Managed aquifer recharge schemes in the Adelaide Metropolitan Area

DEWNR Technical Report 2017/22

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Foreword

The Department of Environment, Water and Natural Resources (DEWNR) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEWNR's strong partnerships with educational and research institutions, industries, government agencies, Natural Resources Management Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

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Summary

Managed Aquifer Recharge (MAR) has developed rapidly over the past 30 years in the Adelaide Metropolitan Area, with significant investment by the government and the private sector to develop MAR technology and increase its deployment. All MAR projects have essentially been motivated by the desire to increase water availability for irrigation, and in most cases, to improve environmental outcomes in waterways. As a result, South Australia has become a global leader in MAR development and application.

Discussions between the MAR industry and the Department of Environment, Water and Natural Resources (DEWNR) identified that there was inconsistent information available on what MAR infrastructure has been constructed and its operational status, which made it difficult to describe the scale of the industry to stakeholders and the general public. Furthermore, this lack of clarity made it difficult to identify opportunities or limitations for the industry.

In response, DEWNR has assembled an inventory of MAR schemes and their related infrastructure, including alternative water distribution main networks, within the Adelaide Metropolitan Area. It provides a short summary of each scheme including its location, purpose, recharge wells, native water quality, source water, catchment description and treatment systems. A summary of opportunities for optimisation, as identified by scheme operators, is also provided to inform future research.

To capture information for this report, DEWNR interviewed operators of all operational MAR schemes, as well as people with knowledge of the schemes that no longer operate. In addition, a comprehensive literature search was undertaken to fill in knowledge gaps of scheme developments.

Through the interviews and literature searches, it was identified that there have been 58 MAR schemes constructed in the Adelaide Metropolitan Area since 1989. Schemes range in size from small, single well operations with a harvest capacity less than 10 ML/y, to large six to eight well schemes with major stormwater diversion infrastructure harvesting up to 1000 ML/y. In addition, hundreds of millions of dollars have been invested in 750 km of alternative water distribution pipelines to transport water from MAR schemes and wastewater treatment plants to areas of demand. These include school ovals, public reserves, industry and private residential areas within the metropolitan area, together with large horticultural and viticultural areas to the north and south of the city.

This report provides a useful summary of Adelaide's MAR infrastructure and it can also be used to inform high-level planning to further optimise Adelaide's alternative water infrastructure.

1 Introduction

Managed Aquifer Recharge (MAR) has developed rapidly over the past 30 years in the Adelaide Metropolitan Area with development ranging from small-scale passive-filtered gravity-fed demonstration sites, to large-scale integrated urban developments with advanced filtration and high-pressure injection wells which represent world-class applications of MAR technology. During that time, there has been significant investment by governments and industry to further develop the technology and increase its deployment. As a result of the rapid development of disaggregated projects, it has been difficult for those not involved in various schemes to understand the progress in MAR infrastructure. This is mainly due to a lack of a single document that describes all of the schemes. Discussions between the Department of Environment, Water and Natural Resources (DEWNR) and the MAR industry also identified that there was inconsistencies in the information made available on the industry. This made it more difficult to identify opportunities and limitations for the industry, in a similar manner to what had been done in the earlier years (e.g. Martin and Dillon, 2002). In response, DEWNR prepared this inventory of all MAR schemes within the Adelaide Metropolitan Area (south of Gawler River, west of the Adelaide Hills, extending south to Aldinga) and their related infrastructure, into a single, publically available document.

Whilst the first trials in Adelaide, South Australia, can be traced back to 1951, MAR has had a relatively short history with the first ongoing scheme established in 1989. Since then, the number of MAR schemes increased rapidly as industry capability developed and with improved understanding and acceptance from communities and the government. During the 1990s several schemes successfully demonstrated the viability of MAR for the city's climate, hydrogeology and water-demand profile. The number of MAR schemes operating in Adelaide expanded rapidly after 2000 in response to the millennium drought and the Australian Government's policy response to this crisis. In addition to the new schemes, hundreds of millions of dollars were invested in alternative water distribution pipelines to transport water from MAR schemes and wastewater treatment plants to areas of demand. These pipelines allow MAR schemes to supply water to school ovals, public reserves, industry, private residential areas within the metropolitan area and large horticultural and viticultural areas to the north and south of the city.

There have been few previous attempts to describe all of the schemes in Adelaide. Gerges (2000) noted what had been constructed up until that year, listing a combined 20 MAR schemes and investigation sites, although only five schemes were described. Martin & Dillon (2002) described seven operating schemes and listed five investigation sites within the Adelaide area, and also provided a detailed description of the potential for MAR in South Australia, and the limitations and emerging issues that were being recognised in the sector. This important report helped define research directions for the next decade. Reports relating to the "Waterproofing the North/South/East/West" projects developed during the past ten years provide additional information on their respective components of MAR development. In 2009, a study into urban stormwater harvesting options for Adelaide listed 13 operational schemes, 31 'committed' schemes and eight additional prospective schemes (Wallbridge & Gilbert 2009). The same report also provided estimates of the design harvest volumes for the listed schemes.

To develop the inventory and MAR scheme descriptions in this report, DEWNR surveyed MAR operators of all operating schemes, as well as people with knowledge of the schemes that no longer operate. This information was supplemented with data found though a comprehensive literature search. Therefore the descriptions of MAR schemes in the Adelaide Metropolitan Area in this report are the most comprehensive to date, however it should be noted that some information was not located or is no longer available. The discussions with MAR operators also gained information about constraints to scheme performance (both yield and economic) which could inform future research directions and are included in this report.

Overall, the survey and literature review identified that 58 MAR sites have been constructed during the past 30 years (Figure 2-1, Table 2-1), as well as 750 km of alternative water pipelines. The harvest capacities of the MAR schemes have also been assessed in this report which have been provided as a range of values because identifying a single value for each scheme can be problematic (see break-out box below).

This report illustrates the extent of Adelaide's advanced water management infrastructure, and provides a basis from which high-level planning of Adelaide's alternative water infrastructure can continue.

Please note that this report excludes some operations such as domestic-scale MAR and sites that are considered to be drainage-only (i.e. do not purposely recharge water for subsequent recovery or trade). Several drainage-only sites are mentioned in this report mainly to remove any confusion as to their purpose. Agricultural MAR schemes were also excluded—the focus has been on schemes that are integrated with urban water management infrastructure (stormwater and treated effluent). It is also not the aim of this report to detail the performance of individual schemes, however issues that inform the discussion of MAR optimisation opportunities and potential research directions to further improve MAR scheme operations, are noted.

MAR scheme harvest capacity

Defining the harvest capacity for a MAR scheme is difficult. Many schemes have had their initial target design harvest capacity quoted in the literature, however this is an unreliable indicator of the actual harvest capacity. These design capacities have been based on desktop studies rather than detailed hydrological and hydrogeological investigations. Few of Adelaide's stormwater drains are actively monitored for flow and therefore assumptions are used to estimate the flow volumes and duration. In addition, scheme construction limitations due to site or budget constraints can compromise the initial designs. For these reasons, the as-constructed capacity is usually lower that the initial target design. Even when a scheme is operational, it can still be difficult to initially assign a harvest capacity because experience has shown that once a scheme begins operations, it can take three years to optimise the scheme for the catchment conditions, for wetlands to mature, to improve equipment specifications and to develop operator experience. Frequently, scheme harvest capacity may only reliably be identified following ten or more years of operation to balance out the commissioning phase and seasonal rainfall/runoff variability. Therefore it is too early to provide accurate estimates of the harvest capacity for many of the schemes in the Adelaide Metropolitan Area. To better illustrate this variability, the scheme harvest capacity is reported as a lower and upper range estimate based on normal operations.

1.1 Report outline

This report has four main sections:

1. **Timeline of MAR development**. This section provides a short history of MAR scheme development.
2. **Scheme descriptions**. This section provides a description of each scheme constructed during the past 30 years. The information has been captured through interviews and surveys with MAR scheme operators, senior industry figures and literature searches. The general information captured for each scheme is:
    - Location
    - Motivating factors for its construction
    - Description of wells and aquifer targeted
    - Native groundwater salinity
    - Source water and catchment description
    - Treatment systems
    - Estimated harvest capacity
    - Notable issues or constraints

    By necessity there is a degree of repetition across the scheme descriptions due to their similarities. Detailed technical information is not provided, as that information is only available in extensive design documentation for each scheme.
3. **Alternative water distribution**. This section provides an overview of the alternative water distribution pipelines constructed within the Adelaide Metropolitan Area and extending out into the major horticultural and viticultural districts north and south of the city.

4. **MAR optimisation opportunities**. This section summarises some factors that were noted by MAR scheme operators as limiting scheme performance and that if addressed, may improve scheme yield or economics.

Summary of aquifers used by MAR schemes in the Adelaide Metropolitan Area

There are four aquifers that are targeted by MAR schemes. A brief description of each is provided here to minimise repetition. Gerges (2006) contains more detailed information about the hydrogeology of the sedimentary aquifers beneath the Adelaide Plains.

- **Quaternary** – The Quaternary aquifers cover most of the Adelaide Plains. The main lithology of the Quaternary sediments is mottled clay and silt, however interbedded sand and gravel beds form aquifers, some of which are used to supply backyard wells.
- **T1 aquifer** – The Tertiary T1 aquifer is defined as the shallowest saturated and permeable Tertiary sediments intersected by wells, regardless of their stratigraphic unit. It can consist of several stratigraphic units which vary in lithology and thickness including the Carisbrooke Sand and the sandy-limestone Port Willunga Formation. This aquifer is located under most of the Adelaide Plains, excluding the north-eastern suburbs of Adelaide, between the city and Tea Tree Gully. It is generally confined to semi-confined. The Port Willunga Formation is also found in the McLaren Vale Region south of Adelaide.
- **T2 aquifer** – The Tertiary T2 aquifer is defined as the second zone of saturated and permeable Tertiary sediments intersected, regardless of their stratigraphic age. The T2 aquifer is overlain and confined by the Munno Para Clay, which is found in the Central and Northern Adelaide Plains. The lithology is usually a sandy-limestone of the Port Willunga Formation. Compared with the T1 aquifer, it has a tendency to contain more limestone and have more karstic characteristics.
- **Fractured rock aquifer** – The fractured rock aquifer underlies all other sedimentary units and outcrops in the surrounding Mount Lofty Ranges and southern hills. Within the Adelaide Plains, the fractured rock aquifer tends to be located at less than 50 metres (m) below ground level in the north-eastern areas of Adelaide, between the city and Tea Tree Gully. Outside of that area to the west of the city, it can often be 200 to 500 m below ground level.

2 Timeline of MAR development

2.1 Early developments (1950–89)

The recognition of MAR's potential to supplement Adelaide's water resources can be traced back to 1951. At the time it was proposed that mains water be directed to existing confined aquifer wells, during periods when Adelaide's reservoirs were full, storing low-salinity water for the dry times (Mason 1951). A motivating factor for this may have been declining aquifer pressures in Adelaide's confined aquifers in 1950–51, when up to 40 wells were used to augment mains supply with 6400 ML of groundwater. Subsequently in September 1951, a recharge trial was undertaken once the reservoirs were filled. A total of 230 ML was recharged to four wells over four weeks, causing nearby private wells to turn artesian (Mason 1952). Upon extraction, the low salinity of the recharge water was found to be retained and this pioneering trial of MAR in Adelaide was considered a success.

> *"We are definitely of the opinion that only good can result from the adoption of this procedure and therefore, the wisdom of artificially replenishing the basin from the mains when this can be done, without drawing on impounded water (i.e. when the reservoirs are overflowing), and at little cost, cannot be questioned."*
>
> (Mason 1952)

While the trial was a success, the scheme lacked demand as the rapidly urbanising Adelaide Plains were displacing market gardens, which in turn reduced extraction from the aquifers. In addition, more dams were planned for construction in the Adelaide Hills, further securing Adelaide's water supply. At the same time, the increased urbanisation of Adelaide was leading to the conversion of natural drainage lines to concrete culverts to dispose of stormwater as an unwanted waste product. The recognition of the value of urban stormwater and its potential for integration with aquifer recharge was described by another geologist at the then South Australian Department of Mines.

> "*…this concept that excess runoff is so much useless material which must be disposed of at all costs and as rapidly as possible by speeding its passage to the sea, is entirely wrong.*" Later continuing, "*I urge serious consideration be given to the possibilities of enhancing the intake into the aquifers by artificial recharge, using the excess runoff which is now being hustled out to sea.*"
>
> (Miles, 1952)

After a hiatus of investigations, the potential for MAR was considered in 1966 as a method to dispose of treated effluent from the yet to be constructed Bolivar Wastewater Treatment Works (Shepherd 1964, Hussin 1966, Shepherd 1966). This project considered the feasibility of recharging treated effluent throughout the year to meet the high seasonal demand of the horticultural irrigation in the Virginia Irrigation District, however an ocean outfall was eventually utilised for disposal. This concept is being revisited with the A$155 million Northern Adelaide Irrigation Scheme (NAIS) announced in 2017 (PIRSA 2017).

Despite recognition of its potential, there was little notable progress of MAR in metropolitan Adelaide during the 1970s and much of the 1980s. In 1975 a short injection trial was operated near the Gawler River using an irrigation well. Injection rates of around 9 L/s were achieved, however the trial highlighted the need for substantial infrastructure to treat turbid water from the Gawler River (Shepherd 1975). Outside of Adelaide, MAR was more successfully trialled in the rural Angas Bremer irrigation district near Lake Alexandrina during the 1980s (Cobb & Beal 1982). However, it was not until 1989 that Adelaide's first successful MAR scheme was established in the south-eastern suburbs.

2.2 Demonstration projects (1989–2000)

The first ongoing MAR scheme in Adelaide still operates today at Scotch College. Constructed in 1989, this simple but effective scheme took advantage of unexpected limitations in the local geology and its proximity to Brown Hill Creek to create a scheme that has operated for nearly 30 years. However, the scheme was not pre-planned, with MAR initially trialled due to the low sustainable yield of the well (Read 1989).

The integration of urban design into MAR has its infancy in small trial sites such as the Brompton Estate which was constructed in 1991. This scheme was small, sourcing water from roof runoff from 15 townhouses and recharging the shallow unconfined Quaternary aquifer. However, the installation of a pump to recover recharged water to irrigate the reserve did not occur as had been intended (Hopkins & Argue 1994, Barton & Argue 2007). Importantly though, this project pointed to the growing recognition of stormwater being a resource in Adelaide, and it was indicative of the innovative ideas being developed in South Australian universities and the former Department of Mines and Energy.

The first large-scale urban-integrated MAR scheme in Adelaide was constructed at Andrews Farm in 1993. The scheme was initially motivated by the Hickinbotham Group property development company which recognised the potential for the scheme to irrigate a "Bordeaux-style" green village development (Dillon et al. 2006). The proposal became a major research and demonstration project with Hickinbotham Group partnering with CSIRO, the Government of South Australia and the then Munno Para Council (now City of Playford) to deliver the scheme. This scheme proved the conceptual design that most of Adelaide's MAR schemes have since followed. Key design features include the large landscaped wetlands helping to cleanse the stormwater prior to injection while providing visual amenity within the residential development and assisting with detention of stormwater runoff volumes; heavily-developed injection wells targeting the confined Tertiary aquifers, and an alternative water or "purple-pipe" distribution main to supply recovered water to parks and gardens.

The success of the Andrews Farm model was rapidly repeated over the next ten years, particularly at existing stormwater detention wetland sites that existed in the City of Salisbury. The government also became involved in directly advancing some schemes initially through the Department of Mines and Energy and later though Catchment Water Management Boards that morphed into the current Adelaide and Mount Lofty Ranges Natural Resources Management Board. The scientific knowledge of MAR was significantly advanced during a pivotal research project established in 1997 at the Bolivar Wastewater Treatment Plant which investigated the practicalities and risks of MAR using the Tertiary sedimentary aquifers (Martin & Dillon 2005). This work became a foundation of scientific information from which a growing regulatory and policy framework for MAR was built. Guidelines on safely implementing MAR also started to become available (e.g. Pavelic et al. (1995)) which assisted the development of governance structures.

By 2000, the number of schemes in Adelaide had increased to 14 sites incorporating variations in design and capacity. The demonstrated success of many of these early projects was fortuitous timing as South Australia began to enter one of the worst droughts it had experienced since European settlement.

2.3 Millennium drought response (2001–17)

The millennium drought, a period of below average to very below-average rainfall between 2001 and 2009 in south-east Australia, had an extensive impact on South Australian and national water policy and infrastructure. South Australian towns and cities reliant on mains water supply were placed on Level 3 water restrictions from 2007 to late 2010. Level 3 restrictions prevented the use of garden sprinklers, washing of cars and boats, and the hand watering of gardens was restricted to one hour per day on certain days of the week. It became commonplace for residents to use buckets to collect water from their washing machines or showers to water their gardens. Many councils had to stop watering reserves, and active sporting ovals had restricted watering. Water security became a primary community and political concern. At the same time, the benefits and success of the early MAR schemes in northern Adelaide suburbs stood out, demonstrating their usefulness to avoid the impact of water restrictions on public reserves and school ovals.

In response to the drought, there was rapid growth in MAR research and MAR feasibility investigations, well beyond what can be captured here in detail.

Significant Australian Government financial assistance was made available to assist state government, NRM Board and Local Government initiatives. From this grew the 'Waterproofing' projects (Waterproofing the North/South/West/East) which supported multiple Local Government-led projects. The Salisbury aquifer storage, transfer and recovery (ASTR) trial even focused on converting stormwater into drinking water through natural filtration in wetlands and then the aquifer. During this period, the skill of the industry participants grew rapidly and now several South Australians are considered to be global leaders in the MAR industry.

In 2009 under the National Water Quality Management Strategy, the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) Managed Aquifer Recharge was published and are still the key document that South Australian regulators refer to with respect to MAR scheme development and approval.

During the period 2001 to 2017, the number of constructed schemes increased by a further 44 sites, and in addition, there were more sites that did not proceed after the investigation phase. The last of the projects whose funding can be traced back to the millennium drought response is the Felixstow Reserve (Waterproofing Eastern Adelaide) scheme which was commissioned in 2017. The conclusion of this phase of rapid expansion of the MAR industry is an opportune time to create an inventory of what has been built over the past 30 years.

The table listing all known MAR scheme and MAR trial sites is provided in Table 2-1, and shown in Figure 2-1. More detailed maps of schemes are provided in Section 7.

Table 2-1. An overview of MAR schemes constructed in the Adelaide metropolitan area

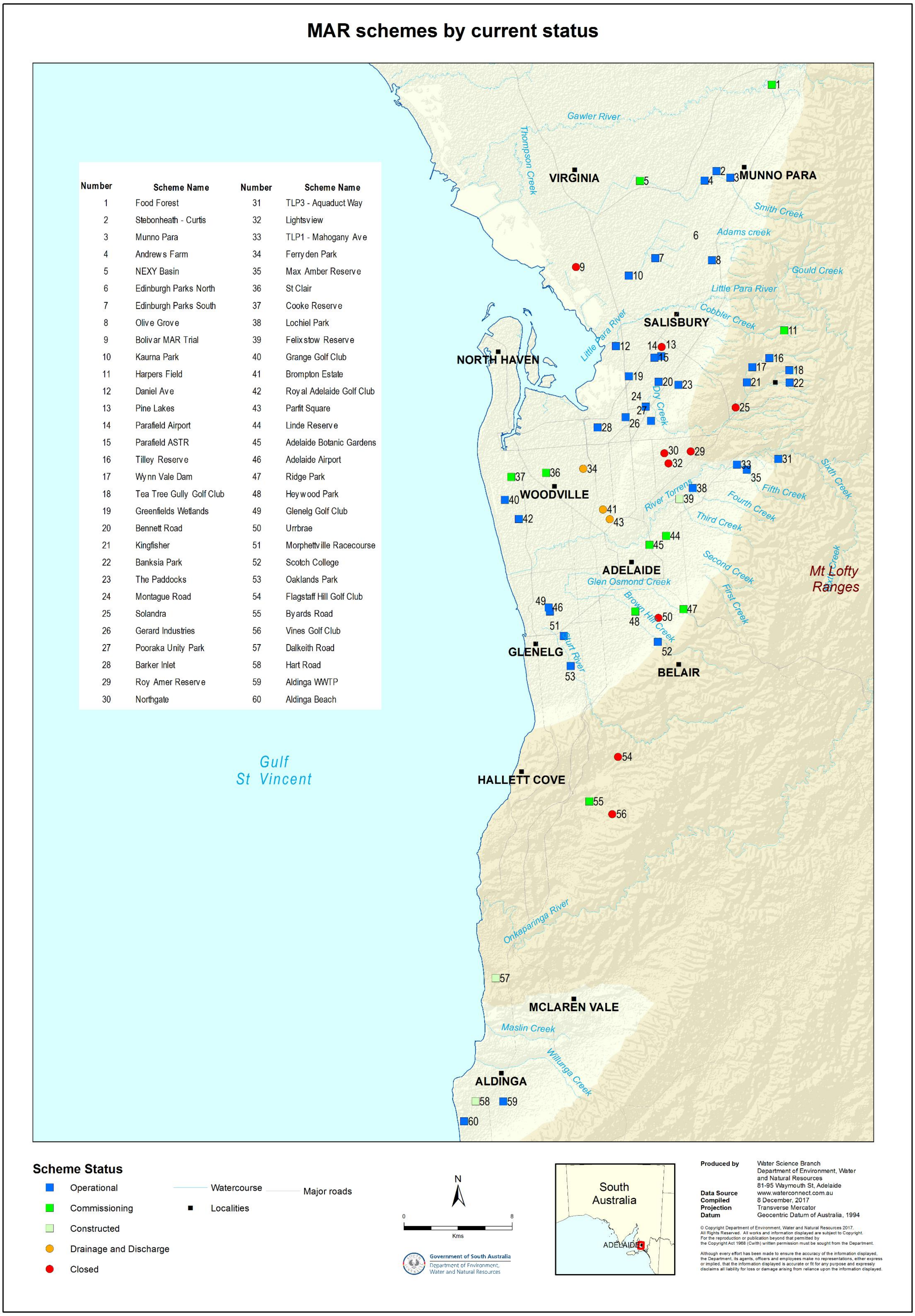
Scheme	Location	Status[1]	Easting[2]	Northing[2]	Source water[3]	Filtration[4]	Estimated harvest capacity[5] (ML/y)	Commence year	Closure year
Max Amber Reserve	Corner George St and Schulze Rd, Athelstone	Operational	289183	6139050	Fifth Creek	Particulate filter, UV	30 – 50	1997	
St Clair	Corner Torrens Rd and Cheltenham Parade, Cheltenham	Commissioning	274339	6138828	River Torrens, Stormwater	Settlement pond, wetland	600 – 1000	2015	
Cooke Reserve	Crown Tce, Royal Park	Commissioning	271759	6138523	River Torrens, Stormwater	Settlement pond, wetland	600 – 1000	2015	
Parfit Square	Drayton St, Bowden	Drainage only	279039	6135395	Roof runoff	Biofiltration	n/a	1995	
Brompton Estate	Francis Ridley Circuit, Brompton	Drainage only	278544	6136110	Roof runoff	Biofiltration	n/a	1993	
Oaklands Park	Oaklands Rd, Oaklands Park	Operational	276148	6124520	Sturt River	Gross pollutant trap, wetland, UV	200 – 500	2014	
Urrbrae	Cross Rd, Netherby	Closed	282643	6128084	Stormwater	Wetland, media filter	n/a	1999	2000
Linde Reserve	Nelson St, Stepney	Commissioning	283224	6134156	Second Creek	Biofiltration, particulate filter, UV	5 – 20	2012	
Acacia Terrace	Acacia Tce, Aldinga Beach	Operational	268271	6090833	Stormwater	Wetland	0.5 – 3	1998	
Dalkeith Road	Dalkeith Rd, Seaford Rise	Constructed	270612	6101428	Stormwater, Pedler Creek	Screen, wetland, particulate filter, UV	Not operating	2014	
Byards Road	Byards Rd, Reynella East	Commissioning	277541	6114504	Panalatinga and Glenloth creeks	Screen, wetland, particulate filter, UV	100 – 800	2015	
Hart Road	Corner Hart and Rowley rds, Aldinga Beach	Constructed	269122	6092313	Stormwater	Screen, wetland, particulate filter, UV	100 – 300	2015	
Munno Para	Corner Curtis Rd and Coventry rds, Munno Para	Operational	287957	6160666	Smith Creek, stormwater	Wetland	200 – 500	2010	
NEXY Basin	Corner of Short and Womma rds, Virginia	Commissioning	281282	6160425	Stormwater	Wetland, particulate filter	200 – 500	2016	
Olive Grove	Yorktown Rd, Elizabeth	Operational	286605	6154556	Stormwater, Adams Creek	Wetland	10 – 50	2010	
Stebonheath – Curtis	Corner Curtis Rd and Stebonheath Road, Munno Para West	Operational	286937	6161150	Smith Creek, stormwater	Wetland	100 – 300	2013	
Andrews Farm	Davoren Rd, Andrews Farm	Operational	286049	6160449	Smith Creek	Wetland	50 – 200	1993	

Scheme	Location	Status[1]	Easting[2]	Northing[2]	Source water[3]	Filtration[4]	Estimated harvest capacity[5] (ML/y)	Commence year	Closure year
Ferryden Park	Ferryden Park Reserve	Drainage only	277071	6139122	Stormwater	Passive lined trench, gravel, sand	n/a	2000	
Roy Amer Reserve	Sir Ross Smith Blvd, Oakden	Closed	285029	6140404	Stormwater	Wetland, UV	50 – 100	1993	2000
Northgate	Corner Dumfries Ave and Folland Ave, Northgate	Closed	283082	6140269	Stormwater	Wetland, UV	50 – 100	2000	2008
Lightsview	Waterford Circuit, Lightsview	Never completed	283387	6139522	Stormwater	Wetland built only	n/a	2006	2006
Kaurna Park	Waterloo Corner Rd, Burton	Operational	280449	6153410	Stormwater	Wetland	400 – 830	1998	
Parafield Airport	Parafield Airport, Parafield	Operational	282859	6147454	Parafield Airport west drain	Wetland	250 – 700	2003	
Pine Lakes ASR	Joseph Broadstock Reserve, Springwood Ave, Parafield Gardens	Closed	282888	6148129	Stormwater	Wetland	n/a	2004	2005
Unity Park	South Tce (near Alfred St), Pooraka	Operational	282099	6142666	Dry Creek, stormwater	Wetland	50 – 100	2004	
Bennett Road	Bennett Rd, Mawson Lakes	Operational	282660	6145551	Stormwater	Wetland	100 – 300	2011	
Daniel Avenue	Daniel Ave, Globe Derby Park	Operational	279501	6148189	Little Para River	Wetland	250 – 800	2013	
Edinburgh Parks North	East Ave, Edinburgh	Partially constructed	285240	6156388	Adams Creek	Wetland	n/a	n/a	
Edinburgh Parks South	Edinburgh Rd, Edinburgh Park	Operational	282405	6154711	Stormwater (RAAF drain)	Wetland	400 – 1000	2011	
Greenfields Wetlands	Salisbury Highway, Mawson Lakes	Operational	280459	6145968	Dry Creek, stormwater	Wetland	300 – 500	1996	
Montague Road	Montague Rd, Cavan	Operational	281698	6143707	Dry Creek, stormwater	Wetland	500 – 1000	2012	
The Paddocks	Corner Maxwell Rd and Bridge Rd, Para Hills West	Operational	284116	6145333	Stormwater	Wetland	50 – 100	1996	
Parafield ASTR	Parafield Gardens Oval, Parafield Gardens	Operational	282347	6147343	Parafield Airport west drain	Wetland	200 – 400	2006	
Wynn Vale Dam Scheme	Park Lake Dr (well locations: Wynn Vale Reserve (Jubilee Reserve), Tilley Reserve, Banksia Park, Satsuma	Operational	289584	6146642	Dry Creek, stormwater	Mechanical filtration, coagulation	10 – 100	2010	

Scheme	Location	Status[1]	Easting[2]	Northing[2]	Source water[3]	Filtration[4]	Estimated harvest capacity[5] (ML/y)	Commence year	Closure year
TLP1 – Mahogany Ave	Mahogany Ave (near Almond Ave), Dernancourt	Operational	288455	6139427	Torrens River, stormwater	Wetland, UV	10 – 30	2008	
TLP3 – Aquaduct Way	Aqueduct Way, Highbury	Operational	291507	6139846	Torrens River	Wetland, UV	10 – 25	2010	
Banksia Park	Petaringa Oval, Steventon Dr, Banksia Park	Operational	292345	6145500	Wynn Vale Dam	Mechanical filtration, coagulation	n/a	2010	
Tilley Reserve	Tilley Recreation Park, Yatala Vale Rd, Surrey Downs	Operational	290859	6147304	Wynn Vale Dam	Mechanical filtration, coagulation	20 – 50	2010	
Harpers Field	Harpers Field, One Tree Hill Rd, Golden Grove	Constructed	291961	6149350	Wynn Vale Dam	Mechanical filtration, coagulation	n/a	2017	
Kingfisher	Golden Grove Rd, Modbury Heights	Operational	289196	6145517	Stormwater	Mechanical filtration, coagulation	10 – 30	2007	
Solandra	Corner Solandra Way and Ladywood Rd, Modbury North	Closed	288351	6143659	Stormwater	n/a	n/a	2005	2009
Heywood Park	Northgate St, Unley Park	Commissioning	280941	6128570	Brown Hill Creek	Particulate filter, UV disinfection	10 – 35	2015	
Ridge Park	Barr-Smith Ave, Myrtle Bank	Commissioning	284493	6128737	Glen Osmond Creek	Biofiltration	10 – 60	2015	
Adelaide Botanic Gardens	Hackney Rd, Adelaide	Commissioning	281987	6133481	First Creek	Gross pollutant trap, settlement pond, wetland, filter 3µm	100 – 200	2014	
Flagstaff Hill Golf Club	Memford Way, Flagstaff Hill	Closed	279657	6117805	Stormwater	Unknown	n/a	2007	2010
Glenelg Golf Club	James Melrose Rd, Glenelg North	Operational	274613	6128566	Brown Hill Creek	Settlement pond, Wetland	100 – 300	2011	
Grange Golf Club	White Sands Dr, Seaton	Operational	271292	6136819	Stormwater	Settlement pond, Wetland	50 – 200	2009	
Royal Adelaide Golf Club	Tapleys Hill Rd, Seaton	Operational	272319	6135409	Stormwater	Settlement pond, Wetland	150 – 220	2009	
Morphettville Racecourse	Morphett Rd, Glengowrie	Operational	275652	6126748	Stormwater	Settlement pond, Wetland	100 – 350	2003	
Bolivar MAR Trial	Bolivar Wastewater Treatment Plant,	Closed	276540	6154046	Reclaimed water	Advanced WWTP	n/a	1999	2002

Scheme	Location	Status[1]	Easting[2]	Northing[2]	Source water[3]	Filtration[4]	Estimated harvest capacity[5] (ML/y)	Commence year	Closure year
	Bolivar								
Lochiel Park	Lochiel Parkway, Campbelltown	Operational	285182	6137692	Stormwater	Wetland, UV	10 – 65	2013	
Adelaide Airport	Adelaide Airport (south-side), James Melrose Rd, Novar Gardens	Operational	274522	6128858	Brown Hill Creek	Media filtration	100 – 350	2014	
Aldinga Reclaimed Water	Corner Colville Rd and Plains Rd, Aldinga	Operational	271164	6092296	Reclaimed water	Advanced WWTP	200 – 400	2009	
Barker Inlet	South Tce, Wingfield	Operational	278151	6142172	Stormwater (HEP drain)	Wetland	100 – 440	2014	
Scotch College	Carruth Rd and Blythewood Rd, Torrens Park	Operational	282598	6126308	Brown Hill Creek	Media filtration	10 – 50	1989	
Tea Tree Gully Golf Club	Hamilton Rd, Fairview Park	Operational	292333	6146412	Semi-rural stormwater	Detention dam, sand filter, UV	10 – 50	2001	
Vines Golf Club	Corner Pine Rd and Reynella Rd, Woodcroft	Operational	279234	6113569	Semi-rural stormwater	Settlement pond, passive lined trench	5 – 10	2001	2016
Gerard Industries	Corner Port Wakefield Rd and Cavan Rd, Dry Creek	Operational	280214	6142934	Roof runoff	Wetland	2 – 4	2009	
Waterproofing Eastern Adelaide	Scales Reserve, Felixstow	Under construction	284203	6136886	Third and Fourth creeks	Screen, settlement pond, biofiltration or wetland	Up to 494	2017	
Gawler Food Forest	80 Clifford Rd, Hillier	Commissioning	291010	6167538	Gawler River	Media filtration	Up to 30	2017	

1. Scheme status is not an official status, but a qualitative judgement based on how long the scheme has been operating, recent performance and reliability as judged by the author in 2016.
2. Eastings and northings are provided in Geocentric Datum Australia 1994, MGA zone 54.
3. Source water is a guide only based on numerous records. Not all individual schemes have been surveyed in detail.
4. Filtration is a guide only based on numerous records. Not all individual schemes have been surveyed in detail.
5. Estimated harvest capacity is based on the current operating (former for closed schemes) infrastructure and catchment development. See the break-out box in the Introduction for further information on scheme harvest capacity.



Number	Scheme Name	Number	Scheme Name
1	Food Forest	31	TLP3 - Aquaduct Way
2	Stebonheath - Curtis	32	Lightsview
3	Munno Para	33	TLP1 - Mahogany Ave
4	Andrews Farm	34	Ferryden Park
5	NEXY Basin	35	Max Amber Reserve
6	Edinburgh Parks North	36	St Clair
7	Edinburgh Parks South	37	Cooke Reserve
8	Olive Grove	38	Lochiel Park
9	Bolivar MAR Trial	39	Felixstow Reserve
10	Kaurna Park	40	Grange Golf Club
11	Harpers Field	41	Brompton Estate
12	Daniel Ave	42	Royal Adelaide Golf Club
13	Pine Lakes	43	Parfit Square
14	Parafield Airport	44	Linde Reserve
15	Parafield ASTR	45	Adelaide Botanic Gardens
16	Tilley Reserve	46	Adelaide Airport
17	Wynn Vale Dam	47	Ridge Park
18	Tea Tree Gully Golf Club	48	Heywood Park
19	Greenfields Wetlands	49	Glenelg Golf Club
20	Bennett Road	50	Urrbrae
21	Kingfisher	51	Morphettville Racecourse
22	Banksia Park	52	Scotch College
23	The Paddocks	53	Oaklands Park
24	Montague Road	54	Flagstaff Hill Golf Club
25	Solandra	55	Byards Road
26	Gerard Industries	56	Vines Golf Club
27	Pooraka Unity Park	57	Dalkeith Road
28	Barker Inlet	58	Hart Road
29	Roy Amer Reserve	59	Aldinga WWTP
30	Northgate	60	Aldinga Beach

Figure 2-1. Adelaide MAR sites by current status

3 Scheme descriptions

3.1 Golf Club schemes

Glenelg Golf Club

Glenelg Golf Club is an 18 hole golf course located on the southern-side of Adelaide Airport. Prior to the development of MAR, the golf course sourced most of its irrigation water from a combination of the T1 aquifer and treated water from the Glenelg WWTP. The salinity of the treated water from Glenelg was a concern and therefore the club looked at other source options. The MAR scheme commenced injection in 2011 and was integrated into an upgraded irrigation system. This scheme is unusual because it injects water into two separate aquifers. Of the three MAR wells, two target the T1 aquifer and one targets the T2 aquifer. The reason this came about is partly attributed to the fact that the Glenelg Golf Club straddles the Para Fault which has significantly offset the height of the Tertiary sediments. Notably the T2 well located south of the fault is 210 m deep and open between 150–210 m, which is not dissimilar in depth to the T1 well north of the fault which is 196 m deep and open between 155–196 m. The T2 well is able to yield approximately 13 L/s compared to 8– 9 L/s in each T1 well.

The scheme captures water from the Brown Hill Creek diversion drain located along the southern boundary of Adelaide Airport. The creek's large catchment maintains periods of steady stormwater flow which is captured to supply the scheme. Harvested stormwater initially flows into a gross pollutant trap, then a deep sedimentation pond, before flowing through two large biofiltration wetlands. The wetlands treat the stormwater to a standard sufficient to avoid clogging of the injection wells without any additional treatment such as media filters. European Carp have caused turbidity issues in the wetland but management methods have been developed to minimize this impact.

In recent years the scheme has injected in the order of 110 ML/y, with the maximum scheme capacity in a high rainfall year of the order of 200 ML/y. The scheme has provided higher water quality for irrigation and the wetlands provide significant aesthetic improvement to an unused area of the golf course. The scheme has been received positively by members and it contributes to the course's community acceptance as a valuable green space during drought cycles.

Grange Golf Club

Grange Golf Club is the largest irrigated area in north-western Adelaide, comprising two separate 18 hole golf courses. The golf club was fully reliant on groundwater from the T1 aquifer for irrigation but water security and increasing groundwater salinity was becoming a concern for turf maintenance. In 2009, a two-well MAR scheme targeting the T1 aquifer was constructed with a sedimentation pond and biofiltration wetlands to treat captured stormwater. One new injection well was drilled to 192 m with an open-hole completion from 174 to 192 m and an injection yield in the order of 15 L/s. The second injection well was a retrofitted 200 m deep irrigation well completed open-hole from 176 m. Despite the second well having a longer open interval, its yield is only around 7–8 L/s, illustrating the benefit of wells being purposely designed and developed for MAR.

The scheme captures urban runoff from a catchment extending east of the golf course. The biofiltration wetlands consist of an initial deep sedimentation pond and a large biofiltration pond which when combined, have an approximate seven day detention time. The wetlands have successfully treated the stormwater to avoid clogging of the injection wells without any additional treatment required.

The system has run intermittently during its first six years of operation due to major upgrades to the golf course. In its current configuration, the estimated annual maximum yield is in the order of 100 ML. Benefits of the scheme include reduced salinity of irrigation water, water security and positive recognition from club members.

Royal Adelaide Golf Club

Royal Adelaide Golf Club is an 18 hole golf course in north-western Adelaide. Similar to other large turf areas in the area, the golf club relied on the T1 aquifer for irrigation water. During the millennium drought water security and groundwater salinity were a concern so in 2009 a MAR scheme was constructed with two injection wells targeting the T1 aquifer. One new injection well was drilled to a depth of 201 m and completed open-hole from 176 m. The second injection well was a retrofitted 203 m deep irrigation well completed open-hole from 180 m. Both wells have injection yields in the order of 10–15 L/s.

The scheme captures urban runoff from a catchment to its east where residential housing is the dominant land use. Similar to Grange Golf Club, treatment occurs in a two-stage wetland system with an initial sedimentation pond followed by a set of four biofiltration wetlands. The wetlands have successfully treated the stormwater so as to avoid clogging of the injection wells without any additional treatment.

The MAR system at Royal Adelaide Golf Club has been successful at achieving its design harvest potential of approximately 200 ML, having been close to that volume in each of the past five years despite some particularly dry years.

Benefits of the scheme include reduced salinity of irrigation water, water security and positive recognition from club members. While no detailed economic study has been undertaken the club has found that the harvested stormwater is significantly cheaper to capture, inject and recover than potable mains water.

Tea Tree Gully Golf Club

The Tea Tree Gully Golf Club is an 18 hole golf course located in Fairview Park at the edge of the foothills in north-eastern Adelaide. The golf club irrigates the course with groundwater from a fractured rock aquifer as well as a small dam that captures runoff from a drainage line emanating from the hills. The scheme was constructed in 2000 when the golf course and the Tea Tree Gully Council trialled an injection scheme at the course. Motivating the trial was marginal native groundwater salinity ranging from 1100–1500 mg/L.

The scheme operates through a single 150 m deep well completed open-hole in the fractured rock aquifer. Surface water captured in the dam is treated through a media-filter and then UV treated prior to injection. The scheme did have some issues with elevated *E. coli* counts but following replacement of the media filters, this problem has been overcome. The scheme can inject water at around 7 L/s and has a maximum annual yield of around 50–60 ML/y.

The Vines Golf Club

The Vines Golf Club is an 18 hole golf course located at Woodcroft in the foothills south of the city. The golf course sources its irrigation water supply from a combination of surface water dams and groundwater. The dams, which also supplied the MAR scheme, capture water from local drainage lines including the Happy Valley Reservoir drainage diversion. In the early 2000s, the club established a small single-well gravity-fed MAR scheme to supplement its groundwater supply using overflow from the dams. The MAR well targeted a fractured rock aquifer which has a native salinity of around 1500 mg/L. The scheme ran only intermittently as the volume of water that spilled from the dams tended to be small and for short durations, with typical injection rates less than 10 ML/y. Water filtration was through a lined gravel-bed before flowing into the well under gravity. The scheme operated for around 15 years before formally closing in 2016.

3.2 Adelaide Botanic Gardens

The Adelaide Botanic Gardens scheme is located on Hackney Road adjacent the National Wine Centre. The scheme was initially proposed by the former Torrens Catchment Water Management Board following a waterways study in the early 2000s, with a decision made to proceed with the scheme during the millennium drought. The Botanic Gardens has a high-demand for low-salinity water and it was therefore dependent on mains water supply at a substantial cost. The scheme was constructed with two MAR wells completed open-hole in a fractured rock aquifer, one 130 m deep, the other 173 m deep. The native groundwater salinity is high at around 3000 mg/L which is unsuitable for long-term irrigation.

The scheme sources water from First Creek via an offtake in the concrete culvert. The water initially flows through a gross pollutant trap and then into a sedimentation pond before flowing through the biofiltration wetlands. Due to the scheme's location in the Botanic Gardens, there was significant landscaping of the wetland including rock-hopping areas for children to explore, an outdoor learning area and a glass wall on one side of a wetland pond. Following initial treatment via the wetland, the water is passed through a 3 μm mechanical inline filter before being pumped to the wells. The scheme has progressively improved its injection performance during the commissioning phase, increasing from 33 ML in 2014–15, to 75 ML in 2015–16 and 145 ML in 2016–17.

The scheme has overcome a number of difficulties through an optimisation process. Initially the wetland was found to leak which made it difficult to maintain sufficient flow of treated water to the wells. The scheme also had problems with large volumes of bulky gross pollutants from the catchment, in particular bricks from old underground drains and leaves from plane trees (*Platanaceae*) which are common street trees. The gross pollutant trap is possibly too small to cope with the high leaf load and consequently, the sedimentation pond is more heavily relied upon for trapping leaves. The leaves can also foul the offtake, leading to substantially diminished inflows unless the intake is manually cleared regularly. Improved performance over the past three years illustrates the importance of scheme optimisation which is common to most MAR schemes.

3.3 Morphettville Racecourse

The Morphettville Racecourse scheme was established in 2003 prior to the full-effects of the millennium drought being recognized. Therefore the scheme had different motivating factors for its construction compared to more recent schemes. In the 1990s, the South Australian Jockey Club was planning to upgrade the track by excavating clay from the middle of the course which could create a dam capable of storing water. Concurrently, issues surrounding water quality in the Patawalonga Estuary led the Patawalonga Catchment Water Management Board to seek locations where stormwater could be captured and treated before it flowed into the estuary. Through collaboration between the Board and the Jockey Club, a wetland in the centre of the track was constructed to treat up to 600 ML/y of stormwater to reduce nutrient and sediment loads in the Sturt River. This stormwater also had a lower salinity compared to the T1 aquifer groundwater they were currently using.

Treated stormwater from the wetland is directed to a two-well MAR scheme that was designed to harvest up to 350 ML/y. Excess treated water from the wetland is directed back into the catchment. One new MAR well was drilled on site to 75 m, targeting the T1 aquifer and completed open-hole between 38.5 m and 70 m. This well is high-yielding and is the main injection well. The second injection well is a retrofitted former irrigation well but has a yield of only about 25 percent of the newer well.

Water treatment for the MAR scheme is achieved entirely by the wetland. It consists of a deep sedimentation pond followed by large shallow biofiltration ponds separated by thin weir plates to avoid preferential flow through the ponds. The detention period for the wetland is in the order of five days.

Like most schemes, there were some early optimisation issues but now the fully established scheme is considered to be highly successful, with the project having improved the water quality used for turf irrigation and the quality of the water that does continue to flow through to the Patawalonga Estuary.

3.4 Urrbrae Wetlands

Urrbrae Wetlands are located on Cross Road within the grounds of Urrbrae High School. The site has had two unsuccessful attempts to establish an operating MAR scheme. A report on the key factors that led to the first failure was published to inform future schemes. These include: a fine-grained sandy aquifer that was prone to clogging, water quality that had an elevated level of suspended solids, sufficient bioavailable carbon to feed bacterial films and vandalism of the well (Pavelic et al. 2008). Other factors that contributed to the problem include the injection pumps were turned on immediately after wiring up the site, prior to filter equipment being commissioned, and the wetland design also supported algal growth due to its large deep pools (Professor Peter Dillon personal communication May 2016).

Another attempt to establish a MAR scheme was made in 2005 by installing two new injection wells which targeted shallow Quaternary sands rather than the deep Tertiary sand. The wells did not achieve a yield high enough to continue with the establishment of a scheme (Professor Peter Dillon personal communication May 2016).

3.5 Felixstow Reserve (Waterproofing Eastern Adelaide)

The Felixstow Reserve MAR scheme is under-construction at the time of writing. It is a large single-site MAR scheme connected to an alternative water distribution main supplying the eastern suburbs of Adelaide. The A$22.1 million scheme will be owned by the Eastern Regional Alliance which is a cooperative of three councils; the City of Burnside, the City of Norwood, Payneham and St Peters and the Town of Walkerville. It has been funded by these councils, the Australian Government and the Adelaide and Mount Lofty Ranges Natural Resources Management Board. The scheme has been planned with four injection wells targeting a fractured rock aquifer with a design harvest capacity of up to 494 ML/y. The scheme will source water from Third and Fourth Creeks just prior to their confluence with the River Torrens. The design includes a wetland and biofilter complex to be constructed in the reserve.

3.6 Scotch College

The Scotch College MAR scheme is Adelaide's first MAR scheme, commencing injection in 1989. The injection and recovery wells are located within Scotch College near the intersection of Old Belair Road and Blythewood Road in Torrens Park. The scheme was not pre-planned, rather it was a response to low productivity from their new 48 m deep irrigation well targeting the fractured rock aquifer. That well began to run dry in 1987 after barely one irrigation season. A second 150 m deep well was drilled in 1988 approximately 10 m away and following pump-testing, it was concluded that the heavily faulted zone they were located in had limited regional connectivity which would normally contribute to recovery of water levels after extraction. Artificial recharge from nearby Brown Hill Creek into the shallow well was suggested to both sustain aquifer yields and also to reduce the salinity of the native groundwater which was 2300 mg/L. In 1989, recharge into the shallow well commenced with extraction occurring from the deeper well. The design of the scheme makes it a pioneering Aquifer Recharge Transfer and Recovery (ASTR) scheme as well. Over time, the scheme reduced the salinity of the water extracted from the deeper well, with the peak seasonal salinity declining to around 1500 mg/L by 1995–96 when the last salinity data was collected.

Water treatment for the MAR scheme is a simple in-line screen filter at the offtake with the water then pumped to a settlement tank to reduce suspended solids. Water then flows into the injection well under gravity.

The scheme continues to operate with typical injection volumes between 40–60 ML/y.

Figure 3-1. Scotch College MAR scheme: The injection well is next to the shed, and extraction well in the foreground.

3.7 Food Forest

The Food Forest MAR scheme is located on Clifford Road, adjacent to the Gawler River at Hillier. The scheme has been constructed by a commercial irrigator. The scheme aims to store stormwater and a portion of their water entitlement from the Gawler River winter-flows in the aquifer, and recover it in summer, thus increasing the availability of low-salinity water for their irrigation needs. At the time of writing, the scheme was beginning its first trials with the goal to eventually recharge up to 30 ML/y. The scheme will use a 70 m deep well completed in the T1 aquifer.

3.8 City of Charles Sturt

St Clair and Cooke Reserve

The City of Charles Sturt's MAR schemes commenced injection in 2015. The scheme is spread over two sites with separate catchments, St Clair at Woodville, and Cooke Reserve at Royal Park with a target design harvest volume of 2400 ML/y.

The St Clair site has been integrated into a large new residential housing sub-division and consists of seven MAR wells which are completed in the T2 aquifer approximately 210–260 m below ground level. The wells in the T2 aquifer tend to have yields in the order of 20–30 L/s due to the semi-karstic nature of the aquifer. The two injection sites can harvest stormwater from two separate sources. Similar to many schemes, the immediate surrounding urban catchment is one source of stormwater, however, a notable feature for both sites is that water can also be sourced from the River Torrens approximately six kilometres away. This is achieved by pumping river water into the stormwater drains near the eastern end of Port Road, where it can be directed into either the St Clair or Cooke Reserve stormwater catchments and captured in the onsite wetlands.

The St Clair site has a large wetland complex with approximately five to seven days detention time at normal flow and injection rates. The wetlands have been extensively landscaped to become the central feature of the new residential housing estate, and has sedimentation basins at its north-eastern end from which the water enters and then flows into linear biofiltration ponds. An advanced control system is able to automatically control the rate at which water is delivered from the River Torrens depending on rainfall conditions in the urban catchment. The St Clair wetlands also provide an important secondary function as local flood control in an area that has historically been subject to localised flooding.

The Cooke Reserve site is similar to the St Clair site in many respects. It has six wells that are completed in the T2 aquifer approximately 210–260 m below ground level, again with yields in the order of 20–30 L/s. The biofiltration wetlands are located across Frederick Road along the edge of the West Lakes Golf Course.

The schemes are still in the commissioning phase. It is common during the first three years of scheme operation for an optimisation process to occur where equipment is modified to achieve the desired results. The operator reported that the wetlands are performing as desired, with the cleaned water typically having a turbidity of less than 6 NTU. This level of water clarity means that more expensive cleaning options such as media or mechanical filters are operated less frequently, which reduces operational costs. The operator indicated that in its current arrangement, the maximum harvest volume is likely to be around 1500–2000 ML/y.

Brompton Estate and Parfit Square

The Brompton Estate scheme is located in the reserve adjacent Francis Ridley Circuit in Brompton. Constructed in 1991, it was effectively an advanced local-scale water-sensitive urban design (WSUD) project, incorporated into a residential development that had MAR incorporated into its design. The project directed the roof runoff from 15 medium-density townhouses into a gravel filled stormwater retention trench installed in an adjacent reserve. Water was then directed from the gravel trench into a 30 m well completed in the Quaternary aquifer. A detailed description of the scheme is given in Hopkins and Argue (1994).

The intention of the design was to then recover the water and use it to irrigate the reserve, and testing at the time did illustrate this was possible. It is thought that this scheme was impacted by unwashed gravel being installed into the trench which contributed to well clogging in the early days of its operation. According to a review of WSUD projects in Adelaide, the local council did not fund the implementation of the pumping and irrigation component and therefore no water has been recovered from the aquifer. However, the infiltration and recharge components of the scheme have continued to function as intended (Myers et al. 2011).

The Parfitt Square scheme, located at the corner of Drayton and Fourteenth Streets in Bowden, was constructed in 1997. It was designed to treat, store and recover stormwater, similar to the Brompton Estate project, but for up to a 100-year ARI from 27 surrounding residential properties (Myers et al. 2011). The concept entailed all runoff being directed to a sedimentation tank, then through a gravel-based reed bed, and then over a 100 m grassed swale that overlies a gravel trench. It is this stage that provided the initial detention. At the end of the buried gravel trench are four wells with a screened upper-section left open to the gravel trench. Water would then drain from the gravel trench into the Quaternary aquifer. The infiltration component of the scheme continues to work successfully. The wells were found to still be in good condition following an inspection by City of Charles Sturt in 2016. As with the New Brompton Estate, the scheme was never fitted with pumps to recover water as had been intended. In this case, it was because water would flow away from the wells too quickly to be recovered (Barton and Argue 2007).

3.9 City of Marion

Oaklands Park

The Oaklands Park scheme has been constructed on the site of a former Department of Transport property adjacent the Sturt River on Oaklands Road at Marion. The scheme was first considered by the Patawalonga Catchment Water Management Board in the late 1990s, however the decision to build the scheme was made during the millennium drought when water restrictions had constrained the council's ability to maintain irrigation of public reserves. The scheme was originally proposed with six wells but it was completed with four wells to meet initial forecast demand. The scheme is located at the south-eastern extent of the Munno Para Clay which forms the aquitard that separates the T1 and T2 aquifers over most of the Adelaide Plains. Therefore despite having one of its wells penetrate though the Munno Para Clay, it is considered to be a "T1 aquifer" scheme rather than a T2 aquifer scheme. The wells vary between 97–108 m in depth and had open-hole completions below 65 m. Despite similar construction, the well yield varies between 3 L/s at one well to 12 L/s at two others.

The Oaklands Park scheme sources its water from Sturt Creek where it has been channelled into a concrete drain. The scheme can pump from the creek at around 50 L/s. The river has a large rural and urban catchment which can provide reasonable baseflow but it can have variable water quality depending on where the water is flowing from. Water is withdrawn from the river via a grated sump cut into the concrete bottom of the drain. A benefit of drawing water from a sump is it can reduce bulk pollutants floating on the surface. The water then passes through a gross pollutant trap into a deep sedimentation pond before passing into the large landscaped biofiltration wetlands. The wetlands detain the water for approximately three days while the turbidity is reduced.

The scheme is still in the commissioning phase and the wetlands are still maturing. The first injection of around 15 ML occurred in 2014, followed by over 80 ML in 2015. When the scheme was inspected in 2016, it was injecting water at around 30 L/s.

3.10 City of Norwood, Payneham and St Peters

Linde Reserve

Linde Reserve scheme is located along Nelson Street in Stepney. The scheme is intended to supply irrigation water for the reserve, as well as supply a community garden and several public fountains. The decision to build the scheme was made during the millennium drought when water restrictions were constraining the council's ability to irrigate public reserves. The scheme is sited along the northern edge of the reserve and it has been designed to add an interesting ornamental feature within a small area. The attractiveness of the scheme's design led it to win several awards.

There is a single 168 m deep MAR well on the site which has been completed open-hole from 90 m in a fractured rock aquifer. Native groundwater salinity is approximately 1100 mg/L. The scheme operates by pumping water from Second Creek alternatively onto one of two vertical biofiltration beds. Rather than working on the principle of horizontal flow through a conventional wetland, this is one of a small group of schemes that use vertical infiltration to cleanse the water of suspended material. The separation of the two reed beds are designed to improve their performance by allowing them to be rested and maintained separately. The water is then passed through disc filters and then UV treated prior to injection into the aquifer.

The scheme was designed to inject up to 30 ML/y but since the first injection in 2012, it has only been able to inject up to 10 ML/y. The performance of this scheme is constrained by episodes of high-turbidity in Second Creek, with preliminary investigations indicating suspended solids, particularly clay as the primary cause of the turbidity. The operator is currently working on developing a solution to reduce the impact of high-turbidity.

Figure 3-2. Lochiel Park MAR scheme: The vertical infiltration beds look similar to a standard garden bed (top), but a closer inspection reveals their purpose (bottom).

3.11 City of Onkaparinga

Acacia Terrace

The Acacia Terrace scheme is located at the intersection of Redgum Avenue and Acacia Terrace at Aldinga Beach. The scheme was small and no longer operates so there are few details available for it. The MAR well was drilled in November 1996 and completed in the Tertiary Port Willunga Formation. Earliest records indicate injection commencing in the 1998–2000 period, with maximum injection of around 2.7 ML in 2001. It continued to operate until 2004, injecting less than 1 ML each year, and it possibly ran on rare occasions through to 2011. The scheme collected water from a stormwater drain running along Boomerang Avenue into a small wetland. No additional treatment prior to injection was thought to be used. It is understood the purpose of the scheme was to maintain water in the wetland during summer. File notes indicate that it injected water when the wetland reached a set maximum level and if the wetland water level dropped below a minimum level, it would switch on the submersible pump and recover the injected water. The infrastructure for the scheme still exists in a small compound adjacent the wetland.

Byards Road

This scheme is located at Byards Road in Happy Valley. The scheme is unusual in two respects. Firstly unlike most of the schemes which are located on the Adelaide Plains, it is located in the southern hills zone; and secondly, the 800 ML design capacity makes it the largest fractured rock aquifer scheme in Adelaide. Construction was motivated by the millennium drought when the City of Onkaparinga was unable to irrigate many of its parks and ovals. There was a growing awareness of the need to make the city more sustainable which led to significant council support for the project. The scheme was built concurrently with an alternative water distribution network and the Dalkeith and Hart Road MAR schemes, as part of the 'Waterproofing the South' urban water-security project. The first injection occurred in 2016.

The scheme has eight wells, completed open-hole in a fractured rock aquifer that are between 73 and 188 m deep. The native groundwater salinity is between 2000 and 3400 mg/L, which is higher than what can be used for general irrigation. The scheme's source water is from Glenloth Creek and Byards Creek where they flow into a large, well landscaped wetland complex through initial coarse screening grills. Following initial treatment via sedimentation ponds and biofiltration in the wetland, the water is passed through a mechanical inline filter and UV treated prior to injection.

The scheme is undergoing commissioning trials and is encountering some difficulties. The operators are pursuing management techniques to improve the performance of the scheme during a trial-phase.

Hart Road

This scheme is located on the corner of Hart Road and Rowley Road at Aldinga and was built at the same time as the Byards Road scheme with the same objectives. The scheme has four wells, although only two are used for MAR at this stage. The two injection wells are 45 and 50 m deep, with open-hole completions in the Tertiary sandy limestone of the Port Willunga Formation. Notably, the first well drilled was backfilled from 84 m due to encountering unexpectedly saline water at depth. The scheme sources stormwater from the surrounding urban and rural catchment, and treats it through the wetland before the water is passed through a mechanical inline filter and UV treated prior to injection. The scheme has a designed harvest capacity of around 150 ML/y. Its first full year of operation was in 2015–16 when it was able to inject over 80 ML, despite being in its commissioning phase and experiencing below average rainfall conditions.

As part of the optimisation process, the operator is managing turbidity issues during high-flows and elevated salinity in the water recovered from the well that was backfilled to 50 m. An investigation into whether the cement plug had sunk further into the hole was being carried out at the time of the survey.

Dalkeith Road

The Dalkeith Road scheme is located adjacent Pedler Creek abutting Dalkeith Road at Seaford Rise. The scheme was constructed at the same time and with the same objectives as the Byards Road scheme. The scheme has seven wells which range in depth from 31 to 66 m with open-hole completions in a fractured rock aquifer. The proximity of the scheme to the sea is highlighted in the sharp groundwater-salinity transition, with salinities ranging from around 3000 mg/L to over 9000 mg/L across the site. Well yields vary from around 10 to 25 L/s, however some holes were effectively dry and were backfilled, which is typical of the variability of fractured rock aquifer environments.

Water treatment for the scheme is similar to the Byards Road scheme, however this scheme includes trash racks and a gross pollutant trap upstream of the wetland. It had been the intention of the original scheme design to harvest most of its water from Pedler Creek. It became apparent at a late stage in the scheme construction that this was not possible and this led to the wetland catchment area being limited to the small urban area to the east of the site. Currently, the catchment yields are insufficient for the scheme to operate and the operator is now investigating alternative sources of water.

3.12 City of Playford

Andrews Farm

Built in 1993, Andrews Farm is Adelaide's first urban-integrated MAR scheme. The scheme is located on Davoren Road at Andrews Farm where it was incorporated into a large new residential development. There were several motivating factors for building the scheme. In order to prevent flooding downstream from increased stormwater run-off due to urban development, a detention storage was required along Smith Creek. In addition, the native groundwater salinity of around 2000 mg/L made it unsuitable for irrigating public reserves in the new subdivisions (using mains water was a more costly option). Harvesting the increased runoff volumes, cleaning it in the detention storage and then storing it underground to create a freshwater resource had the capability to address these issues. The project went on to establish the MAR concepts that most schemes in Adelaide employ today.

The scheme initially had a research focus to prove the concept of aquifer storage and recovery. The scheme included one 125 m deep injection well with an open-hole completion in the T2 aquifer and three observation wells at varying distances to investigate water quality changes and pressure effects. The scheme now operates with two T2 aquifer wells each with a maximum yield of around 28 L/s. The wetlands that treat the water harvested from Smith Creek are large, being nearly 700 m long. Unlike some wetland projects built around the same time, they were specifically designed to improve water quality, with a lesser focus on ecological elements such as islands for bird roosting, which helped to minimise fouling issues. In addition to wetland treatment, the water is passed though mechanical and media filtration prior to injection. An upper estimate of what can be harvested from the urbanized catchment is around 350 ML/y.

The scheme continues to operate successfully today, however the wetlands have been upgraded over time and some wells are due for replacement to take advantage of improved well development techniques.

Olive Grove

The Olive Grove MAR scheme was constructed in 2007 and is located at Ridley Reserve in Elizabeth South. The scheme was the first constructed by the City of Playford without the large research-driven assistance that had accompanied Andrews Farm 14 years prior. The scheme was built as part of a new urban development and motivated by similar factors as the Munno Para scheme. The two injection wells targeting the T1 aquifer are around 140 m deep and have relatively low yields of around 5 L/s. The salinity of the native groundwater is around 2000 mg/L, making it unsuitable for general long-term irrigation. Attempts were made to further develop the wells to increase their yields but this was unsuccessful.

The MAR scheme captured water from Adams Creek which was treated via a wetland and an alum dosing plant. The scheme is now mothballed and the alum plant has been removed. This decision was reached due to a combination of factors, including a leaky wetland that reduced the scheme yield and the low well yields. When the scheme was operating, the injection volumes were typically small. No injection has occurred since 2011, however the wetlands still contribute to stormwater detention and local biodiversity.

Munno Para

The Munno Para MAR scheme was constructed in 2008–09 and is located on Curtis Road at Munno Para. Similar to Andrews Farm, it has been incorporated into a new urban development. The scheme was commissioned as part of a response to water restrictions during the millennium drought, as well as a need to build detention ponds for managing stormwater flows from the urban development. Native groundwater is unsuitable for the long-term irrigation of school ovals and reserves owing to its salinity of around 1700–2000 mg/L. The scheme operates with three high-yielding wells between 115–130 m deep with open-hole completions in the T2 aquifer. The scheme sources its water from Smith Creek. The 3000 ha catchment upstream of the scheme was roughly two-thirds rural and one-third urban when the scheme was constructed, however the urban portion would now be larger. Water treatment is via the wetland only. At times, sediment laden runoff from the urban areas under development has interrupted this scheme's ability to inject water but over time, this problem will abate as the catchment reaches its final urban development potential. The scheme as it has been completed, can harvest around 600 ML/y and it is considered to be a highly successful scheme by the operator. The operator also noted that as the catchment is further urbanized, runoff volumes will increase and therefore harvest volumes should also increase.

Stebonheath-Curtis

This scheme was constructed in 2012 and is located at the intersection of the Stebonheath and Curtis Roads. It is located one kilometre north-west of the Munno Para schemes, and it shares most of the same features including the water source and target aquifer. It has two wells that are 120 m deep completed open-hole. Again, water treatment is by a 2.6 ha wetland and similarly, sediment runoff from urban areas under development has been the only issue with the scheme. In 2016–17, the operator commenced first injection trials with water from the Virginia Pipeline Scheme which supplies treated effluent. The creation of a dual-supply aims to maximise the amount of water the scheme can harvest. Currently, the scheme's maximum harvest capacity is around 300 ML/y and the operator considers it to be a very successful scheme.

NEXY Basin

The NEXY (Northern Expressway) Basin MAR scheme was constructed in 2015 and is the City of Playford's newest scheme. It is located on Short Road at Penfield, within the Virginia Horticultural District. The development of NEXY was motivated by the need to increase supply to meet the demand on the City of Playford reticulation scheme. Interestingly, the water is not directly pumped from the scheme into the Playford alternative water main, but rather the water volume is transferred from the injection site and withdrawn from the T1 aquifer at Andrews Farm. This has environmental benefits as the injection site is near the Virginia Triangle cone of depression in the T2 aquifer potentiometric surface caused by extraction for horticulture, and the recovery is from a relatively under-utilized and slightly brackish area of the T1 aquifer.

The scheme sources water from Smith Creek, but at a location much further downstream from the other Playford schemes. Its catchment is therefore much larger and includes a sizeable portion of the horticultural district. Unlike City of Playford's other schemes, this scheme did not require wetlands to support flood detention capacity. As it is remote from residential housing, it also did not require extensive landscaping. Instead to reduce construction costs, this scheme has a basic rectangular sedimentation and storage basin covered with netting to exclude birds. Harvested water is then treated through mechanical filtration and media filtration. The scheme has three 126 m deep wells with open-hole completions in the T2 aquifer from 93 m depth. Well yields in this area can be very high and yields vary between 30 and 60 L/s. At this stage, the scheme only operates with one well. The other wells are not expected to come online until further urbanisation of the Smith Creek catchment results in increased yields from the creek.

3.13 City of Port Adelaide Enfield

Roy Amer Reserve

This scheme is located in Oakden, north-east of Adelaide. It was one of the earliest demonstration schemes built in Adelaide, being tested during 1992–93 by the then Department of Mines and Energy (Howles and Gerges 1993). It became operational in 1995 when 36 ML of stormwater was injected. The project development was supported by AVJennings, who was lead developer of the surrounding 77 ha subdivision. It is understood that the wetlands were required to detain stormwater from the new development due to the downstream stormwater infrastructure already being at full capacity. Similar to the Andrews Farm development of the same period, the wetlands were landscaped to be a major water feature for the housing development. The purpose of the MAR scheme was to supply water for irrigation of public reserves.

There are two 80 m deep wells drilled for the scheme, one being for stormwater injection and the other for observation purposes. The injection well has an open-hole completion from 45 m in fractured slates and quartzite and has a yield in the order of 15 L/s. Native salinity in the aquifer is around 2100–2600 mg/L making it too saline for long-term irrigation.

The scheme's wetland had to both detain and biofilter the stormwater. This is different to many schemes where the wetlands are located off-stream and are largely treatment systems only. The water was then drained through a filter into an underground pipe under gravity to the injection well. A control valve on the drainage pipe diverted water to the regional stormwater system if water quality did not meet specific parameters. The scheme is thought to have had a maximum design harvest capacity of 40–60 ML/y.

The wetland was one of the earlier designs and after several years of operations, issues began to develop. Yabbies eroded the banks, other fauna damaged the vegetation, carp became an issue and a flock of ibis established themselves on an island within the wetland. The issues led to problems with elevated turbidity and high *E. coli* counts which prevented injection. In 2004, the council undertook a study to improve the wetland performance and remediation works were completed in 2011. However since that time, the scheme has not been operational as it was not considered to be financially viable although the infrastructure remains in place.

Northgate

The Northgate MAR scheme is located on Folland Avenue at Northgate. Similar to Roy Amer Reserve, the scheme was developed by AVJennings as part of a large housing and commercial area subdivision. The project was constructed in 1999 with the first stormwater injection tests carried out in 2000. By this time, the profile of stormwater harvesting had increased and its inclusion into the development was heavily promoted in marketing material. The proposal was to supply the harvested water to homes, businesses and public reserves via a purple-pipe distribution main.

The scheme was constructed with one 94 m deep injection well completed open-hole from 42 m in a fractured rock aquifer. Native salinity in the aquifer is between 6500–6800 mg/L, which is the highest of any scheme attempted in Adelaide.

Stormwater is captured from a 70 ha urban catchment and is treated through three biofiltration wetlands plus a final lake which retained approximately four days injection volume. During 2001 and 2002, turbidity issues prevented injection from occurring. In 2003, the first operational injection of stormwater was achieved with 32 ML injected. Records of injection or extraction volumes from then on are unavailable, nor is there a record of recovery efficiency which would be of interest due to the brackish groundwater salinity. Records indicate that scheme monitoring and water treatment infrastructure such as media filters and UV treatment were upgraded in 2011 but shortly afterward, the scheme was mothballed as it was considered uneconomic to run. Turbidity was considered to be the main constraint to the successful operation of the scheme which was exacerbated by European Carp in the wetlands. It is understood that the Northgate purple-pipe main is now supplied by the City of Salisbury's alternative water network.

Lightsview

This scheme is located on Waterford Circuit at Lightsview. The scheme was mostly constructed in 2006–07, however it was never completed. A biofiltration wetland and three 90 m deep wells completed in the fractured rock aquifer (salinity around 4500 mg/L) remain at the site. The scheme was used to promote the water efficient credentials of the surrounding subdivision at the time, a theme that had particular value during the millennium drought when water restrictions were in place in Adelaide. A conversation with the site developer indicated that low-recovery efficiency was expected to be a problem with the scheme and a decision was taken to source water from the City of Salisbury' alternative water network instead.

Ferryden Park

The Ferryden Park project is a water sensitive urban design scheme aquifer recharge scheme, not dissimilar in principle to the City of Charles Sturt Parfit Square example, whereby water is infiltrated through a swale into a gravel trench and finally into a well. A key design difference is that it is never intended to recover the recharged water and for this reason it is a drainage-only scheme. This scheme is mentioned only to provide clarification of its purpose.

3.14 City of Unley

Heywood Park

Heywood Park is located in the residential suburb of Unley Park. Prior to the MAR scheme being developed, Heywood Park and several other reserves in the area were being irrigated with mains water. During the millennium drought, parks such as these were impacted by water restrictions which motivated the council to seek alternative water sources for irrigation. With the development of this scheme, an alternative water pipeline has been installed in the City of Unley so that MAR water can be distributed to the parks. The Heywood Park site was developed concurrently with the Ridge Park MAR site further east, however they supply separate ring-mains.

There are two MAR wells at the site which target a thin bed of T1 aquifer limestone approximately 50 m below ground level. The wells are screened to avoid fine material damaging the pumps during water recovery. Given the moderate size of the park, the common solution of installing a large wetland complex to treat water was not an option and instead, mechanical filtration has been relied upon. An interesting aspect of this scheme is how well the equipment has been hidden within the park. Water is captured from Brown Hill Creek at the western edge of the parks from where it is pumped to a 100 kL underground storage tank. The water is run through disc filters, a sand filter, and a microfiber filter before being UV treated prior to injection. This treatment system has been carefully packaged into the existing toilet block on the site which is a space similar to a small shipping container. Due to the low-yield of the two wells, the combined injection rate is in the order of 5 L/s.

First injection from the scheme occurred in 2015 and with ongoing optimization, it is expected to yield 20-30 ML/y in most years.

Ridge Park

Ridge Park is located near the eastern end of Glen Osmond Road at Myrtle Bank. Construction of the scheme commenced concurrently with the Heywood Park scheme, with a similar aim to reduce dependence on mains water irrigation. The scheme faced a challenge when the wells were drilled, when unexpectedly high artesian pressure was encountered at the top of the fractured rock aquifer at relatively shallow depths.

The scheme captures water from a detention dam constructed on Glen Osmond Creek. The water is then directed to a vertical infiltration biofilter basin before passing through a microfiber filter prior to injection. The scheme has two wells which have been constructed open-hole in the fractured rock aquifer.

The target harvest capacity for the scheme is in the order of 60 ML/y. At the time of meeting with the operator in 2016, it was in the early stages of commissioning and the vegetation in the vertical biofiltration system was still maturing.

Figure 3-3. Ridge Park vertical biofiltration bed: Water is pumped from the creek and is filtered as it percolates through the wetland bed. An injection well is contained in the grey-domed box.

3.15 Campbelltown City Council

Torrens Valley Sports Field

The Torrens Valley Sports Field MAR scheme, also known as the Max Amber Reserve scheme, is located at the corner of George Street and Schulze Road at Paradise. Prior to the MAR scheme being developed, the oval and soccer pitches were irrigated with groundwater from the fractured rock aquifer, but increasing salinity over time was causing a decline in turf quality. Fifth Creek flows through the reserve and it was identified as a potential source water in the mid-1990s to recharge the aquifer in order to reduce the pumped salinity. During 1997–98, the scheme commenced injection trials which successfully demonstrated that the well could receive recharge at a rate in the order of 12 L/s. The well is 91.5 m deep and has an open-hole completion below 44 m depth.

The scheme operates by harvesting a portion of flow from Fifth Creek into a detention tank from which it then directs water through a bulk pollutant screen filter, disc filter and it is then UV treated prior to injection. The compact treatment system has worked well with average injection volumes in the order of 40 ML and it has reduced extracted salinities to acceptable levels. However a notable limitation is that it only injects a volume approximately equivalent to irrigation demand during years of average rainfall. In low rainfall years, it tends to inject much less than irrigation demand which leaves little freshwater to be extracted during the following summer. Typical of many schemes, harvesting opportunities have been missed due to *E. coli* being detected in the water, although improved understanding of the causes of this has reduced the number of occurrences. On a positive note, it is recognised that there is scope to harvest more water and supply other reserves in the area as the scheme is currently intentionally limited to only harvest what is required at the sports field.

3.16 City of Salisbury

City of Salisbury is the largest owner-operator of MAR schemes in South Australia and was a pioneer in much of its commercial development. The council had a number of wetlands developed in the 1980s to detain and control floodwaters from increasing volumes of urban runoff and also to act as conservation spaces for wildlife. The wetlands were found to be successful at reducing pollutant loads in the stormwater and by the early 1990s, the opportunity to convert the treated stormwater into a water resource by using MAR was recognised. Since then, scheme development has progressed to the point where Salisbury now has a world renowned stormwater harvesting system. To explain its full complexity is beyond the scope of this report where only the simplified summary of the operation of each MAR scheme is presented.

The Paddocks

The Paddocks MAR scheme became the first scheme established in Salisbury in 1994–95. The Paddocks wetlands are located on Maxwell Road in Para Hills West. The scheme has a single 164 m deep MAR well with an open-hole completion in the T1 aquifer. Native salinity in the aquifer is around 1800 mg/L, which was too high for the long-term irrigation of parks and sporting grounds, and therefore MAR provided the opportunity to store fresher water that could be used for summer irrigation. The scheme was one of the early demonstration sites (along with Andrews Farm and Roy Amer Reserve), with research and development led by the then Department of Mines and Energy Resources. After initial trials with mains water, the scheme commenced trials with stormwater in 1996 (Gerges et al. 1997).

The scheme continues to operate. Stormwater is collected from an 80 ha urban-residential catchment extending to the south-east and directed into a sedimentation basin and then through two hectares of biofiltration wetlands before it is injected into the aquifer. The scheme has recharged up to 80 ML in a year, but is typically recharging between 55–65 ML/y. The scheme supplies the large alternative water main that extends throughout the City of Salisbury.

Greenfields Wetlands

The Greenfields Wetlands scheme was established in 1996 and is located on the eastern-side of Port Wakefield Road immediately north of Salisbury Highway at Mawson Lakes. The scheme was originally established with two 150 m deep wells completed open-hole in the T1 aquifer. The scheme was upgraded in 2009 with two additional injection wells. The large wetland complex has been expanded in multiple stages over the past 20 years. The catchment for the wetlands includes local urban development as well as a diversion from Dry Creek which has a large catchment that contains approximately 70 percent urban area. Water treatment consists of sedimentation basins and biofiltration in the wetlands. Native salinity is over 2000 mg/L and is therefore unsuitable for long-term irrigation. Typical injection volumes at the scheme are around 400–450 ML/y since the upgrades were made.

Kaurna Park

Kaurna Park was established by City of Salisbury in 1998 with first injection trials in 1999. The scheme is located on Waterloo Corner Road at Burton and consists of a 22 ha landscaped wetland area. The scheme was constructed to supply the expanding Salisbury alternative water main. The scheme currently has two 180 m deep wells completed open-hole in the T2 aquifer below 120 m depth. The native groundwater salinity is around 2500 mg/L and it is therefore unsuitable for long-term irrigation of parks and gardens.

The scheme harvests water from a drain that enters from the north. The catchment consists largely of partially developed industrial land and the RAAF Edinburgh Airbase, as well as minor residential development and horticulture. The water is treated through the large 40 ha wetland complex which has extensive landscaping as well as education signage educating visitors about the Aboriginal inhabitants of the region before European settlement. The treatment of harvested stormwater is via an initial sedimentation pond followed by biofiltration through the wetlands. Injection volumes varied between 100–250 ML/y prior to 2009, but following upgrades including a diversion from the Help Road drain and the construction of a detention basin at Edinburgh Parks North, the harvest volumes have doubled to around 400 ML/y. The scheme has been very successful however in 2016, the City of Salisbury temporarily switched off the scheme while an investigation was undertaken into potential water contamination concerns stemming from RAAF Edinburgh Base.

Parafield Airport

The Parafield Airport scheme is located on the western-side of the airport at Parafield, with the first injection occurring in 2002 and full operation commencing in 2003. The key motivating factors to build the scheme were to supply water to the industrial wool processor G.H. Michell and also supply a large expansion of Salisbury's alternative water supply network into the new Mawson Lakes residential and commercial development. The scheme has two 180–200 m deep high-yielding wells that are completed open-hole in the T2 aquifer. The native salinity in the aquifer was around 2000 mg/L making it unsuitable for long-term irrigation of parks and gardens.

Stormwater is captured from the Airport West Drain. Upgrades to catchment infrastructure in 2009 now allows the council to divert water from the Cobblers Creek Dam which gives it a catchment size in the order of 2600 ha. The treatment is achieved though the wetlands which are considered to be a particular success story for this scheme due to the high treatment efficiency relative to the space occupied. Due to the scheme's location on airport land that restricts public access, the wetlands were designed purely to treat water without the need to include aesthetically appealing landscaping. As a result, the wetlands consist of simple geometric shapes. Due to concern that the wetlands would attract birds and that would increase the risk of bird strikes with aircraft, the wetlands are also covered with netting to prevent bird access. The wetlands also supply treated water to the nearby Parafield ASTR site. The scheme is considered to be highly successful and over the past five years, it has injected between 350 to 400 ML each year.

Edinburgh Parks South

The Edinburgh South scheme is located on the inside of the southern boundary of the RAAF Edinburgh Base, near Edinburgh Road. The wells for the scheme were constructed in 2003, however it was not until 2011 that injection commenced following investment to complete the scheme as part of the Waterproofing the North project. The scheme has three 180 m deep MAR wells with open-hole completions in the T2 aquifer below 125 m depth. The native groundwater salinity at the site is around 1700 mg/L making it unsuitable for irrigating parks and gardens. The main inflows to the scheme are from the drain flowing in from the north, even though the main detention basin lies parallel to the Edinburgh drain. The catchment is around 3200 ha of partially developed industrial land, the RAAF Edinburgh Base, as well as a lesser portion of residential and horticultural areas further north. Flows are diverted from the drain into a 2 ha, 600 m long linear wetland to initially clean the water. The water is then detained in a 300 m long linear open pool covered with netting to prevent birds accessing the pool (a requirement to minimise bird strike). Flows to this wetland are assisted by detention in the wetland at the Edinburgh Parks North scheme. A smaller additional component of water is harvested from a wetland on the southern side on Edinburgh Road. Following treatment in the wetlands the water is then pumped into the three afore mentioned MAR wells.

The scheme has a design volume of around 1200 ML/y. In 2015–16, the scheme injected over 800 ML which is the largest volume of any scheme in Adelaide recorded that year. This harvest volume is notable given the below average rainfall experienced during that year.

Edinburgh Parks North

The Edinburgh Parks scheme is located on Bellchambers Road at Edinburgh North. The scheme has only been partially completed at this stage with two unequipped wells and the wetland having been constructed. The scheme will capture runoff from Adams Creek which is mainly a residential catchment to the east as well as a small industrial area. Currently the wetland helps to detain and clean flows from that catchment before they continue down the Edinburgh drain on the western side of the airbase into the wetlands for the Edinburgh Parks South scheme, or even further south into the Kaurna Park scheme wetlands. Unusually, the scheme has one well completed in the T1 aquifer and the other in the T2 aquifer.

Parafield ASTR

The Parafield Aquifer Storage Transfer and Recovery (ASTR) scheme was a research and demonstration project with the aim of converting stormwater into drinking water through injection, transfer through the aquifer and then subsequent recovery. The scheme is located on the western side of Main North Road opposite the Parafield Airport scheme. During the research phase, it consisted of a set of four injection wells and two central recovery wells, all around 180 m deep and completed open-hole in the T2 aquifer. The project began injecting in 2006–07 and initially aimed to flush brackish groundwater out of the aquifer between the injection and recovery wells. The source water was the Parafield Airport scheme wetlands. The project partners were City of Salisbury, Government of South Australia, Australian Government, United Water, SA Water, CSIRO and the European Union. The project did achieve its aim and produced bottled water called "Recharge" as part of promoting its success. The scientific learnings from the trial have been extensively reported on and published in peer reviewed journal papers. Since the end of the demonstration project, additional demand for Salisbury's alternative water led to the decision to modify it to run as a standard MAR scheme and now all six wells are used for injection. In recent years, the scheme has injected between 200–300 ML/y.

Unity Park and Montague Road

The Unity Park MAR site is the original component of this two site scheme, beginning operation in 2003 with a single well at Unity Park, Pooraka. A major expansion of the scheme was completed in 2013–14 adding a further nine wells to the scheme (five currently operated) along Montague Road with an underground pipe linking the two sites. The combined scheme supplies water to the City of Salisbury's alternative water mains network. All wells have been completed open-hole in the T2 aquifer and vary between 230–250 m deep. The differences in well yield are substantial between the two sites with the Unity Park well yield around 10 L/s compared to around 30 L/s from the wells on Montague Road, probably reflecting improved construction and development techniques. Native groundwater salinity in the area is around 1800 mg/L which made it unsuitable for long-term turf irrigation.

The scheme harvests water from Dry Creek, with a detention dam constructed in the creek to the east. The Dry Creek catchment is a large, predominately urban catchment with some extension into the rural areas of the Adelaide Hills. The large urban extent provides reliable runoff in response to most rainfall events and the online storage helps detain those flows to improve harvest volumes. The harvested water is transferred from the Dry Creek detention dam to a series of wetlands at Unity Park before flowing through a set of biofiltration beds and then being pumped to the wells. The original scheme was limited to between 50–150 ML/y, depending on rainfall. The expanded scheme is capable of exceeding 1000 ML injection in a year with good rainfall.

Bennett Road

The Bennett Road MAR scheme is located between the Mawson Lakes campus of the University of South Australia and the Mawson Lakes Golf Club. The scheme began operation with one well in 2011 and expanded to two wells in 2014. The scheme was commissioned in response to growing demand on the City of Salisbury's alternative water main network during the millennium drought with assistance from the Waterproofing the North project. Both wells are 210 m deep and have open-hole completions in the T2 aquifer from around 174 m. The salinity of the native groundwater is around 1600 mg/L which is generally above what can be applied to parks and gardens.

The scheme collects water from a 2000 ha catchment that is predominantly urban as well as the eastern side of Parafield Airport. The water is harvested from a low inline weir in the Bennett Road drain from which it is directed to a sedimentation pond and wetland. In its current configuration, the scheme can harvest around 350 ML/y in years with good rainfall.

Daniel Avenue

The Daniel Ave scheme is located at the Daniel Avenue Reserve on Ryans Road at Globe Derby Park, and first commenced injection in 2013. The scheme consists of six high-yielding 200 m deep wells that have been completed open-hole in the T2 aquifer from around 160 m depth. The native salinity at the site is in the order of

3500–4200 mg/L, making it one of the more saline sites in Adelaide to be developed for MAR. The scheme harvests water from long-established wetlands constructed adjacent the Little Para River which has a large catchment extending across the urbanised Adelaide Plains and into the Adelaide Hills. This makes it a potentially very-high yielding scheme if seasonal baseflow is maintained in the river. This is reflected in its design capacity which was targeted to be 1300 ML/y, the largest of all of the Salisbury schemes. Water treatment prior to injection is via sedimentation ponds and biofiltration through the wetland to the west of the reserve. In its first three years of operation, it achieved a maximum total injection of 450 ML (including a below average rainfall year) so during high-rainfall years, the scheme is likely to be able to achieve very large injection volumes.

Pine Lakes

The Pine Lakes scheme was located on Springwood Avenue in Parafield Gardens. It operated very briefly in the early 2000s before being closed as much larger and better designed schemes were being constructed by the City of Salisbury. The scheme consisted of a single well completed in the T2 aquifer and the catchment was a small local catchment surrounding a small wetland in the park. Another factor that led to its closure was the poor performance of the small wetland at improving water quality as it had attracted a resident population of ducks. The scheme closed in 2004.

3.17 City of Tea Tree Gully

The City of Tea Tree Gully has eight MAR sites, six of which are fully operating, one is in commissioning phase and one has closed. Related sites have been grouped together for simplicity of explanation.

Solandra

The Solandra MAR scheme operated between 2006–09. It harvested stormwater in a small wetland to treat it prior to injection into a fractured rock aquifer. The scheme was constrained by a low-yielding well which eventually led to the decision to close the scheme as injection volumes were less than 10 ML/y.

Kingfisher Reserve

The Kingfisher Reserve MAR scheme was the first scheme developed by the City of Tea Tree Gully with the first injection commencing in 2007 at the height of the millennium drought. Previously, mains water was used for the irrigation of sporting grounds in the area but water restrictions applied during the drought preventing this. In late 2005, two wells were drilled in the reserve, one for injection and the other for monitoring. The wells are 91 m deep and are completed open-hole in a fractured rock aquifer. Native groundwater salinity is in the order of 2200-2700 mg/L making it unsuitable for long-term irrigation of the reserves. The first injection occurred in the winter of 2007 with the intention to supply a single sporting ground but the scheme now supplies an alternative water main that transfers water to multiple reserves and school ovals.

The scheme sources water from the urban catchment to the east despite being located adjacent to Dry Creek. Water treatment for the scheme is achieved via a sedimentation pond, a three-pool biofiltration wetland, media filtration and UV treatment. Injection volumes have reached nearly 30 ML/y in good years but tend to average around 15–20 ML/y. Low well-yield limits the scheme capacity to some extent and consequently the scheme is not used for water banking.

Torrens Linear Parks 1 and 3

There are two Torrens Linear Park (TLP) sites; TLP 1 is located at Mahogany Avenue in Highbury, and TLP 3 is located near Historic Drive also in Highbury. Both sites are used to irrigate grassed reserve areas along the Torrens Linear Park. Native groundwater salinities at TLP 1 and TLP 3 are in the order of 1500 mg/L and 1400 mg/L respectively. Investigations of the potential for MAR in this area predate the Andrews Farm scheme, having been investigated in 1991 (Gerges 1991). During the millennium drought, the opportunity was available to build schemes to reduce reliance on costly mains water and avoid water restrictions.

While both schemes take water from the River Torrens, there are slight differences in their catchments. TLP 3 is located where the River Torrens exits the Torrens Gorge so its catchment land use is entirely rural. TLP 1 is located approximately four kilometres downstream and the suburban catchment therefore contributes a portion of the flow to the River Torrens. The injection well is 72 m deep at TLP 1 and 62 m deep at TLP 3 with both having open-hole completions in the fractured rock aquifer.

Both schemes operate with the same treatment system, starting with a small wetland to settle suspended solids followed by screen filtering and UV. TLP1 includes a trash-rack to capture coarse material from the urban catchment. The water is then injected into a single well at each site. Although the schemes can harvest more than 30 ML/y, typical injection volumes are in the order of 20 ML/y which reflects the summer irrigation demand. Turbidity has been the most difficult parameter to manage because it is required to be less than 5–10 NTU (depending on the device used) for the UV treatment to be effective. Clogging potential is occasionally raised as a concern for fractured rock aquifer recharge schemes but it has not been a problem at either site. Recovery efficiency of irrigation quality water has consistently been 100 percent of the injected water.

Figure 3-4. The wetland for TLP 1, located along the Torrens Linear Park

Wynn Vale Dam, Tilley Reserve and Banksia Park

The MAR sites at Wynn Vale Dam, Banksia Park and Tilley Reserve effectively operate as one scheme spread over three injection sites. Wynn Vale Dam is located in Wynn Vale, the Tilley Reserve injection site is located at the intersection of Yatala Vale Road and Hancock Road, and the Banksia Park injection site is located at the reserve on Haines Road. The three sites are all connected via an alternative water main that can transfer injection water from the treatment plant at Wynn Vale Dam to the three injection sites and then reverse the flow when the water is extracted. The schemes were commissioned to reduce the council's reliance on mains water due its increasing cost and water restrictions that were in force during the millennium drought. The dam itself was an existing piece of infrastructure and MAR opened up an opportunity to make better use of it for meeting the irrigation demands. Construction was spread over the period 2007–09 with injection commencing in 2010.

All three sites have wells targeting fractured rock aquifers and have open-hole completions. The well at Tilley Reserve is only 60 m deep, compared to 109 m at Banksia Park and 200 m at Wynn Vale Dam. The well at Banksia Park is the highest yielding site and accepts up to half the scheme's yield. Native groundwater salinity at the sites varies from 1100–1650 mg/L.

The Wynn Vale Dam captures water from a catchment that extends from the foothills to the urban residential area. It also includes a large extractive mineral zone (quarries) which do pose an issue for water turbidity during particularly wet periods. To manage this, the scheme uses an advanced water treatment system that includes the dam itself (settling), coagulation, media filtration and UV. The treatment is sufficient to allow the water to be used to irrigate both public reserves and school ovals. At present, the scheme has had highly variable injection volumes from year to year ranging from 50–100 ML/y. Now that the commissioning of the water treatment plant is complete, scheme yields are expected to be consistently higher.

Harpers Field

Harpers Field MAR scheme is the most recent scheme to be developed by the City of Tea Tree Gully, although first injection is not due to commence until 2017–18. It is located at the intersection of Golden Grove Road and One Tree Hill Road. The intention of the scheme is to replace potable mains water for irrigation of the two large ovals at Harpers Field as well as supply the City of Tea Tree Gully alternative water main. The scheme captures water from a catchment that is comprised of mainly rural land use in the foothills although a small portion of urban stormwater is captured at the bottom of the catchment. Water treatment is through a biofiltration wetland, media filtration and UV.

3.18 SA Water

Bolivar MAR Trial

The Bolivar Reclaimed Water MAR trial was run between 1999 and 2002 and was located inside the grounds of the Bolivar Wastewater Treatment Plant, towards the northern end of the site. The MAR trial was undertaken to determine the feasibility, economic viability and environmental sustainability of storing treated wastewater in the T2 aquifer that could then be recovered during the irrigation season to supply the Virginia Horticultural District. The advanced-treated water was sourced from the Bolivar dissolved air flotation/filtration plant which is still used to supply water for the Virginia Horticultural District via the Virginia Pipeline Scheme.

The trial operated a single 170 m deep well completed open-hole in the T2 aquifer. To observe the fate of the injected water and water chemistry, 17 monitoring wells were installed at various depths and distances from the injection well. Advanced geophysical logging, geochemistry analysis and modelling were used to understand how the water moved and changed its chemistry within the aquifer.

By global standards, the MAR trial was an advanced and complex project that contributed significantly to the knowledge and expertise in MAR that still exists in South Australia. There was significant collaboration between academia, industry and the government in operating the trial and many of the research outcomes have been compiled into a single document (see Dillon and Marin 2005).

Lochiel Park

The Lochiel Park scheme is located at the corner of Lochiel Parkway and Riverbank Circuit in Lochiel Park. The scheme was built in 2006 as part of an eco-village planned by Renewal SA and as this occurred during the millennium drought, water-sensitive urban design was given prominence. The development had a target of reducing potable water demand by 78 percent compared to the 2004 average residential use. The installation included an alternative water scheme to all homes for gardens, toilet flushing and washing machines. The scheme has a single 188 m deep MAR well targeting a fractured rock aquifer. The native groundwater salinity was 1350 mg/L, which is unsuitable for watering household gardens. The scheme has a design capacity of 65 ML/y, with local stormwater from within the development captured and treated in a circular wetland followed by UV and then injected. Recovered water is also treated with UV and then chlorinated.

The scheme has had numerous design and equipment issues which are now rectified. There have also been detections of some pesticides which have had to be traced to their source and eliminated. In 2015–16, the scheme injected 5 ML, increasing to 13 ML in 2016–17. In late 2016, SA Water completed further upgrades which are expected to significantly improve performance.

Figure 3-5. Lochiel Park MAR wetland is integrated into the development's water-sensitive urban design

Aldinga Reclaimed Water

The Aldinga Reclaimed Water scheme is located at the Aldinga Wastewater Treatment Plant on Plains Road near Aldinga. It is also located within the McLaren Vale region, which is one of Australia's major wine regions and this allows the scheme to supply large volumes of water for irrigation of vineyards. The motivation for the scheme was provision of an alternative source of irrigation water. Groundwater from the underlying Tertiary limestone aquifer was the primary source of irrigation water, however this resource was under stress due to high-demand. The native groundwater salinity at the treatment plant is around 2000 mg/L, which is too high for the long-term irrigation of vines.

The scheme has four injection wells which range between 69–81 m deep and are completed open-hole in the Tertiary aquifer, which is similar in lithology to the T1 aquifer on the Adelaide Plains. The injected water is sourced from the Christies Beach WWTP 18 km to the north because that plant treats the wastewater to a higher grade Class B standard, which is suitable for injection. The only additional processing at the Aldinga site is chlorination prior to injection. Because this scheme uses treated wastewater, there is a detailed monitoring program run by SA Water to monitor the movement of the injected water within the aquifer.

Injection first commenced in 2009 with volumes being variable over the years as various commissioning problems have been overcome. During 2015–16, 320 ML was injected which is approaching the scheme design capacity of 400 ML/y. One of the difficulties the scheme has experienced is the lower than expected well yield due to inappropriate well development methods used by the contractor. The salinity of the late-season recovered water has also been a limitation as the scheme has been required to extract 100% of what it injects, leaving no capacity to leave a low-salinity buffer in the aquifer.

Despite the problems experienced during development, this pioneering scheme has helped to alleviate demand on the groundwater resource, allowed the local vineyards to expand and also successfully converted treated effluent that would have been discharged to the sea into a productive resource.

Adelaide Airport

The Adelaide Airport scheme is located on James Melrose Road on the southern side of the airport. The scheme commenced injection in 2014 and similar to many schemes of the era, its construction was motivated by the millennium drought and the need to develop new water supplies for alternative water demand. The scheme has four wells which target the T2 aquifer and a designed injection capacity of around 300 ML/y. The wells are between 220–280 m deep and the native groundwater salinity varies significantly between 970–4300 mg/L. This salinity does increase with depth in some areas of the T2 aquifer which explains some of this variability, however this site is made more complex because it is dissected by the Para Fault.

The scheme sources water from Brown Hill Creek, which in that location has largely been constrained to a man-made concrete-lined drain. The creek has a large catchment extending to the hills resulting in good flows in wet years which can maintain high injection rates. The water is treated through vertical infiltration biofilters and sand filters. One problem the scheme has dealt with during commissioning was the biofilter was filled with unwashed sand which created turbidity problems until it was replaced. The scheme has only injected small volumes in the first two years because the intended customer did not use as much water as originally planned. However the scheme is now being used for irrigating turf trials on the airport grounds and the potential exists to connect into the Glenelg–Adelaide Parklands alternative water main if demand exists.

Barker Inlet

The Barker Inlet scheme is located north of Cormack Road at Wingfield, partially hidden behind warehouses. The scheme was built in response to the millennium drought. One of the reasons for SA Water's involvement in the scheme is that while the scheme can reduce demand for its potable water, it can also reduce the need to upgrade pipelines to supply increasing peak demand in the region. The scheme consists of four wells with a depth between 218–255 m, completed open-hole in the T2 aquifer from around 180 m depth. The native groundwater salinity at that location is around 3000 mg/L which made it unsuitable for irrigating parks and gardens. The scheme sources its water from the HEP (Hindmarsh, Enfield, Prospect) Drain where it flows north into the Barker Inlet. The catchment contains a mix of land use including residential, industrial, railway yards and a golf course. It is a long and thin catchment which commences at the North Adelaide Aquatic Centre. Interestingly, the scheme has trialled pumping water from the River Torrens into the top of the stormwater catchment to assess the potential for this to be an additional source of water for the scheme. According to the operator, the dry conditions prior to the trial meant that much of the water was lost in transit.

The scheme treats harvested stormwater in the wetland, however the operator notes that due to the presence of European Carp, the turbidity of the water can actually increase after entering the wetlands. Ongoing carp management and removal of gross pollutants are the main water quality issues the scheme has had to manage. After treatment, the water is injected into the wells and finally the water is treated with UV and chlorination prior to distribution. The scheme supplies an alternative water main that runs south into the City of Port Adelaide-Enfield. Injection commenced in 2014 and the scheme has been in a commissioning phase during the first two years, improving its yield as the wetland performance also improves. The scheme has a design harvest capacity of around 400 ML/y.

4 Alternative water distribution

A key component of the success of the Andrews Farm MAR scheme was that it was integrated with an alternative water distribution network to supply recovered water to irrigate nearby parks and reserves. This allowed the scheme to have a larger demand which helped justify the cost of the initial investment. The development of alternative water pipeline networks have rarely captured much attention in descriptions of Adelaide's MAR literature however it has required a large share of the total investment. There are more than 750 km of alternative water pipelines in the Adelaide metropolitan area and adjacent horticultural and viticultural districts north and south of the city. There are 15 network 'islands' (networks that operate independently of each other) with 12 separate owners.

This section contains an overview of both the alternative water distribution networks constructed for MAR schemes and the large treated wastewater schemes because of their increasing integration. For example, the Stebonheath-Curtis MAR scheme is now operating a trial using advanced treated wastewater as the source water for recharge during winter. This arrangement can be advantageous to increased scheme yields because the recharging infrastructure is otherwise unused once stormwater flows decline between rainfall events. There is growing interest within the industry in integrating the two supply sources to take advantage of their relative strengths, with wastewater being secure and steady in its supply and stormwater having low salinities.

Figure 4-2 shows the extent of all alternative schemes in the Adelaide Metropolitan Area. The map used a combination of data sources including spatial files and printed maps supplied by some network owners as well as maps found in published references. Therefore as a note of caution, the map should not be relied on having absolute accuracy and rather it is presented to inform the scale of the networks constructed.

SA Water owns the largest network and it does interconnect with some schemes (e.g. Willunga Basin Water Company) but not others even though they appear to overlap on the map (e.g. City of Unley and Waterproofing Eastern Adelaide). Nearly all of SA Water's alternative water network supplies treated wastewater, with the exception being the pipeline supplied by the Barker Inlet and Lochiel Park MAR schemes. The 135 km Virginia Pipeline Scheme supplies more than 400 horticultural customers (Trility 2017). This network is now the source of water for the trial at the Stebonheath-Curtis MAR scheme in the City of Playford, and similarly Bolivar treated effluent is a source for the MAR component of the Northern Adelaide Irrigation Scheme.

City of Salisbury has an advanced network that supplies reserves, schools, industry and some glasshouses in the Northern Adelaide Plains. In recent years, it also began to supply the Northgate and Lightsview residential and commercial developments in neighbouring City of Port Adelaide-Enfield.

The Waterproofing Eastern Adelaide network was still in the late stages of construction at the time of writing this report.

Figure 4-1. Alternative water supplies, indicated by purple pipes and fittings, irrigate many public reserves and gardens

Figure 4-2. Alternative water distribution networks in the Adelaide Metropolitan Area

5 Optimisation opportunities

Although the development of MAR infrastructure in Adelaide has been rapid and generally successful, the learnings from some schemes that have been less productive and the issues that forced some to close, should not be forgotten. The discussions with MAR scheme operators noted factors that had worked well for their schemes, but they also described factors that in some circumstances prevented their schemes reaching their full harvest potential. These factors are described below so that they may inform future research in the MAR industry.

Equipment specification

a) A recurring concern among operators was the installation of unsuitable or faulty mechanical components when the schemes were originally built. This frequently contributed to extended 'commissioning' periods that schemes experienced which were commonly up to three years. Examples of mechanical failures were diverse, including inappropriate water quality probes, undersized water treatment components, unsuitable corrosion prevention within components, and pump and pump-cable failures owing to the large pressure extremes between injecting and extracting. As an example of the need for appropriate equipment specification, one operator commented that the combination of trapped organic carbon and water within the mechanical filters, and extensive idle periods between injection periods, could leave some of their equipment exposed to carbonic-acid if not appropriately managed. That operator found that preventative management of this issue required extensive cleaning and maintenance that they had not initially planned for in their scheme design. Pump specification issues at another scheme had led to a costly replacement program.

Water quality

a) The water quality of the source stormwater for some schemes has been problematic. Turbidity stood out as an issue at several schemes because turbid water can increase water treatment costs or prevent injection. Elevated turbidity can also reduce the effectiveness of UV-treatment to kill pathogens. Several MAR operators noted that intense rainfall events contributed to elevated turbidity beyond what their scheme could treat, and therefore opportunities to harvest water were being lost.

b) Herbicide contamination in stormwater has led to lost harvest opportunities for some schemes and required additional expenditure to identify the source of contamination. In some cases, several persistent herbicides that are available to the general public have been the contaminant and it can be difficult to control their use in domestic gardens.

c) The Environment Protection Authority (EPA) applies a lower limit on the *E. coli* count permissible in injection water for fractured rock aquifer schemes compared with the limit for Tertiary aquifer schemes because there is limited information on the fate of pathogens when injected into fractured rock aquifers. Fractured rock aquifer schemes typically require UV-treatment to kill *E. coli* to meet their water quality licence conditions. For UV-treatment to be effective, very low turbidity levels are required, typically less than 10 NTU which can be difficult to achieve during high intensity rainfall events or if European Carp stir up the wetlands. As a consequence, schemes targeting the fractured rock aquifer are sensitive to elevated turbidity events. Tertiary aquifer schemes have benefited from earlier academic research into the fate of pathogens. For example, the fate of *E. coli* within the aquifer was a component of studies at the Bolivar Wastewater Treatment Plant trial site (Martin and Dillon 2005). That study showed *E. coli* to be a manageable risk which is applicable only to the Tertiary sandy limestone aquifers.

MAR operator training

a) It was common for MAR operators to have learned how to operate their scheme through experience and "trial and error". While the large multi-scheme operators usually have a dedicated role for the MAR operator, the smaller single-site schemes tended to have operators that had multiple jobs and little additional time to focus on further optimising their scheme's performance.

b) Limited time and training may contribute to some operators being unfamiliar with the Risk Monitoring and Management Plan(s) for their schemes.

c) Operators of new or smaller schemes may have little industry experience to identify which contractors are best skilled to optimise the different components of their scheme. This leaves them more exposed to trial and error when resolving issues.

d) Related to point c), no specific MAR-industry training for contractors who are designing, specifying or maintaining the engineering aspects of MAR schemes has been identified. This potentially contributes to sub-optimal equipment selection in some cases.

Governance

a) The issue of complex governance was raised by several operators who found it to be confusing and excessively time-consuming to manage. MAR schemes can require approvals and possibly reporting to the EPA, DEWNR, the Office of the Technical Regulator and the Essential Services Commission of South Australia. In addition some schemes seek a 'Letter of Comfort' from the SA Health as a mechanism to check that their operations do not pose an unacceptable risk to human health. DEWNR currently employs a MAR Case Manager who assists the navigation of scheme applications, and to align functions shared between the EPA and DEWNR. An outcome of this collaboration is that EPA and DEWNR have developed a 'Statement of Intent' which recognises the strategic linkages between both agencies and a shared desire to work together to assist the performance of the parties' respective roles in the regulation of MAR in South Australia.

b) The increasing number of schemes and improved scheme performance can have cumulative impacts on various water resources. Some operators expressed concern that their access to stormwater could be limited by other schemes targeting that same resource. The cumulative impacts of injection into confined aquifers by MAR and changing resource use in the Adelaide Plains can increase pressure levels can pose risks to third-party users when pressure levels become artesian. This issue needs to be managed jointly between multiple MAR schemes, DEWNR and the EPA. In addition, the cumulative impact of extraction of banked water during droughts may pose the risk of aquifer depressurisation or third-party impacts to existing users if not appropriately managed.

Scheme operation costs

a) While several schemes have been promoted for their low unit water-cost, a number of operators highlighted the costs were marginal with mains water. Many of the costs for MAR schemes are fixed asset maintenance and depreciation costs and therefore equipment failures can significantly increase the unit cost of water. Concern appeared to be highest amongst operators with schemes less than three years old, which generally indicates that the schemes are within the commissioning phase when replacement of sub-optimal components is apparently more frequent.

Alternative water distribution pipeline networks

a) As a result of developing the map of alternative water distribution pipeline networks, it is apparent that many of the networks are 'islanded'. There may be scope for some of these networks to be linked to increase the level of assurance that operators can offer customers in case a scheme suffered a major mechanical failure or significant contamination event within the stormwater catchment. Water-banking for drought resilience may also be assisted by improved tradability of alternative water supplies. This opportunity was not raised with MAR operators during discussions as the networks map was yet to be developed, nonetheless it appears to be an opportunity that warrants further investigation.

6 Conclusions

There have been 58 MAR schemes constructed in the Adelaide Metropolitan Area since 1989. These schemes range in size from small, single well operations with a harvest capacity of less than 10 ML/y, to large scale schemes with up to eight injection wells and major stormwater diversion infrastructure harvesting up to 1000 ML/y. In addition, hundreds of millions of dollars have been invested in 750 km of alternative water distribution pipelines to transport water from MAR schemes and wastewater treatment plants to areas of demand which include school ovals, public reserves, industry and private residential areas within the Adelaide metropolitan area, and large horticultural and viticultural areas to the north and south of the city. This demand has created a value for harvested water that would have otherwise flowed out to sea as stormwater or treated wastewater.

Discussions with MAR operators identified constraints to scheme performance (in terms of both yield and economic return) which could inform future investigation and research directions. These constraints included poor equipment specification, turbidity, pesticides, industry training and operational costs which have contributed to sub-optimal performance of their schemes at some point in time.

This overview of Adelaide’s MAR infrastructure can be used to identify opportunities to optimise schemes and further integrate them into a city-wide water management framework which could help Adelaide adapt to climate change and increasing demand for water. It is now 65 years since the idea of MAR was first raised in Adelaide and shown to be viable. The progress of MAR development reiterates that there are consistent drivers for reform of water resource management, including steadily increasing demand and the need for stormwater management. MAR is one solution to these drivers and it is hoped that the momentum of its development will continue in a future influenced by another driver in the form of climate change.

7 MAR scheme maps by sub-region

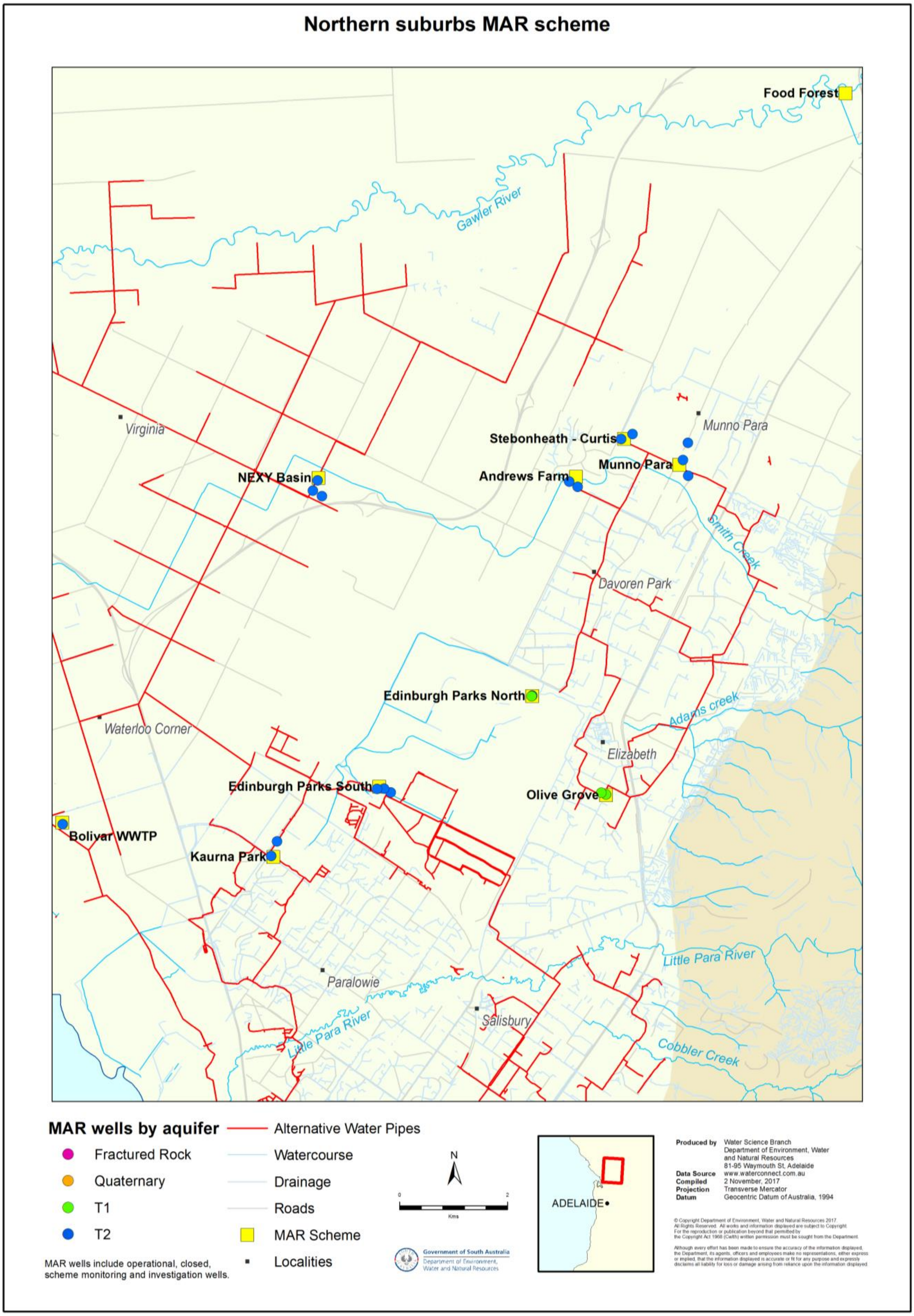


Figure 7-1. Northern suburbs MAR scheme sites and wells

Figure 7-2. North-western suburbs MAR scheme sites and wells

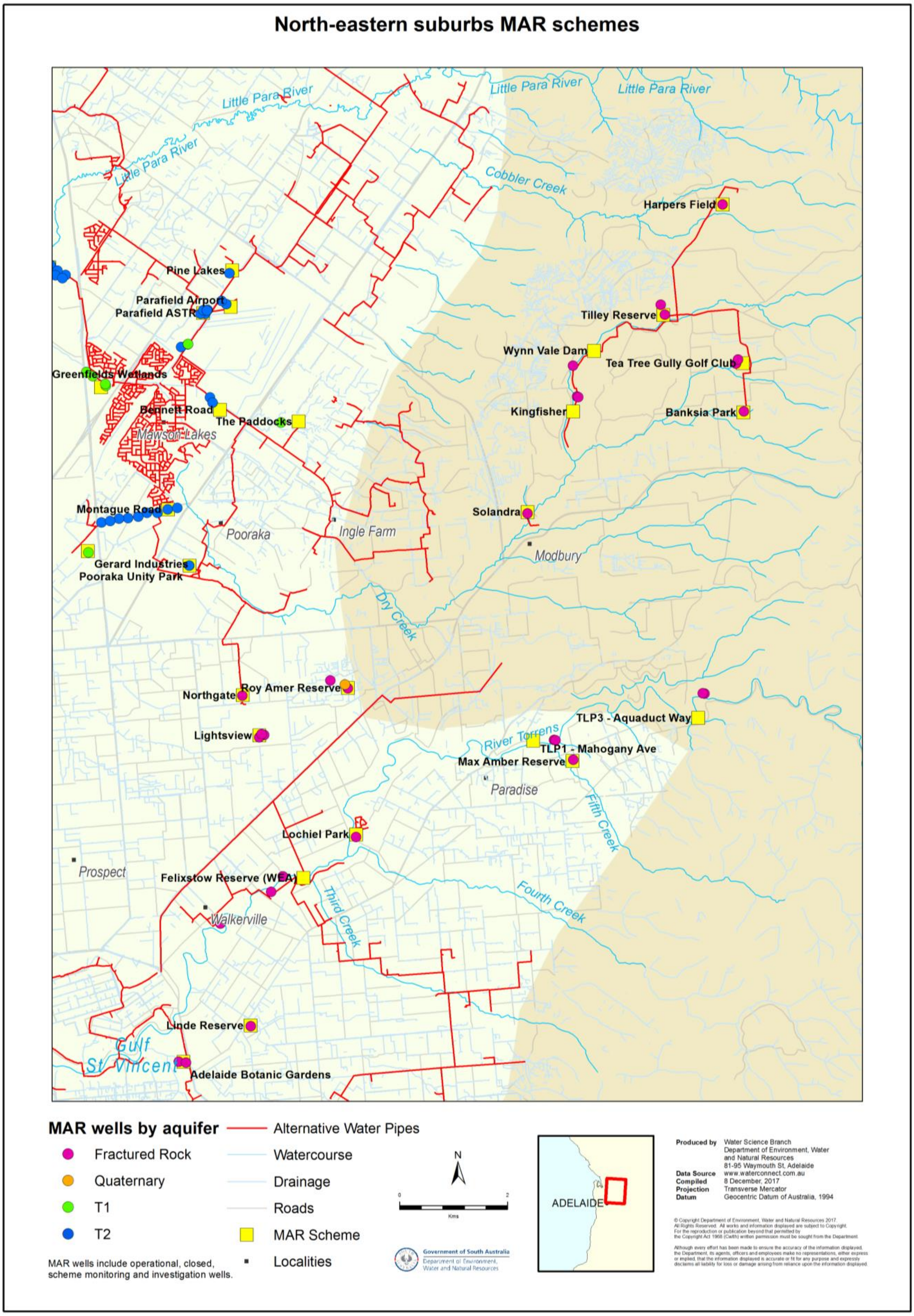


Figure 7-3. North-eastern suburbs MAR scheme sites and wells

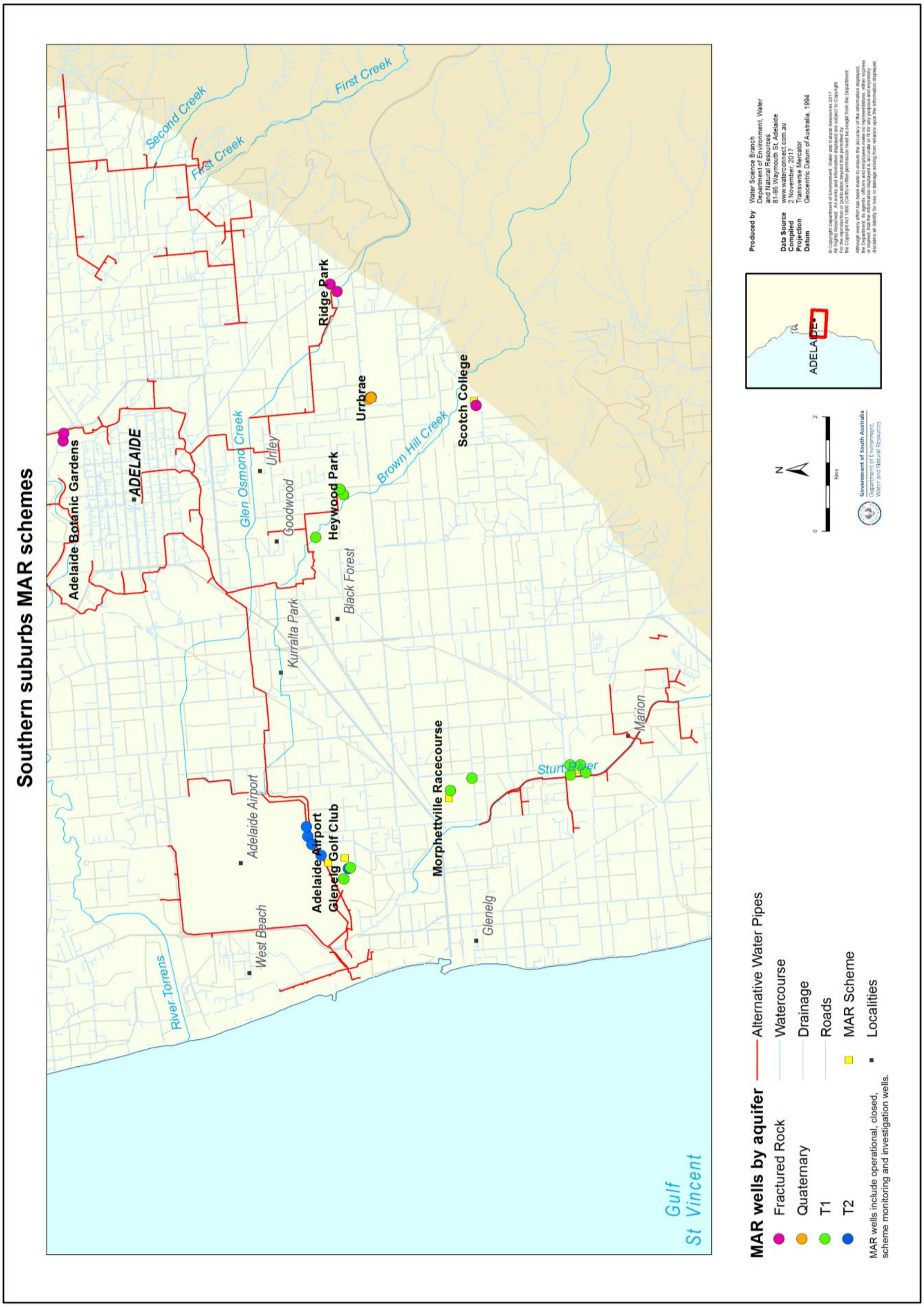


Figure 7-4. Southern suburbs MAR scheme sites and wells

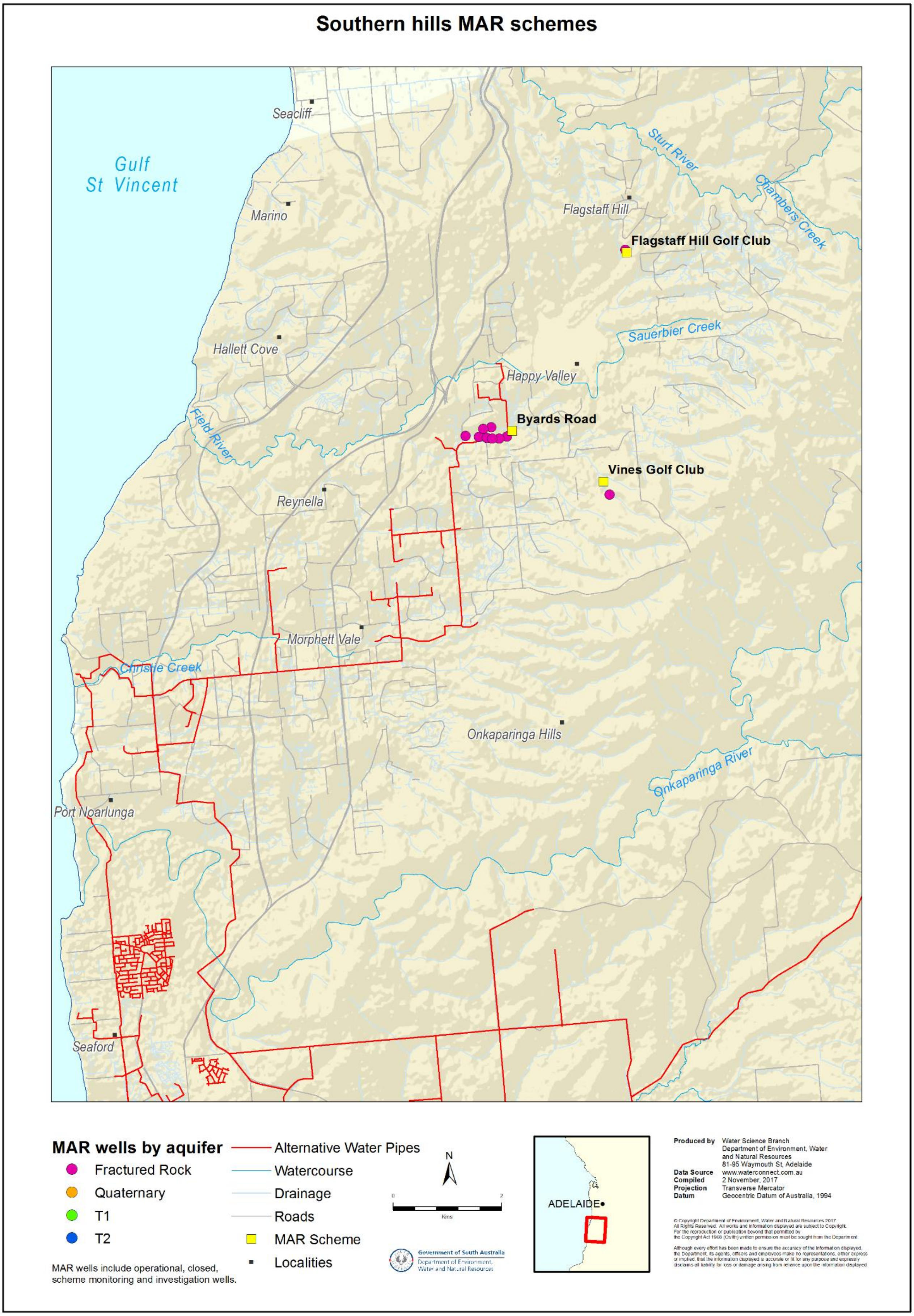


Figure 7-5. Southern hills MAR scheme sites and wells

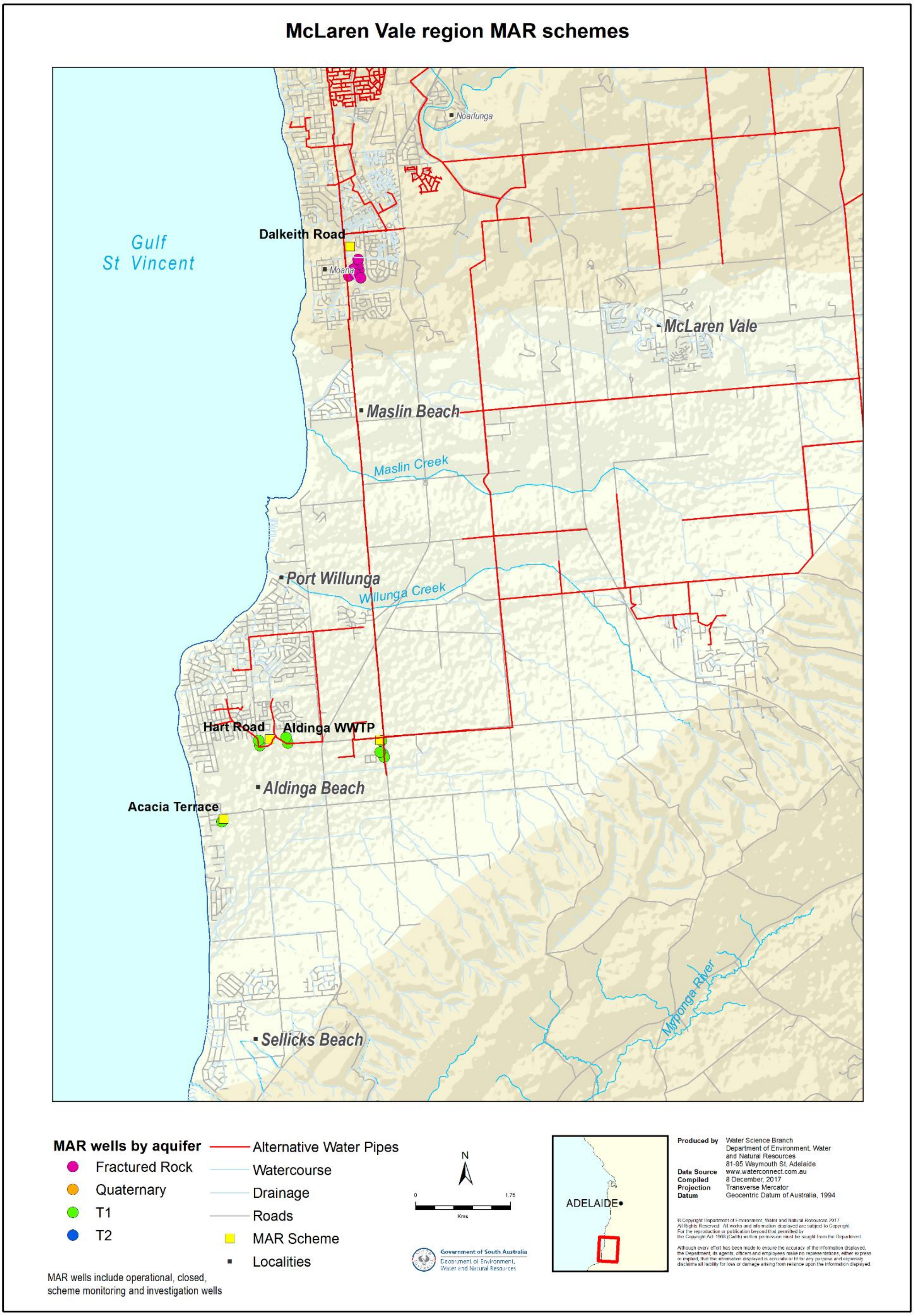


Figure 7-6. McLaren Vale region MAR scheme sites and wells

8 Units of measurement

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

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
hectare	ha	10^4 m^2	area
second	h	base unit	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

8.2 Shortened forms

ASR aquifer storage and recovery

ASTR aquifer storage, transfer and recovery

DEWNR Department of Environment, Water and Natural Resources

EPA Environment Protection Agency

MAR managed aquifer recharge

WSUD water sensitive urban design

NRM Natural Resources Management

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