Integrating passive, traditional and advanced treatment and storage methods to meet changes in recycled water demand: an overview of innovative schemes in southern Australia.

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ABSTRACT

Urbanisation, limited water supplies, extremes in weather patterns and environmental disasters demonstrate the need for more robust and flexible water management strategies which encompass recycling. Water reuse schemes have been successfully implemented in agriculture, domestic dual-reticulation, industrial and municipal uses in southern Australia. In each case, the recycling process is adapted to suit the end use, regulatory water quality requirements and changes in seasonal and or annual demand as a result of growth or as recycling becomes more widely accepted within the community. This paper will consider source water quality and quantity, the integration of advanced and passive treatment technologies, storage and demand management. An overview of innovative schemes and trials encompassing stormwater and wastewater will be presented including the Bolivar, Christies and Glenelg Wastewater Treatment Plants.

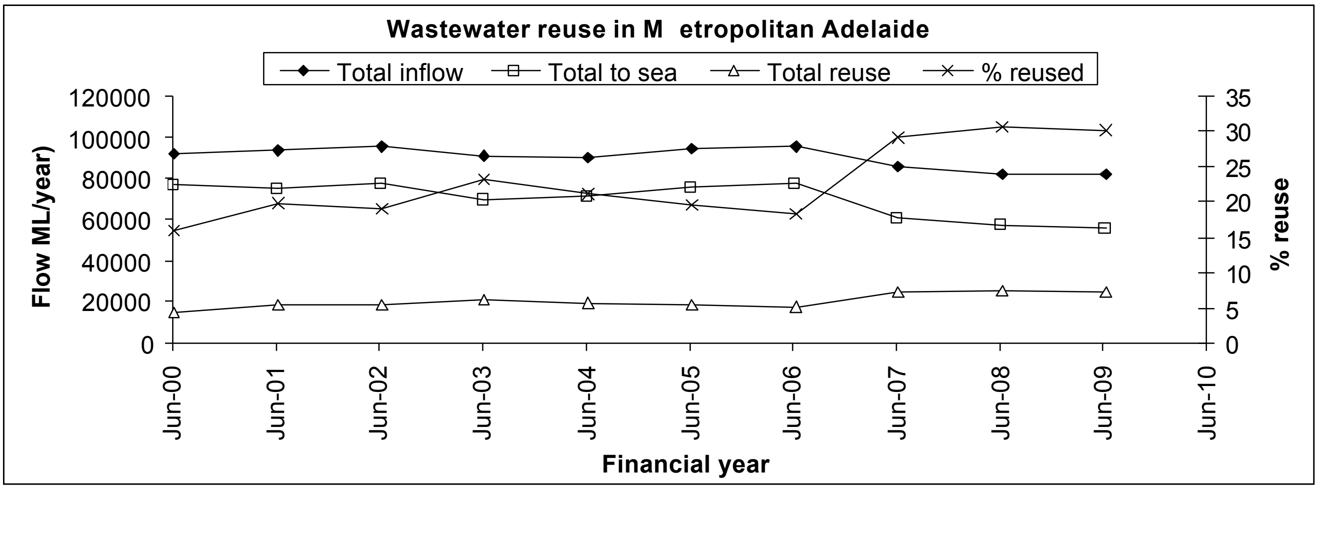
KEYWORDS

Integration, wastewater reuse, demand management, ASR, stormwater

1 INTRODUCTION

Urbanisation, limited water supplies, extremes in weather patterns and environmental disasters demonstrate the need for more robust and flexible water management strategies which encompass recycling. In southern Australia, water reuse schemes have been successfully implemented in agriculture, domestic dual-reticulation, industrial and municipal use (Figure 1). In each case, the recycling process is adapted to suit the end use, regulatory water quality requirements and changes in seasonal and or annual demand as a result of growth or as recycling becomes more widely accepted within the community. Increasingly, systems are becoming integrated with advanced and passive treatment technologies such as combining a conventional wastewater treatment plant with advanced filtration and aquifer storage and recovery or mixing stormwater treated by wetlands with tertiary treated wastewater to reduce salinity in dual-reticulation (Figure 2).

Figure 1 Wastewater flow and reuse in metropolitan Adelaide, South Australia

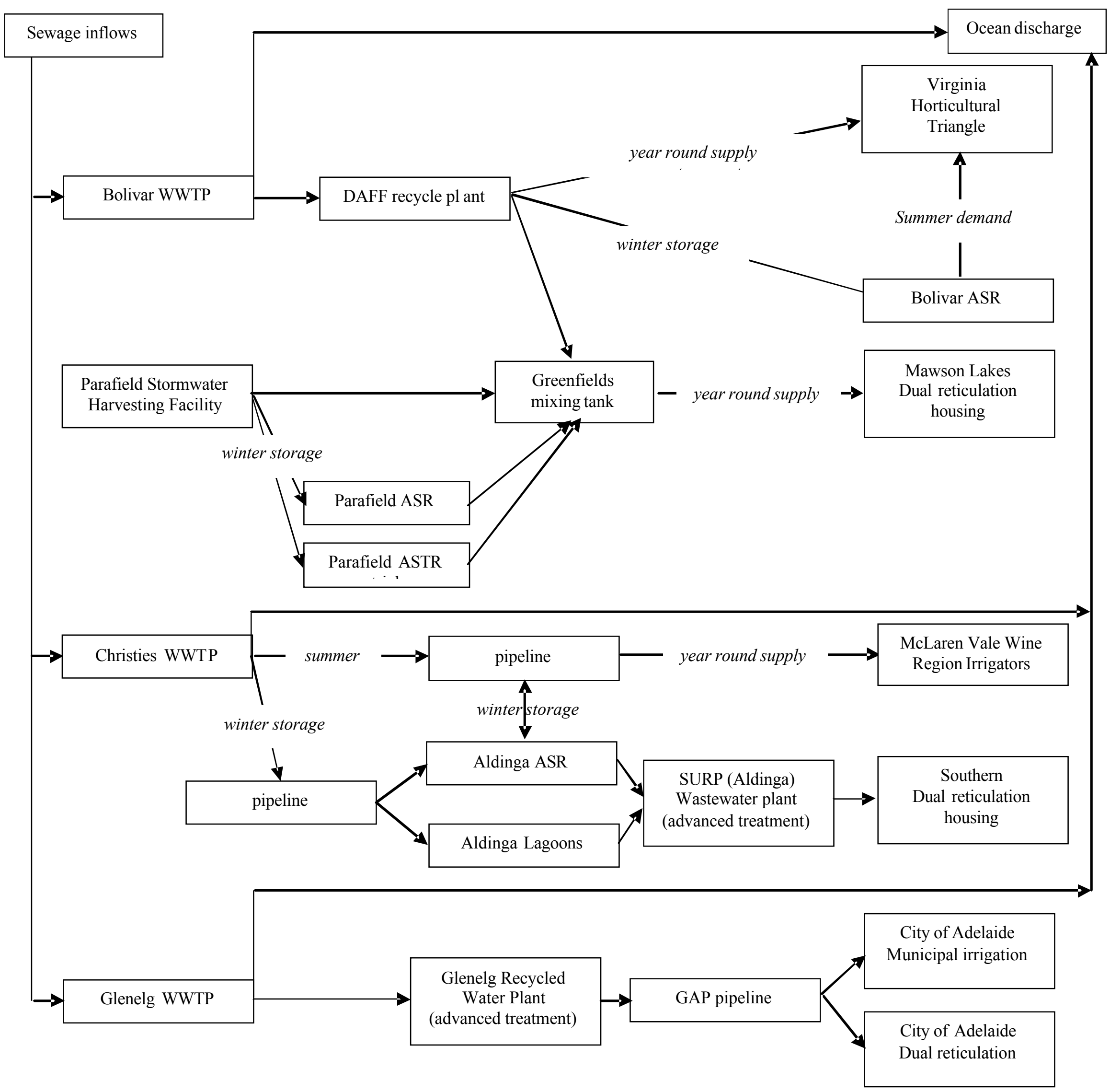


In southern Australia the main drivers for recycling include:

- Drought and reduced rainfall leading to hot dry summers and high evaporation from storages, coinciding with periods of high demand from agriculture and residents,
- Lower flows in the River Murray leading to reduced water allocations for Riverland irrigators & reduced security for water supply reservoirs via interbasin transfers,
- Water restrictions for urban users,
- Lowering of groundwater tables and prescription of resources,
- Reduced rainfall and runoff in the drinking water catchments of the Mt Lofty Ranges watershed,
- Community acceptance of water recycling & potable water substitution for certain end uses,
- Adelaide Coastal Waters study (2006) which identified the need to continually reduce TN being discharged to the Gulf of St Vincent (<400 Tonne TN /year),
- Rehabilitation of sea grass communities along Adelaide metropolitan coastline,
- Reliability of wastewater/ constant flows,
- Commercialism – placing value on recycled water & reduced costs for plant upgrades for N or P removal.
- Opportunism with high rain events in urban areas

This paper will consider source water quality and quantity, the integration of advanced and passive treatment technologies, storage and demand management. An overview of innovative schemes and trials encompassing stormwater and wastewater will be presented including the Bolivar, Christies and Glenelg Wastewater Treatment Plants (Figure 2).

Figure 2 Summary of water reuse schemes in the City of Adelaide, South Australia.



2 CASE STUDIES - REUSE SCHEMES

2.1 BOLIVAR WWTP & DAFF RECYCLE PLANT

The Bolivar Wastewater Treatment Plant (WWTP) is the largest plant in Adelaide, having a typical average daily flow of 150 ML/d with a catchment size of 650,000 people. The treatment process comprises of: screen and grit removal; primary sedimentation; secondary treatment using nitrifying/denitrifying activated sludge and stabilisation lagoons. The effluent can either be disposed to the St. Vincent Gulf or reused via a DAFF tertiary plant. Reuse via the DAFF plant involves coagulation, flocculation, dissolved air flotation and rapid gravity sand filtration and chlorination to produce effluent suitable for unrestricted horticultural irrigation. The effluent standard includes; total chlorine of 2 mg/L, BOD <20 mg/L, turbidity ≤1.5 NTU, SS <20 mg/L, *E. coli* <10/100 mL and pathogens <1/mL.

The DAFF plant capacity approximates 110 ML/day but production is dependent upon raw water quality from the stabilization lagoons and production can be influenced by high turbidity or algal loads during summer. The plant supplies the Virginia Pipeline Scheme (~100 ML/day), followed by onsite plant use (~6 ML/day) and the Mawon Lakes Dual reticulation scheme (~2 ML/day), resulting in a total reuse volume of 19,136 ML/year or 38% of inflow (2008/2009).

2.1.1 VIRGINIA HORTICULTURAL TRIANGLE

The Bolivar WWTP-Virginia Pipeline Scheme is one of the largest reuse schemes in Australia and processes 12% of South Australia's agricultural produce and was designed to protect groundwater resources in the northern Adelaide Plains (Figure 3).

The potential water quality hazards include pathogens and salinity. Salinity varies seasonally but must not exceed 1,500 mg/L TDS for supply to the irrigators.

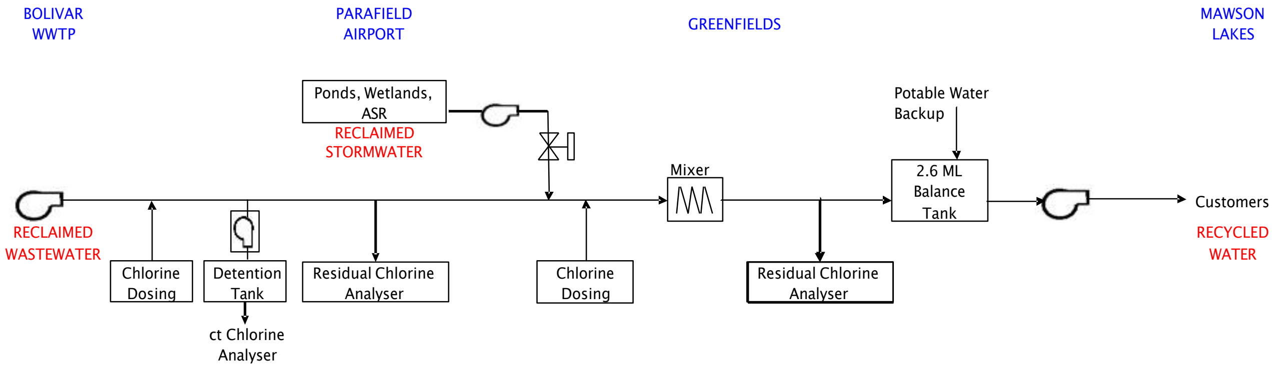
Figure 3. Location of the Virginia Horticultural triangle, Bolivar wastewater treatment plant (WWTP) and the Bolivar ASR trial site.

2.1.2 MAWSON LAKES DUAL RETICULATION SCHEME

Mawson Lakes is a residential, commercial, educational and technical development north of Adelaide with 4,300 allotments and will be able to cater for about 11,000 residents by 2010. The development is a significant dual reticulation scheme in Australia and the objective is to achieve a 50 % reduction in the use of potable water across a major urban development. Recycled water is used for municipal irrigation, ornamental lakes, car washing and toilet flushing with each allotment having a separate recycled water pipe. The scheme utilizes water from different sources with the objective to reduce salinity below 900 mg/L TDS. The sources include the constant availability of treated wastewater via the Bolivar DAFF plant and stormwater with a mixture of approximately 50:50. The stormwater although less reliable in terms of supply, is lower in salinity and therefore dilutes the reclaimed water. The stormwater is dependent upon rainfall within the Parafield Catchment and to overcome variability, managed aquifer recharge schemes incorporating aquifer storage and recovery have been established by the local government to store winter stormwater flows underground for recovery during summer (Marks et al., 2005). Figure 4 provides a schematic of the combining of reclaimed water with stormwater via the Greenfields mixing tank. The water quality requirements include a chlorine contact time of *C.t* 60 mg.L/min. The scheme also incorporates potable water mains to guarantee supply in the event of process failure.

A number of detailed risk assessments were undertaken covering: design, process, construction commissioning and operations (Carr and Kohlhagen, 2005). These assessments resulted in operating procedures, construction procedures, water quality monitoring programs, emergency response plans, reporting protocols and training requirements. A major study titled 'Acceptability of reclaimed water use in urban Australia: establishing a baseline and variations based on experience, consultation and trust' was also undertaken at the Flinders University in South Australia and incorporated the Mawson Lakes schemes (Marks *et al*., 2006).

Figure 4 Process schematic of the Mawson Lakes dual-reticulation scheme



2.2 MANAGED AQUIFER RECHARGE TO AUGMENT PEAK DEMAND

Managed aquifer recharge (MAR) is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit; the managed process assures adequate protection of human health and the environment (NRMMC-EPHC, 2008). MAR can include a range of methods including: aquifer Storage and recovery (ASR), bank filtration, and soil aquifer treatment. In southern Australia, aquifer storage and recovery is the predominant technique involving the injection of water under pressure into a production bore to a confined aquifer. The Tertiary 2 aquifer is the predominant aquifer as it has a strong aquitard between T1 and T2 and has a brackish salinity of 2,400 mg/TDS which lowers its value in a regulatory perspective. ASR can offer a number of advantages including:

- Scaling reuse plant capacities by augmenting peak demand periods during summer,
- a small footprint for a given volume of storage, and does not necessarily need to increase with increasing volumes stored,
- Potentially lower capital costs required for bore construction, recovery pumps and delivery pipe-work and pumps are relatively low compared to dam construction costs,
- Water quality changes may be small over time,
- No influence of algal blooms of evaporation during summer months,
- Value add & optimize the operation of the recycled water plant,
- May improve water quality and provide an additional barrier to pathogens, and
- Natural barrier in recycled water supply.

2.2.1 BOLIVAR AQUIFER STORAGE & RECOVERY

The Bolivar WWTP produces effluent at a constant rate throughout the year, but irrigators at Virginia have a significant water demand for only 4-8 months of the year (Figure 5). The Virginia horticultural demand has increased from 8 GL in 1998/99 to 21 GL in 2009/10. The scheme has a capacity of 32 GL in annual terms but peak daily demand could exceed production capacity. As demand continues to grow, additional water could only be made available through expensive DAFF plant upgrades or alternatively by storing winter production for later use during summer.

Aquifer storage and recovery has been recognized as a viable cost-effective, technical and environmental option for augmenting peak summer demands. Between 1999-2005, a ASR trial was undertaken at Bolivar involving 3 cycles of injection, storage and recovery (Dillon and Toze, 2005). The trial involved a single production bore in the T2 aquifer with a target interval of 100-160 m, 8 fully penetrating observation bores and 8 shallower piezometers. The trial involved injecting Bolivar DAFF water via the VPS pipeline into the aquifer, storing it and recovering it to the ocean. The research focused on changes in water quality between the injectant and ground water including: geochemical reactions, fate of NOM, attenuation of DBP, EDCs, pathogens, nutrients, metals and suspended solids. Well clogging, aquitard stability and recovery efficiencies were also assessed (Martin and Dillon, 2005, Pavelic et al., 2007).

Figure 5 Reuse demand profile for the Virginia and McLaren Vale irrigation schemes.

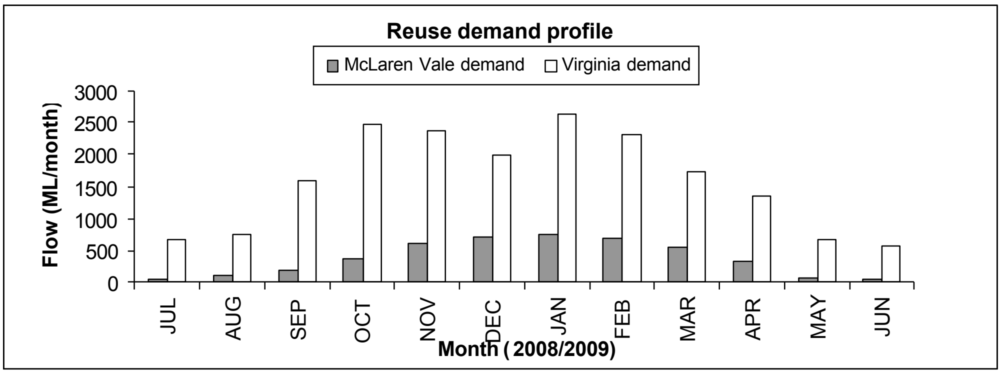
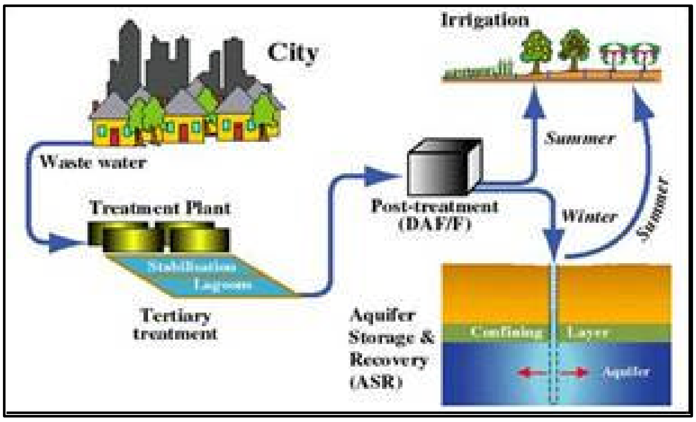


Figure 6 Process schematic for the incorporation of ASR at Bolivar



In 2008, a 4th cycle commenced whereby the scheme moved from a research focus to an operational focus with the intention of the recovered water to be supplied to the Virginia Horticultural irrigators (Regel, 2009, May et al., 2009). Between August 2008-March 2009, 185 ML of DAFF treated effluent was injected into the T2 aquifer (Table 1). In September 2009, the effluent will be recovered and supplied to irrigators at a rate of 15 L/s. Furthermore, a quantitative risk assessment has been carried out for the Bolivar WWTP and potential ASR scheme involving the review of 10 years of operational data. The review found that the scheme had performed in accordance with the initial regulatory approval for pathogen risk and that an ASR step would provide an additional 1 log reduction treatment step for pathogens (Ayuso-Gabella, 2009. In 2010, the scheme is proposed to be upgraded to a scale of 700 ML with an augmentation capacity of 30 ML/day during peak demands.

Table 1 Summary of Bolivar ASR 4th cycle injection flow and water quality

Parameter	Units	Min	Max	Average
Injection flow	L/s	0	13.6	9.8
Daily volume	ML/d	0.29	1.19	0.81
Turbidity	NTU	0.56	4.4	1.4
Conductivity	µS/cm	1,069	2,100	2,009
Salinity	mg/L	593	1,166	1,114
pH		6.67	7.79	7.19
Suspended solids	mg/L	0.4	5.2	1.7
Free chlorine	mg/L	0.04	2.3	0.27
Total chlorine	mg/L	0.32	3.75	1.1
E. coli	/100 mL	0	1	<1

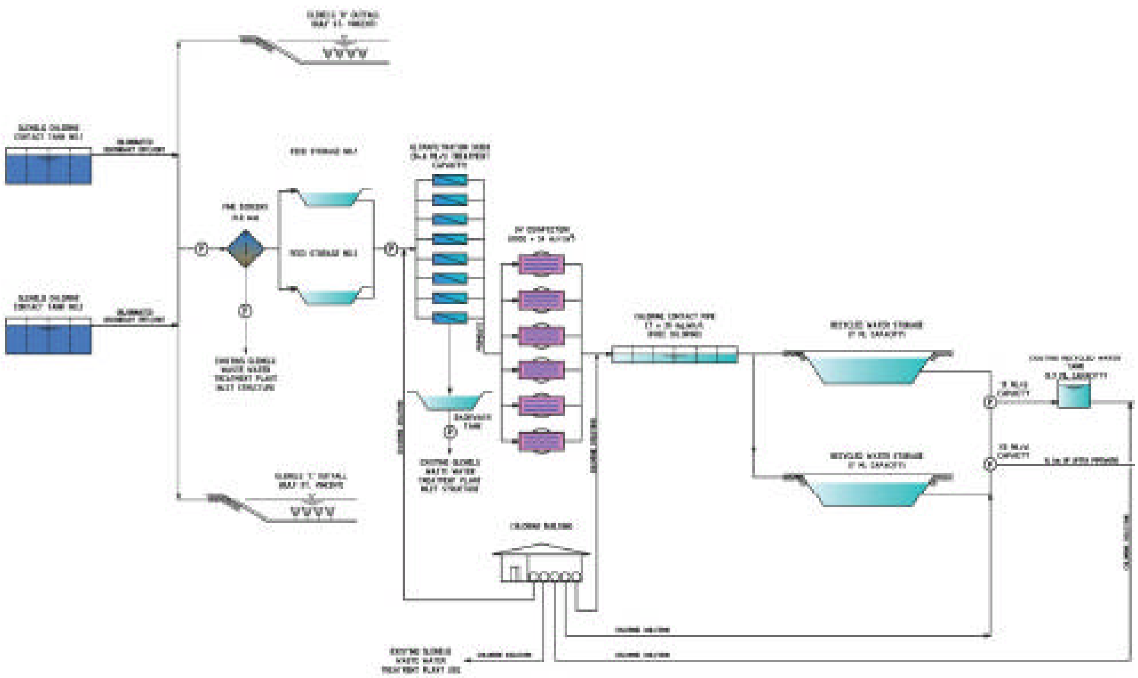
2.2.2 CHRISTIES BEACH WWTP & MCLAREN VALE VITICULTURAL REGION

The Christies Beach WWTP receives an average daily flow of about 22 ML/day. Effluent is reused onsite and via a pipeline scheme to irrigators in the McLaren Vale wine region, with demand also following a seasonal regime (Figure 5). In the summer of 2008/2009, plant production which was intensified by water restrictions could not meet demand by vineyards. In 2002 a research project assessed the initial feasibility of Aquifer Storage and Recovery in Aldinga with Christies Beach effluent. This method was recognized in 2008 as a viable option to augment summer demand in the vine region and subsequently a 100 ML trial was established as a preliminary step to obtaining an ongoing license. Between April and July 2009, 100 ML of Christies effluent was injected into and recovered out of the T2 aquifer via two production bores in Aldinga. The trial appears successful and a submission has been made to the regulator to increase the scheme to 400 ML/year which will incorporate 6 production bores, with 3 bores being dedicated to recovery.

2.3 ADVANCED TREATMENT SYSTEMS FOR UNRESTRICTED DUAL-RETICULATION

The Glenelg WWTP receives approximately 45 ML/day from a catchment population of 200,000 people. The Water Proofing Adelaide Initiative identified that reuse needed to increase at the plant and in 2008, the construction of the Glenelg to Adelaide Recycled Water Treatment Plant commenced with a design capacity of 35 ML/day. The scheme incorporates the existing Glenelg WWTP, microscreens, feedwater basins, UF membranes, UV disinfection, chlorine contact pipe, recycled water basins and a 14 km long trunk main and 30 km ring main to the City of Adelaide parklands and central business district (Figure 7). The end uses will include municipal and eventually un-restricted dual-reticulation.

Figure 7 Process flow diagram of the Glenelg-Adelaide Parklands Recycled Water Treatment Plant.



The Australian Guidelines for Water Recycling (NRMMC-EPHC, 2006) have adopted a multi-barrier approach to water supply and consequently the Glenelg Recycled Water Plant has incorporated a range of advanced treatment processes including UF membrane filtration and UV disinfection to achieve the required regulatory level of pathogen reduction (Table 2).

Table 2 Indicative Log Reduction Value credits for the Glenelg-Adelaide Recycled Water Scheme

Process	Log Reduction Value Credits		
	Viruses	Protozoa	Bacteria
GWWTP activated sludge process	0.5	0.5	0.5
UF Membranes	3.0 / 2.0	4.0	3.0
UV Disinfection (RED > 50 mJ/cm^2)	1.0	1.0	1.0
Chlorination (CT > 20 mg.min/L)	2.0	0.0	2.0
TOTALS	6.5 / 5.5	5.5	6.5
LRVs for unrestricted municipal irrigation	5.0	3.5	4.0
LRVs for dual reticulation (indoor or outdoor use)	6.5		

The regulatory approval of the scheme has involved the development of a management plan following the 12 elements described in the Australian Guidelines for Water Recycling (NRMMC-EPHC, 2006). The 12 elements cover:

- Commitment to Responsible Use and Management of Recycled Water
- Assessment of the Recycled Water System
- Preventive Measures for Recycled Water Management
- Operational procedures and process control
- Verification of Recycled Water Quality and Environmental
- Management of Incidents and Emergencies
- Operator, Contractor and End User Awareness and Training
- Community involvement and awareness
- Validation, research and development
- Documentation and reporting
- Evaluation and audit
- Review and continuous improvement.

Management plans following the 12 elements of the AGWR are currently being developed in partnership with the government for the existing reuse schemes and will be mandatory for all new schemes.

3 CONCLUSIONS

This paper highlighted the reuse activities and innovative approaches that are being evaluated to storing and reusing recycled water in South Australia. The schemes were developed within a risk management framework which provide information on a range of issues that need to be addressed by public health, environment and natural resource regulators and managers. An integrated approach looking at all possible reuse solutions needs to be taken into account when choosing the best option.

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