

# **NORTHERN ADELAIDE PLAINS RECYCLING SCHEME – CHAMPION IN THE MANAGEMENT OF RECYCLED WATER FOR SUSTAINABLE PRODUCTION AND ENVIRONMENTAL PROTECTION**

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## **INTRODUCTION**

In South Australia, SA Water treats annually 95,000 ML of wastewater at its four Waste Water Treatment Plants (WWTP) (Bolivar, Port Adelaide, Glenelg and Christies Beach) in the metropolitan Adelaide. The Bolivar WWTP treats about 46,000 ML wastewater annually and has resulted in high quality treated wastewater being piped to growers on the Northern Adelaide Plains (NAP) through Virginia Pipeline Scheme (VPS). Recently, as part of the Environment Improvement Program, the Port Adelaide WWTP has been replaced with a new high salinity treatment plant at Bolivar. The main objectives of these WWTPs are to reduce the amount of wastewater entering Gulf St Vincent and to recycle high quality treated wastewater for irrigation purposes. The NAP-VPS is the first and largest recycled water scheme in Australia serving around 250 horticultural growers. This paper provides an overview of this scheme focussing on the level of wastewater treatment at Bolivar WWTP, the value of the treated water as a source of irrigation water, carbon and nutrients for crop growth, and the socio-economic and environmental implications of recycled water irrigation.

## **WATER ISSUES IN SOUTH AUSTRALIA**

By global standards Australia is an extremely dry continent with severe limitation of fresh water resources. A current lack in available water is now the most limiting factor to economic growth within the horticultural sectors (Australian Bureau of Statistics, 2004-05). In many parts of the country, continued water extraction for agriculture, declining rainfall trends and increased portioning of water for eco-system servicing have lead to unsustainable rates of water consumption (Stevens *et al.* 2004b).

A total of 24 000GL of water is consumed across all industry sectors and domestic supply. The vast majority (65%) of water is consumed within the agricultural industry for irrigation purposes, followed by household (11.2%) and water supply (11.1%). Mining, manufacturing and service industries consume 2.2%, 3.1 and 5.6%, respectively. However the gross value of water is much higher in industries than in agriculture. It ranges from \$210/ML (Rice) to \$1750/ML (vegetables) in agriculture, from \$32000 to \$680000/ML in manufacturing industry and from \$2137 to \$1 1000 000/ML in service industry.

Under the Murray Darling River initiative, South Australia is allocated 724 000 ML for extraction per year, as much as 75% of this allocation is used for irrigation purposes and a further 18% used to supply metropolitan Adelaide. In an average year Adelaide uses around 216, 000 ML of water with approximately 40% of this amount being sourced from the Murray River. In dry years, however, extraction from the Murray River may increase to as much as 80-90% of Adelaide's total demand to compensate for reduced water harvesting from the Adelaide Hills Catchments.

With an intention to safeguard against water shortages and help restore the health of the Murray Darling River eco-system, current initiatives aim to better manage existing water resources, improve water-use efficiency by both rural and urban users and to better utilise alternative water supplies such as stormwater and recycling wastewaters for irrigation purposes.

## **RECYCLED WATER RESOURCES IN AUSTRALIA**

Recycled water is a generic term given to water reclaimed from a number of sources, including municipal sewage, industrial, agricultural and stormwater waste streams.

*Sewage wastewater* is the component of domestic waste comprising bathroom and laundry effluents (grey water) and sewage waste (black water). Generally this wastewater is processed through municipal wastewater treatment plants to produce a definable quality of sewage wastewater that may be recycled for a range of purposes.

*Agricultural wastewater* comprise of waste streams from farm and agro-industrial operations. In rural areas of Australia, agricultural drainage effluents and livestock effluents provide a major source of re-usable water (Dillon, 2000). These wastes may also provide a valuable source of nutrients (Stevens *et al*, 2004a).

*Industrial wastewater* refers to spent water generated from all areas of industrial and commercial enterprise. Some industries may incorporate a certain degree of on-site treatment and/or recycling, however in built-up metropolitan areas the vast percentage of industrial waste is collected via the municipal sewage reticulation and processed at Wastewater Treatment Plants with domestic wastewaters.

*Storm water* is generally a predominant water source in urban areas. This water source originates from land surface run-off and in many built up areas can contribute a relatively abundant, local source of water during seasons of high rainfall. This resource has been found to have a high level of public acceptance and in many cases storm water harvesting can build upon storm water pollution management facilities, thereby reducing the amount of additional storm water infrastructure required.

Annually large quantity of wastewater is generated in Australia (Table 1). However only a small proportion of this valuable resource is reused in agriculture and industries. For example, the reuse of treated sewage wastewater for irrigation ranges from 5.2% in Northern Territory to 15.1% in South Australia (Radcliffe, 2004). A number of successful wastewater irrigation schemes have been developed in Australia (Table 2).

## **WASTEWATER TREATMENT SCHEMES IN SOUTH AUSTRALIA**

In South Australia, SA Water treats annually 95,000 ML of wastewater across four Wastewater Treatment Plants (WWTP) serving around 1.1 million people within metropolitan Adelaide.

- Bolivar – treats about 45000 ML wastewater annually and has resulted in high quality Class A treated wastewater being piped to vegetable growers on the Northern Adelaide Plains.
- Port Adelaide – treats about 18000 ML wastewater annually and has resulted in the elimination of discharge of treated wastewater to the Port River and provides water for irrigation.
- Glenelg – treats about 21000 ML wastewater annually where treated wastewater is being used to irrigate parks.
- Christies Beach – treats about 11000 ML annually and provides treated wastewater to the important wine growing region of McLaren Vale.

Recently, as part of the Environment Improvement Program, the Port Adelaide WWTP has been replaced with a new high salinity treatment plant at Bolivar.

The main objectives of these WWTPs are to:

- Reduce the amount of treated wastewater entering Gulf St Vincent
- Recycle high quality treated wastewater for irrigation purposes

## **WASTEWATER TREATMENT PROCESS**

At WWTPs, wastewater is treated via a multi-stage treatment process prior to being discharged into the environment or reused. Generally this is a three stage process involving primary, secondary and tertiary treatment.

Primary treatment, the initial stage of the treatment process, is typically limited to physical unit operations that remove solid materials. Initially wastewater will be screened to remove large,

inorganic material such as paper and plastics, and then further screened for finer grit and silt particles that can be abrasive on plant equipment. Following this preliminary treatment, wastewater is then transferred to primary sedimentation tanks where solid particles of organic material are removed from suspension through flocculation using flocculating agents such as alum. Primary sludge is allowed to settle out from wastewater through gravity. Although this primary treatment achieves high degree of removal of solids, the treated effluent remains high in biological oxygen demand (BOD), suspended solids and nutrients.

The primary treated wastewater then undergoes secondary treatment, a process involving the biological break down of dissolved and suspended organic solids and facilitated by naturally occurring micro-organisms. Here, settled wastewater enters aeration tanks or lagoons and is mechanically aerated. The injection of oxygen promotes the growth of micro-organisms and helps to maintain their suspension in the wastewater. During growth and multiplication, the active biomass consumes oxygen and organic pollutants and nutrient constituents of the wastewater

During this secondary treatment stage, the microbial biomass settles under gravity to the bottom of the tank as secondary sludge. Commonly, under activated sludge systems a portion of the settled sludge is retained in the secondary aeration tanks to maintain a healthy microbial population while the remainder is pumped to anaerobic digesters for further treatment. The wastewater along with the microbial suspension is then passed into clarification units that remove any remaining microbial floc and suspended solids.

Once wastewater has passed clarification, it will then undergo tertiary treatment where disinfectants are used to reduce pathogen numbers that may otherwise pose a risk to human health. Most commonly chlorine is dosed into the treated wastewater stream for disinfection, Bolivar however uses large ponds in which UV sunlight energy and other micro-organisms help to reduce pathogen numbers.

Depending on the degree of treatment, a wastewater of definable quality is produced in WWTPs. In Australia, the level of treatment is generally determined either by the specific risks wastewater discharge may have on receiving environments, or where recycled water is concerned, by the purpose in which it is intended for. Where treated wastewater is to be recycled for purposes such as irrigation of food crops or where close human contact is likely, a higher degree of treatment is required.

In South Australia recycled water quality is classified as either class A, B, C or D (Table 3). When recycled water is used for irrigation the level of treatment (i.e. Class) determines the nature of the crops suitable to receive recycled water irrigation and the method by which it can be applied. Recycled water of class A for example has received a level of treatment greater than classes B to D and is suitable for unrestricted irrigation to all crop and fodder types. The use of class C recycled water however is restricted to a more limited selection of crops. In the case of Bolivar WWTP, the introduction of Dissolved Air Flotation Filtration (DAFF) technology utilises micro filtration and floatation to produce a Class A wastewater. This wastewater is then distributed through the Virginia Pipeline Scheme to the Adelaide Plains where it is used for unrestricted irrigation of vegetable and salad crops.

A typical topology of wastewater reuse is given in Figure 1. The ultimate reuse of wastewater for agricultural, industrial and environmental application depends on various factors including the level of treatment, cost of delivery and public perception.

## **VIRGINIA PIPELINE SCHEME**

Commissioned in 1998, the Virginia Pipeline Scheme (VPS) is the first large-scale agriculturally based water recycling scheme in Australia and one of the largest in the world. Historically, the horticulture industry in Virginia has relied on ground water resources for irrigation water supply. As a result of over extraction however, groundwater resources declined to levels thought critically low for maintaining the current rate of horticultural production. Faced with foreseen short falls in water supply, in the 1980's several growers began using Class C recycled water pumping from the out-fall channel of the Bolivar WWTP, to irrigate their market gardens. Essentially growers recognised

the potential of wastewater as a new water source that could provide a secure supply for irrigation. This realization, accompanied by the social, economic and the environmental drivers, led to the development of the VPS 1999 (Thomas, 2006).

The ground water extraction in the Virginia area used to provide around 18 000 ML/year. This however was beyond the estimated sustainable limit of around 8 000–10 000 ML/year (Northern Adelaide and Barossa Catchment Water Management Board, 2000), therefore in response, extension of the Virginia Pipeline to provide a greater area with recycled water was planned.

## **DISTRIBUTION AND USE**

During the development of the VPS, co-operative input was established between three principal parties, the WWTP operators- SA Water, a private company- Water Reticulation Services Virginia (WRSV) and a grower's representative committee called the Virginia Irrigation Association (VIA) (Keremane and McKay, 2006).

A 100 km long network of pipelines distributes Class A recycled water from Bolivar WWTP to horticultural farms 35 kilometres north on the Northern Adelaide Plains supplies growers with over 10 GL per year, a volume equivalent to about 10 % of the wastewater generated and processed across all four of Adelaide's WWTPs (Figure 2). Approximately 250 growers covering an area of 200 km<sup>2</sup> use the recycled water for growing horticultural crops that include various vegetables such as cauliflower, cabbage and potato along with a number of salad crops such as lettuce, tomato and capsicum. Other tree and vine crops such as olives and grapes also receive recycled water.

Through negotiation, a number of water quality assurances such as a permissible upper limit for salinity equivalent to 1500 mg/L TDS (~2340 uS/cm EC) were established to address grower requirements. The DAFF plant commissioned by SA Water in 1999, achieved the high-quality treated wastewater, equivalent to a Class A, which is suitable for unrestricted irrigation of all horticultural crops, including those crops typically eaten raw.

## **SUSTAINABILITY ISSUES**

**Planning:** When considering the successful integration of recycled water into agricultural and horticultural systems, it is imperative that; (i) optimal productivity of that system be maintained, (ii) that any negative impacts to off-site environments due to nutrient and salt loss are minimised, and (iii) on-going protection of the soil and surface and ground water quality is ensured (Bolan *et al.* 2004; Kelly *et al.* 2006).

To ensure sustainable irrigation practices, WRSV maintains irrigation management plans that are regularly reviewed and approved by the EPA for compliancy with environmental legislation. Regulation is coupled by VIA information and education programmes for growers, aimed at promoting awareness of potential effects arising from recycled water irrigation on soils and the natural environment. This association also undertakes regular monitoring of soils and groundwater. This combination of policies, planning, management and public awareness, support and participation has enabled the VPS to continue operation successfully and has resulted in the economic, social, and environmental stability of the NAP region.

The VPS has resulted in reduced pressure on groundwater resources in the Virginia region substantially. Volumes and rates of groundwater extraction by irrigators however continue to remain above levels thought sustainable. Consequentially, an extension of the VPS to include the Angle Vale region is planned. Eighteen kilometres of pipes will be laid, providing farmers in these areas with access to an additional 3000 ML of recycled water per year. This extension will also reduce the discharge of nutrients from the Bolivar plant into the marine environment by a further 6 percent.

**Socio-economic benefits:** In relation to economic sustainability of recycled water use for agriculture purposes, factors such as production volumes and nutrient value of recycled water,

land value as affected by recycled water supply, and markets access to produce grown using recycled water are considered as the sustainability indicators (Keremane and McKay, 2007).

The volume of recycled water use has increased from 6 000 ML in 1999 to 12 100ML in 2005 (Thomas, 2006). This increase is mainly due to the growth of both glasshouse based and broad acre horticultural industry in the region. Glasshouse industries on the Northern Adelaide Plains for instance, currently support approximately 600 growers with expansion of this sector increasing by 8–10 % per year (Northern Adelaide and Barossa Catchment Water Management Board, 2000). The current production area of about 4000 ha under wastewater irrigation in Northern Adelaide Plains will be increased to about 9000 ha with expanded irrigation. Agricultural land value in the Virginia Park region has increased two fold over recent years (Keremane, 2007) and it is thought this may reflect a greater degree of water security shared by farmers serviced by the VPS. The fertiliser value of recycled water irrigation has also been acknowledged by growers.

Overcoming adverse public perception and maintaining market access for produce grown using recycled water is essential in achieving viability of the VPS. It has been noticed that the acceptance level toward produce grown with recycled water is positive throughout all levels of the retail chain (Keremane, 2007). This has been achieved through communication campaigns aimed training and educating key stakeholders – industry, retailers, and the public. In addition, wholesalers are regularly kept informed of important developments of the VPS and given adequate reassurance from growers that product quality is not compromised. Moreover, endorsement of the VPS by the South Australia Department of Human Services and the EPA has also helped to build up confidence levels in consumers

In relation to social sustainability the commissioning of VPS has resulted in expansion of the horticulture industry, which in turn has resulted in the creation of more jobs for the region (Keremane and McKay, 2007). Horticulture being a labour-intensive industry has resulted in increased labour force for the agricultural sector in the region. It is also expected that more jobs will be created through development of downstream enterprises such as packing, processing, and marketing. This does suggest a close link between increased horticultural production and greater job opportunities.

The other important aspect discussed in relation to sustainable development in general, and social sustainability in particular is ‘Social Capital’. Social capital plays an important role in sustainable development (Danchev, 2005) and trust is one of the most frequently encountered elements in definitions of social capital. As argued by Danchev (2005), “ there is no evidence that deterioration of social capital can be compensated for by the rise of other forms of capital; on the contrary, when we observe the worsening of social capital, all other forms of capital including development deteriorate”. Therefore, building social capital can be a powerful mechanism for planners who seek to promote greater equity in and across cities (Vidal, 2004). Thus, social capital makes a difference in terms of a community’s ability to solve its own problem (Flora, 1995). The Virginia pipeline scores high on social capital measured in terms of trust among the irrigators and trust in different stakeholders involved. This is attributed to the fact that irrespective of the group heterogeneity (the irrigators belonged to different cultural backgrounds and ethnicity) they were having frequent and regular interactions among themselves. In addition, the tri-sector partnership formed between the private sector, public sector and the community via Build, Own, Operate and Transfer (BOOT) model had resulted in quality horizontal and vertical networks (Keremane and McKay, 2008).

**Environmental implications:** Some of the major environmental implications of VPS include: (i) reduced use of groundwater for irrigation; (ii) reduced discharge of wastewater to Gulf St Vincent; (iii) accumulation of carbon, nutrients and salt in soils; and (iv) groundwater contamination of nutrients and salt. As indicated earlier groundwater has been the predominant water resource for the Virginia horticultural region until the development of the VPS. Given the over exploitation of groundwater resources, intrusion by saline aquifers has occurred (Thomas 2006). Through the commissioning of the VPS, utilisation of recycled water in replace of groundwater in the area has resulted in increased water levels in the aquifers beneath the region.

Large volumes of effluent are discharged to Gulf St Vincent from the four WWTPs, resulting in the loading of excessive amounts of nutrients and carbon (Table 4). Discharge of nutrient and carbon

rich wastewater to Gulf degrades the quality of the freshwater and the health of its aquatic ecosystem. The use of recycled water from the Bolivar for irrigation has reduced the outflow by 30%, thereby improving the marine environment.

Where recycled water is used for irrigation, a degree of management beyond that normally required for conventional water and nutrient sources is however required. Given the uncoupled nature of water with nutrients and salts, these recycled water constituents are unavoidably applied to soils with irrigation. Therefore the amount of nutrients and salts applied to soils is directly related to the amount of recycled water applied, this in turn is determined by the water demand of the crop. Management of high volumes of applied salts and excess nutrients may therefore pose a number of adverse environmental hazards and management challenges.

Recycled water typically contains higher level of nutrients, salt and carbon compared to the fresh water. The average concentration of nutrients in recycled water varies between Wastewater Treatment Plants and will ultimately affect the total nutrient loadings when irrigation is applied at similar rates. Average concentrations for two wastewater treatment plants in Adelaide, South Australia where wastewater is routinely reclaimed and used for agricultural production, are shown in Table 5.

General nutrient composition of crops (Table 6), are often used as a guide for fertiliser requirements. Ideally nutrient loading rates in recycled water should aim to meet these nutrient demands. Based on the nutrient and salt concentration of the two recycled water sources however, precision in meeting the appropriate nutrient demand of the crop is complicated. Total nutrient loadings per hectare per season have been calculated, for irrigation rates of 3- 5 ML/ha (Table 7). While these figures suggest recycled water can be a valuable source of nutrients, total nutrient and salt loading is strongly dependant on the irrigation depth and concentration of constituents in recycled water, that both invariably differ from site to site.

Generally in soils receiving frequent recycled water irrigation, the concentration of Na and Cl often exceeds that of other macro-nutrients by more than 1-2 orders of magnitude (Unkovich *et al.* 2006), where soil Na is in high concentration it can displace other basic cations such as Ca and Mg and encourage the preferential uptake of Na at the expense of these cations (Grattan and Grieve, 1999).

Total dissolved salt (TDS) content in recycled water from the Bolivar Wastewater Treatment Plant for instance is approximately 1097 mg/l (Kelly *et al.* 2001) which is significantly higher than irrigation water sourced from the River Murray at Tailem Bend, containing approximately 329 mg/l TDS (Unkovich *et al.* 2004). Based on an average irrigation demand of 3-5 ML per ha<sup>-1</sup> yr<sup>-1</sup> in South Australia (Australian Bureau of Statistics, 2004-05) for example, recycled water irrigation would account for an additional salt loading of between 2.3 and 3.8 tons ha<sup>-1</sup> yr<sup>-1</sup> more than when irrigation water is sourced from the River Murray at Tailem Bend. When dealing with such large amounts of salts therefore, careful management of soil salinity is required to maintain soil health and crop quality (Bond, 1998).

High sodium content in the irrigation water is likely to reduce soil permeability and create an unfavourable environment for plant growth (Abdel-Dayem, 1999). The IMP developed by VPS aims to address some of the specific issues that include water and nutrient balances, subsurface drainage and overall irrigation strategy. Although it has been reported that the continuous irrigation with the Class C recycled water from Bolivar WWTP in NAP region has not led to any detrimental changes in soil salinity or boron concentrations in soils, it has led to significant increase in soil sodium adsorption ratio (SAR), which may lead to the development of more sodic, dispersive soils. (Stevens *et al.* 2003). However there has been no reported work on the effect of Class A water on soil properties in this region. In addition, there have been some reports indicating the movement of salt and nutrients in soils thereby resulting in the contamination of groundwater resources.

Although in many instances salt concentration in Class A water supplied at VPS is generally less than some of the bore well water currently used by farmers in this area, sodicity, as distinguished from salinity as a whole, tends to be higher in recycled water (Stevens *et al.* 2003). Commonly

saline bore water is mixed with recycled water to dilute bore water salinity, this 'shandying' may also help to reduce the concentration of Na in the resulting water mix.

Recycled water also contains high levels of bacteria, viruses and parasites that if not given appropriate attention can curtail the success of a land irrigation scheme. Recent global research trends have tended to focus primarily on the risk that biological organisms pose to human health. While preventing human infection by wastewater micro-organisms should remain a predominant driver in this industry, these organisms often lyse quickly once removed from their host and therefore pose minimal long-term threat to soil. There is some risk however of human exposure to these organisms during irrigation. In case of the VPS, training and awareness programmes carried out by the VIA, an agreement to pump recycled water in lilac pipes and display of sign boards to warn about the use of recycled water has taken care of the health hazards to a large extent (Keremane and McKay, 2007).

## CONCLUSION

The Virginia Pipeline Scheme is one of the most successful recycled water irrigation schemes in Australia. The value of recycled water as a source of irrigation water, nutrients and carbon has been well recognised. However the challenge facing wastewater reuse is to minimise environmental risks such as accumulation of contaminants in soils, degradation of soil quality, impacts on plant growth, pollution of groundwater and surface water, disease transmission and greenhouse gas emission.

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Table 1. Some of the major wastewater sources generated in Australia

Table 2. Some of the major recycled water schemes in Australia

Table 3. Major characteristics for South Australian Guidelines for use of various classes of reclaimed water for irrigation and best practice irrigation methods (we can use the table provided at the end instead which is more comprehensive)

Table 4. Amount of treated wastewater discharged and the loading levels of nitrogen, phosphorus, suspended solid and BOD to Gulf St Vincent in 2001/02

Table 5. Concentration of selected nutrients and salts in two recycled water sources processed at Wastewater Treatment Plants in Adelaide, South Australia.

Table 6. Composition of nutrients in a selection of commonly grown Australian vegetable crops.

Table 7. Total amount of nutrients and salts applied to soils annually through recycled water when irrigated at a rate of 3 to 5 ML/ha per year.

Figure 1. A typical topology of wastewater reuse (Keremane, 2007)

Figure 2. Virginia pipeline system

**Table 1:** Some of the major wastewater sources generated in Australia

<b>States</b>	<b>Recycled water usage in 2004 - 05 (ML)</b>		
	<i>Farm effluents</i>	<i>Storm water</i>	<i>Sewage</i>
NSW	4471	< 1000	49748
Victoria	23634	< 1000	69651
Queensland	2737	< 1000	44747
Western Australia	2099	< 1000	15263
South Australia	1277	4000	20491
Tasmania	2464	< 1000	4282
Northern Territory	-	< 1000	1852
ACT	-	< 1000	2189

Source: Australian Bureau of Statistics and Dairy Australia, (2004-05).

**Table 2. Some of the major recycled water schemes in Australia**

Project	Annual Volume (ML)	Water Quality <sup>1</sup>	Application
<b>Virginia (S. Aust.)</b>	<b>22,000</b>	<b>A</b>	<b>Unrestricted irrigation of horticultural crops</b>
South East Queensland	100,000+	A and C	Class A to horticultural crops, Class C to cotton and Cereal farms
Hunter Water	Up to 3,000	C and B	Coal washing, electricity generator cooling
Eastern Irrigation Scheme	10,000	C	Horticulture, public spaces, golf courses, household gardens and toilet flushing
Barwon Water Sewer Mining	Up to 1,000	-	Agricultural and industrial uses
McLaren Vale	Up to 8,000	C	Application to vines for producing premium quality grapes
Rouse Hill	Up to 1,500	A	Dual reticulation system to 15,000 households
Georges River Program	15,000 to 30,000	Varying standards based on application	To serve existing potable water customers and new residential developments
Other projects <sup>2</sup>		All class B or A	Application include horticulture, wine grapes, pasture, fodder, public spaces, golf courses, household gardens and recreational area

Note: <sup>1</sup>States have to treat the water to standards that meet EPA and Department of Health requirements

<sup>2</sup> Includes more than 50 schemes

The scheme highlighted in bold is the project under discussion

Source: US EPA, 2004

**Table 3. Major characteristics for South Australian Guidelines for use of various classes of reclaimed water for irrigation and best practice irrigation methods**

Class	A	B	C	D
Uses	Residential non-potable (garden watering, toilet flushing, car washing, path/wall washing); Municipal use with public access; Unrestricted crop irrigation	Municipal use with restricted access; Restricted crop irrigation; Irrigation of pasture and fodder for fodder animals	Municipal use with restricted access; Restricted crop irrigation; Irrigation of pasture and fodder for fodder animals	Restricted crop irrigation; Irrigation for turf production; Silviculture and non food chain aquaculture
Microbiological criteria ( <i>E. coli</i> /100ml)	< 10; Specific removal of viruses, protozoa and helminths may be required	< 100; Specific removal of viruses, protozoa and helminths may be required	< 1000; Specific removal of viruses, protozoa and helminths may be required	< 10 000; Helminths need to be considered for pasture and fodder
Chemical/physical criteria	Turbidity ≤ 2NTU; BOD <20mg/L Chemical content to match the use	BOD <20mg/L; SS <30mg/L  Chemical content to match the use	BOD <20mg/L; SS <30mg/L Chemical content to match the use	Chemical content to match the use
Typical treatment process	Full secondary plus tertiary filtration plus disinfection Coagulation may be required to meet water quality requirements	Full secondary plus disinfection	Primary sedimentation plus lagooning OR Full secondary (disinfection if required to meet microbial criteria only)	Primary sedimentation plus lagooning OR Full secondary
Best irrigation practices	Plants with large surface area on or near ground = drip or furrow Root crops consumed raw = spray, drip, flood or furrow Crops without ground contact = spray	Plants with large surface area on or near ground = drip or furrow Root crops consumed raw = sub-surface Crops without ground contact = flood Crops with or without ground contact and skin that is removed before	Plants with large surface area on or near ground = drip or furrow Crops without ground contact = drip or furrow Crops without ground contact and skin that is removed before consumption = flood Crops with ground contact and skin that is removed	Crops without ground contact = sub-surface Crops without ground contact and skin that is removed before consumption = drip, furrow or sub-surface Crops with contact with ground and skin that is removed before

consumption = spray

before consumption = drip,  
flood or furrow  
Root crops processed before  
harvesting = spray, drip,  
furrow or sub-surface  
Root crops processed before  
harvesting = spray, drip,  
furrow or flood

consumption = sub-surface  
Surface crops processed  
before harvest = sub-  
surface  
Crops not for human  
consumption = unrestricted

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Source: South Australian Reclaimed Water Guidelines (Treated Effluent), 1999; Note: NTU= Nephelometric turbidity unit; BOD= Biochemical Oxygen Demand; SS= Suspended Solids

**Table 4. Amount of treated wastewater discharged and the loading levels of nitrogen, phosphorus, suspended solid and BOD to Gulf St Vincent in 2001/02**

WWTP	Wastewater discharged (ML)	Wastewater re-used (ML) (% of total)	Nitrogen (Mg)	Phosphorous (Mg)	Suspended Solids	BOD* (Mg)
Bolivar	35,957	9,714 (21%)	477	131	1,981	108
Christies Beach	8,747	1,971 (18%)	230	72	86	55
Glenelg	18,894	1,918 (9%)	520	145	242	173
Port Adelaide	13,731	0.0 (0%)	456	67	235	55
Total	77,329	13,603	1,683	415	2,544	391

Source: SA Water, Australia (2005)

**Table 5. Concentration of selected nutrients and salts in two recycled water sources processed at Wastewater Treatment Plants in Adelaide, South Australia.**

	Concentration (mg/l)						
	N	P	K	Ca	Mg	Cl	Na
Bolivar Wastewater Treatment Plant <sup>1</sup>	10.3	1.2	46.7	40.0	30.8	382.0	273.0
Willunga Wastewater Treatment Plant <sup>2</sup>	26.0	9.2	21.8	41.15	27.82	292.8	198.6

1 Source (Kelly *et al.* 2006)

2 Source (McCarthy unpublished)

**Table 6. Composition of nutrients in a selection of commonly grown Australian vegetable crops.**

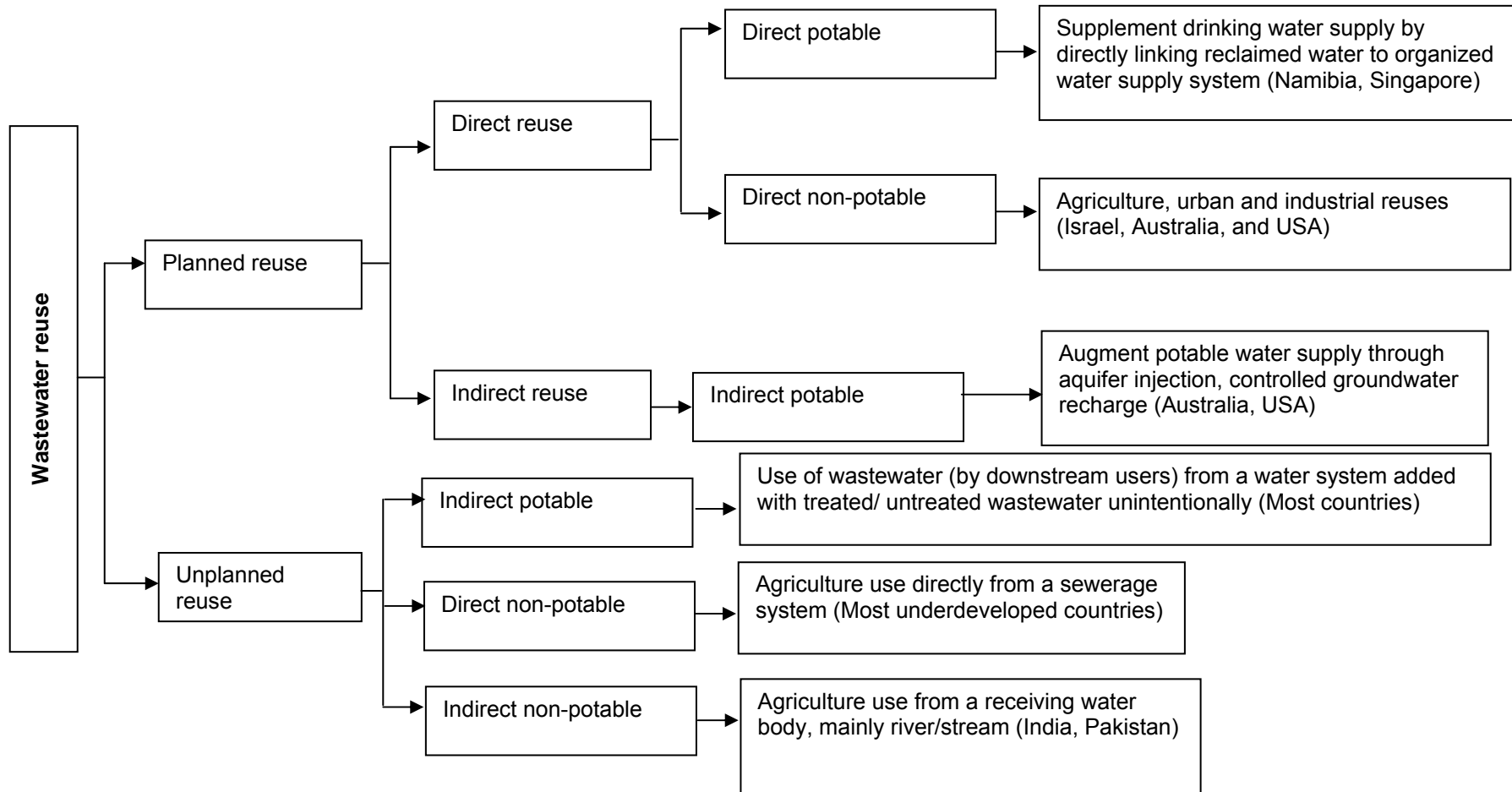
Nutrient	Annual nutrient loading under recycled water irrigation (kg/ha)	
	Recycled water from Bolivar WWTP	Recycled water from Willunga WWTP
N	31 – 52	78 – 130
P	3.6 – 6.0	28 – 46
K	140 – 235	65 – 108
Ca	120 – 200	124 – 207
Mg	93 – 155	84 – 140
Cl	1146 – 1910	878 – 1463
Na	819 – 1365	596 – 993

Source: Creswell and Huett, 1998

**Table 7. Total amount of nutrients and salts applied to soils annually through recycled water when irrigated at a rate of 3 to 5 ML/ha per year.**

	N	P	K	Ca	Mg
	(kg/ha)				
Cabbage	147	24	147	36	13
Cauliflower	181	28	225	127	18
Lettuce	100	18	180	10	3
Tomato	111	46	192	74	22
Potato	264	23	310	66	21

Figure 1. A typical topology of wastewater reuse (Keremane, 2007)



Source: Keremane (2007)

Figure 2. Virginia pipeline system

