Prime Minister's Science, Engineering and Innovation Council

RECYCLING WATER FOR OUR CITIES

28 November 2003

This paper was prepared by an independent working group for PMSEIC. Its views are those of the group, not necessarily those of the Australian Government.

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EXECUTIVE SUMMARY

The continued growth of our cities along with Australia's variable climate, available water storages, and the increasing pressure on our water supplies is cause for concern. In order to manage this increasing demand for water from our cities and maintain continued economic growth we can encourage the public to use less water but we will also have to find alternative sources of water.

Current practices of water supply to our cities are not sufficient to meet future needs and new strategies and options must be investigated and developed. This paper presents an overview of the situation and offers an outline of possible mechanisms by which Australian cities can make better use of their available water resources.

There is no single solution to the provision of reliable water supplies for our cities, and a mixture of initiatives appropriate to the specific circumstances of each of Australia's cities will be required. Public health must be assured, and the solutions sought need to be economically sensible, environmentally sustainable and socially acceptable. Recycled water is one of a number of solutions available. Recycled water is a valuable resource that should not be wasted and which can be used in a safe and sustainable manner to reduce pressures on limited drinking water resources.

The working group advocates that Australia needs to invest now in research and demonstration of some of the options available so that the correct choices for the future can be made. Innovation must be encouraged and any regulations which are put in place must focus on outcomes.

Recommendations

1. The urban theme of the CoAG National Water Initiative should include:

    - Water awareness and education programs to build broad based community support for water conservation and recycling water in households
    - Environmental sustainability and cost effectiveness scorecards for evaluating water supply options, for appliances, new houses and buildings, new suburbs and city-wide, and use of this for accreditation, planning approval, new home grants, and access to related federal resources.
    - Pricing policies for drinking and recycled water that ensure efficient use of these valuable resources. Environmental externalities, the cost of disposal of stormwater and treated effluents and research funding requirements should be factored into the price of drinking water.
    - Encouragement of better integrated water planning and management in urban areas through institutional reform involving local government, catchment boards, water utilities, and state government agencies with relevant responsibilities.
    - The NWI could encourage the development of a range of decision-making tools for urban water management, as well as a scorecard tool.

2. Fast track current proposals for reform of the Health and Environmental Guidelines for the production and use of recycled water.

3. In order to get the most cost effective outcomes any targets for water use should be set on total water use rather than on components such as the volume or percentage of water recycled.

4. Continuing research into treatment processes and sensor development will lead to progressive improvement in costs and efficiency of advanced waste water treatment and should be supported. Substantial opportunities exist in encouraging research into innovative approaches to whole urban water systems that explore ways of putting the various technologies together into water systems that meet the needs of urban communities.

5. Investment in water recycling projects should be stimulated. A grants scheme should be developed to stimulate 'icon developments' incorporating innovative urban water systems and ensuring rigorous evaluation to improve subsequent innovations. Federal funding should be conditional on an integrated approach to the whole urban water lifecycle, implementation of rigorous evaluation of the performance of the development, and transfer of the knowledge gained to all stakeholders through publication and workshops.

CHAPTER 1: THE CHALLENGE OF PROVIDING WATER FOR GROWING CITIES

Introduction

Australians are largely city dwellers, and have become accustomed to having access to plentiful quantities of safe, clean water for household use. Australia has a highly variable climate, and we regularly experience dry spells when we face the challenge of providing enough water to sustain our cities. Because of this variability we have to store larger volumes of water to assure a reliable supply than is the case in many other countries.

Our cities are continuing to grow and the increasing demand for water is causing concern. Many of our cities are now experiencing moderate water restrictions as a consequence of the current 7 year drought, one of the worst since European settlement. This drought has shown that many of our cities do not have enough water to keep going in the ways of the past. Our cities are now using a large proportion of the water that falls on their water supply catchments, and they are finding that people who live in adjacent catchments do not want to give away their water to support the thirst of our growing cities. In addition there are increasing pressures to take less water so as to provide environmental flows to protect the urban rivers and estuaries.

There are also concerns that climate change will reduce the amount of rainfall on the catchments of Southern Australia. CSIRO studies have suggested that Melbourne's annual average rainfall may decrease by up to 5% by 2020 and up to 13% by 2050. Perth has already experienced a dramatic drop in rainfall and a bigger drop in runoff from the catchments, and some experts believe the East coast will experience a similar shift. The suggested changes indicate that we may have to cope with an even more uncertain climate than we currently experience.

We have developed an extensive urban infrastructure of pipes and channels. These systems deliver water to households and other users, and take away wastewater as sewage for treatment and disposal. We also have a system of stormwater drains to remove water quickly from urban areas to minimise any impacts of flooding. These infrastructure investments are designed to protect humans from the infectious material in our wastes and from the physical risks of flooding. The conventional water systems of our cities have been designed to protect public health by separating the drinking water supplies as far as possible from human wastes, and the reduction in the incidence of water-borne diseases has been a dramatic success story of the 19th and 20th Centuries. This concern with public health remains paramount, and as we rethink our urban water strategies it is important to not put public health at risk.

In order to maintain the economic growth of our cities there are only two options. The first is to encourage people to use less water; the second is to find alternative sources of water.

Patterns of Water Usage in Australian Cities

Australian cities consume a similar amount of water per hectare as irrigation areas, and Australian per capita domestic water use (320 litre per person per day) is second highest in the world after USA (Price, 2002).

The way we use water in the average Australian city is shown in Table 1. Households use some 59% of urban water; the rest is used in industry and local Government. The numbers in this table refer to the total for Australia's 22 largest cities with a combined population of 13.4 million people, and are taken from Water Services Association of Australia (WSAAfacts 2001).

Table 1: Water Use in Australian Cities

Component of Water Use	Volume ML	Percentage of Total Consumption	Percentage of Residential Consumption
Residential Gardens	414,000	20.1%	34%
Toilet Flushing	244,000	11.8%	20%
Laundry	183,000	8.9%	15%
Bathroom	317,000	15.3%	26%
Kitchen	61,000	3.0%	5%
Total Residential	**1,219,000**	**59.0%**	**100%**
Industrial and commercial	437,000	21.2%	
Local government, parks, fire fighting	139,000	6.7%	
System losses	221,000	10.7%	
Customer meter errors	49,000	2.4%	
TOTAL	**2,065,000**	**100%**	

Some 54% of the water used in the average Australian household is used for flushing toilets and watering gardens. Such uses do not require high quality drinking water.

Managing the Demand for Water

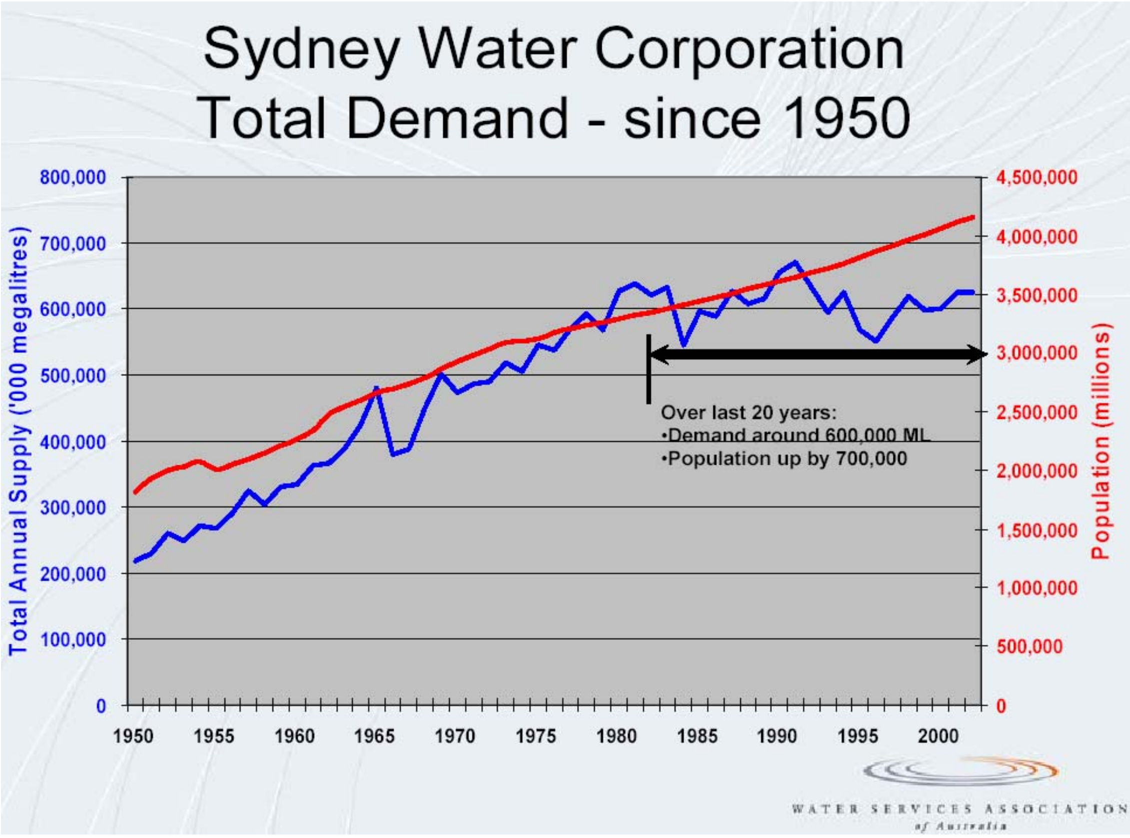
The first plank in managing demand is to set appropriate pricing for water. In the last century, it was common for people to pay for water through a rate on the value of their property. The pricing reforms that started in Perth in the late 1970's started charging for the volume used. A severe drought in eastern Australia in early 1982-3 accelerated the reforms. User pays water pricing was introduced in the Hunter Valley in 1982 with spectacular effect in curbing the growth in water consumption.

Demand management and public education campaigns programs were developed to complement the pricing reforms. Victoria mandated the use of dual flush toilets in new and replacement fittings installed after 1984; by 2000 some 60% of the cisterns in Australia's major cities were dual flush, reducing the average flush volume from 11 L for the original single flush cisterns to 3-6 L for modern dual flush units.

Pricing reform, demand management and public awareness campaigns were progressively implemented across all of Australia's major cities. The Council of Australian Governments (CoAG) Water Reform Agenda of 1994 gave further impetus to complete these reforms and completed the introduction of user pays water pricing. By 2001 some 80% of water revenue across the industry was collected from metered water consumption, compared with less than 10% 15 years earlier.

Sydney provides a good illustration of the success of these demand management programs. Figure 1 shows the growth of Sydney's population and water consumption. In the last 20 years Sydney has absorbed an additional 700,000 people with no growth in water consumption.

Figure 1.



The success of demand management has 'hardened' water consumption making it more difficult to achieve future savings either through efficiency measures, or water restrictions. The 'low hanging fruit' in terms of savings from demand management have been picked.

Australia's cities are continuing to implement demand management strategies to make more efficient use of available water supplies, to reduce the growth in water consumption despite significant population growth, and to defer the date when additional sources of reliable water supply will have to be found. Success in these demand management programs will determine the date when additional reliable water supplies will have to be brought on stream. Implementation of demand management and water efficiency measures may allow Melbourne to defer augmentation of the water supply system until 2030 depending on the magnitude of any climate changes. However, Perth and the Gold Coast are already facing the challenge of finding alternative sources of water. Given the long lead times in implementing major infrastructure changes, all of our major cities should be seriously planning for alternative water supply strategies now.

Reducing the Environmental Impacts of Stormwater and Sewage Disposal

Environmental issues have become more important for urban water planning in the last decade. The realisation that some water must be left in the rivers to ensure river health has emerged, and in some States, agencies are attempting to recover water from users to return it as environmental flows. This is a difficult challenge.

There are also concerns about the environmental effects of wastewater discharge to rivers and coastal waters, and a demand that wastewater be treated appropriately so as to minimize impacts. Another strategy has been to extend ocean outfalls to get it further away from the shoreline. There are also calls from time to time to avoid discharge altogether and to recycle this wastewater to meet our growing water needs. Another strategy has been to try and use the effluents for productive irrigation, and there have been some significant success stories.

There are difficult environmental trade-offs between decreasing the impacts on rivers and estuaries and the considerable energy use and hence impacts on greenhouse gases of improving the quality of effluents. We need to develop a 'sustainability scorecard' that enables us to compare the wide range of economic, environmental and social costs of the various strategies before us on a "whole of lifecycle" basis.

Urbanisation of our landscapes leads to increased runoff, and to runoff being more concentrated in a shorter period. Large amounts of impervious area causes water to be shed quickly to streams. These pulses of rapidly flowing water are a major cause of degradation of the health of urban streams. The poor quality of urban stormwater runoff is a major cause of environmental degradation in urban waterways and adjacent coastal waters. One of the benefits of water sensitive urban developments where unsealed swales and urban lakes hold water back in the landscape is that these damaging pulses of stormwater are reduced.

Finding Alternative Sources of Water

All Australian capital cities discharge more effluent and stormwater than they import as drinking water supplies (Senate Inquiry Report on Urban Water Management, Dec 2002). There are therefore a number of alternative sources of water for our cities, and all must be carefully examined as cities choose the best way forward in their particular circumstances.

Water recycling provides one way of substituting for some uses of drinking water in our cities. This will only be effective if we can actually use the recycled water to replace drinking water for some uses, rather than just find productive uses of recycled water for irrigation developments. In order to increase reliable water supplies for the cities recycled water will either have to be substituted for existing drinking quality supplies to industry, public parks and sportsgrounds, substituted for some domestic uses through dual reticulation systems or be recycled back into the drinking water supply system.

Some countries have embraced water recycling much more than Australia, and it has been demonstrated to be quite safe to human health and may be a cost-effective solution in some circumstances.

The Challenge for Our Cities

There is no single solution to the provision of reliable water supplies for our cities. A mix of initiatives appropriate to the specific circumstances of each city will be required, starting with the most cost effective and environmentally sustainable options first. Recycling is just one strategy for providing reliable water supplies, and its specific role will depend on its relative environmental sustainability and cost effectiveness for the particular city.

Our present practices in supplying water to our cities will not be enough to meet their water needs in the future. We are going to have to develop new strategies. In making the choices that confront us it is important that we consider all options, and that we develop a rigorous framework for examining the financial, health, environmental and social costs of each option.

It is also important that we invest now in research and demonstration of some of the likely possibilities in order to develop our knowledge and experience so that we better understand the ramifications of the choices that will be made. We must encourage innovation and ensure the regulations we put in place focus on the outcomes that must be achieved, rather than be prescriptive in a way that stifles innovation. We also need to engage the community in the decisions before us, so that they understand the various trade-offs and impacts, and are part of making informed community choices.

CHAPTER 2: SOURCES OF WATER FOR OUR CITIES

There is a range of potential sources of water for our cities. Each should be considered on its merits in developing long-term strategies for providing reliable water supplies. Different choices or combinations of choices may be required depending on the specific characteristics of each city.

Catchments and New Storages

There is strong public pressure not to build further storages. New dams are costly to build, but they also have significant environmental costs in terms of the values of the lands that are inundated, and the impacts of dams themselves on river health. Building further dams is however a possibility for some of our cities and despite the unpopularity of this option it must be kept available.

Buying Water from Irrigators

Approximately 75-80% of the water used in Australia is used for irrigation and the CoAG Water Reforms of 2003 seek to establish water rights that can be traded in a National water market. This opens up the opportunity in some jurisdictions where dams are shared or are reasonably close for the city to purchase irrigation water from willing sellers. It is probably the cheapest source of new water for several cities, and it is already taking place to some extent.

Groundwater

Some of our cities, such as Perth are underlain by appropriate aquifers that can supply water for urban use. This water can be replenished with urban stormwater or reclaimed water (Dillon *et al*, 2003). These systems need to be managed to ensure they do not become contaminated or clogged. Aquifer storage and recovery is an exciting approach pioneered in Adelaide where stormwater and reclaimed water is used to replenish aquifers for later municipal irrigation use. Further CSIRO research with the Corporation of the City of Salisbury is proposed to demonstrate that stormwater stored in aquifers can be recovered at acceptable quality on a sustainable basis.

Roofwater and Domestic Tanks

Many urban Australians have been installing tanks to catch the rainwater that falls on their roofs. In the last couple of years, Government subsidy schemes have been in place to encourage the installation of domestic rainwater tanks in Sydney, Canberra, Melbourne and Perth, though uptake of the subsidy has been modest.

Past studies of the hydrology of rainwater tanks often assumed that they would be used to supplement garden watering. They showed that the size of tank needed to store water from wet periods for use in the dry was such as to make the exercise uneconomic.

There has been a change in thinking recently. Proposals now are to use tank water for both toilet flushing, and for hot water supply for general use. These are relatively constant uses throughout the year and, with the reticulated supply as a backup, it is possible to significantly reduce the demand on the city system with modestly sized tanks (eg 5 kL). A 27-unit residential development at Fig Tree Place (Newcastle) has shown a 60% saving in water use through capturing rainwater and stormwater for use within the development (Coombes 2000). Integration of stormwater and rainwater capture within the Hunter valley has been modelled to save 50% of mains water use, and reduce peak demand by 25%. It is important to ensure rainwater tanks are appropriately maintained to ensure safe operation.

Urban Stormwater

The Corporation of the City of Salisbury in Adelaide has been innovative in stormwater conservation, initially for its own parks and gardens. Recently, it has completed a jointly funded venture to store and treat stormwater on Parafield Airport to provide over 1GL/annum to G. H. Michell & Sons, one of Australia's largest wool processors. This water is arriving at a lower salinity than the drinking water it replaced. A further project involves providing harvested stormwater at Elizabeth. Within 3 years stormwater harvesting and aquifer storage and recovery in this location will replace 4GL/year of mains water.

The challenge with stormwater harvesting is the requirement for storage of the water until it is needed. This can be achieved in urban lakes and wetlands, as demonstrated in Canberra, or in recharge to brackish aquifers as has been pioneered in Adelaide.

Desalination of Seawater

Most of our major cities are on the coast and surrounded by limitless supplies of sea water that can now be treated and used to meet drinking water needs for the city. The technology for doing this is improving and becoming cheaper. Desalination is now a feasible technology for providing drinking water in areas where seawater or saline groundwater is available. It can be anticipated the costs will continue to decline, and there are possibilities for solar desalination. An ongoing challenge may be the disposal of the concentrated brines. Cheap, low energy desalination could unlock virtually limitless water resources for some cities.

Reports indicate that desalination is already being considered as an option for Perth, and that water can be supplied for as little as $1.30 per kL, although the high energy use has greenhouse gas implications. Use of renewable energy such as solar or wind for desalination, could overcome the high energy and greenhouse gas implications.

Recycling of Treated Effluents

Australia is recycling around 10% of its sewage (Table 2), but very little of this is replacing drinking water use in our cities. Most commonly it is being used to irrigate land, either for productive agriculture, or for urban amenity of lawns, parks and sportsgrounds (Dillon, 2000).

Table 2: Annual water recycled from water utility Sewerage Treatment Plants in Australia, 2001-2

Region	Effluent, GL/yr	Recycled, GL/yr	%
QLD	339‡	38‡	11.2
NSW	694	61.5	8.9
ACT	30	1.7	5.6
VIC	448	30.1	6.7
TAS	65	6.2	9.5
SA	101	15.2	15.1
WA	126	12.7	10.0
NT	21	1.1	5.2
Aust.	**1824**	**166.5**	**9.1**

‡Subject to revision
Source: Radcliffe, (2003)

There are many opportunities to recycle treated effluents of various qualities, and to make productive use of it. Many of these opportunities are for agricultural or forestry production, and are being developed by a number of water authorities.

This recycling has provided opportunities for economic development, recent examples including the introduction of tertiary treatment and distribution to an expanding group of Northern Adelaide Plains vegetable growers, a self-funded distribution scheme for the new plantings of Southern Vales grape-growers in Adelaide, and the conversion of Nowra dry-land dairy farmers to irrigated pasture production to establish increased productivity and long-term viability. Schemes currently being examined include development of agricultural land on the Werribee Plains for irrigated horticulture at Balliang and an expansion of agricultural enterprises through the Cranbourne – Koo Wee Rup corridor in Victoria.

Some of these schemes have led to agricultural production that can be profitable and more than cover the cost of treatment and supply of the recycled water. However, transporting recycled water over large distances can be very costly, especially when pumping is involved.

The following chapter will explore recycling options in our cities, where the imperative is to substitute recycled water for drinking water.

CHAPTER 3: RECYCLING OPTIONS FOR OUR CITIES

In view of the squeeze on the water resources for our cities, and the impacts of disposal of effluents to rivers and coastal waters, many Governments are establishing targets for recycling, and providing various encouragements to stimulate adoption of such practices.

It is important that communities make sensible decisions in this area, since public health must be assured, and we are seeking solutions to our water problems that are economically sensible, environmentally sustainable and socially acceptable.

In this chapter we will review the various strategies being adopted in Australia and overseas; in the following chapter we will explore the issue of making appropriate choices from the range of options available.

Recycling at the Household Scale

It is possible to treat wastewater from laundries and bathrooms (termed grey water) from a house and to recycle it on-site, for garden watering or for toilet flushing. This however requires a reasonable level of skill and commitment from the householder, and there are strong concerns that public health could be at risk if permanent systems are not well managed.

It is true that many urban residents have recycled grey water during drought periods, and there have been no reported health problems with this practice. However, there are concerns about this as an ongoing practice when people are less conscious of water, and when soils are wetter. The concern is for public health, where faecal material from soiled clothing or nappies could contaminate water with microbial pathogens. Testing of grey water has shown that it can contain substantial amounts of faecal micro-organisms.

Domestic-sized wastewater treatment plants in each of six houses in urban Canberra commenced operation in 1994-5 using two alternative treatment processes to reclaim water for toilet flushing and garden watering. These have proved to be effective, but do require a level of commitment and knowledge that might not be widespread. This has been demonstrated for on-site septic tanks where poor maintenance has been commonly detected.

While we do not believe that current options for on-site treatment at the household scale is feasible in our major cities, we do believe there are real opportunities at the scale of office or apartment block scale where treatment facilities can be incorporated in the building and maintained by professional service companies. At Inkerman Street, St Kilda, a 236 unit housing development has incorporated recycling of domestic greywater (bathroom basins, baths and showers), from about half the units in four buildings using an activated-sludge (aeration) tank, with secondary filtration in a 400 square metre native wetland and sand filtration on the site. There is recycling of the combined grey/stormwater for sub-surface garden irrigation and toilet flushing across the entire development. In a further example the Australian Conservation

Foundation has occupied a refurbished building in Carlton incorporating an in-house biological Sewage Treatment Plant (STP), with water from it being used to flush toilets and irrigate the internal and rooftop gardens.

A potential expansion in the use of small-scale plants in office or residential apartment blocks could underpin a new service industry required to successfully maintain and operate these plants with the necessary level of quality assurance.

Sewer Mining with Small-scale Treatment Plants

It is possible now to develop small scale treatment plants that can be housed in portable containers, or located on site that pump sewage from the sewer, treat it to an appropriate standard, and then use it as an alternative to the reticulated drinking water supply for watering parks and sporting grounds. When watering is not needed, the plant does not operate and material continues in the normal sewerage system. Experimental installations have been trialled in Melbourne's Domain Gardens and Albert Park, in Canberra at Southwell Park, in Brisbane at South Pine Sports Complex and on the Gold Coast. A further sewer-mining project at Flemington Racecourse, facilitated through Victoria's *Smart Water Fund*, will demonstrate 100 kL/day Multiple Water Reuse Technology developed by the CRC for Waste Management and Pollution Control, and licensed to Zeolite Australia Ltd.

Recycling Treated Effluent

Our sewage treatment plants provide a reliable source of water that can be treated to various degrees and recycled. A pipe system to return the recycled water to where it is needed will be required, and often pumping will be needed because we locate our sewage treatment plants at a low level so that effluents flow to them by gravity. To re-use the water we must pump it back up the hill, adding to the costs. The distance from the sewage treatment works is an important cost consideration, leading to the idea that smaller STPs, scattered through the city might be more appropriate for recycling. Recycling will always be cheaper near a treatment plant.

Recycling for Community Amenity Use

The parks and sportsgrounds that could use recycled water tend to be scattered across the city, and so there can be significant infrastructure costs in installing the pipe systems to deliver the recycled water. As stated above recycling is cheaper near a treatment plant, the distance from the sewage treatment works is an important consideration, and the opportunity for community amenity use of recycled water provides further support for the idea that smaller STPs scattered through the city might be more appropriate for recycling. The large end of pipe sewage treatment systems we currently use require extensive pipes and pumping in order to recycle water back to where it can be used.

There are a number of experiences in using recycled water for amenity purposes. These include a number of schemes for irrigating parks, and golf courses in Sydney, the use of effluent in Canberra to maintain the grounds of Duntroon Military College, the use of recycled water from the Werribee Sewage Treatment Plant (STP) for the nearby tourism precinct and for the development of golf courses near the Carrum STP in Melbourne and the introduction of recycled water to the McGillivray Oval in Perth. Whilst these uses can reduce the use of drinking water; the challenge is in providing the pipes needed to deliver the water to where it can be used, and to be able to assure the public of the safety of recycled water. There is also the potential for nutrient and contaminant runoff, nutrient and contaminant build-up in soils and possible contamination of groundwater if this recycled water is applied inappropriately.

Recycling Water for Industry

The demand of industry for recycled water may be much less seasonal than agricultural and amenity uses. An advanced water reclamation plant at Luggage Point STP is now supplying up to 14 ML/day of boiler feed water to the Brisbane BP-Amoco refinery. The Illawarra Wastewater Strategy involves upgrading Wollongong STP to produce 20 ML/day for BHP Steel with concomitant savings in drinking water. The proposal to upgrade the Glenfield and Liverpool STPs in Sydney, and provide up to 100ML of recycled effluent/day through a 53 km pipeline from which sales to industrial and amenity users are to be made, before discharging the remainder through the Malabar outfall, will serve to both improve environmental standards in the Georges River and substitute for drinking water sources currently used. In Perth, new industries in the Kwinana Industrial Strip are unable to access groundwater, and can have only limited access to drinking water supplies, but the Kwinana Water Recycling Project, due to be commissioned in 2004, will make available 5GL/annum of water from the Woodman Point STP for industrial use.

Third Pipe Systems to Recycle Water to Households

Conventionally we service individual households with a two-pipe system. One supplies high quality drinking water (potable water) and the other carries sewage away from the block to a centralised treatment plant before disposal.

In third pipe systems an additional pipe brings back treated water to the household for uses such as garden watering and toilet flushing, thus taking pressure off drinking water. Obviously the distance that water must be transported is a key driver of cost; the other issue is the level of treatment - the higher the level of treatment the greater we protect public health and increase the costs.

A “third pipe” (dual supply) scheme from the Rouse Hill STP is now providing recycled water to 12,000 households in the Parklea, Kellyville and Rouse Hill localities of north western Sydney. The Sydney Olympic Park Authority has developed an integrated effluent/stormwater system to provide recycled water to Olympic Park and the adjacent suburb of Newington through a third pipe system and is described in detail in Box 1. Mawson Lakes, an Adelaide development with a proposed residential population of 10,000, a university campus of 5,000 students and a resident workforce of 10,000 has been designed to accommodate dual reticulation through a “third pipe” system. Its sewage is to go to Bolivar STP for advanced treatment and recycled water will be piped back for mixing with stormwater harvested by the Salisbury Council. Dual reticulation to 9000 residential dwellings is being developed in the new suburb of Aurora, at Epping North, 25 km from Melbourne.

Third pipe systems have also been considered for the Heathwood/Brazil development in Brisbane (Mitchell et al. 2003) and for a 150,000 resident project at Pimpama-Coomera on the Gold Coast.

These third pipe schemes can be a cost effective solution for Greenfield developments that are located away from major trunk sewers. The overall cost of the urban infrastructure is somewhat greater than the conventional, but the use of recycled water can reduce the size of water supply pipes making a significant saving in that area.

Third-pipe centralised water recycling schemes have been in successful operation in pilot schemes in North America for over 40 years (Sheikh, 2003) and for a similar time in Japan and more recently in China, with various strategies, including mandating the recycling of treated wastewaters within high rise buildings for toilet flushing (Asano *et al.*, 1996).

Supply of recycled water of high quality for household gardens, flushing toilets and washing machines could potentially meet approximately 40% of an Australian city's water needs. Construction of dual water supply systems in new subdivisions would progressively reduce the growth in demand for drinking water. Redesign of the plumbing systems in high-rise apartments to require recycling could also make a significant contribution.

Dual reticulation to households requires rigorous attention to reducing the microbiological risks through continuous good practice operation of the advanced wastewater treatment plants. Given that the recycled water may be drunk accidentally the health risks from both microbial and chemical micro contaminants must be effectively managed.

Cross connection of the recycled supply with the drinking supply, which must be laid with "purple pipes" within houses is a significant risk factor that will necessitate modification of plumbing codes, strict regulation and auditing. Experience in constructing and commissioning Rouse Hill demonstrated the importance of close control of private plumbing to avoid cross connection of recycled water into the drinking water supply. Internationally a recent incident in Holland of a cross connection of relatively poor quality river water into the drinking water supply resulted in people getting sick. This incident is a substantial set back for water recycling and every effort should be made to avoid similar incidents in Australia.

Box 1: Sydney Olympic Park case study

SYDNEY OLYMPIC PARK:

URBAN WATER RECYCLING AND INTEGRATED WATER MANAGEMENT

Sydney Olympic Park is a leading demonstration of sustainable and integrated urban water management. The integrated approach has realised significant social and environmental benefits in terms of water conservation, waste minimisation and pollution control and has dramatically increased the knowledge, understanding and community expectations regarding urban water recycling.

The Water Reclamation and Management Scheme (WRAMS) commenced operation at Sydney Olympic Park in July 2000. The Scheme is incorporating collection and treatment of sewage and stormwater and supply of recycled water for non-drinking uses to all residents, commercial premises, sporting venues and for irrigation of parklands and playing fields and is capable of servicing population of approximately 20,000 people.

Recycled water is supplied to all new developments and is suitable for:

- toilet flushing
- washing clothes
- washing cars, windows, brickwork
- washing pets
- filling ornamental water features
- fire-fighting
- watering gardens (including vegetables), lawns, parks and playing fields

Elements of the Sydney Olympic Park System:

Dual Water Reticulation Network: - Separate drinking and recycled water mains are installed throughout the Sydney Olympic Park and the residential suburb of Newington. Each facility has two metered water connections - one each for drinking and recycled water.

Water Reclamation Plant: - Sewage from residential areas of Newington and Sydney Olympic Park venues is treated at the Water Reclamation Plant at a rate of up to 2.2 million litres per day. Advanced biological treatment processes remove pollutants and nutrients, leaving high quality effluent water that is disinfected by ultra violet light. This is then pumped to the water treatment plant for final processing.

Water Treatment Plant: - Water from either the Water Reclamation Plant or the Brickpit reservoir goes through a continuous micro-filtration process that removes particles up to 0.2 microns (including all water parasites, viruses and bacteria). A reverse osmosis process is also available to remove salts. Finally chlorine is used to disinfect the recycled water before is supplied to the customers. The plant can treat up to 7 million litres of water per day.

Stormwater Management: - Stormwater collection and storage is one of the most valuable elements of the integrated water cycle system at Sydney Olympic Park. The Brickpit reservoir has a capacity of approximately 300 million litres and is designed to hold both stormwater and treated sewage effluent, as a source for the Water Treatment Plant.

Cost: Recycled water is sold at $0.83 cents per 1000 litres, 15 cents less than drinking water

Water Safety: The quality of recycled water is the most important aspect of the operation. Recycled water is safe for all specified uses. The quality of recycled water is continuously monitored to ensure public health and safety.

Benefits of Integrated Water Management at Sydney Olympic Park:

- Saves 50 % or about 850 million litres of drinking water per year.
- Almost 100% of sewage is recycled, meaning no discharge to waterways and the ocean.
- Controls stormwater pollution and maximises beneficial use of wastewater resources.

- Builds greater public confidence in using recycled water and future wastewater recycling schemes

Technology - incorporates existing and emerging technologies in the area of biological treatment process, microfiltration and reverse osmosis. Treatment process, operation, performance and monitoring is fully automated and continuously controlled by using highly advanced telemetry control system.

Research - High quality research is an essential feature of future successes of urban water recycling. Sydney Olympic Park Authority, in collaboration with universities and industry, creates opportunity and facilitates research in the area of technological improved, instrumentation, wastewater treatment, water quality, monitoring and detection.

Sydney Olympic Park showcases a new way of solving urban water challenges and demonstrates that large-scale urban water recycling schemes are feasible, safe, reliable and beneficial for the community and the environment. Further, it is highly suitable for new urban developments and instrumental in resolving and sustainable managing many of the stresses on urban water infrastructure.

Recycling Water back into the Drinking Water Supply System

Recycling of treated sewage that has been subject to advanced wastewater treatment back into a water supply system is the option with potential to make the greatest contribution to reliable water supplies. There are historical precedents for this elsewhere: Europe and North America have substantial populations living along inland river systems, such as the Thames, the Rhine and the Ohio where sewage from upstream cities is treated and returned to the river. Downstream cities pump the mix of river water and treated sewage effluent, re-treat it and supply for drinking water supplies. Communities have accepted such recycling when it is shown to be cost effective and to provide acceptable risks to human health. This of course happens with the River Murray water to Adelaide, but as our other capital cities are not located on long inland rivers, this strategy has not yet been widely used.

Recycling involving pumping highly treated effluent back into water supply reservoirs is also an option. Windhoek in Namibia, and more recently Singapore, are the only two cities to practice potable recycling at this stage. In these cases, the sewage effluent is given advanced treatment to achieve drinking water quality and is returned directly into the storage reservoir for distribution for drinking water supply. The Australian community is not yet ready to accept potable recycling and several states have indicated in their water resource planning that they are not prepared to accept it. A great deal of care needs to be exercised in gaining community acceptance for indirect drinking recycling, and a long-term strategy of gaining community acceptance is essential.

A further consideration is that the degree of indirect drinking recycling is limited by the accumulation of salt. Depending on the initial salinity of the drinking water supply and the technology used, a minimum of some 15% to 20% of the effluent would have to be discharged to either evaporating basins or to coastal waters taking the concentrated salt with it.

CHAPTER 4: KEY CONSIDERATIONS FOR URBAN USERS

Ensuring Public Health

The assuring of public health in our cities is a fundamental element of redesigning our water systems. We have achieved much in the last 100 years by separating water supply systems and waste discharge as far as possible. Any recycling strategy that brings recycled water closer to direct human contact must be designed to assure public health.

Our wastewaters contain two general types of hazards for humans. Microbial contaminants, largely present in faecal wastes and requiring inactivation to eliminate their potential to cause massive outbreaks of viral, bacterial and parasitic diseases from short term exposures are our highest priority. The second risk, comes from various chemicals, including pharmaceutical products that end up in wastewater, and which may cause a range of ill effects should we be exposed to them for prolonged periods of time. Both of these hazards require sound risk management systems for effective control.

Risk Management Systems

A suitable management approach for safety and quality assurance exists. Preventive risk management systems are recognised as by far the most effective approach for providing continuous quality assurance of products, including drinking water prior to supply to consumers. The best example of preventive risk management is the Hazard Analysis and Critical Control Point (HACCP) system developed in the 1960s by NASA and the Pilsbury Company to ensure safe food for astronauts. HACCP has been adopted by Codex Alimentarius as an international industry standard for safe food production and as such has a high degree of recognition and acceptance. The Australian water industry has taken the lead in the design and application of risk management systems including HACCP to drinking water supplies.

Over the past three years a Framework for Management of Drinking Water Quality has been developed and incorporated into a new draft of the Australian Drinking Water Guidelines (ADWG). This work was undertaken by representatives from NHMRC and ARMCANZ (then the Ministerial Council responsible for water resource management) and a community representative. Development of the Framework was facilitated by strong support from the CRC for Water Quality and Treatment and involved engagement with the health, water and environment agencies.

The Framework has a basis in the HACCP principles and describes a comprehensive preventive management system that operates from catchment to tap. Essential features include hazard identification and risk assessment, identification of appropriate preventive measures commensurate with risk and operational monitoring of the preventive measures. The aim of operational monitoring is to measure ongoing performance of preventive measures and to ensure that, where required, corrective action is implemented prior to supply of water to consumers. In some cases, for example at treatment plants, such monitoring can be continuous while in other cases lower frequencies are employed. Compliance monitoring of drinking water quality as supplied to consumers is retained to verify that the management system is effective.

The World Health Organisation has followed a similar path. The third edition of the WHO Guidelines for Drinking-Water Quality, which are due for completion this year, incorporate "Water Safety Plans" which are similar in concept to the Australian Framework. Several Australians have played a role in the development of the WHO Guidelines.

Reform of Guidelines for Water Recycling

Recycled water is a valuable resource that should not be wasted and can be used in a safe and sustainable manner to reduce pressures on limited drinking water resources. Increased use of recycled water will rely on demonstrating that it can be undertaken in a manner that is safe and does not impose unacceptable risks to public health. Robust and sustainable guidelines are required.

There are a range of State, National and other guidelines on water recycling that are of varying ages and comprehensiveness. New guidelines need to take account of these as they are prepared. In addition relatively few guidelines exist for substitution of recycled water for household use with most relating to agricultural use or use in public parks and sportsgrounds.

Health based guideline values have been established for some recycled water, most particularly for treated wastewater, but there is no guidance on the development of risk management systems. Such guidance is essential to support increased use of recycled water.

The aim should be to adopt the concepts incorporated in the Framework for Management of Drinking Water Quality to develop a systematic management approach for the use of recycled water. In comparison to the drinking water framework the recycled water management system will also need to consider the various sources and quality of recycled water, types of end-use and potential public exposures.

Recycled water management systems will also need to consider mechanisms for ensuring that lower quality wastewater is kept separate from drinking water supplies. Recycling requires continuous good practice operation of the advanced wastewater treatment facilities.

Table 3 sets out a matrix of water sources with varying qualities against the components of household, industrial and agricultural use. A health risk assessment could define which source and quality of water was allowable for each component of household, industrial and agricultural use. Guidelines could be developed in order of priority starting with the highest priority options for water sensitive urban design, those where innovation is moving fastest, where there are no existing guidelines, and where health and environmental uncertainties are greatest (eg Anderson and Dillon, 2001).

Effective mechanisms for engaging stakeholders will have to be established to draft and refine guidelines for the highest priority options for water sensitive urban design, and to oversee a revision of the relevant guidelines in the National Water Quality Management Strategy.

The Natural Resources Management Ministerial Council has agreed at its Perth Meeting in October 2003 to the following:

(a) To endorse the proposal for the updating of National Guidelines on Water Recycling and stormwater management and reuse under the National Water Quality and Management Strategy;

(b) Agrees to participate with the Environment Protection and Heritage Council and other relevant Councils in the development of these guidelines (consistent with the priority analysis at Annex A) for:

  (i) large scale-treated sewage and grey-water to be used for:
  - residential garden watering, car washing, toilet flushing and clothes washing;
  - irrigation for urban recreational and open space; agriculture and horticulture;
  - fire protection and fire fighting systems;
  - industrial uses, including cooling water;

  (ii) grey water treated on-site for use for residential garden watering, car washing, toilet flushing and clothes washing;

(c) To endorse the draft terms of reference for a joint Steering Committee, including representatives of standing committees of the Environment Protection and Heritage Council (EPHC), Natural Resource Management Ministerial Council (NRMMC), National Health and Medical Research Council (NHMRC) and Australian Health Ministers Council (AHMC), to oversee the development of the Guidelines;

(d) To endorse the process and timeline for development of the guidelines noting the priority for the redevelopment of the *Guidelines for Sewerage Systems – Use of Reclaimed Water (NWQMS 10)*;

(e) To endorse the proposal for the EPHC Service Corporation to provide project management and support to the Steering Committee and associated technical working committees, on a cost-recovery basis; and

(f) To endorse that project management and publication costs be met by EPHC and NRMMC agencies using the standard formula for cost-sharing amongst jurisdictions within Australia (50% Commonwealth and 50% States/Territories by population), noting that any further proposals for expenditure in relation to consultancies or other research will be brought before the relevant Standing Committees.

These resolutions are strongly supported, but we encourage Governments to accelerate this process so that appropriate Guidelines become available as soon as possible.

Table 3: National Water Quality Guidelines – Current Situation and Future Requirements

Functional Use Areas			Water Sources: Potable Water	Rain Water	Stormwater	Greywater	Quality of Recycled Water: Highly Treated	Medium Treatment	Low Treatment
Potable Substitution Uses	Residential / Commercial Indoor	Toilet Flushing	Green	Red	Red	Red	Yellow		
		Clothes Washing	Green	Red	Red	Red	Red		
		Showering / Baths	Green	Red					
		Hot Water System	Green	Red	Red	Red	Red		
		Drinking / Food Preparation	Green						
	Residential / Commercial Outdoor	Residential Irrigation and other urban outdoor uses	Green	Red	Red	Red	Yellow		
	Municipal Controlled Access	Parks & Sportsgrounds and Recreational Activities	Green	Red	Red	Red	Yellow	Yellow	
	Municipal Uncontrolled Access	Parks & Sportsgrounds and Recreational activities	Green	Red	Red	Red	Yellow	Yellow	
	Fire Protection Systems		Green	Red	Red	Red	Yellow		
	Industrial Process Waters	Open Systems	Green	Red	Red	Red	Yellow		
		Closed Loop Systems	Green	Red	Red	Red	Yellow	Yellow	
New Water Uses	Agriculture	Food sold unprocessed and in direct contact with recycled water	Green	Red	Red	Red	Green	Yellow	
		Food processed and not in direct contact with recycled water	Green	Red	Red	Red	Green	Green	
		Pastures	Green	Red	Red	Red	Green	Green	
		Non Food Crops	Green	Red	Red	Red	Green	Green	Green

Red	Guidelines Non Existent or Require Major Work
Yellow	Guidelines Exist - Require Work
Green	Guidelines Well Established and Accepted

Ensuring Environmental Sustainability

Assessing the environmental effects of wastewater disposal and recycling opportunities is rarely done well. It is important to understand the environmental assets that are to be protected, and to have a good understanding of what they need to be maintained in terms of water quality and possibly water flow patterns. It is also important to understand the material and energy costs involved with getting the wastewater stream to the desired standard, for either disposal or recycling. The capital and recurrent costs of various strategies need to be compared in a whole of life basis.

The challenge is to get the disparate types of environmental impact to some common currency to enable useful comparison, since it is difficult to attribute dollar costs to any of them. The challenge is to compare for example the impacts on coastal seagrass from coastal discharge with the greenhouse impacts of the energy required to treat water to a standard suitable for recycling. There are developing life-cycle assessment tools for such comparisons, along with multi-criteria assessment approaches, but they need further development and standardisation.

There are a range of environmental assets that must be considered. The headwater systems that are dammed are changed in significant ways, the urban streams that carry pulses of stormwater runoff are scoured and are degraded due to the frequency of small runoff events, and the rivers or coastal waters receiving treated effluent can also be degraded if treatment is inadequate.

Ensuring Economic Viability

We generally use pricing as the way we allocate scarce resources, and water is no different to other resources that are in short supply. As the cost goes up people decide whether to use less or to pay more. The difficulty is that treating water so that it can be recycled and delivering it to where it is needed may be more costly than the prices we are presently charging for drinking water from our catchments.

At present urban users pay the costs of collecting, treating and distributing water, but generally do not pay a "resource rent" to contribute to the costs of land management in the catchments. The Australian Capital Territory does have a resource rent of 20 cents a kL. No State appears to be charging for the environmental damage the water harvesting causes to downstream rivers and estuaries, despite the 1994 CoAG agreement to move to full costing of water that includes such externalities. It has been agreed again as part of the 2003 CoAG National Water Initiative that States will move to best practice water pricing.

We do know that if we under-charge for a resource like water it will lead to profligate use. This has been demonstrated in some of our irrigation industries. It has also been demonstrated in urban areas where underpriced recycled water has led to increased overall usage, since people see it as so cheap. Conversely, recycled water requires high levels of treatment and often requires pumping to get it to where it is needed, and if catchment water is underpriced, then it will always be difficult to make an economic argument as to why people should use recycled water.

Our communities are concerned about the environmental impact of discharging inadequately treated effluent to rivers and coastal waters. In some situations there is a view there should be no coastal discharge of effluents. A better solution is to build the cost of sewage treatment into the price of water to ensure that all effluents are well treated and can be either discharged without harm or recycled as appropriate.

It is our view that urban water in Australia is significantly under-priced, and that Governments should increase water prices to encourage conservative use of water and to facilitate recycling of water. There are four elements of a new pricing structure that warrant consideration:

- A resource rent of perhaps 20c/kL to provide for catchment management activities;
- An environmental externalities charge to assist with the mitigation of the impacts of water extraction and storage on downstream ecological assets;
- A two tier pricing schedule that charges significantly more for water once a basic threshold is reached to encourage efficient use on gardens; and
- A treatment charge for treating all water to a level where it can be recycled or discharged to the environment without damage.

It is difficult to obtain the real costs of recycling water on a consistent basis across Australia, since there appears to be much cross subsidisation. Given the difficulty in calculating consistent total unit costs for recycled water from the information available, operating costs will be used in this discussion. As a rule of thumb total unit costs would be more than double the operating costs. The unit operating costs for Rouse Hill are anticipated to be $4 per kL including both Sydney Water's and the customer's costs when the entire project is completed. The recycled water is sold for 27.5 cents per kL, a small fraction of the operating costs alone, and considerably less than the 98 cents per kL charged for drinking water. Given that Rouse Hill was the first large scale dual supply system in Australia, the price of recycled water was kept low to gain community acceptance, and the design was perhaps over engineered so as to ensure public health. The low price of recycled water has had the unintended consequence of increasing overall water use. Rouse Hill residents use more water in total than the equivalent households nearby on a single water supply.

Knowledge gained from the experiences of early schemes is driving the costs down. The operating costs at Sydney Olympic Park are $1.60 per kL, and the price is 83 cents per kL much closer to the 98 cents per kL charged for drinking water. The cost estimates for Pimpama Coomera, a new subdivision planned for the Gold Coast are likely to be lower. Economies of scale are important in determining the final costs, as are the learning we are gaining from these pioneering schemes. There is knowledge, however, that is being lost from these schemes, due to the absence of full life-cycle analyses along with human health, environmental and social assessments.

Ensuring Social Acceptability

Without widespread public acceptance of the need for and the safety of recycling water in urban communities it will not happen. There are many examples around the world where local communities have rejected recycling proposals because of a failure to take into account the various factors that such communities see as important.

The reasons for failure are commonly a lack of coordination between the authorities involved in planning health, water supply and environment, and inadequate community consultation on the issue. Success stories often show the recycling agenda being driven by a community organisation that is able to encourage integration between the various arms of Government. They indicate that sustainability cannot be achieved through technical and administrative means alone. The active participation of households and consumers is also necessary.

Many Australians do understand we live in a dry country, and that recycling is an important way we can reduce the waste of this scarce resource. However, these positive feelings often relate to recycling somewhere else and when the proposal is to use the recycled water in their own community or for their personal use they may not be so positive. In these situations, concern for public health often becomes important.

It is a fascinating question for social science as to why people who feel positive about the benefits of recycling water are reluctant to use recycled water themselves.

Part of this is probably due to the "top down" expert based approach to water planning where experts develop solutions and then consult the community. Whether the community accepts such proposals may be a function of their overall environmental attitudes, and their trust of the water planning agency and planning process.

There are important opportunities for the social sciences here. We need to understand the factors that determine the acceptability of recycled water, we need to improve community understandings of the options available and we need to develop better tools for engaging communities in the planning of specific schemes. There have been a number of studies on the acceptability of recycled water. These are summarized in Table 4 from a forthcoming publication of Po, Kaercher and Nancarrow for the Australian Research Centre for Water in Society as part of the Australian Water Conservation and Reuse Research Program (2003) of CSIRO and the Australian Water Association. Improving public confidence and support is fundamental in progressing with any future urban recycled water initiatives.

Table 4: Percentage of Respondents Opposed to Using Recycled water for Specific Uses

	ARCWIS (2002) N=665 %	Sydney Water (1999) N=? %	Lohman & Milliken (1985)* N=403 %	Milliken & Lohman (1983)* N= 399 %	Bruvold (1981)* N=140 %	Olson et al. (1979) N=244 %	Kasperon et al. (1974)* N=400 %	Stone & Kable (1974)* N=1000 %	Bruvold (1972)* N=972 %
Drinking	74	69	67	63	58	54	44	46	56
Cooking at Home	-	62	55	55	-	52	42	38	55
Bathing at Home	52	43	38	40	-	37	-	22	37
Washing clothes	30	22	30	24	-	19	15	-	23
Home toilet flushing	4	4	4	3	-	7	-	5	23
Swimming	-	-	-	-	-	25	15	20	24
Irrigation on dairy pastures	-	-	-	-	-	15	-	-	14
Irrigation of vegetable crops	-	-	9	7	21	15	16	-	14
Vineyard irrigation	-	-	-	-	-	15	-	-	13
Orchard irrigation	-	-	-	-	-	10	-	-	10
Hay of alfalfa irrigation	-	-	-	-	-	8	-	9	8
Home lawn/garden irrigation	4	3	3	1	5	6	-	6	3
Irrigation of recreation parks	-	3	-	-	4	5	-	-	3
Golf course irrigation	2	-	-	-	4	3	2	5	2

*cited in Bruvold (1988) – these studies were conducted in the US.

The studies identified in Table 4 show that the acceptability of recycled water is dependent on how close we come to contact with the recycled water. There is strong resistance to the idea of drinking recycled water but strong acceptance of using it for irrigation of lawns or even vegetable crops. It is widely accepted for flushing toilets, but much less acceptable for washing clothes.

The experience with Sydney Olympic Park is that once the community became used to using recycled water for toilet flushing and lawn watering, they developed increasing acceptance to using recycled water in public places for fountains and water amenity features. Recycled water has also recently been approved for clothes washing and will be fitted to all new homes in the Sydney Olympic Park development.

This indicates that people are likely to become more confident with the use of recycled water as they become accustomed to it, and gain experience with it, as long as they do not experience any incidents that put human health at risk. Ensuring the protection of human health is paramount to maintaining acceptability, and in places where there has been a failure leading to human health impacts there can be a strong rejection of recycling. This means it is essential to design systems that minimise public risk, since any such incidents will substantially set back public acceptance.

We need to improve the water literacy of Australians. A comprehensive and sustained education program to raise public awareness of the issues associated with water recycling is required. Issues that need to be covered include the benefits of water recycling to the community and to the individual and the health and safety issues associated with water recycling.

Increasing public knowledge and understanding of urban water resource issues is essential before meaningful debate with the community can occur. The public is particularly concerned about the issues that have a potential to impact on the quality of life, health and public safety and very quickly becomes negative to the whole concept of water recycling if trust is lost in the source of information. This requires much more than a slick public relations exercise in the context of particular proposals and requires an ongoing and sustained approach to educating all sectors of our society about the importance of water and the ways we can use it more efficiently. It has been interesting to see the responses to water shortages during the current drought.

- There has been widespread acceptance and adherence to water restrictions;
- As restrictions get tougher, some groups argue they should be exempted (eg the watering of sports grounds in Canberra); and
- Periodic calls to just build more dams with little realisation as to the economic or environmental costs of this strategy, or even the lead times involved.

Specific consultation and educational exercises should be designed to increase awareness about true water costs, willingness to pay water charges and to reassure users and public about the short and long term effects associated with responsible approach to integrated water management.

Plumbers have a major role in implementing codes of practice and informing clients on environmentally sustainable options. GreenPlumbers® has been established by the Master Plumbers and Mechanical Services Association of Australia to provide training for plumbers in this role.

The Role of Media

The mass media is recognised as a pivotal tool for the building and mobilisation of public opinion. The print media, in particular, plays a significant role in introducing issues and shaping their importance in public consciousness. There is a need to create a broad-based media platform to address the concept of sustainable development and related issues in a comprehensive and dedicated manner.

To improve the quality of community information about water recycling, there is a need for government and the water industry to embark on an education program that raises awareness and increases public perception. Issues that need to be covered include:

- Benefits (individual, community);
- Positive and enthusiastic approach to urban water management and knowledge-based decision making process;
- Impact (environmental factors, conservation of resources, pollution control);
- Water uses (direct and indirect body contact, practical non-potable applications);
- Competing water needs and responsible demand management;
- Costs and values (price, charges, incentives);
- Technology and controls (natural processes, high tech robust and proven installations, incremental innovation);
- Risks profiles (health, safety);
- Immediate actions and short term planning, versus long-term strategies; and
- Holistic and integrated approach to water management.

Increasing public knowledge and understanding of these issues is essential before meaningful debate with the community can occur.

Engaging the Community in the Consideration of Specific Proposals

Community engagement for water recycling should be based on two premises:

1. The community has good capability to reach sound conclusions if given correct information from a trusted source; and
2. In general the community has poor information and often doesn't trust the sources.

Communities need to be engaged early in water planning projects, and to understand the alternative ways that community needs can be met. Communities need to understand the full range of alternatives, and learn to assess them using the Sustainability Scorecard we have presented in Chapter 5. Late consultation, constrained by decisions already taken, can provoke severe reactions and fundamental loss of community trust in the proponent and the scheme.

National guidelines for consultation and participation of the public in water recycling projects would assist agencies and communities reach appropriate conclusions with regard to specific proposals.

Setting Targets

Some jurisdictions have established targets for the reduction in per capita water use, and for the percentage of water they seek to recycle. While these can be useful aspirations, it may be they will drive inappropriate investments just to meet a target.

A better strategy might be to set a limit on what water a city can expect to take from its catchment. This capping of overall extraction, and then allowing trading of water between various uses is being used to re-allocate water in the Murray-Darling Basin, and has the advantage of allowing water to move to the best uses as well as stimulating innovation and water efficiency.

In Arizona, it is a responsibility of developers of new subdivisions to secure a sustainable water source for 100 years for development approval. They can improve water use efficiency of housing, buy water rights, undertake subsurface water storage and recycle water to achieve these ends.

CHAPTER 5: AN EXAMPLE OF INTEGRATED WATER PLANNING IN AUSTRALIA

The water supply to the Gold Coast requires immediate augmentation to supply a rapidly growing population. The Gold Coast is one of the first water authorities to face the reality of the 'squeeze' between available water and community demands and is seeking innovative solutions including recycling water.

Pimpama Coomera is an area zoned for major urban growth in the future. Gold Coast Water is investigating the water supply options. The objective is to ensure more sustainable urban water use, with sustainability being measured on a whole of life basis via a balance of environmental, social and economic outcomes. This region comprises 5,500 ha of predominantly green field area. It is projected that this area, which has a current population of 5,000 people, will ultimately have a population of 150,000 people.

The concept seeks to integrate the various sources of water. It includes a conventional reticulated drinking water (potable) and conventional sewage collection system. It proposes a third pipe system to take appropriately treated water back to residences for recycling for toilet flushing and lawn watering. It also captures roof water in tanks and urban stormwater. It also includes smart sewers discussed in Chapter 6 that reduces infiltration to sewers. Simple examples of the opportunities presented are where the provision of roof water tanks on houses can reduce the stormwater flows from developments whilst providing another source of water for use in the household. Similarly, the reticulation of recycled water to urban lots, for use in toilet flushing and garden watering reduces the release of treated wastewater to receiving water bodies, whilst reducing the demand on drinking water infrastructure.

The use of recycled water in this project has the primary advantages of:

- Substituting the use of drinking water, for uses where high quality drinking water is not necessary;
- Reducing point source discharges of treated wastewater to the receiving water environments; and
- Reducing urban runoff from small storms to urban streams where it damages river health.

To maximise the effectiveness of a recycled water system, a large storage reservoir is required, to allow the storage of recycled water during periods of low demand and from which flows can be withdrawn in periods of peak demand. These reservoirs can either be located on the surface, such as dams, or underground in aquifers. Surface water bodies can incur evaporation and water quality problems, primarily algal growth.

The Pimpama Coomera Waterfuture project is being completed in association with an Advisory Committee, which has representatives from resident, environmental advocacy, industry, developer and landholder groups and government representatives. The project is using a Multi Criteria Assessment approach (the Environmental

Sustainability and Cost Effectiveness Scorecards) to identify the preferred option from a range of alternatives considered. This method considers social, environmental and financial aspects and the project has identified various criteria to measure performance. These criteria are both quantitative (Criteria 1 to 8 and 13), and qualitative (Criteria 9 to 12).

The key elements of the Business as Usual (BAU), Option 2* and Option 12 and the results relative to the identified criteria are indicated below.

Table 5: Key Elements of Options

KEY ELEMENTS	BUSINESS AS USUAL	OPTION 2* THIRD PIPE	OPTION 12 INDIRECT POTABLE REUSE
Recycled Water Service for:		External, toilet & fire fighting	
Seasonal storage (Aquifer)	No	Yes	No
Wastewater system	Conventional	Smart	Smart

Option 2* considers Dual Reticulation (drinking water and recycled water) whilst Option 12 considers indirect drinking recycling via the discharge of highly treated recycled water into the major water supply dam.

Table 6: Results - The Environmental and Cost Effectiveness Scorecards

	COMPARATIVE CRITERIA	TARGET	BAU	OPTION 2*	OPTION 12
1	Substitution of potable water usage	25%	0	60%	49%
2	Nitrogen discharge to Pimpama River	<40 kgN/day	37.5	10.8	0.3
3	Effluent discharge to Pimpama River	<12.5 ML/day	12.5	3.6	0.1
4	Stormwater discharge volume	5% <(BAU)	0	0	0
5	Reduction in peak potable water demand	15%	0	79%	20%
6	Reduction in average potable system retention	30%	0	12%	15%
7	Reduction in unaccounted for water	20%	0	61%	21%
8	Greenhouse gas emissions	20% < BAU(2050)	0	34%	6%
9	Deferral / elimination of the need for new reservoirs	Scale 1 (low) to 5 (high)	1.0	4.0	3.0
10	Anticipated community response to quality of service	Scale 1 (low) to 5 (high)	1.0	5.0	1.0
11	Anticipated community response to impact on local amenity	Scale 1 (low) to 5 (high)	1.0	5.0	2.0
12	Improvements to the work environment	Scale 1 (low) to 5 (high)	1.0	4.0	5.0
13	Whole of life cost	≤ BAU (%)	0	7% increase	8% decrease

Note: The data presented in this table are based on assumptions, and is the best data currently available, and could change as a result of further investigations.

The following comments are pertinent to the interpretation of the above results:

- The BAU option is forced to comply with Criteria 2 and 3 by the provision of infrastructure to discharge treated wastewater elsewhere;
- The costs are for the provision of the total integrated urban water services of drinking water, wastewater, stormwater and recycled water where relevant;
- The costs are net costs, which include savings in some areas (drinking and wastewater) and increases in other areas (recycled water);
- To achieve these costs specific elements are compulsory;
- The assessment and costs are unique to the Pimpama Coomera region;
- The costs are preliminary as the project is still being completed; and
- The region is predominantly green field and retro fitting of recycled water is not being considered to the existing developed areas.

While the environmental factors and costs that are specific to Pimpama Coomera cannot be translated to other situations they illustrate that in circumstances where the costs of transporting drinking water in and wastewater out of the area are high, dual reticulation and indirect drinking recycling are potentially viable options.

A Sustainability Scorecard for Making Choices

This example demonstrates the complexity of making appropriate decisions about urban water opportunities. The Gold Coast example gives one way of developing environmental sustainability and cost effectiveness scorecards that seem helpful in such decisions. The study of water recycling scenarios for Melbourne uses and develops a similar triple bottom-line evaluation framework.

We see advantages of further developing and negotiating such a Sustainability Scorecard across the country to facilitate rigorous community exploration of the costs and benefits of the various options before them.

Table 7: Sustainability Scorecard Framework

Economic	• Capital costs of collection, treatment and delivery • Recurrent costs of collection, treatment and delivery • Whole of life costing, including externalities • What is the opportunity for new enterprise and economic development? • What are the implications for export of products and services?
Environmental	• What are the environmental assets affected by water collection and storage? • What are the environmental assets impacted by disposal of water to rivers, coastal waters or groundwater and how important in a regional sense are they? • What are the environmental costs of various levels of treatment in terms of chemical use, energy use and the risks of accidents? • Is salt or other contaminant likely to build up in the long term?
Health	• What are the risks of microbial and chemical contamination leading to human disease? • Do treatment processes introduce chemicals that may have health impacts on users or on later disposal?
Social	• Are users likely to be comfortable with, and comply with, the option under consideration? • Is the option equitable on all citizens or does it favour some particular group • What are the implications for employment? • What institutional changes are required for success?

CHAPTER 6: DRIVING INNOVATION IN THE WATER INDUSTRY

PMSEIC considered Innovation in Australia at its sixth meeting in November 2000. The need to develop a culture of innovation was presented as a key to economic prosperity, and a number of key ideas were proposed.

Innovation is critical if we are to find smart solutions to the challenges of water in our cities, and we need to develop a culture of innovation to encourage new and cost-effective solutions. These solutions would be of great value throughout the world, and thus could deliver export opportunities for Australia in addition to the economic benefits within Australia.

Investments in water recycling will stimulate growth in Australia's water industry – a sector in which Australian industry is considered to have internationally competitive capabilities – thus helping the environment industry to realise its Action Agenda vision of achieving annual sales of $40 billion by 2011. Investments in water recycling have dual benefits – environmental and industry development.

The key elements of innovation in the water industry are as follows:

- Investing in research institutions and the people who create new knowledge;
- Investing in people and systems to ensure knowledge is taken from the research base to application (commercialisation);
- Ensuring the regulatory framework does not stifle innovation;
- Ensuring that we encourage demonstration projects to test new ideas and approaches, and that we put in place rigorous evaluation of such projects;
- Promoting skills in systems analysis of urban water systems; and
- Providing water pricing incentives that acknowledge full environmental impacts from conventional and proposed systems.

Technology Opportunities - Improving Water Use Efficiency

Much has already been achieved with the development and application of dual flush toilets and water efficient showerheads. Governments have now announced a mandatory labelling system for water appliances which will help consumers make informed choices, and will drive innovation as manufactures seek the most appropriate rating.

The next big opportunities in household water efficiency probably relate to garden water use with smarter irrigation systems and drought tolerant plants. Current strategies of odds and evens watering during periods of restriction are encouraging frequent light watering leading to shallow root systems. It may be much better to encourage deep rooting by providing one heavy irrigation about every 10 days or so.

Emerging Treatment Technologies

A variety of technologies for treating, transporting and monitoring water currently exist in the market place and incremental improvements to most of them are occurring. However, it is salutary to consider the very long history of mankind's involvement with water management and the fact that we are still bounded by the same physico-chemical principles as the ancient civilisations of Mespotamia. Some of the earliest recorded advice on the treatment of drinking water comes from the Sanskrit literature of about 2,000 B.C., as recorded by Pliny the Elder in Rome during the 1st century AD "It is good to keep water in copper vessels, expose it to sunlight and filter through charcoal". In this one sentence the ancients anticipated the modern treatment technologies of UV disinfection and activated carbon adsorption, as well as the potential catalytic effects of copper. What they could not do, of course, was accurately design a modern treatment plant to cost effectively and reliably perform these duties for cities of a million plus people!

Membranes have been developed in Australia for water treatment and have now found widespread application around the world. Memtech was a successful Australian company that pioneered these technologies. Further innovation in membrane technology, especially to slow or prevent their fouling with contaminants is likely. Ion exchange and reverse osmosis technologies all are likely to improve and become cheaper, opening up new opportunities.

In the final analysis our ability to design and operate treatment plants comes down to our understanding of the basic physico-chemical and biological principles which control what is going on. Furthering our understanding of these basic scientific principles will result in improvements in design and operation and this is why incremental technology improvements continue to happen. It is also true that if such understanding is neglected, then expensive and health threatening failures will occur.

There appear to be particular opportunities in the development of sensors that can detect microbial and chemical risks in real time so that appropriate action can be taken within the short exposure periods that are often associated with outbreaks. The targets for such sensors are unlikely to be pathogens, but surrogates of their behaviour at key control points of a system. In general, with the potential for smaller-scale treatment systems, there is also opportunity for component alarms and telemetry systems to ensure appropriate response, which takes us to innovations at the system level.

Emerging Technologies - Smart Sewers

Conventional sewer systems tend to leak, and during wet periods, significant amounts of stormwater can enter the sewer system, putting a great load on treatment facilities and releasing excess raw sewage to waterways through designed overflow points. Smart sewers, as demonstrated on the Gold Coast and elsewhere are reduced infiltration systems comprising the following elements:

- Longer pipe lengths with fused or solvent joints (not mortar or rubber ring joints) for pressure or vacuum transport of wastewater;
- Elimination of manholes and replacement with fewer sewer inspection points;

- Use of curved pipe to allow reducing numbers of sewer inspection points; and
- Minimise risk of stormwater ingress by requiring a drainage relief that discourages connections of the stormwater to the sewer system for drainage.

This Smart Sewer system allows for the possibility of smaller pipes, smaller treatment and pumping systems.

Emerging Technologies – Source Separation

Treating sewage requires considerable energy to separate solids materials from water. One emerging strategy is to avoid mixing urine and faeces in the first place by the use of a specially designed toilet bowl that separates these materials. These toilets not only use much less water, but the liquid stream of urine contains 50-85% of the major plant nutrients with little infectious material, and so this can be used for agricultural purposes.

Other innovations such as vacuum, low flush and composting toilets can be used in conjunction with urine separation. Hence, 'Smart Sewers' of the future may periodically transport urine from household storage tanks, while at other times concentrated faecal wastes under vacuum. Alternatively, existing sewers may contain additional smaller diameter pipes taking urine/faecal wastes, leaving stormwater to travel in the main pipe for regional recycling.

Opportunities for Conventional Science

The traditional scientific approach of reduction and analysis through which we develop a more detailed understanding of the fundamental scientific principles will lead to improvements in efficiency and reliability.

Some of the questions reductive analysis can answer and their outcome are:

- Why is desalination energy intensive? ⇒ Lower costs, less greenhouse gas emissions;
- Why do membrane systems foul? ⇒ More reliable operation;
- How are pathogens inactivated? ⇒ Safer operation; and
- What mechanisms can be used to concentrate the nutrients in waste? ⇒ Nutrients recovered in a usable form, reduced environmental impact.

Each of these questions is targeting a particular shortcoming of existing technology. For example, while membranes are now widely used in water treatment, they have a history of steadily degrading performance due to fouling of the membrane with small quantities of contaminants in the water. Understanding these fouling mechanisms will lead to insights into either the nature of the membrane material itself or other ways to handle particular contaminants.

Innovation at the System Level

More exciting possibilities exist in working at the system level of the whole water cycle to try and find innovative ways to put the various technologies we have together. This work is based on complex systems analysis and addresses questions like:

- How do we put together the components of an urban water system in such a way as to maximise the benefits, while minimising health and environmental risks? ⇒ Better planning and investment decisions;
- What is the optimum scale for design and operation of an urban water system for a particular location? ⇒ Appropriate and affordable localised systems that facilitate water recycling; and
- What is the most intelligent way to operate a system to minimise operational costs while maximising community and environmental health benefits? ⇒ Safe, affordable water systems that the community accept.

The critical need for work in this area of design synthesis is becoming more evident as various trials of alternative approaches to system design are being tested around the country. At present, no concerted or coordinated effort is being made to capture the knowledge, data and learning that come from innovative urban developments such as Rouse Hill and Pimpama Coomera. Methodologies for analysis of alternative system designs have been developed (mainly in CSIRO), but much further work is needed to refine and validate them.

Enhancing the Research Effort

The research base on water recycling in Australia was analysed by Dillon (2000) and the $2.9M pa expenditure at that time had been largely uncoordinated, site-specific without consideration to extrapolation, poorly communicated, and had significant gaps, notably in the health and public perception areas. Consequently CSIRO and the Australian Water Association developed and recently initiated a national program (Australian Water Conservation and Reuse Research Program) addressing the identified major barriers to water conservation and recycling that is also linked with several major international research programs in this field. Stage 1 addresses in 14 coordinated projects the major barriers and research gaps required to fill them. This work needs further support.

Table 8 identifies some aspects of the urban water cycle and identifies some of the technological approaches being used and the barriers to adoption of various strategies.

Clearly these are important research priorities in the area of sustainability, and should be included in Government priorities for research.

In view of the large costs and long life of urban infrastructure it is important that we encourage research in this area and targeting funding from the Australian Research Council or other area may be appropriate.

The Cooperative Research Centres have provided an effective vehicle for encouraging the Australian water industry to invest in research. A number of successful CRC's are enjoying continuing and strengthening support from industry, and the work from these Centres is being taken up by the industry.

There may now be a further opportunity to encourage the Australian urban water industry to support a further CRC that works at the whole of water cycle system, level for developing and evaluating integrated water cycle plans and water sensitive urban developments for Australian cities. Several research groups are operating in this area, and there may be significant advantages in helping bring them together and enhance the effort in this area.

A vision for the sustainable management of our urban needs over the next 50 years is described in Box 2. This will only be achieved through integrated planning and collaboration.

Technology Opportunities in Collecting and Treating Various Types of Water

Table 8: Technological Opportunities in Urban Water

Water Source ⇒	**Roofwater**	**Stormwater (urban runoff)**	**Greywater**	**Blackwater (toilet wastes)**	**Saline Water (sea or brackish)**
Technological Approach	First flush diversion Storage tanks POU filters UV disinfection	Storage lagoons Aquifer storage and recovery (ASR) Coagulation/ flocculation/ filtration Disinfection	Membrane bioreactors Adsorption Disinfection	Remove blackwater from water based transportation system Treat separately for pathogen destruction and energy and nutrient recovery	Reverse osmosis membranes Multi stage flash evaporation
Barriers to Implementation	Cost Storage space Reliability of filtration/ Disinfection	Ability to capture and store large scale intermittent flows in urban areas Cost of 3rd pipe distribution Fragmented water institutions Plumbing codes, Unscientific environmental and health regulations Lack of awareness of subsurface storage options	Cost and reliability of small to medium scale treatment and disinfection processes Lack of knowledge of fate of constituents in soil and groundwater Lack of science-based regulation Huge range in detergent sodium and phosphorous concentrations	Large investment in existing toilet technology Public acceptance Low cost of water, energy and nutrients Lack of regulation for subsurface storage Lack of regulation and servicing industry for composting options	Cost Brine disposal

Technological Breakthrough Required	Devices to warn of system failure and contamination Smart storage	Cheaper 3rd pipe systems Novel storage techniques Demonstration of subsurface water quality improvements to potable standards	Cheaper, more reliable treatment/disinfection technologies On-line systems to detect system failure and apply Management Framework	Attractive and functional designs for waterless or low volume collection and transportation systems Enhanced energy recovery through thermophilic anaerobic digestion Process for nutrient recovery and concentration	Reduce costs through enhanced membrane performance and/or lower power costs through enhanced energy recovery
Timescale for Application	1-5 years Short term	2-10 years Short to medium term	5-20 years Medium to long term	10-50 years Long term	5-20 years Medium to long term

Box 2: Future Vision

A Vision for Sustainable Urban Water System of the Future & How to Get There

In 50 years time net urban water consumption per head of population will have been reduced by 60% from around 400 l/p/d to 160 l/p/d. This dramatic drop in consumption will not only allow our urban centres to grow, but will also reduce energy consumption, make nutrients available for agricultural recycling and leave water for the environment. These goals will be achieved with no increase in total water costs to the consumer, although the actual price of water will have risen by about two thirds (67%).

This urban water system will be characterised by the following features:

- Toilet wastes will be separated from all other flows and treated to recover energy and nutrients, while destroying pathogenic micro-organisms.
- The existing sewer system will handle only greywater (kitchen, shower, washing machine). 50% of this flow will be used as a local water source, with treatment to drinking water standard allowing direct reuse in the existing distribution system.
- Use of drinking water on gardens will be halved through more efficient garden irrigation.

Clearly, this system represents a radical departure from current practice and will require a long term strategic plan of action for its successful implementation. At present, the general public is averse to schemes involving direct potable recycling and a strategy is required to gradually move them in this direction. Non-drinking recycled water for non-contact purposes such as garden watering and toilet flushing is currently acceptable. The removal of toilet wastes from the source of recycled water and a continuing program of demonstration of best practice recycling will gradually build the required level of community trust and acceptance.

The technologies to support this system design include:

(i) Low water use vacuum or pressurised toilet systems connected directly to a regional treatment facility
(ii) Thermophilic (high temperature) anaerobic digestion of blackwater wastes to provide enhanced energy recovery (methane) and inactivation of pathogenic micro-organisms
(iii) Recovery of nutrients from toilet wastes in a solid, easily transportable form e.g. struvite or magnesium ammonium phosphate
(iv) Non-fouling membrane bioreactors for greywater treatment
(v) Advanced monitoring systems to provide advance warning of system failure
(vi) Cheap, reliable soil moisture detectors linked to simple, computer chip based decision support systems. Such systems will provide advice to the home gardener on efficient garden watering schedules.

An on-going program of research will be needed to support this initiative, not only in the development of the necessary technology, but also in its incorporation into new system designs and the building of trust and community acceptance. The research requirements can be placed in three categories:

(i) Basic research underpinning the proposed technologies
(ii) Social research on the best approaches to community engagement and the building of trust and acceptance
(iii) Research on the integration of technology and system design – in particular, validating design and evaluation methodologies on alternative system designs which are currently on the drawing boards or under construction.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Australia's cities are facing a water squeeze caused by largely by population growth, drought and possibly climate change.

Demand management over the last 20 years has been very effective in reducing water use, but further savings through demand management will be harder to achieve. However, we must continue to stimulate improvement in the efficiency of water use.

We need comprehensive strategies to address the challenges of reliable water supply. Recycling is only one of the tools available to the community in water supply management. Water supply systems should be both cost effective and environmentally sustainable. In sourcing water supplies all options should be considered including roof run-off, storm water, wastewater and desalination.

Currently there is little use of recycled water in our cities. In the household approximately 50% of water is used in toilet flushing and in the garden. Recycled water could be substituted in these instances.

We have appropriate technologies for advanced waste water treatment and the costs and energy of treating waste water are being lowered by further technological advances. We need to implement these technologies in a more meaningful way. Australians have been good at assembling the components of efficient and effective water management systems to provide innovative solutions. Strategically located iconic demonstrations of water recycling are needed to promote community acceptance and further drive innovation.

Protection of public health must be ensured by the development and implementation of best practice guidelines. Studies have shown that approximately 70% of people are opposed to drinking recycled water. Community acceptance of uses which are non-personal are considerably higher than this.

Relatively little water is recycled in Australia, however in one area where it is (Rouse Hill), the authorities have so significantly under priced it to persuade residents to use recycled water that there is some evidence of overuse. Current pricing policies need review and environmental externalities should be included in the price of water.

Investment in research and demonstration is required to facilitate a transition to more sustainable urban water systems. Given that water systems are capital intensive and have operating lives of the order of a century for pipes, a great deal of confidence is needed in the effectiveness and durability of new systems to assist water infrastructure investment planning. In some countries such as South Africa a research levy on water bills is useful in generating research funding.

Recommendations

1. The urban theme of the CoAG National Water Initiative should include:

   - Water awareness and education programs to build broad based community support for water conservation and recycling water in households
   - Environmental sustainability and cost effectiveness scorecards for evaluating water supply options, for appliances, new houses and buildings, new suburbs and city-wide, and use of this for accreditation, planning approval, new home grants, and access to related federal resources.
   - Pricing policies for drinking and recycled water that ensure efficient use of these valuable resources. Environmental externalities, the cost of disposal of stormwater and treated effluents and research funding requirements should be factored into the price of drinking water.
   - Encouragement of better integrated water planning and management in urban areas through institutional reform involving local government, catchment boards, water utilities, and state government agencies with relevant responsibilities.
   - The NWI could encourage the development of a range of decision-making tools for urban water management, as well as a scorecard tool.

2. Fast track current proposals for reform of the Health and Environmental Guidelines for the production and use of recycled water.

3. In order to get the most cost effective outcomes any targets for water use should be set on total water use rather than on components such as the volume or percentage of water recycled.

4. Continuing research into treatment processes and sensor development will lead to progressive improvement in costs and efficiency of advanced waste water treatment and should be supported. Substantial opportunities exist in encouraging research into innovative approaches to whole urban water systems that explore ways of putting the various technologies together into water systems that meet the needs of urban communities.

5. Investment in water recycling projects should be stimulated. A grants scheme should be developed to stimulate 'icon developments' incorporating innovative urban water systems and ensuring rigorous evaluation to improve subsequent innovations. Federal funding should be conditional on an integrated approach to the whole urban water lifecycle, implementation of rigorous evaluation of the performance of the development, and transfer of the knowledge gained to all stakeholders through publication and workshops.

APPENDIX A: TERMS OF REFERENCE

The working group will prepare a paper and presentation for PMSEIC which will:

- Outline the challenges facing the supply of water to our cities over the next 50 years;

- Giving consideration to social, environmental and economic dimensions of the issue identify major opportunities and obstacles for utilisation and development of relevant water technologies, noting international developments and approaches;

- Describe the impact of science, engineering and innovation in addressing urban water recycling issues in Australia; and

- Recommend practical ways in which Australian science, engineering and technology can contribute to improving the way in which Australia utilises urban water.

APPENDIX B: WORKING GROUP MEMBERSHIP AND ACKNOWLEDGEMENTS

Membership

- Dr Deborah Rathjen, Chief Executive Officer and Managing Director Bionomics Limited (Chair)
- Professor Peter Cullen, Professor Emeritus of the University of Canberra (Deputy Chair)
- Associate Professor Nicholas Ashbolt, Deputy Director, Centre for Water and Waste Technology, University of New South Wales
- Dr David Cunliffe, Principal Water Quality Adviser, South Australia Department of Human Services
- Dr John Langford, Executive Director, Water Services Association of Australia
- Mr Andrzej Listowski, Manager Water and Energy, Sydney Olympic Park Authority
- Professor Jennifer McKay, Professor of Business Law, University of South Australia
- Dr Tony Priestley, Deputy CEO, CRC for Water Quality & Treatment
- Dr John Radcliffe, Special Adviser to the Chief Executive of CSIRO

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