Using recycled water for drinking
An Introduction
GHD

Waterlines Occasional Paper No 2, June 2007
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Waterlines
This paper is part of a series of works commissioned by the National Water Commission on key water issues. This work has been undertaken by GHD on behalf of the National Water Commission.

Disclaimer
This paper is presented by the National Water Commission for the purpose of informing discussion and does not necessarily reflect the views or opinions of the Commission.
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Abbreviations and Acronyms

ACTEW  Australian Capital Territory Energy and Water
ADWG  Australian Drinking Water Guidelines
AHMC  Australian Health Ministers Conference
Assembly  City of San Diego Assembly
ATSE  Australian Academy of Technological Sciences and Engineering
AWWA  Australian Water and Wastewater Association
BAC  biological activated carbon
Commission  National Water Commission
CSIRO  Commonwealth Scientific Industry Research Organisation
DHS  Department of Health and Services
EDCs  endocrine disrupting compounds
EPHC  Environment Protection and Heritage Council
Guidelines  National Guidelines for Water Recycling
GWR  Groundwater Replenishment System
HACCP  Hazard Analysis and Critical Control Points
IAP  Independent Advisory Panel
IPR  indirect potable re-use
NHMRC  National Health and Medical Research Council
NWI  National Water Initiative
NWRG  National Water Recycling Guidelines
OCGB  Orange County Groundwater Basin
OCWD  Orange County Water Districts
PUB  Public Utilities Board
RO  reverse osmosis
SCADA  Supervisory Control and Data Acquisition System
USA  United States of America
USEPA  United States Environmental Protection Authority
WHO  World Health Organisaton
WSAA  Water Services Association of Australia
Using recycled water for drinking:
National Water Commission position

In response to Australia’s current water challenges, many towns and cities are increasingly looking to augment their water supplies. Introducing recycled water into the drinking water supply is one viable option to reduce water shortages and make water supplies less vulnerable to climate. As the National Water Commission (the Commission) stated in its report to the Council of Australian Governments (COAG) in June 2006 (Progress on the National Water Initiative: A Report to the Council of Australian Governments, 1 June 2006), it is essential that all water supply options are considered in order to find the most effective combination of means to secure water for our cities.

The Commission believes that the introduction of treated recycled water into the drinking water supply (i.e. indirect potable re-use (IPR)) is an important option to improve Australia’s long-term water security. The Commission strongly encourages objective and even-handed consideration of IPR as one option for communities to augment their water supplies and to enhance their water security and urges leadership by water decision-makers throughout Australia to enable recycled water for drinking to be considered and implemented.

Recycling water is not a new concept to Australia. For decades, towns and cities have drawn upon this resource for watering recreation facilities such as parks and golf courses, supplementing environmental flows and, in some cases, for irrigated agriculture. Recycled water has long been discharged into some Australian watercourses and accessed by downstream communities, including for drinking purposes.

The Commission recognises the risks associated with recycled water for drinking but considers that these risks can be satisfactorily and safely managed. It also emphasises the importance of sound, consultative community decision-making processes, well informed by science and evidence.

The issues associated with recycled water for drinking in any location should always be made clear to communities as they make choices about their water supply options. This paper, produced by GHD at the request of the Commission, provides an accessible overview of national and international experiences of indirect and direct potable re-use and can be used to assist communities when they are considering the option of sourcing recycled water for drinking purposes.
How recycled water for drinking is viewed across Australia depends on several factors including the management of health risks, cost effectiveness and public perceptions or the ‘yuck factor’. Each of these factors will be unique to each region, and each community needs to have the opportunity and the information to understand all water options on their merits. The National Water Commission believes that no options should be discounted, particularly if traditional supplies are not sustainable.

The Commission endorses the conclusion reached in this study that national and international experience indicates that risk associated with recycled water for drinking is manageable.

The National Guidelines for Water Recycling (the Guidelines) currently being developed under the National Water Initiative (NWI) will provide an effective risk management framework for providing safe and reliable recycled water. The new Guidelines will improve flexibility and innovation and are likely to encourage increased water recycling over the longer term. The first phase of these Guidelines, which focus on sewage effluent and grey water, were endorsed by all Australian governments in November 2006. The Phase 1 Guidelines are available from the Environment Protection and Heritage Council website at [www.ephc.gov.au](http://www.ephc.gov.au).

In endorsing the Guidelines, Ministers recognised the importance of safeguarding water supplies for the future, particularly in the face of challenges such as drought, climate change, and the inefficient and wasteful use of water. Development of phase two of the Guidelines, including recycled water for drinking is already underway. This module is expected to be completed by the end of 2007. These Guidelines will be a critical step in building community confidence and helping to ensure that recycled water use is safe and reliable.

How the cost of recycled water compares to other water supply options including desalination, harvesting stormwater and extracting groundwater will also vary across Australia and depend on regional environmental, social and economic factors. In comparing systems, issues to be considered include: energy costs associated with treating and delivering the water; social acceptance of the water source and trust in the water service provider to manage risk; and any environmental impacts where the water is sourced and where the wastewater is discharged.

Australians are facing major decisions in relation to the water future of our cities and towns—decisions not just by governments but also by communities and individual consumers. To help communities make informed decisions about drinking recycled water, quality information needs to be disseminated in an accessible and transparent manner. Each water supply option will have advantages and disadvantages.

This Waterlines publication from the Commission is a contribution to the national debate about the use of recycled water for drinking. Through such contributions, the Commission aims to encourage innovation in water recycling, and ultimately improved water security for Australians.
Executive summary
This discussion paper explores the use of recycled water to supplement drinking water supplies in Australian towns and cities.

This concept involves introducing highly treated recycled water to blend with the source water of an existing water supply. This option may compare favorably with other options to supplement water supplies, but it has only recently formed part of long-term water supply plans in Australia.

Because most of Australia’s towns and cities are sewered, this option is available to most communities. Recycling water for other purposes is happening but is restricted to lower volumes unless new dual pipe systems are added to existing suburbs and houses. Using recycled water to supplement drinking water supplies offers a substantial future water resource for most of our towns and cities. This concept has generated considerable community and industry interest, most notably with the referendum in Toowoomba (July 2006) and the larger scheme for Brisbane which is due to come on line in 2008 to 2009.

The following observations are intended to provide a brief summary of the concepts and ideas in this paper. Each of these observations is explored in more detail in the paper.

This paper is intended for those who are interested in the use of recycled water to supplement drinking water supplies and is not intended to provide a definitive position on this option. The question of water quality and risk to public health is addressed briefly in this primer as it is often raised in relation to this option.

The Environment Protection and Heritage Council (EPHC) and Natural Resource Management Ministerial Council (NRMMC) initiated the development of National Guidelines for Water Recycling (Phase 1, 2006). A second phase of the Guidelines is currently under development and will include the use of recycled water for drinking. More information about these Guidelines are at www.ephc.gov.au/ephc/water_recycling.html.

**Background**

Introducing recycled water of drinking water standard into the drinking supply source is sometimes referred to as ‘indirect potable re-use’ (IPR). ‘Potable’ is a term used to describe water suitable for drinking. It is ‘indirect’ because it is sent back to mix in with the source water as opposed to introducing the recycled water directly into the drinking water system.

There are many existing water supply systems in Australia and around the world where recycled water enters the source water supply upstream of the off-take for a drinking water supply. This is sometimes referred to as ‘unplanned’ indirect potable re-use. Many towns and cities are already using water sources that contain recycled water. Usually, this is recycled water from some other town or city upstream.

This paper discusses ‘planned’ recycling, where recycled water from a town is sent back to the source for that town. There are around 10 operating or proposed ‘planned’ schemes around the world. Some often-quoted schemes are located in Singapore, Namibia and California.

Queensland and ACT Governments have announced their intention to pursue large scale water recycling to augment drinking water supplies (24 April 2007). The Western Corridor project will be the largest ‘IPR’ scheme in the southern hemisphere and will involve the construction of pipelines to enable the transfer of purified recycled water from advanced wastewater treatment plants in Brisbane and Ipswich to end users throughout south-east Queensland.
How does the use of recycled water compare to other water supply options?

Until recently, the use of recycled water for drinking water purposes has not been considered in detail in the majority of long-term water supply plans in Australia. However, the degree of interest is increasing rapidly due to current concerns over the future supply of water to our cities. For example, in 2006, the Water Services Association of Australia (WSAA), the peak body of the larger urban water authorities, released a paper that discusses recycling to supplement drinking water, and includes 10 points for consideration (WSAA Position Paper No 2 2006).

Analysis of potential economic and environmental factors shows that there will be cities and towns where the use of recycled water to supplement drinking water supplies compares favorably with other options. This is most likely to occur when the existing wastewater treatment plants are producing high quality water, and are located relatively close to the current sources of water compared to other options.

Using recycled water to supplement drinking water supplies may also have environmental benefits such as reduced energy use and reductions in volumes of waste discharged to the environment compared to other water supply options. Note that depending on circumstances, the remaining waste stream may be more concentrated and contain the same total load of contaminants.

So in some circumstances, using recycled water can have benefits compared to other options. However, understanding whether these potential benefits actually apply to any particular town or city requires a detailed analysis because the costs and environmental impact are unique for each location and water supply system.

What are the risks and how are they managed?

It is reasonable to be concerned about the introduction of recycled water into water supplies. Untreated recycled water can contain contaminants that pose a risk to human health. These risks are proposed to be managed using advanced treatment technologies such as reverse osmosis (which is also used to desalinate sea water) to provide highly treated water, and also by careful operation and management of the entire system.

Schemes typically involve some detention time in either a reservoir or underground aquifer, which is sometimes called the environmental buffer. Processes in reservoirs and aquifers such as detention time and microbial action assist in managing the risks.

Managing risk from a technical point of view involves more than just advanced water treatment. Risk management when introducing treated recycled water into the water supply system extends from the water source (discharges to the sewers) to the customers’ taps. This will include management of risks at the water source, operation of treatment plants, appropriate institutional arrangements, and research and development to keep up to date with best practice. This approach to risk management is outlined in the Australian Drinking Water Guidelines (ADWG) framework for managing drinking water supplies (NRMMC, EPHC and the Australian Health Ministers Conference (AHMC), 2006).

Some specific areas of risk management such as understanding and controlling discharges to sewers, and the extent and nature of the environmental buffer required, can be as important as the treatment process in managing the risk, and in the implications they have for scheme costs and viability.

In Australia, guidelines for using recycled water to supplement drinking water supplies are currently under development. A risk-based approach is being used which has been successful at managing risks in existing drinking water supplies. The guidelines will be crucial
in providing an authoritative and balanced view of how to manage the risks associated with adding recycled water to drinking water systems.

Community views

Despite the potential economic and environmental benefits, the use of recycled water to supplement drinking water supplies is sometimes excluded from water supply options analysis based on the perception of community concerns. Social research indicates that a majority of people like the idea of using recycled water in general, however a smaller proportion of people support or accept the idea of use in their drinking water supplies. People are more comfortable with recycled water use outside their homes, rather than in their drinking water.

Research on risk communication has developed lists of factors that often lead to community concern. These concerns are not necessarily ‘technical’, but may be more intuitive and reactive.

There appear to be at least two key psychological factors. First, some people have a reaction of disgust at the idea of using water from this source. Technical discussions about risk and purity after treatment may not be of interest to people with this reaction. Secondly, some people are more comfortable if they believe the water is more ‘natural’, i.e. has spent some time in a river, lake or groundwater basin.

Communication with the community and scheme design needs to take these factors into account.

Conclusions

In conclusion, the use of recycled water to supplement drinking water supplies appears to offer a potentially appropriate option for some cities to access a significant new source of water that is independent of rainfall. This option may compare favourably with other options on an economic or environmental basis, but this can only be determined by a detailed analysis for each specific case.

Advanced water treatment technologies and new risk assessment techniques should allow water managers achieve the comprehensive risk management that is required to protect public health.

There will be community concerns, and these will need to be addressed through careful planning and a wide ranging approach. Technical education alone is unlikely to satisfy the community. Scheme design may also need to take community concerns into account.

Structure of this paper

The first section of the paper provides background information on recycling to supplement drinking waters supplies. The next section provides information on comparisons between this water supply option and other water supply options. Risk and water quality are covered briefly in the following section and then community concerns are considered. The paper concludes with a brief discussion.

Questions?

If you have any questions, comments or enquiries about this paper please contact the National Water Commission (the Commission) at enquiries@nwc.gov.au or on 02 6102 6088.
Introduction
This paper has been prepared at the request of the Commission as a contribution to the discussion surrounding the use of recycled water to supplement drinking water supplies, recognising the broader portfolio of alternate water sourcing options and the different circumstances across Australia.

**Background**

Australia is facing a shortage of water in its urban centres. This is driven by two factors. First, our cities are growing, and therefore the demand for water is growing. Second, there has been a reduction in inflows to our dams due to drought and other factors. In some cases this reduced inflow appears to reflect a step change which, if permanent, means significant reductions in available water. Figure 1 illustrates how these two factors affect planning for our cities.

The inflow into reservoirs has in many cases been decreasing around Australia in the last 10 years or more. This has been particularly evident in Perth, as shown in Figure 2, and has stimulated the investigation of alternative water sources. Perth has addressed this water shortage by building a recycling plant for industrial water, a desalination plant and a range of other options including investigating aquifer recharge with recycled water. Aquifer recharge involves storing recycled water in an underground aquifer before it is extracted for use.

*Figure 1: Illustrative water supply and demand in Australia*
Historically, water planning used similar data sets, and when shortfalls appeared likely in the future, new sources of water were identified. Typically, these new sources were other rivers or streams and often involved the construction of new dams. Perhaps because people were familiar with the concept of supply from dams, any community interest tended to be around the construction of the dam itself, rather than whether it was a suitable source of water for drinking.

This traditional approach to water planning has changed in response to several drivers:

- Increasing concern regarding the health of our rivers, leading to a more negative view of increasing extractions from them.
- Reductions in stream flows due to drought or step changes in inflows mean dams are less reliable. Also, suitable sites for many new dam options are further away or more expensive to construct.
- A renewed interest in reductions in consumption, including industrial water management, domestic rainwater tanks, permanent water restrictions, grey water re-use, in-house efficient appliances and others.
- Advances in water treatment mean that options such as seawater desalination and effluent and stormwater recycling are now more viable.

This complexity presents additional challenges for involving the community in making decisions about water planning.

Another driver is the National Water Initiative (NWI). Signed in June 2004, it is Australia’s blueprint for improving Australia’s water management and use. One of its aims is to create water sensitive cities and Australian governments have committed to providing healthy, safe and reliable water supplies and encourage innovation in water recycling where cost effective.
Some terms explained

The following terms will be used throughout this paper and should be interpreted with the following definitions. Further aspects are explained in the Appendices, or as they arise in the paper.

- **Wastewater**: describes the water that is captured in sinks, baths, shower basins, toilets and from industry, and discharged to the sewerage system to a sewage treatment plant.
- **Recycled water**: describes highly treated wastewater from a sewage treatment plant. Recycled water may also refer to treated stormwater, groundwater or a mix of all three water sources.
- **Potable Water**: is the term used to describe water that is suitable for drinking.
- **Indirect Potable Re-use (IPR)**: describes the process of deliberately using recycled water to supplement drinking water supplies. Recycled water is introduced into a drinking water supply, such as a reservoir, river, or groundwater aquifer, where it mixes with the ‘natural water’ before extraction and treatment. This is also known as ‘planned’ IPR as the recycled water is intentionally added to a water sources.
- **Unplanned Indirect Potable Re-use**: is a term used to describe the circumstance where recycled water (usually from some other community) is discharged into a river or other water source somewhere upstream of a drinking water supply intake.

Why would we even consider using recycled water for drinking?

Where recycled water is deliberately used to supplement supplies in other countries it has been selected as a suitable water supply option because people in those places believed that:

- it is a reliable source of water
- it has been cost effective versus other options
- authorities in those countries have concluded that the risks can be effectively managed, and
- there are environmental benefits from reducing the volume of effluent discharges.

Recent rainfall and river flows in Australia have been at historical lows, and climate change predictions suggest these new uncertain weather patterns may continue. So there are concerns that relying on historical approaches and water sources may lead to ongoing shortages.

In Australia, there is increasing interest in alternative options to provide more water from sources that do not depend on rainfall. Recycled water for drinking is one such option. In April 2007, the Queensland and ACT Governments announced their intention to construct large scale water recycling plants to provide new water supplies that are independant of rainfall. The recycled water would be introduced into natural water systems before being extracted, filtered through the drinking water treatment plant and introduced in the drinking water networks.
Where is recycled water used for drinking?

Well-known examples of planned indirect use of recycled water for drinking are in Singapore and Orange County, California. In Singapore a small proportion of recycled water is introduced into water supply reservoirs by the NEW Water scheme. The major and remaining use is in industries, which require very pure water such as the manufacture of computer chips. In Orange County in California, recycled water is used to create a saltwater intrusion barrier for the groundwater resource that is used for 75 per cent of the water supply. This has been in operation since 1976. The original Water Factory 21 has recently been demolished and a new expanded treatment plant is currently under construction.

In the UK, Essex and Suffolk Water supply its customers with up to 40 ML/day of recycled water. Effluent from the Anglian Water’s Chelmsford plant is taken from the effluent discharge pipeline and put through further treatment before being put into the River Chelmer. Water is pumped from the River Chelmer to Hanningfield Reservoir and then treated again before being supplied to customers. The scheme began in 2003 and is believed to be the only planned IPR Scheme in the UK. IPR is also being considered for London with a 1ML re-use pilot project being carried out by Thames Water (New Civil Engineer International Journal, 2006).

Many of Australia’s cities and towns draw their water from sources that have some proportion of recycled water in them. This is true for some of Australia’s major cities including Sydney, Melbourne, Adelaide and Brisbane. Note that the proportions vary and in some cases the detention times are quite long before the water is used.

Figure 3 shows a map produced as part of the information for the Toowoomba referendum showing some local examples of unplanned IPR in south-east Queensland.

Appendix A contains more descriptions of planned and unplanned IPR occurring around the world. Examples such as London drawing water from the Thames, with hundreds of effluent discharges upstream are often quoted. Note that water treatment systems in the UK and Europe are sometimes different from those used in Australia so any comparisons must be viewed carefully.
There are a large number of examples of systems worldwide that draw their water from water sources that contain recycled water from other towns upstream, and a smaller number of examples where recycled water is deliberately sent back to the source for a town. There is only one well-known example in the world of direct use of recycled water for drinking. In the city of Windhoek, Namibia, recycled water is mixed with surface water from Goreangab Dam then treated and supplied to the distribution system. This has occurred since the late 1960s because severe water shortages and deterioration in the water quality in Goreangab Dam as its catchment have become more developed.
History of the use of recycled water for drinking in Australia

The concept of using recycled water for drinking in Australia has a relatively long history. Several schemes were explored in south-east Queensland in the 1980s and 1990s. The concept was discussed in long-term planning documents for Victoria in the 1970s. These schemes and concepts paralleled work in the United States at the same time.

In 1991 Greenfield and Hamilton presented a paper on *Potable Re-use of Treated Wastewater* at the Australian Water and Wastewater Association (AWWA) 14th Federal Convention. This paper looked at flows in waterways that were drinking water supply resources around Australia and that had a wastewater discharge upstream of the drinking water intake. The research was done between 1978 and 1986, and considered a range of flow conditions. Overall the study identified that between 0.1 and seven per cent of water supplies evaluated in Australia had effluent in their source water.

It is interesting to note that the idea of IPR in Toowoomba was mentioned at that time. The culmination of that activity was the construction of a plant at Caboolture to produce very high quality water for recycling to drinking supplies. This plant attracted opposition, which then had some influence on a council election. The final result of this project is that IPR does not occur, and instead the plant discharges most of its high quality water to the environment.

In the last few years several schemes have been considered. A scheme was proposed for Toowoomba, and the concept was put to a referendum in July 2006. When the voters were asked ‘Do you support the addition of purified recycled water into Toowoomba’s water supply via Cooby Dam?’ 62 per cent said no on the day. Sydney Water has also explored the idea of a large IPR scheme as an alternative to the proposed desalination plant. Some data from this cost comparison is presented in this paper. Goulburn in New South Wales faces significant water shortages and is exploring IPR as one of the potential options.

Current status of using recycled water for drinking in Australia

In South-east Queensland a major recycling scheme to supply water to power stations and to Brisbane’s drinking water supply is under construction. This will be one of the largest schemes in the world. Further information on this scheme is provided later in this paper, and more up-to-date information should be sought from the relevant authorities in Queensland. More information can be found at [www.qwc.qld.gov.au/More+info](http://www.qwc.qld.gov.au/More+info).


As part of preparing this paper, a survey of 32 organisations that manage drinking water around Australia was conducted. The responses to this survey reveal that over 50 per cent of the organisations surveyed will need a new water source in the next five to 20 years. Of the water supply options considered, about 30 per cent of respondents had considered recycled water as a drinking water source to meet demand in the next five to 20 years.

In most cases only a high level review was conducted because IPR was either inconsistent with current government policy or was considered unlikely to attract public support. Although public acceptance was a quoted reason for not considering IPR further, only 12 per cent of respondents had actually formally engaged the community on the issue. Overall the survey indicates that IPR has not been considered in detail in many future water supply plans in Australia. WSAA, the peak body for water authorities in Australia, has recently released a paper on recycled water that sets out a position on IPR.
The Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) (NRMMC, EPHC & AHMC 2006) have recently been finalised. This first phase covers non-potable uses of recycled water sourced from treated sewage and greywater while the Phase two guidelines, due for finalisation by the end of 2007, will cover recycled water for drinking, stormwater re-use and managed aquifer recharge using recycled water. Research in Adelaide and Perth is currently examining the suitability of water from managed aquifer recharge for drinking water.

A public consultation draft of the recycled water for drinking component of the phase two guidelines is expected to be released in 2007. A joint steering committee is developing the guidelines which comprises of representatives of health, environmental and water agencies from both state and Commonwealth jurisdictions as well as representatives of the National Health and Medical Research Council (NHMRC) and WSAA. NHMRC was also involved in developing the ADWG, (NHMRC & NRMMC 2004).

The ADWG will be updated through a rolling revision process and, as IPR involves both recycled water and drinking water, these two guidelines are likely to be aligned in future revisions. Victoria has legislation regarding the quality of drinking water: the Safe Drinking Water Act 2003 while other states regulate drinking water through Food Acts and other related legislation.

The United States Environmental Protection Authority (USEPA) has published national guidelines for water re-use (USEPA 2004) that includes guidance for augmentation of drinking water supplies with appropriately treated recycled water. The states of California and Florida amongst others also have guidelines and legislation. In addition to requirements on treatment and water quality, these guidelines sometimes include comments or requirements related to the time the water spends in the environment before being extracted and treated to produce drinking water. More information is provided in Appendix B.

The ‘typical’ urban water cycle and implications for IPR

The urban water cycle is a complex interaction between rainfall, evapo-transpiration, potable water supply, wastewater, stormwater and effluent re-use (Figure 4).

The majority of Australia’s urban water cycles have the kind of features shown in Figure 5. Water is captured in a dam or extracted from a river, treated to some degree and then supplied for drinking and other purposes. Note that in some locations, the reservoir is underground in the form of porous rocks and gravels, this is known as groundwater in an aquifer. The level of development in the water supply catchment will influence the amount of treatment needed to provide safe drinking water. The way in which the risks from the catchment are managed by means of a ‘Catchment to Tap Risk Management System’ are set out in the ADWG and summarised briefly in Appendix C to this paper.
Figure 4: The role of engineered treatment, reclamation, and re-use facilities in the cycling of water

(After Asano and Levine, 1995)

Figure 5: The Typical Urban Water Cycle
The quality of source water in water supplies in Australia can vary greatly, depending on the extent to which the catchment is ‘protected’ or developed as well as other factors. This difference in source water quality leads to a difference in the type of water treatment plant required to produce water suitable for drinking. For example, Melbourne draws most of its water from protected catchments and then stores the water for a long time in large dams, and therefore does not have any filtration on most of its water supplies. The proportion of Melbourne’s supply that does come from unprotected catchments is treated through filtration plants. Brisbane draws water from the Brisbane River, with significant development in the catchment, and therefore has more complex treatment including filtration.

The quality of final wastewater treatment is equally varied, depending on the history of the city’s water supply and management systems, and the nature of the final discharge. Some inland towns which discharge to sensitive waterways have more sophisticated treatment than some coastal towns which can take advantage of the dilution offered by extending outfalls into the ocean.

What is water used for in the cities and towns?

In most circumstances water is supplied via a single pipe to all users of water. In some new developments there is a second pipe that delivers recycled water for toilet flushing and garden watering.

As shown in the following diagrams (Figure 6 and Figure 7) more than half the water used in cities and towns in Australia is used for domestic purposes. Of the proportion used in-households, only a small proportion is actually used for drinking. Note that as water restrictions occur, they start by impacting water use outside the house, with less impact on the volumes of water going to the sewer.

All the water used inside a household or commercial business—and not used on the garden—will end up in the sewerage system. Approximately 50 per cent of water supplied to domestic households ends up in the sewerage system. In most towns and all cities the sewerage system pipes the wastewater to a sewage treatment plant where it is treated and typically discharged to the environment. Therefore, wastewater provides a significant amount of water that could be re-used. Re-use of this water is increasing, but the percentages of re-use in our larger cities are mostly less than 10 per cent to 20 per cent. Some smaller towns achieve higher percentages, but this is typically to provide irrigation of land and only rarely substitutes for the drinking water used in the town. So while this is a beneficial activity, it may not directly improve the supply-demand balance for the town.

Figure 6: Urban Water Consumption in Australia 2000–2001 as a per cent of Total Consumption

(Source: WSAA Position Paper No1 2005)
Recycled water: What is it?

Recycled water could be described as water from a wastewater treatment plant or from collected stormwater that has been treated to an appropriate quality and is then ‘used’ for some beneficial purpose. In the past, recycling was driven more by the desire to reduce impacts on the receiving waters than by the need to conserve water.

Now, recycled water is seen as a potential resource to assist in managing the supply-demand balance. The idea of using recycled water has a range of merits including:

- reduction in the amount of water extracted from the environment
- reduction in discharges to the environment, and
- potential reduction in energy use as the water is available locally.

Social research has shown that many people not only accept the idea of using recycled water, but believe it is a good idea (see later section for more discussion). The degree to which people are confident in the idea depends on how much human contact it involves and the distance and environmental interaction between discharge and consumption.

The degree to which recycled water is treated is often defined in Classes; Class A being the ‘best’ or most highly treated. This classification system differs from state to state and has other complications, as the water in some recycling schemes is notably better than typical Class A.

Some different concepts that have been developed for using recycled water are described below (Table 1).

<table>
<thead>
<tr>
<th>Recycled water options</th>
<th>Treatment required</th>
<th>Constraints on volume</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Irrigation</strong> of open spaces</td>
<td>Typically less treatment than Class A but would vary depending on the end use.</td>
<td>Only a small fraction of city water use is available for substitution in this way, so large volumes can only be recycled to areas outside the city. The Virginia Pipeline Scheme in South Australia, and the Werribee Irrigation District in Victoria are two examples where the recycled water is used for vegetable production.</td>
</tr>
<tr>
<td>such as sporting fields, or</td>
<td>Sometimes the salt levels can be a problem, and this means some desalination of the effluent may be required.</td>
<td></td>
</tr>
<tr>
<td>agriculture or horticulture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>crops.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental Flow Substitution</strong> where recycled water is introduced to a river downstream of a dam to provide base flows in the river. This means more drinking water can be retained for use in the dam.</td>
<td>This idea has not been implemented widely yet so there is limited consensus as to the level of treatment required though it is generally considered that the quality of the water should match that of the receiving waters. It seems likely that very high quality water will be required, with levels such as Class A or higher suggested. Note that if human contact (e.g. swimming) were likely downstream, then recreation and other relevant guidelines would require consideration.</td>
<td>Large volumes might be possible, although the environmental and community constraints on replacing significant fractions of river flows with recycled water would need careful exploration.</td>
</tr>
</tbody>
</table>
### Recycled water options

<table>
<thead>
<tr>
<th>Treatment required</th>
<th>Constraints on volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A or better is required. This often involves membrane filtration such as ultrafiltration together with disinfection. Some recent schemes have also considered treating the water to remove colour and manganese so that customers are not concerned by the appearance of the water.</td>
<td>Toilet flushing and garden watering can make up around 30–50 per cent of household water use, and therefore this appears an appropriate way to recycle large volumes of water. Unfortunately the costs of retrofitting dual pipe to existing cities are high and therefore this option is typically not considered feasible in such situations. To provide a sense of this cost, consider a city of 1 000 000 existing homes. Total cost divided up on a per house basis is probably in the order of $10 000 (there is significant debate around this figure). Dual pipe retrofit would therefore equate to around $10 billion and would lead to considerable construction related disruption.</td>
</tr>
</tbody>
</table>

**Dual pipe:** becoming more common in new housing developments, where a second pipe delivers recycled water for toilet flushing and garden watering.

### Recycling to Industry

*Industry* is a broad description. There are some individual large users in many cities, and these have been identified as possible users of recycled water.

- Schemes include the BlueScope Steel mill in Wollongong, BP-Amoco refinery at Luggage Point in Brisbane and the multi-industry scheme at Kwinana in Perth.
- Larger schemes for supply to power stations are under construction in South-east Queensland and under consideration in Victoria.

- Industry needs vary, but it is interesting to note that all the examples mentioned use microfiltration and reverse osmosis to achieve very high water quality.
- In some cases the water quality is defined as being as good as the drinking water currently coming from the tap.

While the individual users can appear significant, there are limitations. The example schemes mentioned earlier are all around 20 ML/d, which is around 6 GL/yr. This would be around one per cent of Sydney or Melbourne’s annual water consumption but the savings by BlueScope Steel represent about 20 per cent of Wollongong’s consumption.

Many large water consumers are food industries that are reluctant to consider recycled water.

Finally, at many industrial sites, the piping cost to separate drinking from non-drinking uses can be high, thus reducing the attraction of these schemes.

### Indirect Potable Re-use (IPR)

(Using recycled water to supplement drinking water supplies)

- Most currently proposed schemes include microfiltration, reverse osmosis and then some form of advanced oxidation.
- Later chapters elaborate on this process and what it might achieve.
- Water quality produced by this combination of processes is very high.

In principle, large fractions of the water could be recycled, with no need for re-plumbing in the city. All consumers can be reached, thus accessing the existing housing stock.
Some key aspects of IPR, in comparison to other recycling options, are evident from this review:

- large volumes can be recycled
- costs for re-plumbing are minimised and
- there is a gradual increase in the typical levels of treatment, often starting with micro or ultrafiltration for dual pipe, adding reverse osmosis for industrial use, and then adding advanced oxidation for IPR.

Because piping and re-plumbing are expensive relative to additional treatment processes, IPR is often a cost-effective recycling concept for large systems compared to other recycling concepts. It is of further interest that a recent review suggests many of the lower cost alternative recycling schemes may have already been identified (Marsden Jacob Associates, 2006).

How do our major water authorities see recycling for drinking purposes?

WSAA released a position paper in November 2006 titled *Refilling the glass—exploring the issues surrounding water recycling in Australia* (WSAA Position Paper No 2). The position paper was prepared to 'inform communities on the issues associated with recycled water, and enable them to embrace change, contribute to discussions on future water resources, and ensure sustainable water resource outcomes for our cities for future generations'.

IPR is discussed as one of several options to achieve large scale recycling without the cost of retrofitting properties and duplicating water supply networks. In WSAA’s view ‘supplementing our drinking water supplies with recycled water is a viable option that needs to be considered along with all other alternatives, but caution must be exercised if we are to proceed along this path. Because of the nature of the source water, there must be an effective multi-barrier approach to ensure that drinking water is continuously safe for our communities’.

The WSAA position paper was developed to help further community understanding about the opportunities for using recycled water as well as the constraints. The paper outlines that using recycled water to supplement drinking water supplies will be limited without the support of the community. In that context, recycling should be evaluated and presented to the community with other major water supply options such as water trading and desalination.

The position paper outlines 10 key community and technical issues to be addressed in IPR schemes:

1. **Environmental buffers—using natural treatment**
   These buffers provide an additional independent barrier using natural purification systems as part of a multi-barrier approach. They also provide a delay in the system to ensure adequate assessment can be carried out to ensure continuous safety of the supply.

2. **Building community trust**
   It is essential for the agencies and operators to be transparent on all issues associated with the scheme and to be fully engaged with the community.

3. **Modern treatment technologies**
   Treatment technologies used must reflect the need to reliably minimise the risk of any harmful chemicals and microbial pathogens, reliably and to required health standards.

4. **Building institutional capacity—to deliver high quality recycled and drinking water**
   Institutional arrangements in organisations operating such schemes must be capable of supporting the advanced technologies necessary. Specialist staff skills are necessary, effective training essential and quality management systems are required. Institutional arrangements vary across the country and may need to be improved in some cases to support recycled water for drinking.
5. Recycled water quality—to match drinking water quality
The quality of the recycled water needs to meet current drinking water guidelines, plus any specific guidance required due to the source of the water.

6. Industrial waste management
Some industrial waste outputs may need to be isolated from the sewerage system, and require special consideration and stringent controls need to be very stringent to ensure the advanced treatment systems are not compromised.

7. Monitoring and assessment
Effective system process and other monitoring needs to be in place so that the public can be reassured that systems are operating satisfactorily.

8. Environmental considerations
Any impacts on the environment due to the recycling scheme need to be addressed through normal environmental assessment processes.

9. Regulatory guidance and public reporting
Regulatory guidance must be in place to ensure a consistent approach to such schemes. Regulatory agencies must be skilled and well resourced and report to the public on the performance of such schemes.

10. National research capacity
Australia needs to build on its strong research capacity to ensure that future findings about contaminants in water can be factored into our management of these schemes.

The key messages relating to IPR outlined in the position paper include the following:

- The cost and benefits of recycled water options need to be considered on a case-by-case basis among all other water supply options.
- The uses of recycled water for non-drinking purposes will continue to increase, as it has done for the last 10 years.
- Recycled water for non-drinking purposes has gained widespread community support. However the ability for large scale recycling to reduce demands on drinking water supplies will be limited in already established businesses and housing developments because of the prohibitive costs of building new pipe networks.
- Non-household consumption of drinking water represents less than 30 per cent of the total water use in Australian capital cities. Unless recycled water can be used to supplement drinking water supplies, non-drinking water uses will be limited to much less than the 30 per cent of water used for non-household purposes.
- If recycled water is used for supplementing drinking water supplies, the community will prefer (and may demand) that it be placed in an environmental buffer such as a river, aquifer or existing storage dam before it is further treated prior to entering the water distribution system.
- WSAA does not support direct drinking of recycled water as it believes that the absence of an environmental buffer raises the risk profile unacceptably.

Effective leadership on key community and technical issues will be important, as in many cases resolution will require a balance between competing interests. Some of these issues will be explored as part of developing the next phase of the IPR guidelines. Others are dependent on policy positions and investment decisions in different circumstances.
How does the use of recycled water compare to other drinking water supply options?
Brief summary of this chapter

This chapter explores the circumstances in which IPR might compare favourably to other water supply options.

Such comparisons can have a wide range of interpretations, particularly where people have different values and concerns. It does however appear that there are circumstances where IPR would compare favourably with other water supply options on the basis of cost and/or environmental impact.

The physical circumstances when IPR is likely to compare favourably are those that fit some or all of the following criteria:

- There is a need to supplement the central water supply (i.e. when demand management, rainwater tanks, and water sensitive urban design in new housing developments with dual pipe will not completely address the demand/supply imbalance).
- The wastewater treatment plant(s) already produce relatively good quality water.
- The distance and elevation from the wastewater treatment plant back to the original water source is relatively short compared to the distance and elevation required to access alternative water supplies. This is relevant because the cost and energy required to transport water over the typical distances and elevations experienced in cities is comparable to the cost and energy required for treatment of different sources such as recycled water and seawater desalination.
- Unique natural assets such as aquifers with long detention times are available.
- There is available nearby water storage with additional unused capacity.

The questions of criteria such as risk to public health or public attitudes are critical issues explored in later chapters.

The remainder of this chapter explores the comparison of options with respect to their costs and environmental impacts in more detail.

Water supply options

As our cities grow and as dwindling inflows currently reduce the water available from our dams and aquifers, what options are available to us? The following is a summary of some of the options:

- using less water (Demand Management)
- bringing surface water from elsewhere
- using water markets to purchase water from agricultural users
- using harvesting stormwater
- using groundwater (local or from elsewhere)
- using seawater (the ocean)
- using effluent recycling, and
- using other less likely possibilities such as towing icebergs, tanking freshwater in ships, etcetera.

Large-scale options which supply water back into the main piping system are sometimes known as ‘central’ options, and this wording is used in this paper.
Given the complexities and a much wider range of uncertainties and judgements involved to compare ‘at house’ options such as rainwater tanks, demand management, etcetera with large scale ‘central’ options such as seawater desalination and IPR, the evaluation in this paper has been confined to comparison of different central augmentation options.

**What are the conceptual differences between large scale central augmentation options?**

*Table 2* illustrates key conceptual differences between central water supply options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Reliability of source water</th>
<th>Treatment required</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Dams</td>
<td>Limited by stream flows. May impact downstream extractions. Constrained by need to maintain environmental flows.</td>
<td>Complexity depends on catchment. Many ‘new’ catchments are compromised with developments and human activity. So the level of treatment and resulting cost and environmental impact may approach that of other options.</td>
</tr>
<tr>
<td>Temporary transfer and permanent sale from irrigators</td>
<td>Limited by stream flow or allocations. Dependant on willingness to sell and broader water market. Prices may rise.</td>
<td>Complexity depends on catchment. Most irrigation water is drawn from catchments that are compromised. See comments on new dams above.</td>
</tr>
<tr>
<td>Bore water</td>
<td>Limited by entitlements and allocations and sustainable yield.</td>
<td>Complexity depends upon source, often salty therefore requiring desalination. This means costs and environmental impacts may approach or exceed that of other options, although desalination costs including energy costs will generally be less than for sea water due to lower salinity of bore waters.</td>
</tr>
<tr>
<td>Seawater</td>
<td>Unlimited source available.</td>
<td>Desalination to drinking water standards.</td>
</tr>
<tr>
<td>Recycled for drinking (IPR)</td>
<td>Source related to city consumption potentially up to 50 per cent but usually less than 25 per cent.</td>
<td>‘Desalination’ plus other processes to achieve desired water quality.</td>
</tr>
</tbody>
</table>
Comparing water supply augmentation options

How are water supply options compared?

Typical comparisons follow some form of sustainability framework, where economic, environmental and social factors are all taken into account. However, there is no standard framework for comparing options. Even the method used to determine the cost of water in $/ML varies widely. This can lead to confusion when comparing costs, particularly those quoted from other cities or overseas.

A hypothetical case study is provided as a basis for discussion. Note that the concept of a reservoir used here could also refer to an aquifer.

The hypothetical case study

The case study is a city that needs an extra 30 GL/year (approximately 100 ML/day) to meet its drinking water capacity shortfall. The city is located near the ocean, and it is 20 km to send desalinated seawater to the city’s pipes, but 100 km to send the recycled water back to the source dam. Irrigation water could be purchased, but this would have to come from 250 km away.

It is crucial to recognise that each real city will have unique features that will have significant implications for this kind of analysis. Drawing simplistic conclusions will almost always lead to some error. Long history in engineering of large projects has shown that the only way to develop a reasonable understanding of costs is to spend enough time and money to develop options to an appropriate level of design.

Consider three options for this city:

- IPR (green lines)
- seawater desalination (blue lines) and
- purchase water from irrigators (brown lines).

The following sections in this chapter compare these water supply options for this hypothetical city from an economic and environmental perspective.

Figure 8 illustrates the point that each of these options can be separated into two notional components, ‘treatment’ and ‘transport’.

Figure 8: Water supply options for a hypothetical case study

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1 Figure 8: MF = Microfiltration, RO = reverse osmosis and AO = advanced oxidation. These are described in Appendix C.
Figure 9 provides some indicative cost information for a scheme of this size and illustrates the point that water from an irrigation system can be more expensive to use, even though cheaper at source, and that desalination and IPR could have similar total costs if the costs of pumping and piping are included in comparisons.

The key conclusion here is that transport costs for distances that could reasonably be expected in Australian cities are significant in the analysis, and therefore any abstract statements such as ‘IPR must be cheaper’ should be viewed with suspicion unless transport has been considered.

Figure 9: Comparison of water treatment costs and transport costs for a hypothetical case study to supply 100ML/day of an alternative water supply

There is another important input to the total cost—the cost of energy. Table 3 sets out the relative energy inputs and the differences in cost per ML if energy costs were to double for this hypothetical case study.

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost of water due to energy</th>
<th>Cost of water due to energy (If energy costs double)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy cost (in c/kWhr)</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>IPR (say 1.5 kWhr/kL)</td>
<td>$150 /ML</td>
<td>$300 /ML</td>
</tr>
<tr>
<td>Seawater desalination (say 4 kWhr/kL)</td>
<td>$400 /ML</td>
<td>$800 /ML</td>
</tr>
</tbody>
</table>

Table 3 shows that if energy costs alone are considered, for the hypothetical case study presented in this paper, the costs of desalinating seawater rise more than the costs for recycled water. Note that actual energy costs will vary depending on the energy source and the cost of energy is a key factor influencing the relative costs of different water supply options. If total energy use for treatment and pumping in an IPR scheme is higher, then IPR would have the larger cost increase.
If we refer back to the total water costs for the schemes in the hypothetical case study, the doubling in the cost of energy leads to an increase in the cost of water from the schemes as follows:

<table>
<thead>
<tr>
<th>Option</th>
<th>Total cost of water including current energy price</th>
<th>Total cost of water including double current energy price</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPR scheme</td>
<td>$1300 /ML</td>
<td>$1450 /ML</td>
</tr>
<tr>
<td>Desalination scheme</td>
<td>$1300 /ML</td>
<td>$1700 /ML</td>
</tr>
</tbody>
</table>

**Table 4: Sensitivity of water supply options to changes in energy costs**

Are these costs really different?

What can we conclude from this hypothetical cost comparison?

- That for distances as outlined above, these options have a similar cost per ML.
- That generalised statements such as ‘Seawater Desalination is Cheaper’, or ‘IPR is Cheaper’ should be viewed with scepticism unless some kind of detailed site-specific analysis has been performed.
- That the right assumptions are made in regard to costing recycled water treatment facilities and include the distances of pipe-elines which will be unique to each region considering IPR. So in this sense the cost of transportation is integral with the cost treatment.

In November 2006 Marsden Jacobs Associates undertook a review of water supply options for urban Australia. This included a review of the cost of different water supply options, which is shown in **Figure 10**. The figure shows the range of costs for water supply options for Sydney, Adelaide, Perth and Newcastle.

There have been a number of other reviews of costs for various water supply options, and answers often differ depending on the assumptions used. One area where there are often differences is in-house based options such as rainwater tanks and greywater re-use. Coombes and Kozarovski (2005) for example, quote rainwater tank water costs ranging from $1.02 to $7.67/kL. **Figure 10** does highlight that in one broad-brush review, IPR was seen to be a potentially economically competitive option. It also highlights the range of costs for options, which can be wide depending on local circumstances.

**Figure 10: Direct costs of water supply options—Sydney, Perth, Adelaide, Newcastle**

(Source: Figure 1, Marsden Jacob Associates, 2006)
Other costs can change

Finally, it is important to note that other local issues can have a significant influence on costs. For example, the costs of seawater intakes and outfalls are highly variable and can add a significant amount to project costs for seawater desalination.

There are significant differences in the costs for desalination on the Gold Coast versus Perth due to local issues including proximity to the ocean, sensitive ecosystems (aquatic and terrestrial), provision of community education/acceptance programmes and the cost of connecting infrastructure.

Future energy use?

‘The energy use required for seawater desalination is reducing, so the cost and greenhouse impact will reduce.’ This kind of argument has been used to suggest that seawater desalination will be more appropriate in the future compared to IPR. There are some interesting arguments to consider here.

First, the reverse osmosis technology used to desalinate seawater is the same technology used in most current IPR projects. So as the energy use required for seawater desalination decreases, so will the energy use for IPR decrease, although the reduction may not be as significant.

Second, a portion of the energy used for both seawater desalination and IPR schemes is for pumping, control systems and waste disposal within the production system. However, costs associated with the delivery of recycled water and desalinated water should not be included in energy comparison between the two as these are not fixed and subject to local geography and existing infrastructure.

Finally, many proposed schemes to pump water long distances from places where water is thought to be abundant have a total energy consumption well in excess of that required for either IPR or desalination.

Cost comparisons for Toowoomba and Sydney

It is useful to consider some cost comparisons that were developed for two cities, Toowoomba and Sydney. Note that the following points are limited to comparison of cost data reported by others.

Alternative options were considered for Toowoomba; Table 5 summarises some costs developed.

Table 5: Toowomba Water Supply Options

<table>
<thead>
<tr>
<th>Option</th>
<th>IPR (millions)</th>
<th>Oaky Creek Groundwater</th>
<th>Condamine Groundwater A</th>
<th>Condamine Groundwater (higher extraction)</th>
<th>Coal Seam Gas water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>$73.2</td>
<td>$148</td>
<td>$196.8</td>
<td>$275.4</td>
<td>$224.1</td>
</tr>
<tr>
<td>(Source: Selmes et. al. 2006)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

The conclusion drawn from the analysis of options in Toowoomba was that IPR was the most cost effective option. The City Council presented this data to residents in another form, which showed the impact on council rates of choosing different options.

Sydney Water has reported on a comparison between two 500 ML/d (i.e. large) schemes, namely seawater desalination and IPR (Sydney Water 2006). This is illustrated in Figure 11.
The Sydney Water report makes some comments on the reasons why the large IPR scheme is more costly. These include:

- accessing these large volumes means capturing and treating primary effluent from right at the coast, which increases the cost
- transportation back up to Warragamba Dam, with piping and energy costs for pumping, and
- a loss due to evaporation of IPR water in the dam compared to desalinated water which can be introduced directly into the supply system means more input water is required.

The comparison for Sydney illustrates some key elements of comparison on an economic basis. Sydney has less final treatment on its wastewater than some other towns and cities. So there is an additional cost for IPR in Sydney compared to some other towns and cities due to the need to provide additional wastewater treatment prior to the advanced treatment for IPR.

Sydney’s physical layout with high value land at the coast means additional costs to collect and transfer the wastewater back to a treatment plant, again adding to the costs.

The location and elevation of Warragamba Dam, and the water quality based decision to send the water back to this source lead to increased costs and energy use to transfer the water. In contrast, the fact that major demands for water in Sydney are located close to the coast means that desalinated seawater can be introduced with less infrastructure.

The decision about the amount of dilution and detention time required for IPR has an influence on the cost comparison with other options.

**Comparison of IPR with other central options against environmental criteria**

Environmental issues associated with water supply are wide ranging. They include aspects such as environmental health of rivers, impact on the ocean, greenhouse gas emissions, impacts on land etcetera. Many of these are captured in wider metrics such as ecological footprint, sustainability assessments and other approaches.
These wider concerns become important when comparing the wider range of options such as demand management or new cluster type developments. Typically a portfolio of approaches is developed, and evaluated using some form of sustainability assessment. One comprehensive example is explained in a paper by Lundie et al. (2006).

These wide ranging assessments are outside the scope of this paper. However, it is useful to consider some of the central environmental aspects of IPR, and to compare these with some common alternative large-scale options; in this case seawater desalination and extraction of additional water from a river.

By way of example, different criteria might be used to compare these three different options.

- **River health**: We can affect river health by either extracting too much water from the river, or alternatively by disposing of contaminated water to the river.
- **Greenhouse emissions**: Each of our options uses power; to treat the water and to pump it. This may lead to consequential emissions of carbon dioxide, and will vary depending on the power source.
- **Seawater desalination**: Perceived as highly greenhouse gas intensive and, as a result, undesirable. However, an indirect potable re-use scheme that required wastewater to be pumped for a long distance and up a significant lift using the same energy source could contribute equivalent greenhouse gas emissions to those of a seawater desalination plant.
- **Waste disposal**: Each of the options generates a waste stream that needs to be dealt with.

Figure 12 provides a comparison of energy use, and thus greenhouse gas emissions for the hypothetical case study. This graph does not include the energy to pump water to the final elevation, only the losses due to friction in the transfer pipelines.

Table 6 outlines a range of potential augmentation options, which have different distances and lifts for transfer of the water. Figure 12 illustrates the total energy use associated with these different options. The figure shows that the total energy use is made up of the energy for treatment, the energy to pump up a lift, and then the energy to overcome friction losses in pipes.

This figure also shows how energy comparisons between water options are sensitive to the lift and distance, which are unique to the particular city involved. Therefore general energy comparisons are not possible, but must be made after analysis of each unique option in each city.

**Table 6: Possible Augmentation Scenarios**

<table>
<thead>
<tr>
<th>Some Possible Augmentation Options</th>
<th>Treatment Head (m)</th>
<th>Lift (m)</th>
<th>Distance (km)</th>
<th>Energy (kWhr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. IPR Distant and Higher Lift</td>
<td>300</td>
<td>400</td>
<td>200</td>
<td>4</td>
</tr>
<tr>
<td>2. IPR Closer and Lower Lift</td>
<td>300</td>
<td>100</td>
<td>50</td>
<td>1.9</td>
</tr>
<tr>
<td>3. Desalination Distant and Higher Lift</td>
<td>1000</td>
<td>200</td>
<td>100</td>
<td>5.4</td>
</tr>
<tr>
<td>4. Desalination Closer and Lower Lift</td>
<td>1000</td>
<td>50</td>
<td>20</td>
<td>4.3</td>
</tr>
<tr>
<td>5. Pipeline More Distant and Higher Lift</td>
<td>50</td>
<td>300</td>
<td>500</td>
<td>4.4</td>
</tr>
</tbody>
</table>
Figure 12: Comparison of the energy requirement for treatment and transfer

Table 7 sets out a high level comparison of the options against environmental criteria.

Table 7: Environmental comparison of options

<table>
<thead>
<tr>
<th>Central supply option</th>
<th>River health</th>
<th>Greenhouse gas</th>
<th>Waste disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect Potable Re-use</td>
<td>No additional extraction from rivers. May reduce volume disposed (refer waste disposal).</td>
<td>Note that greenhouse gas needs to include both treatment and pumping back to ‘top’ of system.</td>
<td>IPR plant will turn around 80 per cent of incoming water into high quality water; the remaining 20 per cent is waste stream. Usually blended with residual effluent and sent to river or ocean. A large IPR scheme that treated a high percentage of the effluent would lead to a more concentrated final effluent (higher salts, nutrients, metals etcetera). More sophisticated treatment and disposal strategies might be needed.</td>
</tr>
<tr>
<td>Central supply option</td>
<td>River health</td>
<td>Greenhouse gas</td>
<td>Waste disposal</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Desalination</td>
<td>No additional extraction from rivers.</td>
<td>Note that greenhouse gas needs to include both treatment and pumping to the tanks or pipes in the system that can accept the volume of water. This is an important difference from IPR. Desalinated seawater is generally thought to be of high enough quality to be introduced into the mains or tanks in the reticulation system rather than needing to go back to the source dam or aquifer for extraction and further treatment.</td>
<td>From the total volume of seawater that is used by a desalination plant, around 50 per cent becomes drinking water and 50 per cent is concentrated brine (twice seawater). This is usually sent back to the ocean via an outfall ‘diffuser’ to dilute it over a wide area.</td>
</tr>
<tr>
<td>River water</td>
<td>Additional extractions required. The impact of this will depend entirely on the particular river and location. Many Australian rivers are considered to be stressed.</td>
<td>Greenhouse gas primarily from pumping. Note that the head loss along long pipelines, and the ‘lift’ to go over hills can amount to significant energy use. Around five per cent of the flow is produced as a sludge that is usually dried in open lagoons by evaporation but occasionally discharged to streams. Final use or disposal varies. The sludge contains some of the chemicals (e.g. alum) used to treat the water.</td>
<td></td>
</tr>
</tbody>
</table>

Examination of Table 7 and Figure 12 allows some broad conclusions to be drawn:

- Although the energy used for seawater desalination is around three times that for IPR, if pumping for significant distances, or pumping up hundreds of meters of lift are required for IPR, then the production cost and greenhouse gas emissions may be similar to those associated with desalination schemes.
- Although the energy used for treating river water is much lower than IPR, if the additional distance to source the water is hundreds of kilometres, then the production cost and greenhouse gas production may be similar.
- Seawater desalination produces the highest volume of waste, but this typically contains only what was in the ocean originally (with some other chemicals in some cases). IPR produces less waste volume, but it may contain a higher proportion of contaminants such as metals and nutrients. It is difficult to make any comparison of these two wastes in an abstract sense, as local factors are important in assessing the impacts.
- Seawater desalination and IPR may not impact upon river health, as they do not involve extracting more water. In some cases they might improve river health by allowing less extractions.

Even this simple analysis shows that comparing different options on an environmental basis has difficulties. Differences between the options are largely dependent on the source of energy used and this will differ between each treatment system used. Local geography will be important, as pumping energy may be as significant as other energy use. Each option has
different merits against different criteria, so there is also a need to weigh up these criteria against each other.

**How do we treat greenhouse gas in our analyses?**

This is a crucial question in comparing alternative water supply options. It is relatively straightforward to calculate the emissions. The difficulty arises in evaluating the answer. There are different approaches:

- We could use a price for carbon to transfer this question to the economic analysis.
- We could allow for the construction of an equivalent amount of renewable energy to offset the emissions (the approach used for the Perth desalination plant).
- We could compare on the basis of greenhouse gas without reference to the cost, i.e. ‘lower is better’ regardless of the relative costs if we ‘offset’ the impact.
- In this context it is useful to recognise that even for high-energy water sources such as seawater desalination and IPR, the percentage contribution to total household energy use from water supply is low, for example, less than five per cent.

**Some concluding thoughts on cost and environmental comparisons**

This chapter has outlined a comparison of various alternative water supply options with IPR, to explore the circumstances where IPR might be an appropriate option. Later chapters explore the questions of public health risk and community attitude, and therefore this chapter has been confined to economic and environmental factors, with the following key points:

- There are likely to be circumstances where IPR is cost competitive. The ranking of options on cost will depend on local geography, as the costs of transporting water will form a significant proportion of total scheme costs.
- IPR has some environmental benefits, but may also have negative environmental impacts. It may produce less greenhouse gas in a particular case, but have a waste stream comprised of differing compounds which require differing treatment and discharge processes. From an environmental viewpoint, any IPR systems will be uniquely designed to suit the local geology and infrastructure and each system will vary in design, environmental issues and cost.
- Generalised statements such as ‘IPR or Seawater Desalination must be cheaper (or better)’ should be viewed with scepticism unless a comparison of specific local transport costs and energy use has been undertaken.
- Circumstances where IPR is likely to compare favourably have the following features:
  - existing wastewater treatment plants produce relatively high quality water already, or
  - are planned to be upgraded to do so in the near future
  - other water supply options cannot economically provide the volumes of water required
  - the distance and lift to return the IPR water to the source are not greatly in excess of the distance and lift for competing alternatives.
What are the risks and how are they managed?
A brief summary

A key question arises when considering the possible introduction of recycled water for drinking. Is there any increase in risk to our drinking water supplies?

The social research and evidence from public debate, media interest and technical discussion show that most concern relates to the perception of the issues of risk and leads to the most emotive discussion. Untreated recycled water may contain contaminants that pose a risk to health. However, IPR schemes are designed to manage these risks.

There are two main areas of concern: pathogens and chemicals. There is a range of human infective pathogens present in untreated wastewater. In addition there may be chemicals which concern people including endocrine disrupting compounds and pharmaceuticals.

The advanced treatment processes proposed such as reverse osmosis and advanced oxidation have been shown to be effective in reducing the levels of the contaminants. It is also important that these processes are designed, constructed and operated appropriately to provide confidence that they are managing the risks properly.

The drinking water guidelines and recycled water guidelines use the same risk management approach. If this approach is used rigorously in the development of IPR schemes and their operation, it is reasonable to expect that the risk will be managed in IPR schemes to the same extent as in existing drinking water supplies.

In principle, the risks would be managed using the multi-barrier approach set out in the guidelines (see section 3). The barriers are expected to include: management of what is sent to the sewer, advanced treatment to a high standard, some form of environmental buffer, mixing with other waters; traditional water treatment before supply; and rigorous management and operation of all parts of the scheme.

Risks of IPR schemes are examined widely in the literature, and in Australia have been summarised in particular in a paper published by Khan and Roser (2007), and in an earlier paper for the Queensland Department of Health and Aged Care (GHD, 2001).

These reviews reach the broad conclusion that an appropriately designed and operated IPR scheme should not increase the risks to public health. However, the risks are real, and therefore the question of what is an appropriate design, and how it should be managed to ensure it is operated properly need careful attention. A more comprehensive level of risk management will be required compared to that required for water from traditional sources. Because important details will vary from scheme to scheme, it will be important that a rigorous risk assessment is undertaken for every scheme.

The risks and the conceptual approach

The following points provide a simplified summary of the risk to public health that might be posed by introducing recycled water into the sources we draw our drinking water from, and the conceptual approach that has been proposed to manage these risks.

- Recycled water is derived from sewage that contains contaminants such as bacteria, viruses, chemicals, etcetera. There would be real risks posed if untreated sewage were introduced into drinking water supplies. However, risk management techniques and treatment technologies offer the means to manage these risks.
- The separation of untreated sewage from drinking water has led to significant health benefits throughout the world.
The combination of wastewater treatment processes with advanced water treatment processes can remove contaminants to very low levels—in some cases below the detection level of current measurement techniques.

The schemes are expected to include other barriers such as management of inflows to the sewers and time in an environmental buffer such as a reservoir or aquifer.

Risk management techniques such as those set out in the Australian Drinking Water Guidelines (ADWG) and the Hazard Analysis and Critical Control Points (HACCP) process can provide confidence in the operation and performance of such treatment processes. This requires rigorous monitoring, auditing and operation of the treatment and other barriers.

There are guidelines under development that are expected to outline how to manage the risks associated with recycled water use. These parallel guidelines for the supply of drinking water which are also based on the principal of controlling risk. The approach used to manage risk, and the level of risk should be consistent for water from any source.

These risk management techniques, when combined with the necessarily advanced treatment facilities require specialist and skilled staff with formal training in required areas. Regulatory oversight arrangements need to be in place to ensure these techniques and skills are maintained for as long as the scheme exists.

Technical risks and guidelines are described further in Appendix B.

In summary there is recognition that any water source could pose a health risk, but this can be countered by a combination of advanced treatment technologies, other ‘barriers’ and risk management systems.

‘What does ‘Low Risk’ mean? Is it safe or not?’

The Australian guidelines for both recycled water and drinking water incorporate a risk management framework. In risk management science, there is no such thing as ‘no risk’. Instead the aim is to manage or reduce the risks below an agreed threshold. The levels of risk in drinking water are lower than in many other areas of life, which reflects the higher expectation the public has of drinking water quality versus other activities such as travel in cars.

However, this kind of language is often unfamiliar to the public, and there is often an expectation that someone will simply say ‘it is safe’. This issue is worth consideration in the final wording of the recycled water guidelines.

The Environmental Protection and Heritage Council initiated the development of National Guidelines for Water Recycling (Phase 1, 2006). A second phase of the guidelines is currently under development which will include the use of recycled water for drinking. Those who want more information, wish to provide information or to make comment are directed to www.ephc.gov.au/ephc/water_recycling.html.

What about Endocrine Disrupting Compounds (EDCs)?

EDCs and other groups of chemicals such as pharmaceuticals are often raised as a particular concern in recycled water.
What are EDCs?

EDCs are defined as the group of compounds that disrupt the endocrine systems of organisms. EDCs have been linked to impacts such as changes to fish. Examples of EDCs include hormones and pharmaceuticals. People who are concerned about EDCs raise issues such as ‘feminisation’ of males, and interference with the development of females. Technical commentators note that the range of compounds that might have such effects is varied. A fair summary of the concerns might be this: ‘Are there chemicals in the water which will have potentially long-term effects?’

Why might these compounds be present?

Analysis of various water sources—including rivers in Europe—has shown low levels of the kinds of compounds thought to have these effects. Examples of sources include various drugs that might be excreted or just thrown away into the sewers. So there is a logical argument to show that they might be there. A key issue and question is the concentrations at which these compounds might have a health effect.

How is this risk managed?

The following points briefly address the question of management of the risks related to EDCs. This list of points is not definitive and is provided for information only. Those who have a particular interest in this area are directed to the recycled water guideline process mentioned earlier in this document.

- Various analyses by a range of different methods show that the types of chemicals thought to have these effects are the types of compounds that are significantly reduced in concentration by the treatment processes involved. Note that this removal cannot be guaranteed to be absolute, and that the use of multiple processes with different characteristics is important. Some compounds are affected by biological treatment, some others by reverse osmosis and others by advanced oxidation. Time in an environmental buffer may also have an effect.

- In some cases the amounts directly consumed through other sources such as pharmaceutical prescriptions may be many orders of magnitude higher than that which could conceivably be present in recycled water.

- Some of our existing water supplies already have a fraction of recycled water in the source water, so if very low trace levels are a concern, we have existing water supplies both here and overseas to allow us to assess the risk rather than waiting until an IPR scheme is in place.

Past thinking on guidelines for drinking water has dealt with these questions; i.e. compounds that might be present but for which we do not yet have measurement techniques or understand their effects. So the risk assessment approach that has been successful for those other risks should be applicable to EDCs, or other as yet unidentified compounds.

In conclusion

EDCs are a legitimate health concern in general, and a complex one given the wide range of possible compounds and the low concentrations at which they might have an effect and can be measured. The comprehensive risk management approach proposed in the phase 2 national water recycling guidelines to manage IPR schemes will need to be used to ensure that there is no additional risk arising from IPR schemes due to EDCs compared to that posed by our existing water supplies. It will be important that this specific issue is addressed in the recycled water guidelines to provide guidance to designers and operators.

Finally, it is important to note that EDCs are a specific example of a wider group of potential risks, i.e. that posed by various chemicals which may be present at low concentrations in sewage. So guidelines and approaches used to manage the risks from EDCs should be developed with this wider aim in mind.
What are the advanced treatment technologies?

Current and proposed IPR schemes typically incorporate the following advanced treatment components (Figure 13).

Figure 13: Typical Advanced Treatment Technologies of IPR Schemes

- **Sewage**
  - Typically involves microbial activity in an aerated tank and settling of solids and some level of disinfection.

- **Wastewater treatment**
  - Treated or ‘secondary’ effluent—this is often the quality currently discharged to the environment.

- **‘Micro’filtration or ‘Ultra’filtration**
  - This is a membrane filtration process that excludes particles, including many pathogens such as bacteria and some virus. Different systems have different pore sizes and therefore remove different percentages of the contaminants.

- **Reverse Osmosis (RO) membranes**
  - ‘Tertiary’ effluent—or ‘Class A’ quality. This is the quality typically supplied for use in dual-pipe supplies. For many parameters it could be measurably better in quality than current source river water quality.

  - These membranes can exclude certain molecules (such as salt) while letting water molecules through. Larger particles such as viruses and larger molecules (many chemicals of concern) are ‘rejected’ by the membrane. This is the same system used to desalinate seawater.

  - The water is now of very high quality, and for many parameters (e.g. turbidity, TDS, hardness) could be ‘purer’ than tap water. There is no consistent name for water like this, but ‘Class A plus’ and ‘six star’ have been used.

- **Advanced Oxidation (UV-Peroxide)**
  - In one type of system, a dose of peroxide is added to the water and then it is irradiated with UV light. This oxidises and destroys any residual organic molecules and acts as a powerful disinfectant.

  - We might call this ‘IPR Water’

- **IPR water**
  - To environmental buffer
The previous flow diagram summarises some aspects of treatment. Figure 14 illustrates a comparison of planned and unplanned IPR showing how risks are managed at each stage of the scheme.

Figure 14: Comparison of risk management between planned and unplanned IPR schemes

A discussion on the management of risks in using treated recycled water for drinking

General

Some would argue that there are legitimate concerns regarding the perception of introducing sewage into our water supply: historically and currently in poor areas of the world, untreated sewage has been and continues to be a key source of illness. So people are naturally concerned. So how can we consider using IPR?

The key words here are ‘untreated sewage’. IPR involves advanced treatment to produce high quality water. No-one can reasonably argue any similarity between the level of risk associated with this water and the level of risk in untreated sewage.

A more measured question might be: ‘OK, I accept the water is ‘high quality’ but is it good enough to put into drinking water supplies? Can I still trust the water coming out of the tap?’

This kind of question must be explored from two directions. First, the questions of ‘good enough’ and ‘trust’ include dimensions of community views and social aspects which are addressed later in this paper. Second, we can attempt to put this question into the language used in the ADWG and the National Water Recycling Guidelines (NWRG).

Will supplementing our supplies with recycled water increase the risk?

This paper has briefly explained some different ways of addressing this question. These are summarised below:

- Many existing water supplies already have some recycled water in their water sources. While proposed projects will increase the amount that is recycled, the advanced
treatment and risk management approaches will be much more stringent than used for the existing systems.

- The Hazard Analysis and Critical Control Points (HACCP) or risk management approach used to manage the risks from ‘catchment to tap’ in drinking water has been successful in managing similar risks for existing water supplies and in the food industry. Provided it is applied with rigour, it is reasonable to assume it will also manage risks from IPR.

- The water produced by existing or pilot facilities has been tested for a range of contaminants, and the water is reported to have high quality and meet various standards. This work could continue on local sources to provide additional data.

- There are new probability-based techniques (quantitative risk assessment) that can be used to analyse the risks for proposed schemes, with the objective of demonstrating that the likelihood of public health impacts is below the guideline limits.

- It is possible to calculate the percentage (sometimes expressed as ‘log’) removal of each step in the treatment process and to show that the final concentrations of particular contaminants will be below target values.

Management of risks in IPR is dependent on advanced treatment technologies and comprehensive risk management approaches to achieve the objective of reducing the risk to a level consistent with current drinking water supplies, which may have a lower risk than the original source water. Schemes need careful attention in both design and operation. It will be important that the schemes have sufficient organisational capacity and skilled designers and operators to ensure that this objective is met. It is necessary for the organisations operating these schemes to have skilled staff such as specialist process engineers and ready access to microbiologists, chemists, environmental scientists and risk managers.

Advanced monitoring systems such as the Supervisory Control And Data Acquisition System (SCADA) for process control and continuous water quality measurement are likely to be necessary. A systematic quality system management approach is also required based on systems such as HACCP, ISO 9001 or the risk framework in the NWRG. To do this effectively requires a continuous focus on the recycled water system and for the relevant organisations to be well resourced. The management arrangements for water supply and wastewater treatment vary widely across the country and may not be sufficiently resourced or focussed to achieve these requirements. In addition, external regulatory assessment (or audit) of the systems and processes in place needs to be regularly carried out for the life of the scheme so that no slippage of standards can occur. As this is a specialist area, there may be need for a nationally consistent approach to this type of assessment. The question of how to measure, assess and audit this organisational capacity over time may be useful topics for discussion when the guideline development process is still underway.

Risk management issues which vary for different schemes

The following points outline some areas of risk management that will vary for different schemes.

- **Catchment Management.** In a traditional water supply, catchment management typically involves activities related to land use in the area where rain falls and runs off into the storage before treatment and supply. In an IPR system, the catchment is the various discharges to the sewer. This includes the wastes from domestic households and discharges from commercial or industrial premises. The latter is sometimes known as ‘trade waste’ and typically separated from the waste stream and disposed of separately.

  Some existing systems such as the Namibia and Singapore examples do not have significant amounts of trade waste in their source sewer networks. Understanding the nature of discharges of all types and managing any risks associated with them will be important, and may be time consuming and have costs. Because each of our towns and cities have different arrangements of sewers and wastewater plants, and differ also in the nature of industry and trade waste that is present, different approaches will apply in different cases. It will be important to assess the likely approach early to ensure the overall scheme design and approach matches the particular catchment.
• **Environmental Buffer.** This phrase is used to describe the practice of adding the recycled water back to the source river, dam or aquifer to allow time in the environment and blending with other surface or ground water before extraction and further treatment. Social research shows that the community feels more comfortable if this kind of buffer is present, and in broad terms there may be technical benefits due to activity such as microbial action, UV irradiation and other factors. However, each system will have unique characteristics that will need to be examined. Some key elements will be the detention time, and avoiding short-circuiting. Definition of the nature and extent of an appropriate environmental buffer should be a key part of the design of any recycled water system.

• **Final Water Treatment.** Our cities have varied water treatment on their current supplies, depending on the nature and quality of the source water they currently receive. This treatment forms an important barrier, but it varies in nature from place to place. Therefore, the degree of treatment in the IPR system should take into account the degree of final water treatment.

**Some conclusions**

There are contaminants in the untreated wastewater that pose a risk to human health. These are managed through using a multi-barrier approach that will include advanced treatment technologies such as reverse osmosis and advanced oxidation. Comprehensive risk management including other elements such as careful scheme design and operation and environmental buffers will also be important.

The drinking water guidelines and recycled water guidelines use the same risk management approach. So if this approach is used rigorously in the development, design and operation of IPR schemes, it is reasonable to expect that the risks will be managed consistently between current drinking water supplies and IPR.

However, there will be differences between the treatment and risk management needed for different cities depending on the local circumstances. A comprehensive risk assessment for each town and city will be required to ensure these local circumstances are taken into account. The particular question of the nature and extent of the environmental buffer has an influence on scheme design and costs, and therefore it will be helpful if the phase 2 guidelines provide specific guidance.

Given the reliance on risk management to provide acceptable risks for water from an IPR scheme, it may be appropriate to consider some form of independent auditing or assessment. Independent panels or similar arrangements have been a feature of other schemes such as the NEW Water scheme in Singapore.

Finally, the rigorous risk management must continue over time, so the assessment of any scheme must include an assessment of all the elements in the ADWG framework, including aspects such as staffing and training and maintenance, to ensure that the scheme is viable in the long term.
Community views
A brief summary

Recently a number of reports have been published on the subject of public attitudes towards recycled water. Typically, there is a high degree of public support for recycled water, but this is significantly influenced by whether or not the water is to be used to supplement drinking water supplies, and whether the respondent is being asked to drink the water personally.

In many cases, concerns regarding the use of recycled water to supplement drinking water supplies appear linked to the question of perceived health risk (see section titled What are the risks and how are they managed?). This is complicated by the additional factors of the disgust reaction and the idea that the water has a history. When these complications are combined with the fact that choices in some schemes have also involved the much wider question of public decision making, it is evident that the question of public attitudes does not have one simple answer.

Some people have a disgust reaction to the idea of recycled water for drinking. This reaction may be unchanged despite education. Connected to this is the question of the history of water. Some people will look to the history of the water and no matter how it is purified, will still be concerned. Then there is the question of contact with ‘nature’. Time in an environmental buffer appears to address concerns for a proportion of people.

It also appears that many people are not aware of, or do not make the connection between the unplanned recycled water they receive now, and the proposed planned schemes.

Given these factors, it appears unlikely that schemes will gain unanimous support. There will always be a proportion of people who are concerned, regardless of the level of information they are provided. However, this proportion can be reduced through effective engagement with the community, and through ensuring the actual scheme design acknowledges the elements that address public concerns. For example, involvement of the community in the decisions around the detention time and nature of the environmental buffer is likely to increase confidence in a scheme.

Many of the causal factors that are critical in public attitudes towards recycled water are the same factors that risk communicators around the world have identified as key factors in the public’s understanding of risk, and their likelihood to either accept or reject new projects or technologies. It appears that a key element of public attitudes toward recycled water use is the question of perceived risk. Technical evaluations do not match the community’s level of acceptance, so understanding risk communication is likely to be valuable. Utilising the risk communication lessons from other industries could prove beneficial to the water industry in considering how to introduce IPR as one of the options being considered ‘on its merits’ by the community.

Research on attitudes

In relation to public support for re-use schemes

There are generally high levels of public support for the use of recycled water outside the home. A national survey in 1999 showed that over 90 per cent of the 2500 people surveyed in Perth and Sydney were in favour of using recycled water for purposes that did not involve human contact (Marks et al. 2006). In the same survey the proportions of people in favour of IPR was around 25 per cent in Sydney and 16 per cent in Perth.

Over the past 30 years the percentage of people who support or oppose substituting recycled water into the potable water supply has been broadly consistent, with approximately 30–50 per cent of people opposed to the concept of drinking recycled water. Greenfield (1991) addressed the social acceptance of potable re-use and that acceptance would be a key part of any successful scheme. The paper provided a summary of research that had been done in...
the United States which suggested that in the late 1970s and early 1980s around 30–40 per cent of people were either in favour of, or would accept, potable re-use.

This level of acceptance was also reflected in the Toowoomba referendum where people were asked ‘Do you support the addition of purified recycled water into Toowoomba’s water supply via Cooby Dam as proposed in Water Futures—Toowoomba?’. The outcome of the referendum was that 38 per cent were in favour and 62 per cent against.

Gaining public support for the concept that Australia needs to genuinely consider the use of recycled water to supplement water supplies as part of a sustainable water strategy may be easier than finding people who are willing to drink recycled water. The literature suggests that the acceptance of potable re-use is generally higher when considered in the abstract (Marks 2006); in other words agreeing ‘in principle’ to the concept of drinking recycled water, is easier than coming to terms with drinking it yourself.

A recent survey in the *Weekly Times* (December 2006) had 52 per cent of respondents say ‘yes’ to the question ‘would you drink recycled water’? Subsequent web polls by *The Age* and *The Australian* (February 2007) newspapers showed even higher acceptance. However, these surveys did not reflect a response to a real proposed scheme. Further newspaper and academic surveys are continuing even as this paper is being prepared; readers who have an interest are encouraged to seek the latest information.

**Public consultation is important**

Many researchers support the contention that a genuine public engagement process is critical to facilitate trust in the process and the proponent. Marks (2004) makes the point that transformations in community thinking will be more easily achieved if authorities work with communities to earn their trust via transparent consultation processes.

Generally, there is growing acceptance among social researchers that both the public and experts have a role to play in risk management, and that wider community values have to be considered and addressed in planning processes.

**The political and community environments are interdependent**

Whilst community engagement is thought to be critical, there is also evidence to suggest that an effective community outreach programme can be undermined if the political agenda is not aligned. The debate on the viability of a re-use scheme is vulnerable to the political situation. In San Diego, where there was both precedent (existing IPR schemes in California) and an extensive public engagement and outreach programme, the proposed introduction of recycled water to supplement San Diego’s drinking water supply is still on hold. It has been quoted that the project became ‘entangled in political campaigns which eventually caused the whole project to be halted’ (CSIRO, 2003).

If the environment in which the public makes its judgements includes scientific or regulatory bodies in opposition, evidence indicates that the public may become frightened and/or sceptical rather than evaluate the proposed technology. If there are credible opposing perspectives, the conclusion of the observing public may not be that the risk must lie somewhere in the middle of the opposing perspectives, but rather that the whole thing is unpredictable and must therefore be opposed.

**The ‘perceived risks’ associated with indirect potable re-use are high**

Another significant influence on public acceptance is the perceived health risks associated with drinking recycled water. As is often the case with controversial technologies, there may be significant variance in perception of risk between the technical experts and the interested public. Some critics of the proposed schemes have used graphic depictions of the perceived ‘gender bending’ properties of the hormones in the water to voice their concern.
The research undertaken by practitioners in risk communication, analysing a variety of different case studies, shows many similarities between public acceptance of IPR and other controversial technologies. This research indicates that the public evaluates risk according to a different set of values, which takes into account whether people feel they have control over their own risk exposure, whether they trust the organisation, whether the risk is familiar or ‘exotic’, artificial or natural, whether the risk is perceived to be catastrophic, etcetera.

So research suggests that education may not be the complete answer to getting a match between technical and public views on risk. Questions such as trust and institutional arrangements may be equally important. In simple terms, a proportion of the public may not trust the evidence provided by those they see as proponents of these schemes.

Providing opportunity for the community to discuss the experience of using this water with those from other communities who have had it in place for some time would be one approach which has been effective in other industries. However, this would mean learning from people from overseas until there are schemes operating in Australia.

A ‘decline in deference’ to experts means that a transparent credible process is required to assess risk

The process used to assess and communicate the risks is fundamental to the perceived credibility of the outcomes, in a context where a global ‘decline of deference’ to experts is at its highest in history. There are a variety of reasons for this including a number of high profile examples of supposedly ‘safe’ technologies resulting in major health impacts.

The decline in deference is fuelled when expert statements in support of IPR are met with opposing statements from other experts. This scenario has been dubbed ‘duelling PhDs’ by risk communicators.

The degree of trust in the governance and regulatory framework is key

Trust in institutions varies. So the community may be concerned because of the institution involved as well as because of the scheme itself.

Utilising the involvement of external third parties, which do have a high degree of public trust, such as some form of independent advisory boards is one effective method of demonstrating accountability, and reassuring people that the process is transparent and open.

Need to acknowledge the ‘yuck factor’

A common element to the research findings is the fact that many people find the ‘thought of drinking recycled water disgusting’ (Roseth, 2000; & Marks 2003). This is the ‘dread’ element, or the visceral or ‘gut’ reaction that is an emotionally driven immediate reaction towards the thought of drinking recycled water. This is different to a discussion on perceived health risks.

Although social researchers have called for further studies to investigate the relationship between ‘disgust sensitivity’ and opposition to using recycled water, Po et al.( 2003) cites that a large scale survey conducted by Sydney Water in 1999 highlighted a correlation between the individual perception of disgust and overall individual support for the various uses of recycled water.

Addressing dread is difficult to do, because it is such an instinctive reaction. It is also easy for critics of IPR to exploit the ‘yuck factor’.

The direct correlation between dread and people’s reluctance to accept the technology is difficult to quantify based on the research, however, in Peter Sandman’s Weightings of Risk

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Communication Factors, factors such as responsiveness, sharing control and trust are rated as more significant in influencing how people are likely to react in any given situation. While this is not hard evidence to suggest that if all else is equal, the ‘yuck factor’ won’t prevail, the information is useful in understanding that there are other drivers that are likely to also be significant.

Language has emerged as an important component of the ‘yuck factor’. Whilst slogans such as ‘Toilet to Tap’ may be crude, they have been effective rallying cries for critics of schemes. The natural reaction is to want to shift away from the emotion-laden language used successfully by critics. New terms are defined to try and shift the emphasis. In almost all cases, it doesn’t work. Media or critics continue to discuss the ‘sewage in the water’ despite consistent efforts to use other language.

Being brave enough and creative enough to acknowledge the ‘yuck factor’ will be important in having a genuine and transparent communication process with the community.

An urgent need for water may not influence public acceptance of re-use schemes

Both research and evidence indicates that even in cases of clear-cut urgent need, stakeholders react largely ‘emotionally’ rather than ‘logically’. Presenting people with data on water scarcity, and expecting them to act logically to conclude that there is no option but to consider a potable re-use scheme may lead to problems. Po et al. (2003) noted ‘a heightened need for additional water sources does not necessarily warrant public acceptance of water re-use’.

Some thoughts on community perceptions

Experience from other industries may provide beneficial insights into successful risk communication approaches. Key elements include a transparent approach where the public agrees that there is a trusted and independent evaluation of the risks, combined with offering a genuine opportunity to say no.

People are typically in favour of recycling water, particularly for uses external to the house. Many communities support the concept of water re-use, however apparently ‘technically’ sound schemes have failed because communities have rejected them.

Presenting IPR as one option in a suite of water supply options is likely to generate a more balanced merit base debate than a specific campaign to implement IPR.

Continuing to try and ‘educate people’, or using a traditional public relations approach of ‘selling’ the merits of IPR may be a risky strategy. Evidence both within the water industry, and in other sectors indicates that the public will respond far more positively if they are given the opportunity to judge the merits of the technology for themselves.

According to the research, an open, transparent and consultative approach will maximise the chances of a ‘merit’ based debate on the use of recycled water to supplement our drinking water supplies. This kind of process can be time consuming, and therefore if possible this process should commence as early as possible.

Some thoughts on community engagement

The previous sections of this paper highlight the importance of community engagement in the implementation of recycling schemes. The following section is about processes for community engagement and how it can be used to increase the debate about IPR and elevate the consideration of IPR to one of the options commonly considered in water supply planning. If

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2 The weighting of risk communication factors was determined in consultation with Peter Sandman as part of the process of developing the ‘Engage’ Software with Qest Consulting. This software is used to predict community reaction to different scenarios.
Australia wants to have IPR considered as a water supply option then a transparent process to engage the community will be needed.

The water industry in Australia is undergoing a paradigm shift in the way it does business. Historically, as a relatively ‘benign’ industry, it has not been exposed to the daily battles with stakeholders that the forestry, mining or waste sectors have experienced. As a result of the prolonged drought in Australia, water is scarce, many communities are on water restrictions, and all of a sudden everyone wants a say in how this precious resource is used.

The water shortages around the country and the subsequent introduction of new technologies such as IPR and desalination inevitably change the public context for the water industry.

**Aligning the public, political and regulatory environments**

There is now a significant body of work looking at public acceptance criteria for IPR. The existing data is useful in understanding the factors that govern behaviour, but it doesn’t fully explain why some schemes are successful and some aren’t.

A review of the research developed by Sandman suggests any scheme that fails to simultaneously address the public, political and regulatory environment contains potential flaws, because it is exposed to polarisation and dissent. Whilst some public dissent is inevitable, consideration suggests it will be a more constructive debate if regulators and the water industry are aligned. In this context, WSAA’s paper ‘Refilling the Glass’ is a helpful example of the industry working toward a more consistent position.

The debate on IPR in Australia has been stimulated by the referendum in Toowoomba, the more recent decision to proceed in South-east Queensland, and other water shortages around the country. If Australia decides that IPR should be one of the genuine options for water security, we might benefit from a more national approach.

For any debate to succeed in increasing trust, it must be a genuine review of the viability of IPR encompassing all factors (i.e. economic viability, environmental suitability, social acceptance, risk management). Risk communication theory suggests that allowing an ‘opt out’ option creates an opportunity for people to listen and genuinely weigh up the data, by averting the ‘fight reaction’ of those that feel cornered.

There is also a need to ensure that debate is not limited to technical people in the water industry and that it considers the emotive elements as well as figures and facts.

The involvement of a group of independent technical experts and publicly respected figures (critics as well as advocates) would help to lead and mediate a debate. If they have genuine authority, the wider public will feel that they are empowered to call a halt if there are genuine concerns.

**The paradox of open debate**

We must accept that debate may still leave some people unconvinced that IPR is one of the options for water security that should be considered, but an open, transparent and inclusive approach will provide an opportunity to genuinely consider it. Such a debate will assist to reinforce and involve the public in the broader debate on water supply options for the future. The process for development of Phase 2 of the Guidelines to include using recycled water for drinking purposes may provide an opportunity for such a debate.
Discussion
The planned use of recycled water to supplement drinking water supplies has been examined from a number of different directions in this paper:

- In what circumstances would it be viable, and how does it compare other options?
- What are the risks and how are they managed?
- What can we learn from social research about peoples’ views on using this water to supplement water supplies?

**Appropriate circumstances and comparison with other options**

Work earlier in this paper examined the circumstances where IPR would be one of the appropriate water supply options. This examination was limited to a comparison of IPR with other large central options, rather than the more complex question of comparison with demand management or new methods of arranging our housing and infrastructure. The circumstances that would mean IPR was economically appropriate are likely to be those where:

- there is growth in the city, substantial existing housing stock and falling inflows to our dams, as in these circumstances, new central water supply options are favoured
- existing wastewater treatment plants produce high quality effluent, thus reducing the investment in additional treatment required for IPR
- the wastewater treatment plants are not ‘too far’ from the water source which the IPR water will blend with, relative to other options, and
- other water supply options are not available, or do not provide enough water.

In addition, there may be environmental benefits such as reduced effluent discharge to the environment, or reduced impact on rivers or groundwater compared to options which access water from those sources. In some cases, the energy use will be less than for seawater desalination, depending on the comparative pumping after treatment.

The following points emphasise the potential benefits of IPR as one of the options worthy of consideration:

- it is a reliable source of water, not sensitive to climate
- it is available in all our large towns and cities as they are all sewered
- in some cases it will have economic advantages, and
- in some cases it will have environmental advantages.

Given the sensitivity of cost analyses to distances of the order of 50 km to 200 km, which are of the order experienced in our cities, it is unlikely that IPR can either be discarded, or named as the best option, without some specific investigation and initial design development.

So it seems reasonable to examine IPR further in each location to determine if it is a worthwhile option or not.

**What are the risks and how are they managed?**

First, consider the potential risks to public health. It is reasonable for people to be concerned on a technical basis, as there are organisms and chemicals in untreated sewage that could potentially lead to public health risks. In addition there is a more visceral concern, perhaps best expressed as ‘I don’t like the idea’, which is not necessarily linked to any technical concerns. These two concerns are quite different and need to be considered separately.
The technical concern is largely addressed by understanding that these same organisms and chemicals could be in our current source waters, that the effluent would be highly treated, and that the risks would be managed using the same risk management system which we currently use to manage our drinking water quality. There may be residual concerns regarding the actual levels of treatment and management required to provide an acceptable level of risk if IPR is used.

For example, the concepts of ‘catchment management’ and ‘environmental buffers’ and how they might apply to IPR are areas that have not been explored as widely as the advanced treatment technologies involved. These concerns need to be addressed through the IPR guideline process and associated consultation. We have the technologies and risk management techniques to allow us to become technically confident that the water in a city with IPR has the same level of risk, or less, than our current water supplies. The approach in different towns and cities may be different due to unique local circumstances.

Ongoing management of the systems so that this rigorous management of the risks is provided into the future is also critical. This means that the system itself needs to be designed to be as reliable as possible, and also that the institutions and management systems are reliable. Ongoing independent auditing and review may help to provide more confidence in this area.

The visceral, or gut level concern is also important, but perhaps needs to be addressed differently. It is a concern for those who have either not been part of or do not have the time or the technical inclination to understand the guidelines and their basis. It is important that the technical confidence exists, and also that the confidence is supported by institutions which people trust. For some, providing additional information will be useful, but for others it may not. A key element here will be to acknowledge these issues and to have a community engagement process that is driven from the community’s viewpoint, not ‘top-down’ from the technical ‘experts’. This may mean involving the community in some key elements of system design, such as the nature of the environmental buffer.

What are the community’s views on using recycled water for drinking?

It may be that there will always be a fraction of people opposed to IPR, regardless of our level of technical confidence or education programme. Is this a reason not to have it as one of the options under consideration?

These questions have not always generated straightforward answers. In fact, in considering the various ideas and issues raised in this paper, one way of expressing the complexity seemed to be to outline some of the contradictions inherent in discussion of IPR.

- **People want recycling, as long they don't have to drink it.** In other words, the research shows that a high percentage of people support recycling of water, but a much lower percentage either support or are confident in introducing the water into their drinking water supplies. Their concerns appear to be partly driven by perceived health risk, but there are other factors such as the disgust reaction. Further, the research suggests that these views occur despite a lack of understanding of their current water supply and what might be in the existing water sources.

- **You need time to have an open debate, yet we need water now.** IPR has been portrayed as the option of last resort (when you are really short of water), yet it is an option that both technical people and the community need time to understand. However, it has not been considered in many long-term water supply plans, which may restrict the time available to have an informed and open debate.

- **Is it risky or not?** The language of ‘risk management’ causes concern for some people in the community, yet it is thought to be the best technique to protect the community. Risk management approaches involve identifying risks and managing them. However, the
community appears to sometimes interpret this language as meaning ‘it is risky, i.e. not safe’. The wider community may not understand that exactly the same frameworks and language are used to manage their drinking water quality now.

- **Is it an option or not?** Australia is developing national water recycling guidelines, yet some opponents believe that the concept is either not mature or that it is philosophically inconsistent with the ADWG. Further, it does not currently appear to be an option in many long-term water supply plans.

The evidence is strong that there will be a proportion of the community that is concerned. On this basis many planners have not considered IPR. Yet if it is not considered, we may miss an opportunity for economic and environmental benefits, but we will avoid the most contentious option with the wider community. So, if IPR is to be adopted as one of our potential water supply options we can expect significant community interest and debate.

How can we best support the community in this debate?

**First:** we should accept that many people like the idea of recycling but do not like the idea of drinking it, and that this is a natural reaction which may not be dismissed with technical education.

**Second:** we need ‘trusted’ institutions to provide advice on the question of risks. Perhaps we need a national advisory panel to ensure long-term consistency. Certainly finalised national water recycling guidelines will help.

**Third:** we need to provide a lot of resources—human and not always ‘technical experts’—to support the community in understanding the scheme. This means additional people and training for them that may lie outside the resources of some current water authorities. So support in this area will also be helpful.

**Fourth:** we need a rigorous assessment of the economic viability and ecological sustainability of different water supply options, and this may then mean we need to keep an open mind regarding the values used to judge which option is best.

**What could increase community concerns?**

Given the research on people’s attitudes and the wider research work available on public reactions, we know that picking IPR as the only option and then trying to get people to accept it is likely to be challenging. Providing the community with enough information and trusted institutions to support whichever choice is made is important. Giving the community an opportunity to be involved in as many parts of the planning process and then the scheme design as possible will increase confidence.

The challenge for proponents of IPR is to accept that although an open approach is a good way to provide a forum for a merit based debate on different options, the public may still prefer another option.

A benefit of having IPR ‘on the table’ early in water supply planning is that it is sure to engage public interest. For example, we may have rain again in the near future, and therefore the current sense of crisis may diminish. However, our long-term plans may still require options such as IPR to meet future needs. If IPR is under consideration along with other long-term options we are more likely to have ongoing public interest, which will help to ensure our future water planning is aligned with public expectation.

**Are the times a-changing?**

One idea mentioned by many in discussions regarding this issue, has been the fact that we face a new level of public interest and thinking on water. The drought, and potentially the ‘long drought’ of climate change may be creating new attitudes. So we may need to be cautious in assuming past research on attitudes will remain valid.
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Appendix A—Case studies
Potable re-use case studies

Windhoek, Namibia

Existing Direct Potable Re-use

Background

Namibia has a population of 200,000 people and is one of the most arid countries in southern Africa with low rainfall, high evaporation and a limited drinking water supply catchment. The surrounding surface and ground water supplies had been exhausted and in 1960 low rainfall caused a short fall in the water supply to meet demand. Therefore the country had to develop a long-term water supply strategy. The strategy involved a long-distance pipeline to supply water from the Eastern National Water Carrier, extensive groundwater extraction, development of a local reservoir (now called Goreangab Dam), and construction of a recycled water plant (USEPA Re-use Guidelines). As the water quality has deteriorated in Goreangab Dam due to pollution sources in the catchment, recycled water has become a major source of water for the city.

Scheme description

The Goreangab Water Reclamation Plant began supplying recycled water directly into the distribution system in 1967. Initially effluent from sewage treatment plant and Goreangab Dam were treated separately then mixed together. However due to the deterioration in quality of the dam water the streams are now mixed together before treatment by the Goreangab Water Reclamation Plant.

Treatment processes: The original Goreangab Water Reclamation Plant consisted of dissolved air flotation, sand filtration, carbon filter (Biological Activated Carbon (BAC)), break point chlorination, secondary chlorination and booster chlorination. The wastewater treatment plant consists of trickling filters and activated sludge with enhanced phosphorous removal (USEPA Re-use Guidelines).

The plant was upgraded in the late 1990s and consists of pre-ozonation, Dissolved Air Floation, Sand Filtration, Ozonation, two Carbon Filters (BAC and Granular Activated Carbon (GAC)), Membrane filtration, chlorination. The reclamation plant was also extensively upgraded (completed in 2002) to build on experience from operating the plant over 30 years, as well as to be in line with the latest water treatment technologies (City of Windhoek website).

The recycled water plant only accepts effluent from sewage treatment plants that treat domestic and commercial wastewater. Industrial wastewater is treated separately, which influences city planning and the location of where industries can be based in the city (WRRIC website).

Community consultation: There is no information published about the community consultation undertaken in Namibia about indirect potable re-use.

Cost: The cost for the upgraded plant was approximately US$15 million for capital, electrical and mechanical. Total operating costs $0.76/KL (VAtech). A high proportion of the operating costs come from the extensive water quality monitoring programme (WRRIC website).

Comments

The Goreangab Water Reclamation Plant is the only example of direct potable re-use in the world. The recycled water supply is used intermittently during times of peak demand (WRRIC website). Recycled water contributes up to 25 per cent of the Windhoek drinking water supply (Briefing Paper 10/05).

Studies have not indicated that the incidence of illness or disease has increased with the direct potable re-use undertaken in Windhoek (ATSE 2004). Evaluation of toxicity and carcinogenicity has indicated the recycled water produced in Windhoek is a safe alternative water supply for drinking purposes (USEPA Re-use Guidelines).
Singapore

Existing Indirect Potable Re-use

Background

Singapore has a population of 4 million people that live in an area approximately 680 Km², which is a small area for this number of people. Singapore receives a high annual rainfall averaging 2500 mm/yr but due to its small size has to import half its supply from Malaysia (UESPA Re-use Guidelines).

The water supply for Singapore is insecure as the supply from Malaysia is subject to periodic renegotiation (ATSE 2004). Therefore the Public Utilities Board (PUB) of Singapore has investigated other sources of water. PUB has been investigating alternative means to diversify and secure Singapore’s water supply. They developed a ‘four taps’ vision with water supply from:

- surface water
- imported from Malaysia
- recycled water from NEWater plants and
- seawater desalination (Briefing Paper 10/05).

Scheme description

In 1998 a joint initiative between PUB and the Ministry for the Environment conceptualised the Singapore water reclamation study, known as the NEWater Study. The objective of the study was to determine the suitability of using NEWater as a source of water to supplement the drinking water supply for Singapore (Expert Panel Review 2002). In 2000 a demonstration water recycling plant was built to produce NEWater from treated wastewater (ATSE 2004). The NEWater plant operated for two years and a rigorous testing programme was undertaken to demonstrate the reliability of the treatment process.

Treatment process: The NEWater treatment plant uses the following treatment processes in the order listed: clarification, an activated sludge process, micro screening, microfiltration, reverse osmosis, and UV disinfection. Singapore has six secondary wastewater treatment plants with an activated sludge process that typically discharge to the ocean (UESPA Re-use Guidelines).

Community consultation: An extensive public communication programme was undertaken with the development of the NEWater plants. A visitor centre was also established at the Bedok NEWater plants (ATSE 2004).

Cost: The costs are not widely available.

Comments

Since February 2003 high quality recycled water has been supplied to industries, commercial and office buildings for processes and non-potable use. Recycled water supply to industry has been occurring in Singapore since the 1960s (UESPA Re-use Guidelines).

Currently recycled water makes up less than one per cent of the drinking water supply. There are plans to increase this to 2.5 per cent by 2012 (Briefing Paper 10/05).

An expert panel reviewed the plant operation and showed it had an 80–82 per cent recovery with greater than a 7 log reduction of microorganisms (ATSE 2004). A health effects study was also conducted. The expert panel concluded the plant was operating reliably producing water safe for IPR and that the Singapore Government should consider the water safe for supplementing the drinking water supply (ATSE 2004). The water produced by the NEWater factory was consistently better that the standards set for drinking water by the World Health Organisation (WHO) and the United States Environmental Protection Authority (Briefing Paper 10/05).

At the NEWater visitor centre, bottles of New Water that are filled directly from the NEWater treatment plant are given out to visitors. On average around 400–600 bottles of NEWater are given out daily.
Orange County, California

Existing Indirect Potable Re-use

Background
The Orange County Groundwater Basin and (OCGB) has been used since early settlement to supplement water supplies. As development and agriculture increased the demand on the groundwater increased which lowered the water table. In the 1930s the Orange County Water District (OCWD) was formed to protect the groundwater resource. By the late 1950s the groundwater level had been lowered to such an extent that it was below sea level and salt water had encroached approximately eight kilometres inland (Water Factory 21 Brochure).

OCWD obtains 75 per cent of its water supply from the OCGB and 25 per cent from the Colorado River Aqueduct and the State Water Project via the Metropolitan Water District of Southern California (Briefing Paper No 10/05). The primary source for recharging the OCGB is the Santa Ana River. During summer, more than 90 per cent of the baseflow for the Santa Ana River is tertiary treated wastewater from upstream treatment facilities (National Water Research Institute 2004 ‘Orange County Water District’s Santa Ana River Water Quality and Health Study’). Protecting the OCGD is a key aspect of securing a water supply for Orange County.

OCWD evaluated a number of water sources that could be used to provide a barrier for further saltwater intrusion into the groundwater basin. The options included using deep well water, desalted seawater, imported water and recycled water. By 1976 the first blend of recycled water and deep well water was injected into the coastal barrier (Briefing Paper 10/05). The recycled water was produced with a pilot recycled scheme developed by the OCWD in the 1960s which is now known as Water Factory 21 (Water Factory 21 brochure).

Recycled water was determined to be the most suitable option because it was cost effective and there were significant environmental benefits including:

- Reduction in the volume of effluent discharged into the ocean.
- Reduced dependency on the Colorado River and State Water Project.
- Constant supply of water for the saltwater intrusion barrier. In times of drought, saltwater intrusions barriers are the lowest priority (Water Factory 21 brochure).

Scheme description
The blended recycled water is injected across 23 multi-point injection wells forming a freshwater mound that stops the saltwater intrusion into the groundwater.

Use of recycled water in the Orange County District is being expanded to increase the groundwater recharge. In October 2004 the Groundwater Replenishment System (GWR) was launched which will take recycled water and place it in basins where it will percolate into the groundwater basin. This will occur under the same processes that rainwater naturally replenishes the groundwater. The GWR system will allow 70 million gallons per day (approximately 280 million litres/ day) of recycled water to be produced for groundwater replenishment (Briefing Paper 10/05). In 1999 the first milestone was reached for GWR system with certification of environmental review documentation (GWR System website).

Treatment process: The original Water Factory 21 used the following treatment processes in the order listed: chemical clarification, re-carbonation, filtration (multi-media and GAC), reverse osmosis and chlorination. The new purification plant being built as part of the GWR, which is due to be commissioned in late 2007, will use microfiltration, reverse osmosis and advanced oxidation using UV/hydrogen peroxide.

Community consultation: Water Factory 21 offers tours to adults of the treatment plant. There was no published information about the community consultation programme for Water Factory 21.
GWR has undertaken an outreach programme to engage political and business leaders and active community members in Orange County. The outreach programme provided information about the high-quality and safety of the near distilled water that comes from this treatment process. A key aspect to the information was that it related the sophisticated technological purification process to everyday items in a person's life.

**Cost:** Water Factory 21: Capital and Construction (1970s figures) US$10.3 million. Operating costs at maximum capacity of 22.6 million gallons per day—$0.93 / 1000 gallons (Water Factory 21 brochure).

GWR total capital cost estimate US$487 million ((Briefing Paper 10/05).

GWR communications budget (1997–2001): research: $30 000, public relations consultant: $500 000, staff hours: 10 000.

**Comments**
Up to five million gallons per day (approximately 20 megaliters/day) of recycled water blended with eight million gallons (approximately 24 megaliters/ day) of deep well water is injected into the coastal saltwater barrier which meets the United States of America (USA) drinking water standards. The recycled water not only provides a barrier to stop saltwater intrusion but it also replenishes the groundwater basin (Water Factory 21 brochure).

It is expected that the recycled water will take around 12 months to move from the barrier to extraction points used for drinking water.

The proposed GWR system will increase the amount of recycled water making up the water supply. Before implementation of the scheme a widespread community engagement programme has been undertaken. A review of publication and the media indicate a majority of the public support the GWR system.

**City of El Paso, Texas**

Existing Indirect Potable Re-use


**Background**
It was identified in the early 1980s that the Hueco Bolson aquifer, which was at that time the primary source of drinking water for the city of El Paso, Texas, was being overdrawn. It was estimated that the aquifer would run out of usable water by 2025 if not replenished from another source.

**Scheme description**
Since 1985 recycled water has been used to recharge the Hueco Bolson aquifer. The recycled water is treated to drinking water standards at the Fred Hervey Water Reclamation Plant before it is injected into the aquifer. This IPR project is a part of maintaining adequate water supplies for El Paso's future. The city has a population of 700 000 and is the fourth largest in Texas.

Approximately 21 million litres (5.25 million gallons) of recycled water is produced daily. Recycled water is preferentially used for irrigation and industry with the remainder being used for the Hueco Bolson aquifer recharge. The recycled water is contained within the aquifer for six years where it blends with other water present in the aquifer.

**Comments**
The Fred Hervey plant has received thousands of visitors since it became operational in 1985. Many local students, environmentalists and private citizens also tour the facility, providing evidence that El Paso residents are comfortable with the concept of wastewater re-use.
Toowoomba

Indirect Potable Re-use Scheme that was rejected by the community

Background

Toowoomba has a population of 125,000 people and is located on the summit of the Great Dividing Range in south-east Queensland and has no water sources located at a higher elevation than the city. The lift to pump water to the city is one of the highest in Australia and makes up almost 50 per cent of the cost of delivering water to customers in Toowoomba (Water Futures Water Book, 2006). Total energy cost approaches seawater desalination.

Since 2001 the water levels in Toowoomba’s three dams have been dropping and were around 16 per cent capacity in March 2007. The dams that supply Toowoomba with water include Lake Cooby, Lake Perseverance and Lake Cressbrook, and water is also extracted from basalt bores. The Queensland Department of Natural Resources, and Water uses climate and rainfall data to determine the amount of water Toowoomba can use from the dams and bore field that supply the city. In 2004, the amount was revised and the allocation did not meet the demand. Therefore Toowoomba needed new water source urgently (Water Futures Water Book, 2006).

A number of water supply options were evaluated including IPR, importing water from three different sources and replacing it with recycled water, and collection by-product water from a coal seam gas production plant and treating it for use. The options were compared in terms of cost, sustainability/reliability, a qualitative triple bottom line assessment of social, environmental and economic issues. The review concluded that IPR was the most suitable option with the lowest capital cost and it provides a diverse renewable water resource. The other options were too expensive, not considered to be sustainable or were not guaranteed by the state government to be available for use by Toowoomba (Selmes et al. 2006).

Scheme description

All wastewater in Toowoomba is treated through the Wetalla Water Reclamation Plant. The Water Futures scheme proposed that this would be followed by an advanced water treatment plant that would supply water to Cooby Dam. Water extracted from Cooby Dam would then be mixed with water from the other supplies and treated through the existing Mount Kynoch water treatment plant before supply to customers.

Treatment process: The proposed Toowoomba advanced water treatment plant would have used the following treatment processes in the order listed: ultra filtration, reverse osmosis, UV disinfection/advanced oxidation.

This would then be followed by natural processes during storage in Coody Dam, and conventional water treatment at the Mt Kynoch Water Treatment Plant before supply to customers.

Community consultation: A campaign was undertaken by Toowoomba City Council. The campaign involved numerous presentations to groups of people, ‘kitchen table conversations’ at people’s homes, a website dedicated to the project, and various publication materials.

Cost: Capital cost $73.2 million. Annualised unit cost before funding $1.68/KL and after funding $1.06/KL. (Selmes et al. 2006).

Comments

With reduced dam levels, it was proposed to introduce recycled water into Cooby Dam and by 2025 it would make up 25 per cent of the water supply. If the dam were full, the recycled water would have about four years detention before extraction.

There was both significant public support and opposition for the project. A plebiscite was held to determine if the project would proceed. The plebiscite was a condition attached to federal funding. When asked ‘do you support the addition of purified recycled water into Toowoomba’s water supply via Cooby Dam as proposed in Water Futures—Toowoomba?’ 62 per cent of people said ‘No’ and 38 per cent said ‘Yes’. On the basis of the result, Toowoomba’s Mayor announced that she would approach the state government for a solution to the city’s water shortage. Further community consultation and engagement was part of the implementation plan if the community of Toowoomba accepted IPR.
San Diego

Planned Potable Re-use that was rejected by the community but is being considered again with a range of other recycling options

Background
San Diego has a population of 1.3 million people and imports 80–90 per cent of its drinking water from the Colorado River and California State Water Project. The remaining amount of water is supplied from local run off collected in reservoirs (Water Re-use Study, 2006).

In 1993 the City of San Diego and the Water Authority began planning an IPR project called the Water Purification Project. The project progressed through the various stages of planning, regulatory reviews, and preliminary design stages. It also had the support of the Department of Health Services (DHS) who granted conditional approval in 1994. Many groups supported the project including the Environment Protection Agency, the San Diego Medical Society, the United States Bureau of Reclamation, and a variety of business and community interests. However in 1998 the project became the topic of political campaigns and concerns about the scheme were raised. In 1999 the council stopped the project.

The City of San Diego remained committed to beneficially using recycled water and an alternate means to proceed was developed. The city developed the 2000 Updated Water Reclamation Master Plan and continued expansion of existing recycled water schemes.

The Strategic Plan for Water Supply was developed by the city in 1997 and updated with the Long-Range Water Resources Plan. These plans identified the need for the City to develop local water supplies to provide reliability of supply and protection from water supply shortages. In 1999 the San Diego County Grand Jury recommended the development of additional local water supplies including recycled water. In 2004 the San Diego City Council directed the City Manager to conduct a study, the Water Re-use Study, to evaluate options for increasing recycled water use in the City.

The Water Re-use Study was published in March 2006 and considers IPR as one potential use for recycled water. The study conclusions have been consolidated into a number of strategies that incorporate a combination of re-use opportunities. The strategies offer the City of San Diego a set of diverse re-use options for both the North City and South Bay systems.

The strategies proposed in the Water Re-use Study for both areas of the City include small and large scale IPR. The IPR strategies are more expensive but provide the largest amount of water. The City’s Natural Resources and Culture Committee and Council are now considering the strategies and will determine the City’s future course of water re-use development (Water Re-use Study, 2006).

Scheme description
The Water Re-use Study describes a number of options for IPR for San Diego. This includes both reservoir augmentation and groundwater recharge.

Treatment process: The proposed treatment plant would have used the following processes in the order listed: membrane filtration, reverse osmosis, ion exchange, advanced oxidation using ozone, and disinfection (Water Re-use Study, 2006)

Community consultation: The Water Re-use Study was developed by a diverse team of people that began with City of San Diego staff and consultants. The group expanded and diversified to include stakeholders, specialists in the field of science technology, health and safety, and economics. After the project began two groups were formed: the City of San Diego Assembly (Assembly) on Water Re-use and an Independent Advisory Panel (IAP).

The Assembly involved 67 people including academics, business people, government officials, media, policy makers, community leaders and other interested individuals. The Assembly formed the participatory stakeholder component of the Water Re-use Study. The
Assembly was involved in a number of workshops throughout the study and reviewed the draft report. *(Water Re-use Study, 2006).*

The IAP members were contracted through the National Water Research Institute to provide independent oversight and guidance to the study team.

**Cost:** North City full IPR scheme (NC-3): $1.63/month increase per household or $1630 per Acre-foot (1 Acre-foot is 1.2 ML) or $1360 per mega-litre.

South Bay area full IPR scheme (SB-3): $0.89 / month per household or $1530 per Acre-foot or $1275 per mega-litre *(Water Re-use Study, 2006).*

**Comments**

IPR by reservoir augmentation and groundwater recharge are were both considered for the San Diego. Regulations require recycled water to be stored in a reservoir or groundwater for a minimum for 12 months before extraction to allow for natural treatment. The proposed scheme would have two years of detention in San Vicente Reservoir *(Water Re-use Study, 2006).*

The re-use opportunities identified in *(Water Re-use Study, 2006)* for San Diego were presented to the IAP and Assembly (outlined above) formed as part of the study. The key concern of all recycling schemes, both potable and non–potable uses, that were presented to the IAP and Assembly was that the water needs to be safe and public health is protected.

San Diego and many other cities are planning for a future where traditional water sources are becoming less available. The city has long recognised the need to develop local water supplies and reduce its dependence on imported water. The water recycling opportunities identified in the *(Water Re-use Study, 2006)* are still under evaluation.

**Goulburn**

Indirect Potable Re-use in the planning stages

**Background**

Goulburn is an inland city with a population of 22 500 people and has limited water resources. With declining reservoir levels and reduced flows in the Wollondilly River Goulburn is on level 5 water restrictions. A number of options are being considered for alternative water sources for Goulburn (Parsons Brinkerhoff 2005).

Goulburn extracts its drinking water from the Wollondilly River at Rossi Weir. Typically Lake Sooley and Pejar Dam release flows in the Wollondilly River upstream of the weir, however with reduced inflows into the dam the amount of water that Goulburn can extract is significantly reduced.

One option for using recycled water to supplement the drinking water supply that has been explored is piping recycled water from the Gorman Street wastewater treatment plant to upstream of the Sooley Dam.

**Scheme description**

The proposed scheme would involve upgrading the Gorman Street wastewater treatment plant and installing an advanced treatment system. The highly treated recycled water would then be transferred upstream of Sooley Dam into Burman Creek via the existing Copford Pool transfer pipe (Parsons Brinkerhoff 2005).

A series of wetland ponds are proposed for Burma creek rehabilitation as part of the scheme and the recycled water would flow through these ponds before reaching Sooley Dam. The recycled water would also be discharged into Burma Creek in the Kingsdale limestone aquifer area which will help with recharge of the aquifer (Parsons Brinkerhoff 2005).
Treatment process: The advanced treatment system would involve the following processes in the order listed: membrane filtration, ozone, GAC, reverse osmosis, chlorination (Parsons Brinkerhoff 2005).

Community Consultation: A discussion paper is due to be released about the community and stakeholder consultation that has been undertaken, and about the water supply options.

Cost: $21 million (Parsons Brinkerhoff 2005).

South-east Queensland

Purified recycled water through the Western Corridor Project

http://www.qwc.qld.gov.au/Purified+Recycled+Water

Background

The recent drought in south-east Queensland and throughout Australia has highlighted the potential for water shortage in the near future. With projected population in south-east Queensland to roughly double by 2050 the government has prepared the South-east Queensland Regional Plan (August 2006) to provide incremental additional water supplies to meet the demand projected in 2050.

There are a range of proposed projects in south-east Queensland to provide additional water. Two examples are a new seawater desalination plant at Tugun on the Gold Coast (to supply 125 ML/day) and a large recycled water project (Western Corridor Project) which will send 245 ML/day of purified recycled water west from Brisbane and Ipswich to replace current use of potable water by south-east Queensland power stations and to augment the drinking water supply for south-east Queensland via Wivenhoe Dam.

Scheme description

The Western Corridor Project will recycle water from most of the wastewater treatment plants in Brisbane and Ipswich. Construction will be split into two stages, with the project scheduled for completion by the end of 2008.

Treatment process: This project is being developed in two stages. For the first stage treated effluent will be collected from the Oxley, Goodna, Bundamba and Wacol treatment plants and then supplied to an advanced water treatment plant at Bundamba. Stage Two will involve construction of two additional advanced water treatment plants to treat the effluent from the Luggage Point and Gibson Island wastewater treatment plants. The advanced treatment systems used at these three plants will involve the following processes in the order listed: membrane filtration, reverse osmosis, advanced oxidation using UV/hydrogen peroxide followed by chlorine disinfection.

Community consultation: While the urgent need for new water supplies in south-east Queensland has not permitted community involvement in the decision-making process for the Western Corridor Project, a serious effort is being made by the Queensland Water Commission and the Western Corridor Recycled Water Project to inform and engage government, community and industry during detailed planning and construction. Project stakeholders are diverse, numerous and located across a large geographic area.

To inform stakeholders a number of public consultation activities are planned as part of the environmental and approvals process. This process will continue throughout the project. A Project Information Desk with a free call number and a website have also been set up to facilitate stakeholder and community consultation.

Cost: $1.7 billion for the Western Corridor Recycled Water Project.

Comments

The Western Corridor Project in south-east Queensland has received significant attention since it has become an IPR scheme. This is the first IPR scheme in Australia and one of the largest in the world.
Summary of less well known examples of planned IPR

Berlin, Germany
Surface water lakes are recharged with treated effluent. This surface water is then used to artificially recharge aquifers, which are used as a drinking water supply.

Upper Occoquan Sewage Authority, Virginia
For 25 years recycled water has been discharged into Upper Occoquan Reservoir which supplied 1.2 million people. 120 ML/day Average 8–10 per cent. Up to 90 per cent of inflow into the reservoir in dry conditions. Capacity being expanded to 200 ML/day.

Summary of unplanned IPR

Johannesburg, South Africa
In the inland areas of South Africa the return of wastewater flows to rivers has been considered an important part of water management. For example, up to 50 per cent of the flow in the Hartbeespoort Dam is recycled water and this dam supplies Johannesburg with drinking water (USEPA Re-use Guidelines).

London, United Kingdom
Around 360 sewage treatment plants discharge into the Thames River upstream of the London water supply off take on the river.

Las Vegas, United States
Lake Meed (Hoover Dam) Las Vegas Water District extracts 360 GL/yr from Lake Meed, which is near the limit of its entitlement. To secure water entitlements, 180 GL/yr of wastewater is returned to the Lake. The district receives credits for doing this and thus secures its water entitlement. (AATSE Report, Water Recycling in Australia 2004).

Richmond (Sydney), NSW
Penrith discharges into the Nepean River upstream of the off take for the Richmond drinking water supply.

Melbourne, Victoria
The Lilydale sewage treatment plant discharges into a stream which flows into the Yarra River. This is upstream of the extraction point for drinking water that is treated and supplies some of Melbourne.

South-east Queensland
(source: Water Futures website)
Dalby—Toowoomba discharges treated effluent into the Condamine River upstream of the drinking water extraction point for Dalby.

Nanango—Yarraman discharges treated effluent into Cooyar Creek upstream of the drinking water extraction point for Nanango.

Kingaroy—Kingaroy discharges treated effluent into Kingaroy creek, which flows into the Stuart River which is then dammed at Gordonbrook.

Wondai—Murgon discharges treated effluent into Barambah creek upstream of the drinking water extraction point for Wondai.

Murray River
All the towns and cities along the Murray River including Adelaide.
Appendix B—Managing recycled water and ensuring drinking quality
Guidelines

In Australia each state has its own guidelines for recycled water use with national guidelines currently in the final stages of development.

The guidelines provide direction on how to manage the risks associated with using recycled water.

The ADWG set requirements to be considered for the management of drinking water supplies. The ADWG are not specific about IPR but outline a risk based-approach to managing drinking water supplies. This approach prefers the use of low risk water sources for drinking water sources.

The NWRG are currently under review and considering IPR. The approach used by WHO is being considered for the NWRG. WHO use daily adjusted life years (DALYs) to set limits for water quality parameters. DALYs are a measure used in probability based risk assessment. Therefore it might be expected that future rolling revisions of the ADWG will include DALY’s for setting limits and IPR.

In the USA there are no federal regulations for recycled water but many states have developed their own regulations. In 2002, 25 states had regulations, 16 with guidelines or design standards, and only 9 without any recycled water regulations or guidelines (USEPA Guidelines 2004).

Five states in the USA have guidelines for groundwater recharge and IPR of recycled water. These states are California, Hawaii, Washington, Florida and Massachusetts. For groundwater recharge, the amount of treatment required varies between states and in some states the treatment is to be site specific for the water quality required.

One aspect of the guidelines in the USA is defining the circumstances in which recycled water going to a water supply is considered IPR. In California, the DHS does not consider it to be IPR if the recycled water discharged into a water source makes up less than five per cent of the total water supply (Water Re-use Study, 2006). In Florida, discharges of wastewater effluent to public water supplies are classified as IPR when it is within 24 hours travel of the drinking water extraction point (USEPA Guidelines 2004).

Another requirement in the USA that is specified in Washington and California is the need for an environmental buffer with a minimum detention time. The regulations in both these states require that the recycled water be retained in the environmental buffer (aquifer or reservoir) for at least 12 months before being withdrawn and treated for drinking water (USEPA Guidelines 2004).

Treatment technologies used to manage risks in recycled water

Table 8 reflects the current typical approach proposed or used at plants around the world:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Contaminants it removes or partly removes</th>
<th>What happens to the contaminants?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary treatment of raw sewage: including biological treatment and settling.</td>
<td>The bulk of the solid and organic material in sewage. A proportion of the chemicals. A proportion of the pathogens.</td>
<td>Predominantly is turned into ‘biomass’ (micro-organisms which are deliberately grown in the system). This is then settled out and must be disposed of—often called ‘biosolids’.</td>
</tr>
<tr>
<td>Technology</td>
<td>Contaminants it removes or partly removes</td>
<td>What happens to the contaminants?</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Filtration (typically with micro or ultra filtration membranes)</td>
<td>The remaining solids, in fact all particles down to less than around 0.1 um. This means bacteria and many viruses are also removed. Percentage removal of protozoa and bacteria is greater than 99.99 per cent.</td>
<td>Backwashed off the membranes periodically, forming a stream with the solids etcetera in it.</td>
</tr>
<tr>
<td>Reverse osmosis filtration (similar to that used to remove the salt from seawater)</td>
<td>The membranes remove dissolved constituents including salts. So the majority of nutrients, colour and other chemicals, including any residual pharmaceuticals, pesticides etcetera are removed to varying degrees depending on their characteristics. Not all compounds are completely removed. Any residual viruses and other pathogens are also excluded, as they are quite large in relative terms. Percentage removal through reverse osmosis varies from less than 95 per cent (e.g. nitrogen compounds) to &gt; 99.99 per cent (for protozoa).</td>
<td>The compounds are found in a concentrated stream often called the ‘brine’ as it is usually somewhat salty.</td>
</tr>
<tr>
<td>Advanced oxidation.</td>
<td>The advanced oxidation attacks residual compounds.</td>
<td>The compounds are turned into gaseous CO₂ and other compounds, or remain in the stream as different and less harmful by-products.</td>
</tr>
<tr>
<td>Disinfection with chlorine.</td>
<td>‘Kills’ any remaining pathogens and provides a measurable residual which remains in the water.</td>
<td>Remain in the water but are non-viable, i.e. ‘dead’, and do not show up in a culture.</td>
</tr>
<tr>
<td>Dilution and other processes in aquifers and storages.</td>
<td>Many contaminants are reduced in concentration in the natural environment, firstly by dilution, secondly by breakdown over time, and finally by attack by micro-organisms and UV light.</td>
<td>A wide range of fates.</td>
</tr>
<tr>
<td>Final water treatment of blend of IPR and existing water source.</td>
<td>Most proposed IPR schemes have final traditional water treatment, including coagulation, filtration and chlorination. Additional removal of 99 per cent and higher is expected for many contaminants.</td>
<td>Removed in the sludge.</td>
</tr>
</tbody>
</table>
What are the technical risks to water quality posed by using recycled water to supplement drinking water supplies?

As a starting point it must be recognised that there are real risks posed by the introduction of sewage into water supplies. The separation of the two has led to significant health benefits throughout the world. However, modern risk management techniques and treatment technologies offer the possibility to manage these risks.

The risks can be summarised in the following concepts:

**Known contaminants which have a well understood impact on public health (for example pathogenic bacteria)**

Here it is possible to determine the appropriate level of removal to lead to a manageable level of risk. Provided the various barriers are working properly, then the risk is managed. This is the same concept used to manage risks in current water supplies. The specific details of this analysis are expected to be in the new IPR section of the NWRG.

**Failure of one of the various ‘barriers’**

First, designers aim to have ‘multiple’ barriers, so that failure of any one system is not critical. Second, use HACCP systems (a QA system developed by NASA and used in the food industry to check things are working properly). As an example, measure the performance of our treatment plants by (say) a turbidity meter or chlorine residual meter, and if the performance is out of spec, take action.

The IPR approach is reliant on sophisticated treatment processes being operated well, so appropriate investment and ongoing attention including operator training, auditing and review and other similar factors will be important.

**Contaminants with unclear impacts on public health**

The history of water quality and water treatment includes many examples of contaminants that have emerged through research and have then required management. Two examples are disinfection by-products and cryptosporidium. This is a key part of the continuous improvement process, and is likely to continue to some extent as research and development continues.

How will these ‘new’ risks be managed? This remains to be seen. There are several broad possibilities. First, ‘catchment management’ might occur, i.e. prohibiting the use or disposal of some particular substance into the sewers. Second, existing treatment processes might prove effective against such contaminants. This is one of the arguments in favour of using reverse osmosis and advanced oxidation. We know these processes remove molecules of a certain size and properties, so even if we have no data on a particular new contaminant we can infer something about likely removal.

In 2001 GHD undertook a review of the health issues associated with IPR for the Queensland Department of Health and Aged Care. The key conclusions from this study were:

- It will not be possible to define health based guidelines for all parameters. Even if health-based guidelines could be defined for all parameters it would not be practical to operate a re-use system based on monitoring all individual parameters for recycled water.

- Successful potable re-use will require an approach that includes:
  - guidelines and a risk-based approach
  - guidelines and controls based on treatment processes and technologies determined to provide an acceptable level of risk
  - the use of indicators or surrogates such as turbidity, colour, total organic carbon, etcetera as indicators of performance of the treatment process.
• There is sufficient data available for many potential health issues.
• Given that unplanned IPR occurs widely it could be interpreted that it is safe providing the
  appropriated controls are in place.
• Further research is needed to determine health affects from IPR.

The central recommendation from the study was that a management framework be
established for recycled water schemes, similar to that adopted for drinking water in the
ADWG. This needs to be supported by measurable limits that verify a treatment process is
operating effectively, and research using available data to assess any potential health effects.
The new recycled water guidelines provide such a framework.

Environmental buffers and catchment management

All existing and proposed IPR schemes (except Namibia) include some blending with other
water and then some detention time before further water treatment and delivery to the
reticulation system. This occurs in either aquifers, mixers or storages and has come to be
called the ‘environmental buffer’. This buffer is mandated in some USA guidelines. Times
mandated are around six months to a year or more. Benefits from such a buffer are both
social and technical.

These potential benefits include:
• increased comfort for the community as research shows contact with ‘natural’ processes
  increases confidence in the water quality
• improved quality assurance due to time available to measure water quality and check the
  results
• improved risk management due to processes such as microbial activity, UV irradiation,
  sedimentation, groundwater ‘filtration’ etcetera which remove pathogens and chemicals.

There are some issues with the use of environmental buffer. Examples include:
• water quality can deteriorate due to natural processes such as algae growth
• water quantity can reduce due to evaporation.

There is an additional strategic question regarding environmental buffers which has significant
implications for future IPR projects: How much detention time is required?. So some definition
or guidance on this question will be an important aspect of the IPR guidelines.

Catchment management for recycled water for drinking

Catchment management is an integral part of the risk management approach in the ADWG. It
has not yet been explored widely in Australia as part of recycled water for drinking.

The following list indicates examples of actions that might be taken—note that if explored to
their fullest extent, some of these actions could add considerable costs to the concept of IPR:
• exclusion of some key high risk wastes from the sewer
• tighter controls and limits for trade waste discharges
• changes to city planning or some other approach to exclude industry from some sub-area
  of the system
• increased attention paid to spills etcetera
• some form of control or education regarding disposal of various items in the sewer in
  homes.

In summary

The principles used to currently manage risks in drinking water supplies will continue to apply.
Advanced treatment technologies offer the opportunity to produce a very high quality water.
Rigorous risk assessment and ongoing operation is needed.
Appendix C—Background information—‘Catchment to Tap’
Drinking water quality: ‘catchment to tap’

The ADWG define drinking water supply as a system in Australia. These guidelines require an examination of risk from ‘catchment to tap’. (In Victoria drinking water quality is regulated by the Safe Drinking Water Act 2003. It is not regulated as explicitly in other states.)

The catchment to tap model serves as a useful framework to understand the various aspects of a system.

The ‘catchment’ is the area of land from which ‘runoff’ is drawn for a particular supply. It is typically a valley or set of valleys which feeds a particular stream or river.

The ‘land use’ and general geography in catchments affects the water quality in the waterways. Typically, water from catchments which have no development has better quality than water from heavily developed catchments.

The land use in catchments which supply water to Australia’s towns and cities varies significantly from place to place. Some towns and cities draw their water supply from more than one catchment, and these often vary also.

The following highly simplified table (Table 9) illustrates the kinds of activities or land use which occur in Australian water supply catchments and the impact they might be expected to have on the water quality. Refer to the ADWG 2004 for further information.

<table>
<thead>
<tr>
<th>Activity/land use</th>
<th>Potential impacts on water quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undeveloped native forest</td>
<td>Turbidity (cloudiness)  Colour</td>
</tr>
<tr>
<td></td>
<td>Pathogens (e.g. bacteria and virus etcetera) from native animals</td>
</tr>
<tr>
<td>Agriculture</td>
<td>As above plus</td>
</tr>
<tr>
<td></td>
<td>Pathogens from farm animals</td>
</tr>
<tr>
<td></td>
<td>Increased Turbidity and Colour</td>
</tr>
<tr>
<td>Rural housing (septics)</td>
<td>As above plus</td>
</tr>
<tr>
<td></td>
<td>Pathogens from people</td>
</tr>
<tr>
<td>Industry</td>
<td>Discharges</td>
</tr>
<tr>
<td></td>
<td>Trade waste</td>
</tr>
<tr>
<td></td>
<td>Spills of a wide range of chemicals</td>
</tr>
<tr>
<td>Urban centres</td>
<td>Pathogens</td>
</tr>
<tr>
<td>– sewers</td>
<td>Chemicals</td>
</tr>
<tr>
<td></td>
<td>Nutrients</td>
</tr>
<tr>
<td>– stormwater</td>
<td>Oil</td>
</tr>
<tr>
<td></td>
<td>Metals</td>
</tr>
<tr>
<td></td>
<td>Pathogens</td>
</tr>
<tr>
<td></td>
<td>Nutrients</td>
</tr>
</tbody>
</table>
The concentrations of these various contaminants will vary widely depending on:

- the location and intensity of the land use
- the intensity of runoff; severe rain events often lead to worse water quality
- dilution and other processes in the catchment, river(s) and streams.

These residual risks are dealt with by the full catchment to tap approach including treatment. The elements of this are:

- ‘catchment management’ to identify high-risk activities and reduce their impact
- ‘storage’ in dams and similar which can lead to improvements in water quality—due to settling, detention time, biological activity and UV from the sun
- ‘water treatment’ which today can (and often does) involve a train of different processes designed to deal with the particular feed water quality.

Most water treatment plants have some of the following elements (Figure 15). Refer to Appendix B for more information on treatment.

Figure 15: Typical elements of most water treatment plants

In summary, drinking water quality in Australia is managed as follows:

- **Understand and Manage the Catchment**
  - to see what risks you need to cater for
  - to see if you can reduce the risks at the source

- **Understand and Manage the Supply System**
  - to see if dams etcetera reduce the risk(s)
  - to see if new risks arise (e.g. algal blooms)

- **Design Water Treatment to Manage any remaining risks**
  - could vary from disinfection alone (e.g. Melbourne with its protected catchments) to
  - complex treatment (e.g. microfiltration–ozonation–activated carbon–disinfection in Bendigo).

- **A Risk Management Plan** to provide ongoing review and control of this system, including elements such as ‘critical control points’ which are drawn from the HACCP approach which is used to manage the quality of food.

**Multiple barriers**: catchment protection, storage in reservoirs and various stages of water treatment form ‘multiple barriers’ to contaminants.
Drinking water supply—volume and end use classification

With the exception of new developments that have ‘dual-pipe’ (e.g. Rouse Hill in Sydney, Aurora in Melbourne, Mawson Lakes in Adelaide, and many others), houses and industries in Australian cities are supplied with a single pipe. This pipe supplies water for a range of different uses. Figure 16 provides some typical data that:

- domestic houses use most of the water (note that many ‘non-domestic’ consumers are in practice shops, offices etcetera where much of the water use is for toilets, showers, kitchens—eg similar to domestic use)
- most use is not specifically for drinking.

Figure 16 Drinking Water Classifications

Typical Water Use in Australian Households

Urban Water Consumption in Australia 2000–2001 as a percentage of Total Consumption

(Source: WSAA Position Paper 2005)

Reducing water use through demand management is a key action currently happening in all areas around the country. Reductions of around 20 per cent have occurred over the past few years.

Demand Management

‘Demand Management’ is a term used to describe a broad range of possible options to reduce water use or find alternate supplies such as roof water harvesting etcetera at the consumers house.

These options range from campaigns to request less watering, to subsidised rainwater tanks; to labelling schemes for appliances to consumption targets for new homes (e.g. BASIX in New South Wales).

One final point: this water is distributed to consumers via a complex network of pipes often known as the ‘reticulation’. In a large city this network is very extensive. The pipework represents a key significant investment with a long lifetime. However some of this infrastructure may be reaching the end of its life or need upgrading to meet increasing demands.

Wastewater

Wastewater is produced by each water consumer in urban centres. All the water used in the house (with the exception of small volumes exhaled by people and caught in wet washing) is captured in sinks, batches, shower basins and toilets and thus becomes wastewater.

In many small towns this wastewater is sent to septic tanks (which dispose of water onsite). However our large towns and cities are serviced by sewerage systems.

Sewerage systems are like a mirror image of our water supply pipework. They collect wastewater from throughout the city and it is then directed to the wastewater treatment plant(s) which service the city. After treatment at these plants it is either recycled or discharged to the environment, typically a river or ocean.
There are typically two or three additional sources of flow into our sewerage systems in addition to ‘domestic sewage’.

These are:
- ‘trade waste’—wastewater from non-domestic premises which is different to domestic wastewater
- rainwater or stormwater, though is generally illegal to divert stormwater to sewers, nevertheless often makes its way into the sewer—this is common and leads to flows two to three times dry weather flows during wet weather events
- inflows from groundwater—in areas where groundwater is salty (e.g. near the ocean) there can be a significant contributor to salt levels in wastewater.

**Wastewater quality and treatment**

The wastewater from our houses and industries has been contaminated by users. The following list is a simplified summary of the source of contaminants.
- ‘grey water’ from showers, washing machines, sinks and dishwashers
- ‘black water’ from toilets
- industry (trade waste)—highly varied depending on industry.

For more information refer to the NWRG.

These various contaminants can create a range of problems for a receiving environment if effluent is not treated. These include:
- health risks if human contact occurs
- shifts in species due to toxic effects or additional nutrients
- aesthetic issues such as odour, foam, colour etcetera.

These potential impacts are managed through a combination of two strategies:
- ‘wastewater treatment’—to reduce the concentration of the various contaminants
- ‘dilution’—this is often achieved with ocean outfalls, where the flow is sent along a long pipeline with multiple outlets to ensure concentrations at each point remain low.

Wastewater treatment is as varied as drinking water treatment. It is driven by a mirror image of the drinking water model: the more pristine or sensitive the receiving environment, the higher the level of treatment.

In cases where the receiving environment is particularly sensitive—more sophisticated treatment trains are adopted.

A typical wastewater treatment process includes the elements shown in Figure 17. Refer to Appendix B for further details on treatment.

**Figure 17: Typical elements of wastewater treatment**