Stocktake of Operating Stormwater Managed Aquifer Recharge Schemes in SA

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Stormwater Managed Aquifer Recharge (MAR) has been undertaken in South Australia SA for over 30 years with over 20 schemes now operating capturing, treating and reusing over 10 GL of stormwater per annum. Drivers supporting the growth of MAR have included state government initiatives to replenish aquifers and reduce stormwater flows to receiving waters, local government uptake (led by the City of Salisbury), aquifers conducive to storage and recovery, Australian Government water reforms and funding and the recent drought that raised the value of recycled water sources. This stocktake of operating schemes has been undertaken to gain an overview of the benefits, difficulties and management issues that have been experienced. The commonalities and differences between schemes are documented along with areas of outstanding need. The level of stormwater capture and water reuse has been examined and an assessment of water quality improvement and aquifer condition made. Capital costs can be significant although efficiently operating larger scale schemes can provide relatively low cost fit for purpose water. Most of the recent schemes have been undertaken with large injections of federal, state and local government funding. The viability of these schemes without seed funding has been explored. The

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development, construction and operation of MAR schemes in SA are regulated by up to five different pieces of legislation. Many issues have arisen as a result of this and much work has been done on streamlining the processes. The success of this process and the issues that remain are also to be documented.

I. Introduction

Managing Aquifer Recharge (MAR) has been undertaken in South Australia (SA) for over thirty years and has expanded rapidly over the last decade due to a number or key drivers. Initially promoted by State Government Agencies, followed by Australian Government initiatives to promote the use of recycled water, local government and private organisations using large quantities of groundwater or mains water took up the practice.

The adjacent northern suburb Cities of Salisbury, Playford and Tea Tree Gully have all embraced stormwater MAR installing a number of wells with extensive delivery networks providing "fit for purpose" water for their own irrigation purposes aiming to improve their sustainability and reduce their reliance on mains water. They are also providing this water to customers for non-potable use in industry and "third pipe" household systems.

The South Australian Jockey Club, based at the Morphettville Racecourse, the Royal Adelaide Golf Club, the Grange Golf Club and the Glenelg Golf Club have all installed MAR schemes to provide themselves with water for turf irrigation and reduce their demand on depleting natural groundwater. All seven of these operators have been running MAR schemes for at least 5 years and have amassed a wealth of experience and knowledge in their daily management and operations. Interviews were held with representatives from each of them and their collective experience is documented.

II. History

Initial schemes were established with the main aim to replenish depleted aquifers beneath the Adelaide plains that have been accessed for over 100 years to provide water for potable, industrial and irrigation uses. Large cones of depression and increased salinity resulted from this long term extraction and the collection, treatment and recharge of urban stormwater provided a source to replenish the aquifer with low salinity water. Utilising urban
stormwater had the added benefit of reducing the amount passing to the marine environment carrying loads of harmful pollutants. The wells installed were also trialed for aquifer storage and recovery (ASR) extracting the lower saline groundwater for irrigation and industrial use with a percentage (usually 20%) left in the aquifer.

The replenishment of aquifers was initiated by the Department for the Environment Water and Natural Resources (DEWNR) (in various previous permutations) and the trials were supported by the CSIRO who began a series of extensive research projects. The first of these was undertaken Andrew’s Farm in the City of Playford, between 1993 and 1998 providing five years of research which demonstrated that ASR could be successfully undertaken in the tertiary aquifers of the Northern Adelaide Plains (NAP). The City of Salisbury drilled their first ASR bore in 1994 and the ball had been set in motion. This activity was supported by the Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLR) (formerly four metropolitan Catchment Boards) as a major activity to reduce the amount of polluted urban stormwater. As part of significant water reforms the Australian Government established the National Water Initiative (NWI) in 2004 which promoted a range of water reforms including promoting the use of recycled water (stormwater, greywater and sewage). Support included research and development, development of guidelines and the funding of on-ground projects. The period of extended drought suffered across Australia at the end of the last decade further reinforced the value and reuse of recycled water.

A key outcome of the NWI was the development of the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks Phases 1 & 2 which included a volume in Phase 2 dedicated to MAR. All of the operators reviewed in this paper contributed funds to their schemes but they all benefited from Australian Government funding from the NWI and were also supported by State Government funding.

### III. Aquifer Systems

The plain on which the city of Adelaide is situated overlays an intracratonic sedimentary basin (Hodgkin 2004) that continues under the Gulf St Vincent. A number of sub-basins each with a mix of Quaternary, Tertiary sedimentary and fractured rock aquifers span beneath the plain. The Adelaide Sub-plains basin is the largest of these passing across the north western side of the basin. The Golden Grove Embayment is adjacent forming a
band passing to the South East. Further to the South East the foothills of the Mount Lofty Ranges rise and are underlain by a fractured rock aquifer system. The Adelaide Plains Sub-basin and the Golden Grove Embayment both contain a "layer cake" of Quaternary, Tertiary and Fractured rock aquifers. The upper tertiary aquifers labeled T1 and T2, consisting predominantly of limestone, sandstones and sands, have been the most productive for ground water extraction and provide the best targets for MAR. The Adelaide Plains Sub-basin tertiary aquifers are the most substantial and contain the vast majority of the aquifer bores examined in this paper. They dip from North to South and the T1 thins in to the North. Typical well depths required to access them are T1 80 to 100 metres and T2 150 to 250 metres.

The Adelaide Plains aquifer system has been proclaimed by DEWNR and is being prescribed to become the Adelaide Plains Prescribed Wells Area (APPWA) to control its use. A moratorium currently exists while the prescription process takes place and the Water Allocation Plan (WAP) is prepared. The northern area of the basin is known as the Northern Adelaide Plains (NAP) and was proclaimed and first prescribed in 1976 because of the intensive extraction undertaken for irrigation of market gardens that are located over this area. In 1997 the NAP evolved into the NAP Prescribed Wells Area (NAPPWA) and was prescribed in 2000 with a WAP in place. The APPWA now incorporates the NAPPWA together with the Kangaroo Creek PWA and the Dry Creek PWA, which was prescribed in 2008.

IV. Scheme Summaries

The City of Salisbury installed its first operating MAR scheme in 1994 at the Paddocks wetland adjacent to Maxwell Road, Para Hills. Prior to this through the 1970s and 1980s Salisbury began to install stormwater detention basins to assist with controlling flows and flooding. They soon realised the associated benefits of improved amenity, biodiversity value and the water quality improvement achievable from constructed wetlands. In 1997 Salisbury began industry trials using Paddocks MAR water, that lead to the construction in 2001 of the Parafield Airport Wetland and MAR scheme to capture stormwater, treat and store it to provide an alternative recycled water source, at a greatly reduced cost, for the Michell wool processing plant in Salisbury South. Salisbury continued their expansion and they now operate a total of 63 MAR wells (including ASR, Aquifer
Storage and Recovery and License Transfer wells). They have set up a business unit and operate as a recycled water retailer to local industry. The total capital cost of schemes is in the order $70 million. Salisbury has provided substantial funds and they have received funding assistance for some recent projects over the last ten years from the Australian and State Governments. Waterproofing Northern Adelaide (WNA) was one of these which saw the Cities of Salisbury, Playford and Tea Tree Gully collaborating to gain funding of over $40 million to support a number of separate projects in each city.

The City of Playford had the first MAR research site installed at Andrews Farm in 1993. Major expansion of MAR schemes began in 2007 from their involvement in WNA when they invested $28.6 million in a number of projects including an upgrade of Andrews Farm into what is now known as Stebonheath Park. Waterproofing Playford Stage 1 was born and encouraged by results achieved Playford sought further funding to assist with Waterproofing Playford Stage 2 to expand and link their network of MAR schemes while making their city more sustainable. They were successful and a further $22.6 million has been invested. Playford now has five MAR sites injecting water primarily into the T2 aquifer apart from the Olive Grove scheme on the western flank of the city that injects into T1 and fractured rock aquifers. Playford provides fit for purpose water for its own irrigation use and has commenced retailing recycled water to customers.

The City of Tea Tree Gully had delved into stormwater capture and MAR with the Solandra Reserve scheme but their involvement in WNA expanded the number of schemes and water reuse significantly. After an investment of $16 million they now have seven operating MAR wells all of which are utilising fractured rock aquifers. The recycled stormwater is used for council irrigation and Tea Tree Gully is also being sold to external customers.

The South Australian Jockey Club installed their MAR scheme at the Morphettville Racecourse as an initiative of the AMLR NRM Board (at the time the Patawalonga Catchment Water Management Board). The scheme was completed in 2002 at total cost was $2.4 million and its two wells access the T1 aquifer. The racecourse is now fully self-sufficient for using only recycled stormwater for irrigation.
Following the success of Morphettville the AMLR NRM Board went on to support schemes at the Royal Adelaide, Grange and Glenelg Golf Clubs. Funding assistance was also provided by the Australian Government and a total of $6.5 million was invested ($2.35 million each from the Australian and State Governments and $1.8 million from the clubs) across the three schemes. Royal Adelaide accesses the T2 aquifer, Grange the T1 aquifer and Glenelg accesses both T1 and T2. Royal Adelaide and Glenelg are reaching increasing levels of self-sufficiency utilising recycled stormwater while Grange still has some way to go because of operational difficulties.

Figure 1. Scheme localities
V. Stocktake Process

The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) Managed Aquifer Recharge* (AGWR MAR) separate MAR schemes into seven phases that provide a convenient way to plan, design, examine and review them.

![Figure 2. Schematic of the phases of an MAR scheme. Source: AGWR MAR](image)

These seven phases provided a focal point for a series of questions that were put to key operators of the MAR schemes examined. To simplify the process phases 3 (Recharge), 4 (Subsurface storage) and 5 (Recovery) were grouped as were 6 (Post treatment) and 7 (End use). Operators with more than one scheme had the choice of providing answers to one or grouping them and all multiple schemes operators chose to group them.

VI. Survey Outcomes

A. Capture zone

All of the schemes are sourcing urban stormwater collected directly from residential, industrial and open space suburban stormwater pipe systems, channels and creeks that receive this water. The cities of Salisbury, Playford
and Tea Tree Gully also access creeks that originate in the foothills of the Mount Lofty Ranges and Tea Tree Gully sources water from the River Torrens.

The proximity of collection basins to local residents has meant that an ongoing dialogue needs to be maintained by most operators. Mosquitos are a common concern to many residents particularly in the early life of a wetland although they have not manifested themselves. RAGC installed a snake proof fence to alleviate the concerns of their neighbours. Maintenance of basins needs to be undertaken ensuring that disturbance (i.e. noise, dust, odor) are minimised.

Operators with sensors installed at intakes invariably encountered them being fouled or damaged and needed to mount them at a place in the intake that minimises the chance of being damaged. Some operators have had problems with the operation and control of intake pumps. Others reported pumps being fouled and even damaged by trash and organic matter that was not removed prior to reaching the pump.

Generally the quality of the source water was rated as "fair to good" quality, by the majority of operators, particularly when sourced from established areas. The common major pollutants are trash, organic matter, sediment and turbidity and all operators need to conduct routine maintenance to clear grates, trash racks and gross pollutant traps (GPTs) in readiness for storm events. In some cases sediment and turbidity is caused by the colloidal nature of the stream beds from where the water flows but the most common source by far is sediment from construction and building sites. This is predominantly due to the "greenfield" suburban development such as what is occurring in the north eastern section of the City of Playford.

It was most operators view that mid-winter rains provided the best quality source water compared to the storm flows that occur in summer that pick up debris and sediment that has collected in stormwater systems. However Tea Tree Gully experiences sediment loads at some sites that sporadically have significant impacts on operational performance. These are washed down the catchment from upstream sources and are exacerbated during intense rain events when they avoid harvesting water. Tea Tree Gully experiences highly variable and regularly low dissolved oxygen levels less than 6 mg/L in source water.
The Mophettville scheme continues to be challenged annually by the detection of Simazine in inlets in early spring. Simazine is an early emergent herbicide which is strictly controlled in many parts of the world but is available for domestic use in Australia. When it is detected water is not pumped to the wetland.

While many schemes (particularly the most recent) were constructed with an objective of removing polluted stormwater from passing to the marine environment some older schemes are operated to avoid capturing the most polluted first flush water.

B. Pretreatment

Most of the schemes reviewed employ a similar wetland based treatment system typically comprising a gross pollution trap (GPT), sedimentation basin and treatment wetland basin/s. Where persistent turbidity issues exist media filtration units have been installed. At its Olive Grove scheme the City of Playford has installed a small flocculation plant site to assist to reduce sediment and turbidity before the water passes to the wetland. They have also constructed a fully automated mechanical system at the Northern Expressway collection basin to treat water prior to injection. The City of Salisbury has constructed gravity biofilters to supplement constructed wetlands at its Unity Park site, designed to increase the volume treated per unit land area.

Some schemes like those in the City of Tea Tree Gully that are injecting into fractured rock aquifers have been required, as part of their EPA license conditions, to install ultraviolet (UV) filtration systems to ensure pathogens are removed prior to injection. This is due to the hydraulic uncertainty of fractured rock aquifers which creates the risk that another aquifer user could unknowingly have direct access to this injected water.

All the operators reported that they were able to produce water of a good consistent level of water quality suitable for recharge to aquifers once treatment systems were established, properly maintained and testing equipment remains in place. Although they all discussed early difficulties and sharp learning curves before gaining the knowledge and experience they now have in operating their schemes.

During commissioning and the first injection years of schemes a number of unforeseen issues have arisen that have needed to be dealt with to maintain consistent water quality. Salinity problems in wetlands occurred at a number of systems established during the drought years in SA when highly saline groundwater was used to
maintain early reed and vegetation growth. When the wetlands were finally filled the salt stored in the soils passed back into the water sharply increasing its salinity.

The treatment systems require a varying level of maintenance to maintain the efficiency of the system. As already discussed GPTs need to be cleaned frequently and sedimentation basins require periodic de-silting. When the sediment needs to be removed depended greatly on the amount that is carried by the source water and the size of the basin but cleaning times range from 5 to 10 years. The biggest challenge for sediment removal is whether a dedicated sedimentation basin with easy access for heavy machinery has been built into the scheme or whether aesthetic design has prevailed over practicality. Some schemes have inadequate sediment control and have basins that do not include easy access for mechanical equipment to remove sediment making removal most challenging.

Treatment wetlands need varying levels of attention although most operators have needed to put into place a regular maintenance schedule.

A major common issue is infestation from European Carp which either make their way from creeks or are released by irresponsible community members. These fish grow rapidly and feed from the bottom of ponds stirring up high levels of silt and turbidity in the process. A variety of methods have been employed to eradicate them. The most common method of eradicating Carp is to drain the wetlands and remove the fish. Glenelg have retrospectively installed a dedicated pump and drainage network rather than employing temporary pumps.

Depending on the plantings in the wetland the drying process can also be beneficial. This has not been well received by some residents and local businesses members because of the loss of amenity while the basins are dry. This highlights the flow on aesthetic and economic value that can result from the installation of water features into our urban landscapes.

Playford has taken the most extreme action and dosed their Munno Para wetlands with Rotenone to eradicate the large Carp population. This was undertaken with appropriate regulatory control and guidance from staff from SARDI Aquatic Sciences. Rotenone is a chemical compound which occurs naturally in some plant species that can be used as a selective pesticide and rapidly degrades in sunlight. It is particularly effective on Carp and related
fin fish species with minimal impact on other marine life such as yabbies and shrimp. Netting was also undertaken in the wetland. A total of 12,000 (7,000 Rotenone and 5,000 netting) carp were removed!

Royal Adelaide has significant problems with a water fowl that strips large amounts of reeds out of their wetland which need constant replacement. All the golf clubs undertake constant weed eradication in their reed beds which requires the use of biodegradable herbicide such as glyphosate or hand weeding.

Salisbury has a unique problem at their Parafield and Edinburgh sites, alongside airport runways, where the wetlands are covered with netting to deter birds. The long established reeds have grown to such a height that they have broken through the protective netting. They are currently repairing the netting and reducing the height of the reeds. Morphettville reported that their reed beds are fairly self-sufficient requiring minimal attention. Glenelg has had problems of algal build up in their wetlands which requires constant circulation of water.

Where media filters have been put into the treatment train they generally need replacement every three years and if mixing tanks are used they need to be periodically cleaned.

Better management of catchments can impact greatly on the maintenance required for a scheme. As an example if routine street sweeping is kept up in a stormwater catchment upstream of a wetland system can reduce amount of sediment and leaf litter that needs to be removed from GPTs and sediment basins. Similarly improved management of soil and sediment from upstream building sites would assist greatly. From a council perspective these two issues highlight how important it is for ASR systems to be acknowledged as an integrated major asset not just a standalone add on.

C. Recharge, Sub-surface Storage & Recovery

Injection and extraction rates vary from scheme to scheme and are dictated by the specific characteristics of the aquifer unique to each MAR well. The main issue is the response of the aquifer with regard to what is achievable and whether scour and degradation is likely to occur. Salisbury reported the highest injection rates of 25 to 45 litres per second (L/s) into the T2 aquifer of the NAP. Playford has adopted a standard rate of injection and extraction of 25 L/s to minimise aquifer damage, backflushing and pump wear. Tea Tree Gully has the lowest injection rate of 2.5 L/s into one of their fractured rock wells.
Dissolution of the aquifer and scouring has been common in most tertiary wells. The resulting sediments can clog bores and cause significant damage to pumps, irrigation lines and sprinklers. Glenelg has had a well collapse severely reducing injection and recharge rates and Grange and Morphettville have constricted T1 wells with reduced efficiency. The scoured sandy sediment needs to be periodically removed by backflushing or air lifting and schemes should to be plumbed and equipped to achieve this expediently.

Tea Tree Gully has restricted flow into their fractured rock aquifers and over pressurisation can result if injection rates are not carefully monitored.

Aquifer pressurisation in tertiary wells has become apparent at a number of schemes with the result that neighbours bores may become artesian unless capped or injection rates are monitored and controlled. This is an issue that now needs to be managed for adjoining schemes accessing the same aquifer.

Tea Tree Gully also has experienced clogging as a result of iron bacteria which is activated by the naturally occurring metals in the fractured rock aquifer. Wells need to be periodically treated to remove excess build up.

All operators have modified discharge and extraction flow rates, which may be below the maximum possible match the capabilities of the receiving aquifer. This reduces the aquifer scour, resulting sediment creation and minimises wear and tear on well pumps.

D. Post treatment & enduse

Generally there have not been issues with the quality of extracted water once schemes are established and stabilised after a series of injection cycles. Although during the extended drought some schemes encountered rising salinity levels because of the reducing fresh water bubble and ingress of higher salinity groundwater. With a good rate of annual injected water the salinity of extracted water remains at a consistently low rate and turf remains in very good condition during summer irrigation. The down side of this is that, as reported by the golf courses, the weeds also benefit,

The extracted water is used for fit for purpose irrigation, industrial use and limited household (e.g. toilet flushing). Recycled water is provided to industry and private allotments through a separately plumbed dual pipe. At Mawson Lakes, Salisbury has collaborated with SAWater to mix a blend of treated wastewater and
recycled stormwater which is delivered to households and businesses. None of the schemes are required to do any post treatment for water stored in aquifers.

E. General issues

System control and data acquisition (SCADA) systems are installed on all schemes however various levels of manual control and automation are imposed depending on the operator’s confidence in the different aspects of their schemes. A range of distribution and irrigation control systems have also been installed on particular schemes. The control systems have improved significantly over the years and earlier schemes have made changes and upgrades to their control systems. As an example Grange have replaced their original control system, reprogrammed operation and hardwired their switch boxes with optical fibre to ensure they have full control.

Many difficulties and ‘teething problem’ were encountered during establishment of schemes until operators gained a good level of understanding and established a constant level of operation. Most operators said that they would have benefited with a better handover and training on how their schemes were designed to operate. They also said that if they did build another scheme, as Salisbury and Playford have now done more than once, they would take on a much greater level of control of the design and construction.

Schemes are not ‘set and forget’ and become an integral part of the business of the organisation with a scheduled maintenance program planned, resourced, budgeted and implemented. All schemes require dedicated staff or contractors to undertake this maintenance. The pumps, pipework, valves, monitoring and control sites throughout the schemes all need regular inspection, maintenance and replacement when necessary. A few operators like Glenelg have had to replace significant amounts of their initial set up due to the installation of inferior components and poor placement. (e.g. PVC pipes and control boxes exposed to direct sunlight). Glenelg had valves installed incorrectly and still has problems with varying pipe pressures.

All of the schemes are licensed by the Environment Protection Authority for their discharge to aquifers and operators are all relatively happy with current regulation and have a good understanding of what is required of them for monitoring and reporting. The drilling and maintenance of wells requires a permit from DEWNR and similarly operators are comfortable with their requirements for these actions. They all reported that this
understanding has developed over time with improved relationships with people involved. The requirements could still benefit from better guidance for new operators.

DEWNR also permits the extraction of groundwater and because of the moratorium that is currently in place over the APPWA until the WAP is in place this is a protracted process under a “Section 128”. Some operators are reported frustration at the lengthy process involved in this.

The three councils who are retailing water also now require a license under the Water Industry Act 2012 and must maintain their quality control, undertake substantial periodic reporting and pay a significant licensing fee. The Essential Services Commission (ESCOSA) oversees this Act and it is administered by a Technical Regulator. This imposes a significant demand on the councils and they have all needed to set up a strict business approach to deal with it.

All operators reported that they are currently happy with their schemes but that it had taken time to understand the needs of the scheme, allocate the necessary resource to maintain it and ensure adequate budget is set aside. Those operating schemes with low yields are frustrated that their schemes are not working to the level that they anticipated. The access to low salinity “fit for purpose” recycled water has been a benefit for all schemes. The aesthetic value of wetlands is something that all operators have benefited from both in the suburban and golf course setting particularly at Glenelg where they have been fully integrated into the course design.

There was general consensus that there were far greater costs involved in operating and maintaining schemes than first envisaged and they needed to operate at an economy of scale that made them viable. There were varying approaches taken to costing the recycled stormwater they were using but most of them reported that they were benefiting compared to traditional sources. Most of them would like to see more work done on the cost benefit ratios of schemes. Tea Tree Gully and Grange are still working on improving the performance of their schemes to better evaluate and realise benefits. The golf clubs reported the benefit that had been gained by their organisations and members gaining a better understanding of the “true” cost of water.

There was some caution expressed by most operators as to whether they would build another MAR scheme. Generally the response was that they need to carefully evaluate the requirements of the scheme and the benefits to
be gained. Incentive funding to initiate schemes if available would only be a small component in evaluating the viability of a new scheme. A number of operators expressed an interest in exploring alternative water sources such as recycled treated wastewater if they require more water.

VII. Conclusion

A total of over $76 million has been invested in the seven MAR schemes that have been reviewed. All operators have experienced and overcome many difficulties and challenges to get to their current level of operation. There are many common issues and some quite unique. They have needed to design and put into place vigilant monitoring and maintenance schedules to maintain the performance of schemes. They also have needed to make their schemes part of their ongoing business operation with adequate resourcing.

Having reached their current level of understanding all operators are relatively satisfied with their schemes particularly the consistent low salinity recycled stormwater that they produce. The viability of schemes still needs to be better explored. Individually and collectively their experiences provide a wealth of knowledge to pass onto other MAR scheme operators.

A number of other stormwater MAR schemes have been and are being developed in South Australia, since these schemes were commissioned. These include schemes by the City of Onkaparinga, the City of Charles Sturt (Waterproofing the West), the Eastern Region Alliance (Cities of Burnside, Norwood, Payneham and St Peters, Campbelltown, Tea Tree Gully and the Town of Walkerville) (Waterproofing Eastern Adelaide), the Botanic Gardens, the City of Marion and SA Water.

There is an opportunity to pass on experiences to newer operators and this has been acknowledged by the formation of a MAR Users Group. Also there will be a vast amount of further experience, understanding and knowledge to share in the future.

Acknowledgements

Peter Newland thanks Bruce Naumann (City of Salisbury), Chris Burgess (City of Playford), David Baldwyn (City of Tea Tree Gully), Andrew Gay (Royal Adelaide Golf Club), Daryl Sellar (Glenelg Golf Club) Richard
James (Grange Golf Club) and John Tonani (South Australian Jockey Club) for the invaluable information that they have willingly provided for this paper.

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