed water resource. A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Prescribed watercourse. A watercourse declared to be a prescribed watercourse under the Water Resources Act 1997.

Prescribed well. A well declared to be a prescribed well under the Water Resources Act 1997.

Property right. A right of ownership or some other right to property, whether real property or personal property.

Proponent. The person or persons (who may be a body corporate) seeking approval to take water from prescribed water.

PWA. Prescribed Wells Area.

PWCA. Prescribed Watercourse Area.

PWRA. Prescribed Water Resources Area.

Ramsar Convention. This is an international treaty on wetlands titled The Convention on Wetlands of International Importance Especially as Waterfowl Habitat. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar, Iran in 1971, hence its common name. The Convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

Recharge area. The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. (See artificial recharge, natural recharge.)

Reclaimed water. Treated effluent of a quality suitable for the designated purpose.

Rehabilitation (of waterbodies). Actions that improve the ecological health of a waterbody by reinstating important elements of the environment that existed prior to European settlement.
Remediation (of waterbodies). Actions that improve the ecological condition of a waterbody without necessarily reinstating elements of the environment that existed prior to European settlement.

Restoration (of waterbodies). Actions that reinstate the pre-European condition of a waterbody.

Reticulated water. Water supplied through a piped distribution system.

Riffles. Shallow stream section with fast and turbulent flow.

Riparian landholder. A person whose property abuts a watercourse or through whose property a watercourse runs.

Riparian rights. These were old common law rights of access to, and use of water. These common law rights were abolished with the enactment of the Water Resources Act 1997, which now includes similar rights under s. 7. Riparian rights are therefore now statutory rights under the Act. Where the resource is not prescribed (Water Resources Act 1997, s. 8) or subject to restrictions (Water Resources Act 1997, s. 16), riparian landholders may take any amount of water from watercourses, lakes or wells without consideration to downstream landholders, if it is to be used for stock or domestic purposes. If the capture of water from watercourses and groundwater is to be used for any other purpose then the right of downstream landholders must be protected. Landholders may take any amount of surface water for any purpose without regard to other landholders, unless the surface water is prescribed or subject to restrictions.

Riparian zone. That part of the landscape adjacent to a water body, that influences and is influenced by watercourse processes. This can include landform, hydrological or vegetation definitions. It is commonly used to include the in-stream habitats, bed, banks and sometimes floodplains of watercourses.

Seasonal watercourses or wetlands. Those watercourses and wetlands that contain water on a seasonal basis, usually over the winter/spring period, although there may be some flow or standing water at other times.

State water plan. The plan prepared by the Minister under Part 7, Division 1, s. 90 of the Act.

Stock Use. The taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act).

Stormwater. Runoff in an urban area.

Surface water. (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any other manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Taxa. General term for a group identified by taxonomy — which is the science of describing, naming and classifying organisms.

To take water. From a water resource includes (a) to take water by pumping or syphoning the water; (b) to stop, impede or divert the flow of water over land (whether in a watercourse or not) for the purpose of collecting the water; (c) to divert the flow of water in a watercourse from the watercourse; (d) to release water from a lake; (e) to permit water to flow under natural pressure from a well; (f) to permit stock to drink from a watercourse, a natural or artificial lake, a dam or reservoir.

Total kjeldal nitrogen (TKN). The sum of aqueous ammonia and organic nitrogen. Used as a measure of probable sewage pollution.

Transfer. A transfer of a licence (including its water allocation) to another person, or the whole or part of the water allocation of a licence to another licensee or the Minister under Part 5, Division 3, s. 38 of the Act. The transfer may be absolute or for a limited period.

Underground water (groundwater). Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Volumetric allocation. An allocation of water expressed on a water licence as a volume (e.g. kilolitres) to be used over a specified period of time, usually per water use year (as distinct from any other sort of allocation).

Wastewater. See domestic wastewater, industrial wastewater.
**GLOSSARY**

**Water affecting activities.** Activities referred to in Part 4, Division 1, s. 9 of the Act.

**Water allocation.** (a) in respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence; (b) in respect of water taken pursuant to an authorisation under s. 11 means the maximum quantity of water that can be taken and used pursuant to the authorisation.

**Water allocation, area based.** An allocation of water that entitles the licensee to irrigate a specified area of land for a specified period of time usually per water use year.

**Water allocation plan (WAP).** A plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

**Water licence.** A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area. This grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water. A water licence confers a property right on the holder of the licence and this right is separate from land title.

**Water plans.** The State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act.

**Water service provider.** A person or corporate body that supplies water for domestic, industrial or irrigation purposes or manages wastewater.

**Waterbody.** Waterbodies include watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers.

**Watercourse.** A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; and a lake through which water flows; and a channel (but not a channel declared by regulation to be excluded from this definition) into which the water of a watercourse has been diverted; and part of a watercourse.

**Water-dependent ecosystems.** Those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of flowing or standing water, above or below ground. The in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.

**Water-use year.** The period between 1 July in any given calendar year and 30 June the following calendar year. This is also called a licensing year.

**Well.** (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

**Wetlands.** Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic/intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six metres.
REFERENCES


