The Challenge of Implementing Water Harvesting and Reuse in South Australian Towns

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(School of Civil and Environmental Engineering)

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PART I
OUR WATER RESOURCES

Aerial View of Coober Pedy, South Australia (Rabone 2003)
Chapter 1
Introduction

“Concerns for man and his fate must always form the chief interest of all technical endeavours. Never forget this in the midst of your diagrams and equations.”

ALBERT EINSTEIN

1.1 OVERVIEW

Water is a fundamental element of life on earth. Its conservation is of great environmental, economic, social and ethical importance. Australia needs to manage its freshwater resources wisely; reuse of treated effluent and urban stormwater runoff can play a role in achieving this. It has the potential to relieve pressure on the environment and make economic development more sustainable. Currently, less than 10% of the water used by urban and industrial consumers in Australia is recycled (Melbourne Water 2003). Increasing our sustainability involves changing the community’s perception and cultural understanding, as well as meeting scientific and implementation challenges. The financial, hydrological, and sociological difficulties faced when attempting to implement water reuse or harvesting schemes are challenging to overcome. Water is a precious commodity, particularly in South Australia; the driest State in Australia. Over 80% of our land area receives less than 250mm of rainfall per year, compared with the national average of 450mm per year. Water from the River Murray plays a critical role in the life and economy of South Australia.

NOTE:
This figure is included on page 3 of the print copy of the thesis held in the University of Adelaide Library.

Figure 1  Location of South Australia  (TravelOnline.com)
Due to the implementation of some successful non-potable water reuse projects in South Australia, opportunities are being pursued to increase the use of recycled, low quality water in both urban and country areas. As a result of the application of water restrictions in 2003, the first for more than forty years, accessing the potential benefits of local water harvesting and reuse has become more important. Many people see it as an investment in the future of South Australia and essential to our community’s development.

1.2 OBJECTIVES OF THIS STUDY

Increasing the environmental awareness of local governments, businesses and the general community regarding water usage is vital. Gaining an increased understanding offers South Australia a unique opportunity to develop and manage non-potable water harvesting and reuse schemes for public parks, gardens and possibly in the commercial sector. The various challenges that must be overcome in order to achieve this goal are presented in order to assist communities in developing solutions. The key objectives of this research are:

Objective 1: Assess viability of small-scale, non-potable water supplies

The primary aim of this thesis is to investigate the feasibility of developing a local, non-potable water supply for towns in South Australia, based on a review of the experiences of selected operational schemes. Relevant data was gathered to determine the challenges that prevent sustainable water usage being achieved. A significant intention was to promote awareness of the social, environmental and economic benefits of developing and sustaining localised water resources. The goal is to encourage communities to undertake an audit of local water resources as a starting point in identifying the availability and suitability of water supplies which could be accessed locally.

Objective 2: Role in urban water supply performance

The secondary aim of this research is to objectively analyse the prospects of meeting part of South Australia’s urban water demand with locally harvested and recycled water. Such practices may support the State in reducing its dependence on the River Murray, reduce pollution of surface waters associated with waste discharges from urban centres (ie. rivers and the ocean), and support population and economic growth. The intention of this review is to contribute to the effort of developing policies and practices that optimise existing and new infrastructure and provide best total value to the people of South Australia.

Objective 3: Identify areas for further research and development

There are many challenges in implementing water harvesting and reuse schemes in regional and metropolitan South Australia. The identification of factors that prevent South Australia achieving positive outcomes in water reuse and harvesting projects is undertaken. This objective is tightly linked with the others and is considered concurrently throughout the study.
1.3 SCOPE OF RESEARCH

This study reviews the practicality of, and limitations associated with, the development of local community water harvesting and reuse projects in South Australia. It also looks at how these schemes can be delivered in a way that safeguards public health, minimises detrimental impacts on the environment and improves the standard of living or amenity in the community. The principal water resources considered are:

- harvested stormwater runoff from urban areas; and
- reused treated wastewater effluent (sewage).

The study excludes water harvesting and reuse at the individual domestic householder level. However, many of the principles discussed are applicable to all scales of planning and development, from the single family residence to the design and layout of subdivisions and entire communities.

1.4 TOPICS OF REVIEW

The following topics were investigated for the purpose of developing this research:

- The technical, commercial and social issues that need to be addressed by communities in order to sustainably develop their local water resources through water harvesting and reuse;
- The relationship between regional rainfall and evaporation rates, water consumption, wastewater reuse, local hydrology, proximity to major supply pipelines and town planning in determining the hydrological feasibility of water harvesting and reuse schemes;
- The use of various existing township infrastructures such as roads, kerbs and stormwater drains to assist in the economical implementation of water reuse schemes in small urban centres;
- The significance of support from township communities and businesses in the successful establishment, operation and maintenance of water harvesting and reuse projects;
- The importance of data collection in enabling a complete and comprehensive design of a water harvesting and reuse scheme as well as ongoing system monitoring to ensure the scheme meets expectations and operating efficiencies; and
- The role of building capacity for individual’s and organisation’s ‘water wisdom’, advancing long-term adjustment in our society’s values and water use culture. I aim to encourage water-saving policies and practices.

A major theme of the research is the importance of information sharing, as if everyone is familiar with and understands the facts regarding water harvesting and reuse they will encourage and support the development of these resources. Not all water needs to be drinking quality, and existing social infrastructure may be able to be more beneficially used.
1.5 STUDY OUTCOMES

The outcomes of the research are as follows:

- Identification of a process that can be used by communities to identify the challenges that will be faced and assess the potential for implementing a safe water harvesting and reuse scheme, based on their collective regional knowledge and experiences;

- Development of guiding principles to help community groups make informed decisions about sustaining and developing their local non-potable water resources; and

- Establishment of key recommendations for developing more effective, efficient and sustainable water services in urban centres in South Australia, with special emphasis on the potential of small-scale water harvesting and reuse in towns.

1.6 STRUCTURE OF THESIS

This thesis has been organised into three parts as shown in Figure 2. The structure adopted has resulted in some information from selected South Australian case studies being presented more than once. Experiences drawn from the case studies are incorporated into the feasibility assessment framework discussed in Part I as well as in the detailed write up of selected case studies in Part II which could be published independently as a community reference.
Figure 2  Structure of Thesis
1.6.1 Part I – Water Harvesting & Reuse Potential

Part I of the thesis, forming the main body of research, consists of eight chapters.

- Chapter 1 provides an introduction to the research into the potential for water harvesting and reuse in country towns in South Australia.

- Chapter 2 contextualises water globally and summarises issues related to the equitable allocation and sustainable use of the world’s limited natural freshwater resources; broadly comments on philosophical elements of water use and raises questions involving the resolution of complex ethical matters.

- Chapter 3 describes the water industry in Australia and reflects on whether urban centres in Australia are using water in ways and quantities, that are sustainable. This chapter explores the influence that the prevailing climate of a region has on the water demand pattern. Special emphasis is given to the impact of ongoing national reform within the water industry, which is anticipated to move us closer to sustainability.

- Chapter 4 sets the scene for achieving more sustainable water infrastructure and services in Australia’s growing urban centres, while maintaining a high level of service provision. Key issues discussed include; demand management (ie. water efficiency and conservation), supply augmentation (including natural and recycled), water sensitive urban design and development (including policies and practices), and the promise of technology. It raises question regarding when the transformation of existing systems and infrastructure, (often with an asset life between 50 and 100 years) to more modern technology should occur, making way for more sustainable practices.

- Chapter 5 reviews the interwoven social and political history in South Australia regarding the development of water, wastewater and stormwater services. It presents a summary of the development level of South Australia’s water resources and what this means for water harvesting and reuse in the future. The impact of national policy on water use trends and patterns is examined.

- Chapter 6 presents findings from reviewing the challenges and opportunities faced by a number of South Australian communities that have developed local water harvesting and reuse projects. Considerable success has already been achieved with the development and use of urban stormwater and treated wastewater in rural communities.
Chapter 7 examines practices that can assist in achieving successful water reuse and harvesting schemes, including extensive feasibility studies and clear communication with members of the general community. This chapter sets out an approach for assessing the challenges and feasibility of developing a local, non-potable water supply in order to make decision making easier. It also identifies that although technical feasibility and planning are vital, community relations are another key in achieving optimal outcomes.

Chapter 8 presents the conclusions and recommendations arising from the investigation into the challenges and potential for local water harvesting and reuse projects in regional South Australia.

At the conclusion of Part I there is a bibliography which summarises the literature reviewed during the course of this research.

1.6.2 Part II Selected South Australian Case Studies

A major obstacle to the research and development of small, localised water harvesting and reuse schemes has been the difficulty in obtaining operational data and information about existing projects, some of which have been operating for over 20 years. Part II seeks to address this issue and provides a comprehensive account of the South Australian case studies reviewed. This information was assembled with the assistance of local people operating schemes in the towns, from field visits and from published literature (where this exists). This review provides insight into the feasibility of developing water harvesting and reuse for country towns in South Australia. Fundamental issues which arose from these studies are described in Chapter 6 and form the basis of the feasibility assessment and planning process presented in Chapter 7. The information presented in Part II is a subset of the research work that could be published independently as a community reference.

1.6.3 Part III- Supporting Information

Part III provides additional detail in the form of appendices to support principles discussed in Part I. Several appendices set out data, statistics, and analyses in a tabulated form for a number of towns (across all prevailing climate conditions in South Australia). The information presented includes average monthly rainfall, evaporation, runoff and irrigation requirements as well as historical water consumption data and population information for these towns. This information may be used to assist in assessing the feasibility of local water harvesting and reuse projects for non-potable uses.
Chapter 2
Water Resource Management – Global Perspective

“There is enough water in the world, but only if we change the way we manage it. The responsibility to act is ours for the benefit of present and future generations”

MINISTERIAL DECLARATION
INTERNATIONAL CONFERENCE ON FRESHWATER (2001)

2.1 THE QUEST FOR WATER

Humans have always consumed freshwater and for many millennia human impact on water resources was insignificant and local in character. This resulted in the illusion that water resources were an inexhaustible, free-of-charge gift from the natural environment (Shiklomanov 1999) others believing it to be a gift from God. For example, Genesis 26 of the Bible depicts the relationship between water and ultimate security in the Promised Land (Starr 1993). Similarly, the Koran explicitly states that water is the most precious and valuable resource of the physical environment (Starr 1993). These ancient texts tend to indicate that those who governed millennia ago understood their spiritual connection to the water. Sadly, over time the sense of awe and responsibility has been lost.

Water is the most widely distributed resource on our planet and is available in different forms and amounts everywhere on Earth. The total amount of water on our planet hasn’t changed since the beginning of time, but it is highly susceptible to degradation if not used in a sustainable manner (Fleming 1999). Being both a social and economic good, water must be equitably and sustainably allocated, firstly to basic human needs, secondly to functioning of ecosystems and then to different economic uses.

Water is expected to be the most sought after natural resource in the 21st century, as continued growth of populations and economies is dependent on the quantity and quality of freshwater resources (Wolf 2003). Water is a key element to global sustainability, and is crucial to its social, economic and environmental dimensions (GTZ 2001; WHO 2003). Sustainable water resource management requires integrating appropriate water sensitive principles into the water supply, sanitation, irrigation and drainage sectors. This will involve different forms of service provision to awaken society’s water consciousness.

Understanding this global perspective provides an important context for the need to recognise, and learn to overcome, the challenges of implementing water harvesting and reuse in our own region.
2.2 WATER: A HUMAN RIGHT

From the beginning of the development of social infrastructure, it has been recognised that water, poverty and health are closely linked (Pigram 1986; GTZ 2001). The connection between polluted water and disease was proved by the state of London’s sewers in the 1800s. At the beginning of the 21st century, of the world’s population of approximately 6 billion, at least 1.1 billion people live in poverty without access to safe drinking water (AWA 2000; WHO 2003), and almost 2.4 billion have no access to proper sanitation (GTZ 2001). Figure 3 shows the distribution of populations without access to safe water supply and sanitation services. It should be noted that while Asia has the highest number of people unserved by either water supply or sanitation, proportionally this group is actually bigger in Africa due to the difference in population size between the two continents (UNESCO 2004).

NOTE:
This figure is included on page 12 of the print copy of the thesis held in the University of Adelaide Library.

![Figure 3 Distribution of Unserved Populations (UNESCO 2004)]

Safe and sufficient water and sanitation are basic human needs (Pigham 1986; GTZ 2001; WHO 2003). Providing reliable and safe water supplies, adequate waste disposal systems and a comprehensive education program can significantly improve the health of communities.

2.2.1 Human Rights

Many argue that human rights documents would have explicitly included a right to water if it had been foreseen that reliable provision of a resource as fundamental as clean water would be so problematic (AWA 2000; Starr 2003). The right to the highest attainable standard of health was enshrined in the World Health Organisation’s (WHO) constitution over 50 years ago, and recognised in article 12.1 of the International Covenant on Economic, Social and Cultural Rights (WHO 2003). This right extends to the underlying determinants of health; central among these are safe water and adequate sanitation. This link was recognised explicitly in an enquiry into the provision of water and sanitation services to Australia’s indigenous communities (HREOC 2001):
“...satisfactory health is a precondition of the full enjoyment of almost all human rights and fundamental freedoms, water is crucial in a chain of factors affecting the fulfilment of other human rights, and the right to water is implied throughout many of the more wide ranging provision of the various instruments.”

Water rights, in theory, extend to all human beings (Starr 1993). Recognising water as a basic human need and a human right entitles everyone to sufficient, safe, physically accessible and affordable water and it must be enjoyed without discrimination and equally by men and women (WHO 2003). In the case of water, this minimal level includes ensuring people’s access to enough water to prevent dehydration (WHO 2003).

### 2.2.2 Sufficient Water

The minimum amount of water required to sustain life ranges from about 2 litres per capita per day (Lpcd) in temperate climates to about 4.5 Lpcd for people in hot climates who carry out manual work (Howard & Bartram 2003 in WHO 2003). In addition, people need at least 2 litres of safe water per day for food preparation. Hazeltine and Bull (2003) also consider five litres of clean water as the minimum amount needed per person per day to sustain human life. Table 1 sets out the definition of different levels of access to water and the associated likely volume of water to be used adopted by the World Health Organisation.

#### Table 1 Service Level & Quantity of Water Used (WHO 2003)

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NOTE:
This table is included on page 13 of the print copy of the thesis held in the University of Adelaide Library.
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Part I Our Water Resources

The recognised service levels span ‘no access’ being less than 5 Lpcd to ‘optimal access’ being 100-200 Lpcd. The global target for currently unserved populations (ie without access to sufficient water) is the provision of at least ‘basic access’ being 20 Lpcd (WHO 2003). In Australia, most centres of population are connected to a reticulated water supply and therefore have ‘optimal’ access. But there are areas where remote communities and individual households are responsible for providing their own water supplies. In these areas, provision of an assured supply of safe water is problematic due to isolation and the small size of the communities and lack of good quality water sources (Heyworth et al. 1998).

2.2.3 Safe Water

Lack of safe water is a cause of serious diseases such as diarrhoea, which kill over 2 million people every year, the vast majority being children in developing countries (WHO 2003). Increasing access to safe water provides water for drinking, food preparation and hygiene and encourages improved living conditions. Drinking water must be free of organisms that are capable of causing disease, such as those listed in Table 2 below, and from minerals and organic substances that could produce adverse physiological effects (AWWA 1990).

Table 2 Waterborne Diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrhoea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typhoid Fever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatitis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enteric Fever</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: This table is included on page 14 of the print copy of the thesis held in the University of Adelaide Library.

*a* All of the diseases listed can also be transmitted by means other than water.

*b* Not all of the organisms listed cause the associated waterborne disease.

Water safety is an important aspect of protecting public health (GWP 2003). Many of the investments that the water industry makes are attempts at preventative health expenditure. However, the health of a community supplied with safe water does not necessarily improve if public health and wastewater disposal issues are neglected (Hazeltine & Bull 2003). Protection of public health is achieved by treatment processes that reduce concentrations of pathogenic bacteria, parasites and enteric viruses in the water (US EPA 1992; CCC 2003; Millis 2003). It is widely recognised by health and water authorities that providing safe water to small and rural communities is an ongoing challenge. Access to safe water in some small, remote and isolated communities is still a political concern in Australia.

**2.2.4 Physically Accessible Water**

Many people in the world currently without access to safe potable water (refer Figure 3 above) will not realise the goal of water access at home in the short- or even medium-term. In many places water has to be collected from distant sources and it is generally women and children who perform this duty. Research has shown that, on average, households in rural Africa spend 26% of their time fetching water (DFID 2001 in WHO 2003). This work prevents women from spending time on more productive work in the home or elsewhere, or children may miss school. In addition, carrying heavy loads can sometimes cause spinal injuries. Circumstances such as these create great respect for water; people are water conscious and optimise its use.

Improved access gives the poor, especially women, control over basic aspects of their life (WSP 2003). Household consumption rises with convenience of physical access to water, ie. the number of taps connected to a central reticulated supply. This increase is often accompanied with a decline in social water consciousness; a combination of introducing people to new uses and infrastructure that supports use of abundant amounts of water at little or no charge. Example 1 below describes the decline in social water consciousness which occurred in countries in the Arabian Gulf. When deciding on the appropriate level of service of a water supply for a community in a developing country, Hazeltine & Bull (2003) suggest adopting the per capita daily water demand values set out Table 3. In addition, Hazeltine & Bull (2003) also support prohibiting the use of drinking water for garden watering in developing countries as it leads to an enormous water demand for non-essential purposes.

**Table 3 Influence of Physical Accessibility on Water Demand**

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Per Capita Water Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply with public hand pumps</td>
<td>15 - 25 l/person per day</td>
</tr>
<tr>
<td>Supply with public standpipes</td>
<td>20 - 30 l/person per day</td>
</tr>
<tr>
<td>Supply with yard connections</td>
<td>40 - 80 l/person per day</td>
</tr>
<tr>
<td>Supply with multiple tap house connection</td>
<td>80 -120 l/person per day</td>
</tr>
</tbody>
</table>

*Source: Hazeltine & Bull (2003)*
### Example 1

**Physically accessible water & water consciousness: Arabian Gulf**

Akkad (1990) described the transformation of the Arabian Gulf societies from simple, traditional communities characterised by a subsistence economy and modest water development technology to a modern society with advanced technologies and affluent economy. Traditionally the rural areas outside the city initially develop their water supply and sewage disposal facilities on a private, house-by-house basis. People had great respect for water and their water needs were simple and matched their water development technologies. They were water conscious and tried to optimise its use.

This great societal value declined following the development of water systems. As an area became more developed and the population density increased community water systems emerged. Consequently, the previous interest in saving water diminished and has been replaced by an extravagant use of water as it became a readily available commodity. The average water demand in Saudi Arabian cities is estimated to be 322 litres per capita per day in 1990 and 358 litres per capita per day in the year 2000. The residential water consumption increases 40% if landscaping is maintained.

Source: Akkad 1990

Many countries including Australia have experienced a similar decline in social water consciousness following the implementation of large-scale, centralised water supply systems which support an enormous water demand for non-essential purposes. However, education and pricing policies can act to moderate household consumption levels by encouraging changes in water use practices.

#### 2.2.5 Affordable Water

The right to water specifically rules out exclusion from a needed service according to ability to pay, ie. water must be affordable for everyone (WHO 2003). It is a sad irony that it is often the poor who receive the least reliable quantity and quality of water supply must pay most per litre for their water – for example, from water vendors in the street (Katko 1991; WSP 2002). According to one recent estimate, the poor in developing countries pay on average 12 times more per litre of water than their counterparts who have a municipal supply (WHO 2003).

Equity demands that poorer households should not be disproportionately burdened with water expenses when compared with richer households (WHO 2003). Ensuring affordability of water requires that the service which is provided matches what people can pay. This may include the use of a range of appropriate low-cost techniques or technologies (with the potential for progressive upgrading) and appropriate pricing policies such as free or low-cost water and income supplements (GTZ 2001; WSP 2002; Hazeltine & Bull 2003).
2.2.5.1 Willingness to Pay

The amount of money spent on resold and vended water demonstrates that consumers are able and willing to pay for reliable water service (Katko 1991; Garrett 1991; WHO 2003). Many countries accept the principle established at international conferences in Dublin and Rio in the 1990s, that the poor are willing to pay for good quality services and should be charged for them (WSP 2002). A user's willingness to pay for water supply may exceed actual water charges as well as full cost recovery, or alternatively, it may be far below full cost recovery (NFI 1991).

There is no need for the optimal charge to reflect the willingness to pay, except that the charge can not exceed the willingness to pay. Many countries with long histories of water supply subsidisation, including Australia, have faced significant political and social challenges in implementing such a pricing policy. Table 4 shows the unit cost of potable (drinking) water for various countries.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>A$/kL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Germany</td>
<td>$2.93</td>
</tr>
<tr>
<td>2</td>
<td>Denmark</td>
<td>$2.83</td>
</tr>
<tr>
<td>3</td>
<td>United Kingdom</td>
<td>$2.02</td>
</tr>
<tr>
<td>4</td>
<td>The Netherlands</td>
<td>$1.87</td>
</tr>
<tr>
<td>5</td>
<td>France</td>
<td>$1.78</td>
</tr>
<tr>
<td>6</td>
<td>Belgium</td>
<td>$1.68</td>
</tr>
<tr>
<td>7</td>
<td>Italy</td>
<td>$1.19</td>
</tr>
<tr>
<td>8</td>
<td>Spain</td>
<td>$1.17</td>
</tr>
<tr>
<td>9</td>
<td>Finland</td>
<td>$1.06</td>
</tr>
<tr>
<td>10</td>
<td>Sweden</td>
<td>$1.01</td>
</tr>
<tr>
<td>11</td>
<td>Australia</td>
<td>$0.90</td>
</tr>
<tr>
<td>12</td>
<td>United States</td>
<td>$0.89</td>
</tr>
<tr>
<td>13</td>
<td>South Africa</td>
<td>$0.70</td>
</tr>
<tr>
<td>14</td>
<td>Canada</td>
<td>$0.62</td>
</tr>
</tbody>
</table>


Water is affordable in Australia, particularly when compared to the price charged in other developed countries such as Germany, Denmark, and the United Kingdom. A fundamental consideration to system sustainability is the balance between affordability, cost recovery for the service and efficient use of resources. Achieving these objectives requires use of appropriate technologies, appropriate pricing structure and well as a willingness to charge for water use.

2.2.5.2 Willingness to Charge

Cost recovery means the extent to which actual charges collected cover capital and recurrent costs of production, delivery and discharge of water. The concept covers anything from providing water completely free (zero cost recovery), to partial, full or more than full cost recovery and can be compatible with many different charging regimes (NFI 1991). Example 2 below describes a case where cost recovery for rural water supply in a low income country has been achieved.
### Example 2 Cost Recovery for Rural Water Supply: China

Rural water supply is a high priority for the central Government, which has received World Bank assistance of US$628 million for four successive rural water and sanitation projects in the last 17 years aimed at serving 23 million people in 18 provinces. While the central Government provided a ‘basic’ level of service, typically through hand pumps, rainwater collection systems and tube wells, the Bank assisted projects offered a higher level of service through piped water supply to individual households. It logically followed that the users had to pay more for these improved services.

In the context of the China projects the World Bank typically financed about half of the capital cost of piped water supply systems installed. The Bank made credit/loan to the central Government for a period of 35/20 years was ‘on lent’ to the provincial government after adding an additional 3-4% and reduced repayment period of 15 years. If the latter falls behind the central Government automatically deducts the debt service amount from routine transfers to the province. For the remaining upfront costs, the provincial and county governments jointly finance 25% and the users contribute 25%, usually in the form of a cash and labour combination.

Poverty was a major criterion used to select provinces and countries for these projects. Within the selected countries, denser areas were chosen to make the cost of supplying piped water economically viable. Since users also service the Bank debt through payment of the water tariff, they effectively finance 75% of the overall investment cost as well as 100% of operation and maintenance costs.

For more remote and less densely populated areas of the project provinces, however, the approach was to provide ‘basic’ level of service (similar to central Government). Debt servicing is not passed on to the consumers of these lower service level schemes. However, they still have to contribute the full cost of labour (typically 30-40% of the investment cost) and operate and maintain the schemes on their own.

Cost sharing by users has promoted financial sustainability to water supply systems. The costs appear to be affordable for these projects at around 3.5% to 4.0% of the average annual income. While most consumers can probably afford to pay the present level of water tariffs, the possibility of increases in future years could lead to problems in terms of affordability. This should be minimised as the Price Bureau regulate pricing to protect the interests of both consumer and provider.


The Chinese Government has implemented partial user-financing (between 40% and 75%) of the overall capital cost as well as 100% of the ongoing operation and maintenance costs to inculcate the sense of “ownership” and responsibility for ongoing maintenance of the water supply and sanitation facilities. The key to the success of this example is that an increase in the level of service accompanied the additional costs as well as the government’s willingness to price water services at a financially sustainable level. These conditions are not met in many other countries, including Australia, where subsidies are common in public utility services, especially between metropolitan and rural water supply systems (WSP 2002; Gomez-Ibanez 2003).
2.2.6 Government Obligations

Regardless of a country’s available resource, its government has an obligation to ensure that the minimum essential level of a right is realised. *The Right to Water* (WHO 2003) ascribes the following three duties to government.

2.2.6.1 Duty of Respect: Not Going Backwards

The right to water may be realised, partially or fully, as a result of a person’s own actions, government assistance or a combination of both. For example, where the means exists to obtain drinking water, such as government maintaining a water supply infrastructure system or providing social assistance to purchase water services, the removal of such mechanisms should not be permitted (with the exception of severe economic conditions or where an adequate alternative is available). A person must never be placed in a situation of having no water (WHO 2003).

2.2.6.2 Duty to Protect: Regulation of Third Parties

Individuals and corporations have the potential to interfere with a person’s or community’s water supply. The duty to protect requires that governments diligently take all necessary steps to ensure that the sufficiency, safety, affordability and accessibility of water are protected from interference. For example, pollution from factories, farming or sewage can greatly damage the quality of water used by others for drinking. This will usually require a strong regulatory regime that should include independent monitoring, genuine public participation and imposition of penalties for non-compliance (WHO 2003).

2.2.6.3 Duty to Fulfill: Going forward

This requires that governments take active steps to ensure that everyone enjoys the right in the shortest possible time. Steps may include the use of a range of appropriate low-cost technologies, education concerning hygienic use of water, protection of water sources and methods to minimise wastage (WHO 2003).

2.2.7 Other Stakeholders

Governments have the primary responsibility for ensuring that the right to water is achieved, but the involvement of other stakeholders plays an important role. To guarantee that water is a human right, governments and local communities need to work together in its fulfilment. For example, individuals contribute financially, by way of payment of an affordable fee for connection to safe water and method of disposal of wastewater and in other ways (in kind) to ensure the realisation of their water rights (WHO 2003). Financial institutions play an important role through their financing and influence on the use of domestic resources by national authorities. Their influence may also contribute towards ensuring programs are non-discriminatory, viable and sustainable (WHO 2003).
2.3 NATURAL OCCURRENCE OF WATER

Water is the most widespread resource to be found in the natural environment and many human activities affect its distribution, quantity, and quality. The natural water cycle is a complex system; from the climate system that drives it and the materials that water flows across and through, to its modification by human activities. Nature has recycled and reused water for millions of years through the natural water cycle. The first step towards efficient and sustainable use of water is an understanding of the distribution of water, the natural water cycle and the mechanisms for transfer, storage and treatment to provide water to communities.

2.3.1 Water Distribution

Water is available everywhere in different forms and amounts. Scientists believe that the total amount of water on Earth has remained almost exactly the same since the beginning of time (Burgess 1991; Starr 1993). However, while the total quantity of water on Earth never changes, the demands placed on it and associated pollution is increasing (Fleming 1999; Schoenfeldt 2000; GTZ 2001). For example, twenty-five nations are experiencing chronic water shortages and contaminated waters cause almost 80% of the illness in developing countries (Starr 1993). However, a key issue is that most of the Earth's water is non-potable (refer Figure 4).

Of the Earth’s water, 97.5% is salt water found primarily in the oceans that cover 75% of the earth's surface. Seawater, ice caps and brackish groundwater are large resources not currently utilised to the fullest, mainly because of limited technology and/or its cost effectiveness. The remaining 2.5% is freshwater, almost all of which is stored in the ice caps of Antarctica and Greenland, and as groundwater. Only 0.26% of the total amount of freshwater is renewable (active) and is concentrated in lakes, reservoirs and river systems where it is vital for water ecosystems as well as being easily accessible for use by society.
2.3.2 Distribution of Active Water

The management of water resources is further complicated by the fact that the active portion of the world’s freshwater is not distributed equally across the continents as shown in Table 5. The distribution of water is influenced predominantly by climatic and geomorphological conditions.

Table 5 Distribution of Rainfall & River Discharge for Continents

<table>
<thead>
<tr>
<th>Continent</th>
<th>Average Annual Rainfall (mm)</th>
<th>River Discharge (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>600</td>
<td>5</td>
</tr>
<tr>
<td>Africa</td>
<td>900</td>
<td>10</td>
</tr>
<tr>
<td>North America</td>
<td>1200</td>
<td>15</td>
</tr>
<tr>
<td>South America</td>
<td>700</td>
<td>8</td>
</tr>
<tr>
<td>Europe</td>
<td>1500</td>
<td>10</td>
</tr>
<tr>
<td>Asia</td>
<td>700</td>
<td>6</td>
</tr>
</tbody>
</table>

*NOTE: This table is included on page 21 of the print copy of the thesis held in the University of Adelaide Library.*

After Schoenfeldt (2000)

Australia’s average annual rainfall and river discharge are both significantly lower than that of other continents. On a global scale, Australia (together with Southern Africa) experiences higher runoff variability than any other continental area (McMahon & Mein 1986; MDBC 1997). Australia's climate, compounded by the variability of its rainfall, means that entire river systems are subject to considerable variation (fluctuation) in flow from one year to another. Despite these facts, many researchers (Clark 1987; GSA 1999; Schoenfeldt 2000) argue that Australia has enough water for present and future needs provided careful, flexible and innovative development of social infrastructure leads to sensible use of available water resources (ie. natural and recycled). The challenge will be to determine if Australia also has enough water to adequately allow for the natural environment to survive (ie. maintenance of a sustainable ecosystem).

2.3.3 Natural Water Cycle

It is important to understand the natural water cycle and the mechanisms for transfer, storage and treatment of water when studying questions of efficient and sustainable use of water. All water is part of the “natural water cycle”, which is vital for sustaining the environment and human life. The natural water cycle describes the permanent movement and transformation of water. It connects living things with all elements of the environment in a manner that any changes result in a chain of consequences which spread throughout the ecological system (Jermar 1987). Figure 5 is a simplified illustration of the natural water cycle and the processes by which water continuously circulates from the oceans to the air, over the surface of the land and underground, and back to the oceans. This process consists of evaporation, precipitation (rain), interception by vegetation & evaportranspiration, surface storage, infiltration & percolation and surface runoff (streams, overland flow) and groundwater flow.
Part I Our Water Resources

Figure 5  Natural Water Cycle (Pidwirny 2004)

Energy from the sun causes water to evaporate from the world’s open water surfaces (such as the ocean, rivers, lakes and wetlands). Water in the form of precipitation falls back to the surface, either as rainfall or snowfall after being intercepted by vegetation and other obstructions such as buildings, and then begins to infiltrate the soil. The amount of infiltration depends on the characteristics of the soil and catchment. Water that does not infiltrate the soil may pond on the surface or collect to form streams which discharge into wetlands, lakes or the ocean (WA WRC 1986). Ponded water is then recirculated back to the atmosphere as evaporation and the cycle begins again. This simplified order of events does actually take place, although the cycle is very complicated and frequently has many mini loops and u-turns in it. For example, water may by-pass part of the system by falling as rain directly into the sea, a river or lake. Through this natural water cycle, the Earth has recycled and reused water for millions of years.

Wide variations exist in the rate at which the water moves through the cycle (Brassington 1983), both in spatial and temporal distribution (Pigram 1986) and this affects availability of renewable (active) water for sustainable use. For instance, the period for complete recharge of oceans takes about 2500 years, for groundwater some 1500 years, while water storage in lakes is fully replenished in 17 years and in rivers about 16 days (Shiklomanov 1999). Importantly, in the process of turnover, river runoff is not only recharged quantitatively, its quality is also restored. Water will only return to its natural purity when humans stop contaminating rivers (Pidwirny 2004). The speed at which water moves through the water cycle controls how quickly these human-induced effects come about.

Water required for humans, stock and pasture has traditionally been withdrawn from the natural water cycle system from three renewable (active) freshwater sources; rainwater, surface water and groundwater. Generally, the closest, most accessible or highest quality sources of water are developed first. However, the natural water cycle is disrupted when human land usage intensifies.
2.3.4 Water Harvesting

For thousands of years, people lived in relatively small communities where change occurred slowly. Water supply needs for communities were met from local sources using simple techniques. Throughout history, engineering works of all sizes have been constructed to distribute water from places of abundance to places of need in response to the natural variability of water occurrence, i.e., water not being present at some locations and times where and when it is needed. These include river regulations, storage reservoirs (dams and aquifers), and transfers by large pipelines or canals. To meet increasing demands from agricultural, social and industrial sectors, more extensive water infrastructure is usually developed. Table 6 below lists typical man-made water infrastructure and its effect on the movement of water through the natural water cycle.

Table 6  Effects of Water Supply Development on the Natural Water Cycle

<table>
<thead>
<tr>
<th>Water Infrastructure</th>
<th>Effect on Natural Water Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam and Reservoir</td>
<td>Delays and restricts surface water flow. Modifies riverine environment downstream.</td>
</tr>
<tr>
<td>Bore</td>
<td>Modifies the amount of recharge needed to keep the underground reserves balanced.</td>
</tr>
<tr>
<td>Water Main</td>
<td>Redirects the transfer of water.</td>
</tr>
<tr>
<td>Sewerage System</td>
<td>Redirects the transfer of water (sewage).</td>
</tr>
<tr>
<td>Drainage</td>
<td>Transports excess water away from areas to be protected from inundation.</td>
</tr>
<tr>
<td>Wastewater Treatment</td>
<td>Treats sewage and redirects the transfer of water.</td>
</tr>
<tr>
<td>Effluent Outfalls</td>
<td>Modifies the flow pattern of water and wastewater to the environment.</td>
</tr>
<tr>
<td>Reuse</td>
<td>Modifies the return of water and wastewater to the environment.</td>
</tr>
</tbody>
</table>

Water supply development and management traditionally focused on harvesting renewable (active) water resources from individual aspects of the water cycle. Much of the water harvested for human activity is eventually returned to the natural system after one use and in some cases such as stormwater systems without being used. However, it may be contaminated making its harvesting and reuse further down the natural water cycle pathway difficult or impossible (Fleming 1999). For example, sewage effluent and stormwater have historically been discharged to the sea or some major water body (AATCE 1998; DEHAA 1999), having an adverse effect on the health and amenity of receiving waters. This separate approach to water supply development has resulted in a number of quite separate fields of water science. Better understanding has resulted in an emphasis on integrated water resource management to achieve sustainable water resource development and use.
2.4 WATER ALLOCATION & USE

Water is a finite resource to be equitably and sustainably allocated, firstly to basic human needs, secondly to functioning of aquatic ecosystems, and then to different economic uses (GTZ 2001; WSP 2002; WHO 2003). The primary objective of water supply infrastructure is to ensure the necessary quantity and quality of water is available where it is needed to support the user demands. That is, the provision of water for people (urban demand), food (agriculture), nature (environment), and other uses (industry). Apart from sustaining life of communities, water is fundamental to almost every economic activity. Therefore, understanding how water is used in each country is essential to effectively plan for present and future needs of water users of that community.

2.4.1 Water Use by Continent

Human use of the world’s limited natural freshwater resources (being 0.26% of all water) has escalated over the centuries, due to both population increases and per capita water use increases (NCIE 1993 and CSIRO 2003). At present, some 70% of the world’s water use is used for irrigation (WHO 2003), 20% is used by industry, and 10% goes to people and houses (NCIE 1993; Brown 2002; World Bank 2003). The pattern of water use varies greatly from country to country, depending on levels of economic development, climate and population size. Africans, for example, devote 88% of their water use to agriculture (mostly irrigation), while highly industrialised European country’s allocate more than 50% of their water to industry and energy (hydroelectric) production (NCIE 1993). In arid countries and regions, such as Australia, the Middle East and south western United States, where rainfall is low, evaporation is high and crops must be irrigated most of the year (Akkad 1990) agricultural water use is often high (WHO 2003). Figure 6 shows the average per capita water use (including irrigation) by continent, with Australia having the highest water use per capita compared to the other continents.

NOTE:
This figure is included on page 24 of the print copy of the thesis held in the University of Adelaide Library.

Figure 6 Per Capita Use (inc. irrigation) by Continent (QLD DNR 2000)
The high level of per capita water use in Australia is a reflection of several factors including, the predominantly arid climate extending over most of the country, the pattern of water use between economic sectors (ie. more than 70% of water use for agricultural irrigation), the level of optimal water and sanitation coverage approaching 100% of the population, the inexpensive price of water for drinking and agricultural purposes, and a relatively small population (for area of land) exhibiting controlled growth. Australia has invested in large-scale water supply infrastructure for agricultural production which produces food for local consumption and for export and trade. Nevertheless, Figure 6 implies that there is potential for increasing water use efficiency to ensure sustainable limits are achieved in a water scarce country like Australia as Australia is a comparably extravagant user of water resources.

2.4.2 Water for People (Urban Demand)

Demand for water from urban populations often competes with those of other major water users such as irrigators, industries and natural ecosystems. Recognising water as a basic human need, and a human right, entitles everyone to sufficient, safe, physically accessible and affordable water (as discussed in section 2.2). The global target for populations currently unserved (ie. without access to sufficient water) is provision of ‘basic access’ being 20 Lpcd compared with optimal access’ being 100-200 Lpcd (WHO 2003). The quantity of water required within households to meet basic health and sanitation needs (ie. indoor uses, excluding gardening) is well established. Sadly many people in the world, currently without access to water to meet basic health and sanitation needs, will not realise the goal of home access in the medium-term.

In other parts of the world, particularly industrialised countries, where water is readily accessible via large scale water developments, at little or no cost to the user, past respect (ie. consciousness) for water is commonly replaced by extravagant use. Today, in many industrialised countries, there is a significant difference between the amount used and the level needed. Further, with many communities around the world approaching or reaching the limits of their available water supplies, urban areas must alter the way in which water services are provided in order to be more sustainable (Newman & Mourtiz 1992; Fleming 1999; COA 2001). Smaller and/or locally based organisations such as community groups and local government, are often portrayed as having better records on sustainability, but are inherently limited in scale (Davis & Iyer 2002).

Urban water demand can be separated into domestic (people), industrial, commercial and institutional (public parks and gardens) use; however, only about 10% of the total water use demands high purity for drinking, cooking and other purposes. In Australia, urban centres are the second largest water use sector (after irrigated agriculture) accounting for about 12% water use (COA 2004). Urban water demand is subject to uncertainty being influenced by many factors; including population growth, consumer behaviour, household formation rates and density, business activity and climate (McLaren et al. 1987; WRSCMA 2001). For example, in Australia between 30% and 50% of the mean annual household water use is for garden watering (Pigram 1986) compared with 3% in the United Kingdom (COA 2002). This level of non-essential water use presents an
attractive target for demand management (Murray-Leach 2003). By managing demands for non-essential water uses (i.e. not required to meet basic health and sanitation needs), the potential exists for households to conserve water and support continued population growth. Chapter 3 provides a detailed examination of challenges facing the Australian urban water industry.

2.4.3 Water for Food (Agricultural Irrigation)

Irrigation plays an important role in producing enough food to meet global needs of a growing population. Irrigated agriculture accounts for nearly 20% of land under cultivation and produces 40% of the world’s staple foods (WHO 2003; World Bank 2003). It is also the world's largest user of water accounting for 70% of global water use (World Bank 2003). The benefits of irrigated agriculture to a country include increasing the commercial value of the irrigated produce, the ability for the population to grow, and food security for the country. The area of irrigated land worldwide nearly doubled between 1900 and 1950 and more than doubled again between 1950 and 1990 (NCIE 1993; Fleming 1999). Further expansion of irrigated agriculture to new lands is unlikely in many countries (GTZ 2001; Lamm 2002).

In Australia, the area of irrigated crops and pastures is only 0.4% of the total area of agricultural holdings (MDBC 1997) but accounts for more than 70% of water use (COA 2004). Irrigated agriculture represents 22% of total exports from Australia or around $33.6 billion per annum (COA 2004) with almost 50% located within the Murray-Darling Basin as shown in Figure 7.

NOTE:
This figure is included on page 26 of the print copy of the thesis held in the University of Adelaide Library.

Environmental issues associated with irrigated agriculture are complex with far-reaching effects, particularly in terms of land and water salinisation. These interrelated problems threaten the viability of irrigated agriculture in the Murray-Darling Basin (MDBC 1997; Marohasy 2003). This water use sector offers the largest potential in terms of total volume of water savings that could be shared with other water use sectors. Rural communities can expect reduced agricultural output as water is returned to the environment and some agricultural land retired (Marohasy 2003). However, this debate is outside the scope of this investigation.
2.4.4 Water for Nature (Environment)

Environmental water requirements refer to the water requirements needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity. Water dependent ecosystems include water courses, wetlands, flood plains, estuaries, and aquifer systems. The social, economic and ecological wellbeing of a community depends not only on water quality and quantity, but also on maintaining the integrity of the ecological processes and diversity in these ecosystems. Past human development and practices have left the current generation a legacy of degraded water bodies and associated water dependent ecosystems that require remedial actions. Increasing levels of extraction from water resources, and the impact of stormwater and wastewater disposal in the water courses have contributed to these changes.

Deep public concern has been a major factor in generating political interest in the environment. There has been an increase in the level of wastewater treatment and a movement away from discharges to inland waterways (COA 2001). However, the condition of many ecosystems is still at risk of further deterioration (Pigram 1986; MDBC 1997; Fleming 1999; GSA 2000). The lesson is that there are limits to the sustainable use of our water resources and their dependent ecosystems. The environment is a legitimate water user (Fleming 1999) and is recognised as an important part of water allocation and management processes that balance social, economic and environmental needs. Water for the environment includes aquatic biodiversity, environmental flow requirements, water pollution control, and wetlands management (World Bank 2003). The allocation of water for the environment is an issue of socio-economic and environmental significance representing a major investment by the community. It has become an important policy issue in the Murray-Darling Basin, as outlined in Example 3 below.

Example 3 Water for the Environment: River Murray, Australia

In November 2003, State and Federal governments agreed to return up to 500 GL of water to the River Murray. While less than the 1,500 GL recommended the quantity is nevertheless significant. The water will be bought back from irrigators and can be expected to cost Australian taxpayers in excess of $600 million at current prices for irrigation water. This is not the first time that water has been given back to the River Murray. For example, the Barmah forest has enjoyed an environmental flow of 100 GL per year since 1993. Under the current plan, an additional 105 GL will bring the allocation to 205 GL per annum. This represents an investment of approximately $246 million for watering this forest.


In Australia’s national context, the level of water required for sustaining aquatic ecosystems, including their processes and biological diversity, is a subject of ongoing national debate, but will most likely be sourced from within the current irrigation allocation (currently over 70% of water use in Australia). The costs and benefits of allocating water to the environment should be assessed alongside all other options to ensure that the least-cost approach that best meets the requirements is found.
2.4.5 Water for Other Uses (Industry)

The availability of water of appropriate quantity and quality is fundamental to the operations of most forms of manufacturing, a major employer in any region. Water requirements for different industrial processes can vary widely depending upon the particular industrial undertaking, the manufacturing procedures involved, the extent of water reuse, and management practices. Industry is often more concerned with the security and consistency of supply than the actual quality (Polin 1977). The quality of water required therefore varies depending upon the intended use.

In Australia, industrial water use is recognised as a component of urban water supply because the bulk of Australia’s manufacturing industry is located in urban centres. Many firms have expressed a willingness to accept non-potable water, especially if it is available at a lower price (Pigram 1986). Industrial processes can use recycled water or be designed to use less water. Water harvesting and reuse within the industry offers another opportunity to reduce potable water demand and has been implemented in many countries including Australia (Fleming 1999).

2.5 URBANISATION & HYDROLOGICAL CHANGE

The natural water cycle is disrupted when human activity intensifies and can result in pollution of the environment. Table 7 below summarises some of the many factors that determine the water quantity and quality in a given location.

Table 7 Basic Parameters of Water Occurrence

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Volume</td>
<td>• Physical indicators</td>
</tr>
<tr>
<td>• Variability (reliability)</td>
<td>- temperature</td>
</tr>
<tr>
<td>• Discharge</td>
<td>- turbidity</td>
</tr>
<tr>
<td>- sediment transport</td>
<td>- true colour</td>
</tr>
<tr>
<td>- velocity of flow</td>
<td>- salinity</td>
</tr>
<tr>
<td>• Runoff</td>
<td>- suspended solids</td>
</tr>
<tr>
<td>- catchment area</td>
<td>• Chemical indicators</td>
</tr>
<tr>
<td>- annual</td>
<td>- pH</td>
</tr>
<tr>
<td>- seasonal</td>
<td>- dissolved oxygen</td>
</tr>
<tr>
<td>- average</td>
<td>- biological oxygen demand (BOD)</td>
</tr>
<tr>
<td>- minimum</td>
<td>- nutrients (phosphorus, nitrogen)</td>
</tr>
<tr>
<td>- maximum</td>
<td>- heavy metals</td>
</tr>
<tr>
<td>- fluctuation</td>
<td>• Biological indicators</td>
</tr>
<tr>
<td>- bank protection</td>
<td>- algae</td>
</tr>
<tr>
<td>- land use</td>
<td>- bacteria</td>
</tr>
<tr>
<td>• Water table</td>
<td>• Aesthetic indicators</td>
</tr>
<tr>
<td>- depth</td>
<td>- taste</td>
</tr>
<tr>
<td>- fluctuation</td>
<td>- odour</td>
</tr>
<tr>
<td></td>
<td>- floating matter</td>
</tr>
<tr>
<td></td>
<td>• Radioactive indicators</td>
</tr>
</tbody>
</table>
The degree and impact of the operative factors vary depending on the type and characteristics of the source involved. The effects of human activities on the quantity and quality of water resources is felt over a wide range of space and time scales because these two dimensions are so closely linked.

### 2.5.1 Impact on Quantity

For many millennia, people lived in small communities and depended on their immediate environs for sustenance. Adverse environmental impacts, if any, occurred locally and went relatively unnoticed because the natural ecosystems were able to assimilate these local impacts (Fleming 1999). However, to make land available for agriculture and urban development involves removal of vegetation and wetlands. Urban centres tend to decrease evapotranspiration, increase stormwater runoff, and decrease infiltration to groundwater (WA WRC 1986). These effects are shown in Figure 8.

**Figure 8** Impact of Urban Areas on Natural Water Cycle Processes
Urban catchments are more efficient in shedding water from their surfaces than the natural landscape. The consequences of urbanisation on the water environment are (O'Loughlin et al. 1992):

- a higher proportion of rainfall runs off as stormwater;
- flow travel times are shortened due to low resistance to flow over surfaces that are smoother than natural and vegetated surfaces;
- dry weather flows in urban watercourses have been altered in their timing, quantity and quality; and
- capacity of higher flood flows and volumes to wash off and transport solid materials (ie. soil, litter) into receiving waters.

From the viewpoint of water quality and resource management, the increases in stormwater runoff and transport of solid materials are generally viewed as undesirable. The need to control the impact of urban development on the natural water cycle, with respect to quantity and quality of resources, increases as the scale of urban development increases. An outcome of urban development is management and disposal of stormwater runoff and sewage effluent, commonly referred to as ‘urban wastewaters’. Drainage systems are constructed to transport urban wastewaters away from urban centres to a point of discharge, sometimes impacting on the surrounding environment.

The increase in quantity and rate of stormwater runoff is associated with the extension of impervious areas and the introduction of gutters and stormwater pipes (Tomlinson et al. 1993; Clark e. al.1997; Codner et al. 1988). The corresponding decrease in catchment storage resulted in traditional stormwater management to be focused on flood control by way of formal drainage systems. These systems are efficient conveyers of stormwater and the pollutants therein to where they discharge (Clark et al. 1997; Hunter 1997). These phenomena can be observed in the shapes of the runoff hydrographs of two adjacent catchments, Giralang (urban) and Gunghalin (rural), in Canberra for one rainfall event in February 1981 presented in Figure 9. The peak flows observed from the urban catchment are three times higher and linked closely to the intensity of rainfall (ie. occurred earlier) in comparison to the runoff from the rural catchment.

NOTE: This figure is included on page 30 of the print copy of the thesis held in the University of Adelaide Library.
Natural catchments have become effectively camouflaged by urban development. The cost of the traditional approach to stormwater management is now apparent and the side effects of the engineered solution, while ignored in earlier decades, are now perceived as having adverse impacts on other resources (O'Loughlin et al. 1992). The quality of urban stormwater depends on factors that include population density, land use, sanitation and waste disposal practices, soil types, climate and hydrology. In some cases, the changed hydrology will open opportunities for water reuse, particularly stormwater runoff and treated effluent, as volume of the urban wastewaters grows in proportion to the size of the urban centre.

Urban environments can be designed to make the most effective use of their rainfall and local water resources (WA WRC 1986). New water systems must be planned and designed with regard to long term sustainability. Many researchers conclude that a condensed village-style urban form is more sustainable than continued sprawling development patterns (Newman & Mouritz 1992; Hickinbotham 1997; Fleming 1999; Davis & Iyer 2002). Technology to support this concept is emerging, as are the new management approaches such as water-sensitive urban design, total water cycle management and integrated catchment management.

2.5.2 Impact on Water Quality

Contaminants can be introduced into water from various sources throughout the water cycle. The decline in the quality of drinking water sources became a concern when population growth and industrial development produced a concentration of society’s wastes that imperilled public health. As a consequence, acute waterborne diseases, such as cholera and typhoid fever, were common in the late 1800s and early 1900s. Potential sources of contamination to water resources are numerous and can include the application of pesticides and fertilizers to cropland, direct discharges from sewage treatment plants, industrial facilities, and stormwater drains.

The quality of urban stormwater, for example, depends on factors that include population density, land use, sanitation and waste disposal practices, soil types, climate and hydrology. Impervious surfaces associated with urban development, such as roads, inadvertently collect quantities of solid materials. The collected solid material can include contaminants from roads, motor vehicles, litter, atmospheric dust, and nutrients from parks and residential gardens (Codner et al. 1988). These pollutants are washed off the surface by rainfall and runoff (Tomlinson et al. 1993; Hunter 1997) into other receiving water bodies such as rivers, lakes, estuaries or the sea. From here, the contaminants may be diluted, concentrated, or carried through the cycle with the water. However, the concentration of contaminants finding their way into water bodies is greater from urbanised areas because of the increased rate of runoff (see Figure 9 above). The pollution entering the receiving water bodies may cause damage to the aquatic environment for which the remedial costs are difficult to quantify in monetary terms.
Example 4 below shows how a contaminant, in this case methyl tertiary butyl ether (MTBE), can be introduced throughout the water cycle. MTBE has been added to petrol to replace lead since 1979 in the United States. This practice has resulted in air quality benefits; however, it has also produced water quality problems. MTBE is not added by Australian domestic refineries; however, it may be present in imported supplies (Duffett pers. comm. 2004).

Example 4 Water Contamination & The Water Cycle: MTBE, USA

Methyl tertiary butyl ether (MTBE) is used as an additive in petrol as a replacement for lead to reduce emissions of carbon monoxide and organic combustion products in concentrations up to 15%. Its use has resulted in reports of significant improvements in air quality; meanwhile evidence of its detrimental effect and contamination of drinking water supplies is mounting. Exposure to MTBE can occur through ingestion of potable water and recreational water. In addition, inhalation and skin absorption can occur when individuals shower with contaminated water. Although concentrations found in water supplies examined in the study were nearly all below the thresholds for taste and odour and health effects, the presence of MTBE is still a concern. Compared with other components of petrol, MTBE is more difficult to remove from contaminated water.

The main sources of localised MTBE contamination of groundwater supplies are leaking underground storage tanks and pipelines, spills, and MTBE manufacturing sites. The primary sources of MTBE in urban surface water supplies are releases from recreational watercraft and atmospheric deposition through precipitation of industrial or vehicular emissions. Atmospheric deposition in areas where MTBE is used may also result in a non-point source for the transport of MTBE into shallow groundwater. Stormwater contaminated with MTBE from petrol leaks and spills may also contribute to groundwater or surface water pollution. The potential pathways of MTBE contamination of the environment are summarised in Figure 10.

Figure 10 Pathways for MTBE contamination (Gullick & LeChevallier 2000)

Source: Gullick & LeChevallier (2000)
MTBE is of concern to the water industry because of its strong taste and odour effects, potential risk to human health, tendency to migrate rapidly in groundwater, and resistance to conventional water treatment processes. This example shows that availability of drinking water, in terms of quality, is open to change, depending on the treatment methods used and most importantly the constituents found in the source water (ie. its quality). Accordingly, the natural water cycle is an important consideration in the development of an effective water quality management strategy to protect water resources. Environmental security can only be ensured by integrated management of all water resources.

2.6 GLOBAL SECURITY ISSUES

Water is expected to be the most sought after natural resource in the 21st century, as continued growth of populations and economies is dependent on the quantity and quality of freshwater resources (Wolf 2003). The world’s growing population remains a stumbling block to global sustainability in terms of food and water. Water is a key element to global sustainability, and is crucial to its social, economic and environmental dimensions (GTZ 2001).

2.6.1 Population Growth

On a global scale, the limited availability of freshwater is a very real problem. Figure 11 shows the threefold increase in the annual water use along with population over a 50 year period (NCIE 1993; Brown 2002).

NOTE:
This figure is included on page 33 of the print copy of the thesis held in the University of Adelaide Library.

Figure 11 Population & Water Use (NCIE 1993)
Current trends indicated water scarcity is likely to threaten up to 50% of the world population in the next generation. Water scarcity is now the biggest single threat to global food production. Almost all of the projected population growth to an estimated 8.1 billion in 2030 and 8.9 billion in 2050 will occur in developing countries (Figueres et al. 2003). It is here that the major food security challenges are centred, as are the water resource challenges, because food is the largest water-consuming activity. For example, the production of every tonne of a food commodity such as wheat requires a water input of about 1ML (Figueres et al. 2003). If the water challenges facing poor communities in water scarce regions can be solved, there is a good chance of doing so in less water-scarce regions.

However, Fleming (1999) pointed out that human impact on ecosystems is not just about absolute numbers of people, but also how society (culture) consumes available resources. For example, many countries experience an increase in per capita water use (reduced water consciousness) where water supply infrastructure introduces people to new uses for water at little or no charge. In addition to economic measures, public awareness, education, and training are key components to changing human values and moving society toward sustainability.

2.6.2 Transboundary Management

The political stability of nations rests largely on their sustained supply of usable water (GTZ 2001). Such is the significance of water that basic principles of allocation and protection were contained early Jewish law (ie. the Bible and Talmudic texts). For example, the Talmud, a code of law written between the third and fourth centuries A.D, recognises public wells and the right for every traveller to use them (Starr 1993). Water scarcity has exacerbated political tensions around the globe, most notably between Arabs and Israelis, Indians and Pakistanis, and all ten riparians of the Nile River (Starr 1993; Wolf 1999).

There are over 260 international watersheds (catchments) and an untold number of aquifers are shared by two or more countries, which creates the potential for disputes (Wolf 1999). For example, Egypt, the last nation the Nile flows past, has little impact or control over the actions of the upstream governments that impact the quantity or quality of water. Management of these shared international water resources is complex as a result of the following factors (Wolf 1999):

- water migration ignores political and country boundaries;
- water fluctuates in both space and time;
- there are multiple and conflicting demands on the use of water; and
- international water law is poorly developed and difficult to enforce.

Water security (access and quality) may be the cause for conflict between countries; however, evidence favours it as a catalyst for cooperation. Wolf (1999) found nations have signed 3,600 water-related treaties since AD 805, while in the same period, there have been seven minor international water-related skirmishes (each of which includes non-water issues). In fact, water allocation is prominent in the existing peace treaty between Israel and Jordan, and the Oslo agreement between Israel and Palestine (Adar 2003).
Management of transboundary water resources must include sharing the available water and maintaining its quality to assure safe yields for future generations. A key element to long-term harmony with nature and neighbour is cooperative arrangements at the water basin level (GTZ 2001). Critical factors for management of transboundary water resources include a shared vision, sustained political commitment, public support and broad-based partnerships (AWA 2000). In Australia, collaborative arrangements are in place between the States for regulation, and equitable, efficient and sustainable use of surface and groundwater water resources that cross state boundaries. Most notably, the Murray-Darling Basin Agreement first signed in 1914 (after 20 years of negotiation) regulates the sharing of water from rivers in the basin to five States.

2.6.3 Climate Change

The impact of global warming and associated climate change is a significant environmental threat facing the world today (CSIRO 2003). During the 20th century, the Earth's temperature increased by an estimated 0.6°C and sea levels rose about 150mm (CSIRO 2003). Most of the warming observed over the last 50 years is thought to be due to human influences. The associated increases in ambient temperatures, droughts and flooding will affect people's health and way of life. Scientists predict that continued increases in greenhouse gas levels will lead to regional climate change. This may impact on the performance of water infrastructure and agriculture to provide food for the growing populations.

Predictions of future climate are imperfect, being limited by uncertainties that stem from the natural variability of the climate, our inability to predict accurately future greenhouse emissions, the potential for unpredicted (ie. volcanic eruptions) or unrecognised factors (ie. new or unknown human influences) to upset atmospheric conditions, and our incomplete understanding of the total climate system. Cock (1992) suggests that the effects of climate change can be predicted by constructing a scenario of 'a plausible future'. The ability of a model to predict the climate of the future can be measured by its success in simulating what is known to have happened in the past. Data that describe significant events in the past provide a test of the reliability of climate models.

The major effect of global climate change in terms of water infrastructure and services is the redistribution and consequent change in availability of regional water resources. In Australia, the mean temperature has increased by an estimated 0.7°C from 1910 to 1999 (CSIRO 2003). The effect of continued warming on local weather patterns is uncertain, however, climate models predict an increase in temperature and evaporation, with a corresponding decrease in rainfall. Even small changes in rainfall can markedly affect what can be extracted on a sustainable basis from natural catchments (Fleming 1999). In addition, changes in local climates may be accompanied by modified demand for water and affect viability of agricultural production in a given region. Actively managing water demand can be insurance for future prosperity and growth, if it balances supply with demand.
2.7 SUSTAINABILITY

There is only one alternative to sustainability: unsustainability (Bossel 1999 in Bell & Morse 2003). Unsustainable use of society’s resources needs to be addressed if society wants to ensure a future where children and grandchildren can provide for all without jeopardising the quality of future life. Intervention at a global level is required to limit environmental threats (such as climate change), to protect human health and safety from hazards, and to protect things which people need or value, such as wildlife and landscapes (Cocks 1992; Newman & Mouritz 1992; Fleming 1999; GTZ 2001; GWP 2003). For example, current trends indicate water scarcity is likely to threaten up to 50% of the world population in the next generation (Figueres et al. 2003). In the 1980s, the concept of sustainability evolved as a forced response to these concerns. Sustainability is essentially all about keeping the options open for the future (ie. the precautionary principle).

2.7.1 As a Theoretical Construct

An understanding of the concept of sustainability is a precondition to assessing the sustainability of management, allocation and use of the world’s water resources. The ‘sustainability movement’ for development was conceived almost 20 years ago; however, the detail of what comprises sustainable development has continuously been the subject of debate. While many definitions have been proposed the central underlying elements of all definitions include changes over time (ie. current and future generations) and balancing use of resources to maintain the environment and support human life. Conceptual models of sustainability are useful to represent interactions between the main components of economic, social and environmental factors. Figure 12 shows two of the more advanced conceptual models, the Sustainability Whirlwind and Sustainability Space Model.

NOTE:
This figure is included on page 36 of the print copy of the thesis held in the University of Adelaide Library.
The Sustainability Whirlwind model developed by Fleming (1999) attempts to demonstrate the importance of strategic planning and an integrated development framework to coordinate activities. At a given point in time, the envelope which describes the potentially achievable degree of sustainability is determined by the state of technology and level of political decision-making. Fleming (1999) concluded a longer and less sustainable path is followed when an unbalanced approach to economic, environmental and social issues is adopted. The Sustainability Space Model (also in Figure 12) developed by Foley and Daniell (2002 in Daniell et al. 2004) differs in that sustainability is measured as satisfying goals on each of three axes while accounting for time, political and technological advances. In this model, sustainability can be maximized by achieving predetermined goals for economic, social and environmental factors in the system under consideration. The point of maximum satisfaction ($S_{\text{max}}$) can move to represent changes in sustainability goals to reflect changing social values, technological improvements or political decisions. Thus, sustainable development is a conscious and continuous reflection; sustainability represents the process itself and not the end point of a process (COA 2002; Bell & Morse 2003). Life is a learning process and our beliefs, values and attitudes are not static but may change so as to alter what we perceive as quality of life.

### 2.7.2 As a Realistic Goal

Although the concept of sustainability appears relatively simple, the task of implementing these principles - indefinitely and planet wide - may actually be an unachievable ideal. Any development expert intuitively knows that no single pattern of development is the most appropriate for all countries of the world at any specific point in history. Human needs and values are culturally and socially defined, therefore sustainable development means different things to different people and will be very context-specific. In order to design appropriate policies for sustainable development, goals must have specific indicators. However, these choices are subjective by nature and dependent on the cultural preferences of an individual, a community or a country. This implies that different societies with differing social, economic and cultural conditions may choose different sustainability criteria, and may even select different paths to sustainability (Raskin et al. 1998 in Figueres et al. 2003). The degree of sustainability that can be achieved is dependent upon the state of knowledge and management decisions of the country. Consequently there is no detailed global blueprint, only a broad statement of philosophy.

While concepts such as integrated water resources management or sustainable development have become popular and are extensively mentioned in national and/or regional policies, their effective incorporation and implementation have proved to be extremely difficult, irrespective of the country concerned (Figueres et al. 2003; Ashley et al. 2004). Rabone (2005a; Appendix 1) conducted a strategic literature review to outline the underlying conceptual issues and relevant aspects of sustainability associated with the provision of effective and water services to urban communities that can be sustained over time. As a result of this review, the concept of sustainability being a characteristic of a system has been adopted as the theoretical framework of this research.
2.7.3  Sustainability Assessment Framework

Applying systems of thinking to sustainability is becoming a widely accepted approach. Systems theory offers a good basis to describe and measure whether or not a system is sustainable, at least in relation to key resources of that system (Foley et al. 2003) and the importance of location to overall sustainability (Daniell et al. 2004). It also provides a means to reflect on the links between humans and their ecosystems within an integrated framework, and gives an understanding of the change processes arising from their interactions (Costanza et al. 1993 in Keen et al. 2005). Example 5 describes how systems thinking can be applied to measuring sustainability as a characteristic of a system.

Example 5  Application of Systems Thinking to Sustainability

*Human systems can be large and complex, for example, an industrial region with a high population exports consumer products and imports necessary resources. Other systems may be relatively simple and small such as a sparsely settled agricultural region. In all cases, it is important to identify the boundaries of the relevant system, as well as adjacent systems which interact with the one being studied (see Figure 13). The various components of the system and their interactions also need to be identified.*

![Diagram](image)

**Figure 13  System Representation (Foley et al. 2003 in Daniell et al. 2004)**

*To understand how any system behaves it is necessary to focus on the system resources. These include natural resources, human resources, financial resources and manufactured resources, i.e. physical infrastructure and manufactured goods. The condition or state of the system can be expressed quantitatively in terms of a number of key variables that express quantity and quality of resources. These will alter over any given time increment, either increase, remain unchanged or be depleted, as the system processes the resources. The magnitude of the changes will depend in part on system characteristics such as processing efficiencies or ability to adapt to change, and partly on the management strategy adopted. The sustainability of a system depends on the level and quality of the key resources, and on the ability of the system to function effectively over time, without exhausting these resources.*

*Source: Foley, Daniell & Warner (2003)*
Renewable resources, such as water, should be used in ways that do not endanger the viability of the resource or cause damage or pollution to the environment (Cocks 1992; Fleming 1999). Importantly, a systems theory framework does not limit the assessment of sustainability solely to the maintenance and management of natural resources but also incorporates human resource, semi-permanent infrastructure of society and consumable products. Manufactured resources exist in all human systems and play an essential role in processing resources within a system (Foley & Daniell 2002). For example, the sustainability of the water supply system for a township is reliant on the infrastructure within the system. If the infrastructure fails it would affect the ability of the township to continue to function satisfactorily. Similarly, accepting sustainability as a characteristic of a system does not mean denying the use of non-renewable resources like oil and gas, but ensuring efficient use and that alternatives are developed to replace them (Cocks 1992).

A limitation of the application of systems theory is defining the boundaries of any system, ie. those parts and interactions that are 'inside' as against 'outside', as these are always subjectively determined by the human observer (see Figure 13). Groups or individuals identifying ostensibly the same system will typically set differing boundaries and so perceive a slightly different system (Keen et al. 2005). This is because a system does not exist as a 'thing in the world' but a 'system of interest' to an individual, community or country (Dyball pers comm. 2005). In other words, systems are relationships between variables selected by an observer and, at least in part, are a result of the tradition of understanding the observer (Dyball pers comm. 2005). Systems are interrelated and dynamic with many elements. For these reasons, explicit definition of the system boundaries may be subject to debate and sensitivity analysis to determine the influence of decisions on the perceived sustainability of the system is warranted.

2.7.4 A Question of Ethics & Values

Sustainability is a complex ethical issue; there is no easy answer or quick fix. The primary goal of a sustainable individual, community or country is to meet 'basic resource needs' in ways that can be continued in the future. While it is logical to determine the 'basic resource need' and how to meet those needs effectively, this does present some difficulties, particularly where there is a significant difference between the traditional amount of water used and the basic level needed. For example, Foley & Daniell (2002) estimate an average South Australian household without efficient fixtures or conservation attempts would use 175Lpcd whereas a water-conscious household would require about 100Lpcd (ie. equivalent to optimal access – see section 2.2.2). Another Australian review quoted 50Lpcd (ie intermediate access) as the basic water requirement for drinking, sanitation, bathing and cooking (COA 2002).

So then, what exactly are the 'basic resource needs' of the present Australian generation as against the 'wants' or 'desires'. More importantly, is the Australian society at large likely to agree on the present 'basic resources needs' (ie. Sust_{max}) particularly, where restrictive behavioural change is required.
Another impediment of the sustainability debate lies in the difficulty of predicting what ‘people of the future’ will need, i.e., what resources will be valued and how they will be balanced at that time. There is also debate on which ‘people of the future’ or how many generations ahead should we consider (i.e., our grandchildren or those inhabiting the Earth in 500 years). Some have visualised various horizons (influence, attention and responsibility) that link time and space in sustainable development framework (see Figure 14).

**Figure 14  Horizons of Sustainability (Bossel 1999 in Bell & Morse 2003)**

Further complicating our understanding is the behaviour of humans themselves; they do not necessarily respond the same way when subject to the same influences. The reactions can vary greatly across space and time in response to changing values, contexts, incentives or understandings (Keen et al. 2005). The demand on a system’s resources can be reduced by using efficient technologies, optimising the use of resources that exist within the system, reducing the dependence on adjacent systems, maximising the ability of the system to adapt to changing resources levels over time, and maximising the reuse of resources within the system (Foley et al. 2003). However, an individual, community or country may reject the required behavioural changes to accommodate the transformation to a more sustainable system. Answers rest not only on scientific knowledge but also on value judgements on issues such as 'quality of life'. Education in all its forms will be essential to sustainable development because it can increase the capacities of people to transform their visions of society into operational realities. Human values are a driving factor in sustainability; consequently, learning to reconcile different perspectives will be an important element in moving towards a more sustainable point.
2.7.5 *Are we getting there?*

For any intervention to be effective it must have a plan for sustainability and equity built into the design, and some means of verifying the progress achieved once implementation gets under way (WSP 2003). Sustainability, like democracy or progress, is difficult to define and measure. Particularly, as a researcher is not separate from the researched (ie. an objective and natural observer) but has an integral relationship with the system being observed (Bell & Morse 2003). Nevertheless, society naturally needs to know whether an investment is (or has been) successful in terms of achieving the desired outcome or change. Even if the starting point is a statement of intent (rather than precisely defined) the requirement for implementing measures forces a critical analysis of what needs to be done, by whom, where, for how long and when.

2.7.5.1 **Link to Decision-Making Process**

There is not much point finding out at the end whether or not the investment achieved sustainable and equitable outcomes. For instance, what questions should be asked to determine whether a proposed water infrastructure development will be sustainable or not? This is further complicated because often what is appropriate for one part of a city or region may not be a *sustainable solution* for another area once all the lifecycle impacts are taken into account. Progress towards sustainable water services requires integrating the understanding of the dimensions and their links into the decision-making process. Table 8 sets out the five interrelated dimensions of sustainability, each with specific equity perspectives, in relation to providing sustainable water services to a community.

**Table 8  Dimensions of Sustainability (WSP 2003)**

NOTE:
This table is included on page 41 of the print copy of the thesis held in the University of Adelaide Library.

*Source: Water & Sanitation Program (2003)*
Tools are available for analysis of environmental impact and resource utilisation, risk assessment and economic evaluation; however, methods for evaluating socio-cultural and functional criteria must be further developed (Ashley et al. 2004). Regardless of people's understanding of, and commitment to, sustainability outcomes, the institutional frameworks of society need to facilitate actions in keeping with sustainability (Harding 2005). Beyond these structural arrangements, economic and regulatory drivers are also needed to facilitate decisions in favour of sustainability outcomes. However, gauging the sustainability of an intervention or development before it has actually resulted can only be hypothetical at best. By accepting sustainability as a characteristic of a system rather than the end point of a process, the concept of change (ie. resource levels and levels of use) can serve as a gauge of progress towards sustainability goals (ie. Sust\textsubscript{max}).

2.7.5.2 Gauging Progress

Tools and methodologies designed to help gauge progress towards sustainability exist, such as the concept of an ecological footprint based on the carrying capacity of the environment. But perhaps the most popular approach has been the use of indicators and indices (ie. a combination of more than one indicator). Indicators, whether qualitative or quantitative, are in fact used on a day-to-day basis by people for making decisions. For example, a blue sky in the morning indicates that the weather will be good and a T-shirt can be worn (Acton 2000 in Bell & Morse 2003). Indicators and indices also have a long record of use in the economics field. Here numbers that represent dimensions of change are used as measures to show; direction of change (space), pace or rate of change (time), scale of change (order of magnitude).

Therefore, the use of indicators to gauge progress towards sustainability may seem obvious; however, there are a number of key questions related to their development and application. These include (Bell & Morse 2003):

- What indicators should be selected to measure sustainability?
- Who selects them?
- Why are they selected?
- How are the various dimensions of sustainability balanced?
- How are the indicators measured?
- How are the indicators interpreted and by whom?
- How are the results communicated, to whom and for what purpose?
- How are the indicators to be used?

The above questions serve to highlight the complex and unbreakable connection between the 'concept of sustainability' and people. Inevitably, each sustainability indicator reflects the base discipline (ie. environmental management, economic, engineering, etc.) from which it was developed. Whether we like it or not, sustainability is all about people and the difficult issues of multiple perspective and public participation are not optional extras to be tagged onto a science-based analysis; they are central to it. The decision is how to achieve this in practice. There still remains a gap between the generation of the indicator frameworks and putting these into practice in order to influence policy and behaviour.
It is not enough to just report the outcomes of an agreed monitoring program. It is also important to objectively analyse (evaluate) the observed change (or shift) and determine if this is good, bad or irrelevant. In other words, tracking change is an iterative process and relies on monitoring, evaluation and reporting (i.e. communicating the change). Condensing complex information to allow digestion and interpretation by non-specialists, such as the public, politicians and decision-makers, is clearly desirable.

2.7.5.3 Communicating Progress

Despite being a vital part of people's lives, the term ‘indicator’ conjures up the idea of numbers and statistics that can only be used by specialist technocrats. Fortunately, indicators can be condensed and translated into less threatening visual forms for communicating change with non-specialist audiences (public, politicians and decision-makers). Figure 15 presents a relationship between data, indicators and indices.

NOTE:
This figure is included on page 43 of the print copy of the thesis held in the University of Adelaide Library.

Figure 15 The Information Pyramid (Braat 1991 in Bell & Morse 2003)

The basis of the communication device employed is bound up with the uses to which it will be put (i.e. compliance, awareness, performance, alerting, or review). That is, tailoring information to suit the intended target audience to take some action (intervention). Scientists and technicians are primarily interested in data presented as tables, graphs or raw uncondensed data. Decision-makers and managers typically require some condensation of data, primarily in terms of how it relates to goals and targets, which is capable of being unpacked to reveal underlying data. The public often prefer highly aggregated data and visual devices.

A number of effective communication devices are available to increase clarity for users including; tables, graphs, traffic lights, report cards, scorecards, simple arrows, GIS maps, spider webs, pyramids and the like. However, it is important to remember they are not tools for assessing progress towards sustainability but simply a way to communicate direction of change. Yet supplying information in a condensed form does not mean that the public, managers or policy-makers will act on it. In comparison to unemployment and crime rate indicators, government response linking sustainability indicators through policy is still in its infancy.


2.8 SUMMARY

Water scarcity is one of the most important issues facing the world today. Water is expected to be the most sought after natural resource in the 21st century. Although water is available in different amounts everywhere on earth and the total quantity never changes, the demands placed on are constantly increasing (Fleming 1999; Schoenfeldt 2000; GTZ 2001). Current trends indicate water scarcity is likely to threaten up to 50% of the world population in the next generation. The effect of continued global warming on local weather patterns is uncertain; however, climate models predict an increase in temperature and a decrease in rainfall in many areas of the world.

The complex issue of water distribution has far reaching social and economic ramifications. The ecological, social and economic wellbeing of a community depends not only on water quality and quantity, but also on maintaining the integrity of ecological processes and the diversity of these ecosystems. Human use of the world’s limited natural freshwater resources has escalated, due to population increases and per capita water use increases (NCIE 1993 and CSIRO 2003). Deep public concern has been a major factor in generating political interest in the environment, including our use of water resources.

Water, poverty and health are closely linked. Lack of safe water leads to many serious diseases and causes almost 80% of the illness in the developing world (Starr 1993). Water supply issues are the biggest single threat to food production today. The majority of population growth over the next generation will occur in the developing world. The growth of economies in the developing world is dependent on the quality and quantity of the freshwater resources they can harvest and supply. To meet increasing demands from agricultural, social and industrial sectors, more extensive water infrastructure is usually developed. Unfortunately, this often leads to extravagant water use.

Water scarcity is one of the biggest social, political and environmental issues currently facing Australia and the world. Reliable water supply is integral to our manufacturing and agricultural industries, which make up a large proportion of the Australian economy. In Australia, urban centres are the second largest water use sector after irrigated agriculture. Between 30% and 50% of the mean annual household water use is for garden watering (Pigram 1986). Compared to other industrialised countries, this is a very high level of non-essential water usage. Our high per capita water use is due to both cultural and physical factors, including the predominantly arid climate extending over most of the country. Cultural factors are very difficult and slow to change. Successful cultural adaptation will not take place until industrialised societies are educated about the impact of their current lifestyles. Unfortunately, in the developed world, consumers are often disconnected with the true value of water because of the ease of supply.
With many communities throughout the world approaching the limits of their available water supplies, traditional water management practices need to be reappraised. Water is a key element of social, economic and environmental sustainability. There is potential for increased water use efficiency to ensure sustainable limits are achieved. Sustainability is a complex ethical issue; there is no easy answer or quick fix. There is a need to aim to meet ‘basic resource needs’ in a way that can be continued in the future, but defining what ‘basic resource needs’ are for this generation and the next poses many problems.

Governments around the world have the primary responsibility for ensuring that adequate access to water is achieved everywhere, but the involvement of other stakeholders at all levels of industry, and the community is vital if this goal is ever going to be achieved. Unsustainable use of society’s resources needs to be addressed if we want to ensure a future where people can continue providing for their basic needs. Although the concept of sustainability appears simple, implementing these principles on a global or local scale poses many difficulties. Smart water use and reuse is vital in meeting our world’s demands. Substantial cultural changes and restrictive behavioural changes as well as strategic investment in appropriate infrastructure will be required, which poses many challenges to governments today.
Part I Our Water Resources
Chapter 3

Water for Urban Australia

“If we are going to stop being the ‘lucky’ country and start being the ‘clever’ country, we must recognise our own particular problems and opportunities. We must be prepared to understand the distinctiveness of our own society”

D. Horne
Weekend Australian May 1991

3.1 INTRODUCTION

Water is one of Australia's largest industries, with assets valued at over $90 billion in replacement cost terms, with some $40 billion of these assets in country areas (Productivity Commission 1999). The overall water service strategy is simple; one pipe system delivers water to consumers, a separate pipe system collects discharged wastewater by them, and a third system transports stormwater away from the urban area. This investment in centralised water systems has improved the standard of living (ie. lifestyle) enjoyed by Australian communities (large and small). Access to continuous (ie. 24 hour) safe and affordable water services has become a normal expectation.

The urban water industry in Australia provides services to 13 million people, however the water supplied to households accounts for less than 10% of all water used (COA 2002). Water supplied to urban centres is used for a wide range of purposes by domestic, industrial, and commercial consumers. Typically, water services have been provided through development of the closest, most accessible, and best quality sources of water. Invariably, there will come a point at which the urban water demand cannot be met from developed resources. Established water systems in many Australian rural centres need to be upgraded just to meet existing demand. In addition, most Australian cities will face challenges over the next 20 years (COA 2002) as competing demands for the water increase.

In Australia, government is responsible for the management of natural and developed water resources to meet the competing needs from irrigated agriculture, households (domestic), industry and the environment. All levels of government have a responsibility to create conditions that bring about optimum use of water resources; that is, measures to modify urban water use patterns to maximise efficient use (ie. conservation) of developed resources. The current water economy is characterised by a sharply rising cost of supplying additional water, more direct and intensive competition among different kinds of users, the high (and rising) cost of subsidising water to rural communities. Over the last decade, the Australian water industry has undergone major reform.
Further extraction or diversion of more water from the environment is not currently supported by Australian communities. Consequently, the Australian urban water industry must adapt to incorporate new supply options, such as water harvesting and reuse or desalination, into water systems serving both established and new urban development. These alternatives represent safe and reliable new water supply that provides insurance against times of droughts or shortages in imported water. They also provide a foundation for maintaining and improving the quality of life in Australian urban and rural communities alike.

3.2 WATER GOVERNANCE

The supply of water for consumption was one of the earliest concerns of government. Water governance refers to the political, administrative, economic and social systems that exist to manage water resources and provide access to water services for domestic and productive purposes. Water infrastructure has been provided to Australian communities through the cooperation of Federal (Commonwealth), State and Local Government. In the Australian context, the global drive to improve the performance of water utilities means more efficient water services (ie. water, wastewater and stormwater) without putting the health, social and economic well-being of the community at risk. To ensure sustainable water use into the future, water governance must take into account all sectors dependent on water supply and not just the supply of urban (drinking) water.

3.2.1 System of Governance in Australia

In Australia, all levels of government (ie. Federal, State and Local) are charged with the responsibility of maintaining a safe, healthy and prosperous environment for their communities (LGA 2000). Table 9 below summarises the relationship between the levels of government and the legislative (law making) powers vested in the Commonwealth and its States. Under Australia's system of government, responsibility for health, water supply (including natural and developed water resources), environment, generally resides in the State and Territory governments. In relation to water resources, the role includes protection, maintenance and, where appropriate, development. However, the local government has the most direct impact on facilities present in any given community.

All stakeholders (water users, water related agencies and government) are susceptible to incentives provided by the institutional arrangements around them. The institutional complexity associated with the three levels of government has resulted in institutional fragmentation within jurisdictions, particularly with regard to implementing and enforcing sustainable water use policy. Health departments, water resources departments, price regulation, agriculture, infrastructure and water suppliers are all involved, however these generally fall under different ministries with limited linkage (integration), either in law or in policy and regulations. This has led to considerable differences in regulation across Australia (Water 2000) and has been a barrier to achieving greater progress towards more sustainable water management in Australia (COA 2002).
Table 9  Relationship between the Levels of Government

<table>
<thead>
<tr>
<th>Federal Government</th>
<th>State Government</th>
<th>Local Government</th>
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<tr>
<td><strong>Exclusive Powers</strong></td>
<td><strong>Exclusive Powers</strong></td>
<td><strong>Statutory Duties</strong></td>
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<td>• defence</td>
<td>• education</td>
<td>(required by law)</td>
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<tr>
<td>• taxation</td>
<td>• health</td>
<td>• town planning and building assessment</td>
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<tr>
<td><strong>Deferred to Commonwealth (overrides State Legislation)</strong></td>
<td>• police</td>
<td>• environmental health</td>
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<tr>
<td>• bankruptcy</td>
<td>• electricity</td>
<td>• fire prevention</td>
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<tr>
<td>• marriage and divorce</td>
<td>• water supply</td>
<td>• dog control</td>
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<tr>
<td>• immigration</td>
<td>• environment</td>
<td><strong>Discretionary Services</strong></td>
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<tr>
<td>• trade (interstate and international)</td>
<td>• transport</td>
<td>• local roads and footpaths</td>
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<td>• external affairs</td>
<td>• main roads</td>
<td>• street lighting</td>
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<td>• foreign, trading and financial corporations</td>
<td>• ports</td>
<td>• traffic and parking regulations</td>
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<td>• telecommunications</td>
<td>• public housing</td>
<td>• stormwater drainage</td>
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<td>• postal services</td>
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<td>• local environmental management</td>
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<td>• national highways</td>
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<td>• waste management</td>
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<td>• interstate industrial arbitration</td>
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<td>• parks, sporting ovals and facilities</td>
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<td>• meteorological observations</td>
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<td>• census and statistics</td>
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<td>• copyrights, patents, and trade marks</td>
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<td>• tourism</td>
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</tbody>
</table>

Compiled from information available at the following Web Sites:
2. Commonwealth of Australia:

Institutions and the manner in which they foster good governance determine the long term ability of a country to manage its water resources (Figueres et al 2003). During the 1980s, Australia’s political leaders were of the opinion that to prosper as a nation, maintain and improve living standards and opportunities for Australian people, they had no choice but to improve the productivity and international competitiveness of the country’s institutions and businesses. This meant that Australian organisations, irrespective of their size, location or ownership, needed to become more efficient, more innovative and more flexible (Hilmer et al. 1993).

Most areas of the economy were to be affected, with the greatest impact on sectors previously sheltered from competition such as major infrastructure industries (ie. water, gas, electricity, telecommunications, rail, airports) and some areas of agriculture. These industries (often called public utilities) involve networks that distribute products or services over geographic space and in most cases the networks are capital extensive and the investments are durable and immobile (Gomez-Ibanez 2003). In the closing years of the 20th century, all dimensions of this institutional framework came under challenge and all levels of government recognised the need for coordinated action.
3.2.2 **Australia’s Water Industry**

Infrastructure has special characteristics (i.e. capital extensive, natural monopoly, universal access to basic service) that have traditionally justified or encouraged government involvement (Gomez-Ibanez 2003). Further, provision of infrastructure is considered an important factor in local economic development. Along equity considerations, this view led governments in Australia (all levels) over the past 200 years to invest in more extensive water infrastructure (including irrigation schemes, dams, and major transfer pipelines) than could be financed with price that water users are willing to pay (Hilmer *et al.* 1993; Tasman 1997; Clark *et. al.* 1997; Fleming 1999). Governments have often required public enterprises to engage in cross subsidisation, generally for the benefit of the rural community.

The widespread practice of charging prices that are less than the real unit costs of providing water services (i.e. underpricing and cross subsidisation) is problematic. Underpricing of water services has led to a disconnection between the value of water and water users (i.e. inefficient water use patterns and behaviours). However, concern about ‘public interest’ may explain why governments in Australia encouraged monopoly conditions. Further, it is not an offence, under the trade practices policy, for a firm simply to dominate a market or even to be a monopoly (Baumol *et al.* 1988). However, during the 1980s it was argued that publicly owned and operated water utilities lacked incentives to operate efficiently (Haarmeyer 1992; Gomez-Ibanez 2003). The general conclusion appeared to be that creating market competition would promote greater efficiency.

3.2.2.1 **Forces Driving Reform**

As one of Australia’s largest industries, the potential economic gains by changing how the water industry was managed were considerable. The structure of the water industry and the regulatory regime in which it operates should encourage the industry to innovate and change (WRSMA 2001). Applying this viewpoint to the Australian water industry would not be straightforward, since the water infrastructure was already in place and monopolistic in nature. Further, although the dominant organisational structure - a statutory authority, with monopoly function, extensive power to tax and regulate - it was fragmented between jurisdictions (i.e. legislative power vested in the States and Territories).

Events at a national level contributed to significant structural changes in the way government business enterprises operate and how water resources are managed around Australia. The major national events that have and continue to influence the Australian water industry are the:

- Review of Commonwealth Trade Practices Act (1992),
- Council of Australian Governments Water Reform Framework (1994), and

Additional information on the major directions, policies and guidelines is provided in Appendix 1.
3.2.2.2 Reform Implementation


If reform in the Australian water sector is not accelerated, water will continue to be wasted, the community will continue to invest in poorly performing water assets and the environment will be placed in further jeopardy.

The COAG response in 1994 was to agree to a framework to reform Australia's water industry that would be fully implemented by 2001. Elements of the water reform included separation of regulation and service delivery, cost recovery (i.e. functional and investment efficiency), consumption based pricing, reduction in or transparency of subsidies, recognition of the needs of the environment, allocation and trading in water entitlements. Nevertheless, wastewater management, including reuse of treated wastewater, received limited attention in the reform package (Cooper et al 2005) as did the emerging practices of harvesting stormwater for non-potable use. The prime focus of these reforms was to create conditions that would encourage more efficient water use within urban and rural centres and by the irrigated agriculture industry.

The Federal government strengthened and sustained the pressures for change through financial incentives. From 1995 onwards, compliance with COAG water reform commitments became a requirement for States and Territories in order to receive their full share of the Commonwealth payments under the National Competition Policy (NCP) reform. Some observers alleged this arrangement made the water industry vulnerable to political pressures at State and/or Federal level (Gale 2000). On the other hand, water managers in Australia have been at the interface of politics since settlement (Hammerton 1986; MDBC 1997; COA 1999) and as such must understand and balance short term political commitments with longer term community needs.

The Productivity Commission (1999) noted the progress in implementing the water reforms varied markedly amongst the jurisdictions despite the tight link with significant financial incentives. Likely adverse social and economic impact of reforms on sectors of the community, particularly in country areas, proved to be a major stumbling block for many jurisdictions. As a consequence, the full suite of reforms was not able to be implemented by 2001 and the timeframe was subsequently extended to 2005 for certain aspects. Nevertheless, without a doubt the policy and institutional setting within the Australian water industry was vastly different to those in 1994.

3.2.2.3 Changes Impacting Urban Water Supply

Australian water utilities in most jurisdictions are no longer simultaneously resource managers, service specifiers, regulators and service providers. A majority of water utilities (particularly ‘major urban’) have become corporate entities responsible for service delivery, with regulation responsibilities assigned to different arms of the respective State governments (Evans 2000). In other words, the provision of water services is by public or privately operated utilities
and government is responsible for regulation (including resource management). This separation is designed to avoid any potential conflict of interest between price setting and setting of health and environmental standards (Gomez-Ibanez 2003; GWP 2003). Separation means that Australian water utilities can be more focused on delivering services to specified standards and their cost competitiveness. They can also avoid entanglement in any other concerns (ie. ‘the public interest’).

All Australian’s rely on infrastructure services, they have a common interest in seeing that infrastructure is provided reasonably efficiently and priced not too much above cost. Efficiency seeking by water utilities (ie. reducing operating costs) yielded immediate productivity dividends in most jurisdictions (Evans 2000). However, costs within the water industry will remain dominated by infrastructure investment in the longer term. Accordingly, it is fundamental that the price path set reflects the full cost of providing water services (including externalities) to each community. However, is not easy to accept the notion that higher prices can serve the public interest better than lower ones, especially for something as basic as water services.

Advocacy of higher prices for any service to communities in regional Australia is seen as a mandate for political disaster, and therefore often rejected by politicians in favour of encouraging public enterprises to continue to provide services at a financial loss. For example, frequently the cost of providing water supplies is not covered by the income generated by water charges in many country communities in Australia. In the past, water utilities made up the loss by obtaining higher profits from its other sales (ie. cross subsidisation from their urban water business); a practice only possible where a public enterprise is protected from price competition and entry of new competitors.

This situation has changed as part of the water reform. Where government requires a public enterprise to meet public interest goals, it is now expected to specify this as a community service obligation (CSO) and provide compensation to the organisation. The payment (subsidy) is to be met by taxpayers in general, rather than by the targeted groups of water users and the amount of the subsidy should be a matter of public record. Similarly, low (subsidised) pricing is not considered a suitable (or sustainable) way to help low income people or people with large families; rather, it is a matter for social welfare policy (Dixon & Baker 1992). Even so, public or privately operated water utilities continue to respond to informal influences from government.

The reforms are gradually correcting the underpricing of water in Australia. The greatest challenges to the water industry reform may have been the application of commercial criteria to the evaluation of water agencies and defining of water users as ‘customers’ (Colebatch 2005). However, with time and familiarity (ie. the decade of reform) these views have now become the way in which the water industry in Australia is understood (ie. part of normal expectations). The focus of the Australian water industry has moved away from increasing the quantity of water available towards more efficient water use and better management of Australia’s resources.
3.2.2.4 National Policy Directions

The national COAG water reform between 1994 and 2004 contributed to significant structural changes in the way government business enterprises operate around Australia. Additionally, demand management strategies introduced by water utilities as part of the reform have been very successful, particularly, in relation to urban water use (WSAA 2003). The observed improvement in water use efficiency was delivered through a combination of consumption based pricing structures (i.e. financial incentive), technological change and education campaigns. The intention of the suite of measures is to encourage a sustained behavioural (i.e. cultural) change in patterns of water use. Because the water industry is capital intensive, each dollar invested in water efficiency will reduce the amount of or defer investment required to increase the capacity of the existing water infrastructure.

In August 2004, under the pressure of prolonged drought conditions, environmental flows, growing value placed on the environment and increasing demand for water, COAG endorsed the National Water Initiative (NWI). This $2 billion initiative states what Australia’s governments have agreed to do to build on the achievements of the 1994 COAG framework. Expressly, the NWI seeks to maintain water industry productivity gains, stretch water use efficiency benefits to sustain growth in rural and urban communities, and guarantee the health of river and groundwater systems. Importantly, the NWI openly incorporates better use of stormwater harvesting and recycled water use in Australian cities (urban centres) into the water reform framework considerations (COA 2004; Cooper et al 2005).

Specific inclusion of non-conventional strategies was not the result of a ‘decision’ by an authoritative figure, but rather, as Colebatch (2005) comments, a shift in the institutionalisation of practice - that is, a response to changes over time in the way in which the activity is understood and normalised. For example, around thirty years ago Sloan (1977) remarked on the intellectual shock experienced by public health practitioners being asked to consider conditions under which beneficial use of wastewater might be allowed. At that time, the exclusion of wastewater from man’s food and water supplies had been actively promoted and pursued for more than a century. Yet today, there is a growing number of operational water harvesting and reuse projects around Australia, albeit principally focused on larger urban communities.

Open inclusion of water harvesting and reuse in the NWI is important because the practice is still a challenge in most jurisdictions to established institutions in Australian water industry. In cognitive terms, it reframes the ‘water supply process’ to officially encompass ‘water cycle management’ rather than just the traditional ‘supply and disposal’ matters (Colebatch 2005). This philosophical shift generates a somewhat different set of tasks and calls on different skills within the water industry. A parallel change in the water quality focus from ‘pure’ (drinking) water to ‘fitness for use’ also challenges customary ways of thinking about health and risk in relation to water (Colebatch 2005). In the end, good water governance has everything to do with skilled and capable water managers and policy emerges from the way they frame and address problems.
Part I Our Water Resources

3.2.3 Australian Urban Water Utilities

The Australian Constitution leaves control of water to the State and Territory governments and this has led to the evolution of different service models in each jurisdiction. Table 10 provides a simplified summary of the predominant water service model predominant in each jurisdiction; there are exceptions.

Table 10 Summary of Water Service Models in Australia (AWA 2002)

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Service Model</th>
</tr>
</thead>
</table>
| Victoria     | Source: AWA 2002

| NOTE: This table is included on page 54 of the print copy of the thesis held in the University of Adelaide Library. |

The agency and infrastructure created through legislation is owned and controlled by the government. In recent decades, the traditional size of the public sector in Australia has significantly reduced due to contracting out of services.

3.2.3.1 Size and Context

Australia has a total of nearly 300 urban water utilities serving a population of around 19 million. A majority of the water utilities in Australia are corporate entities focused on delivering cost competitive services to specified standards. Table 11 below provides a breakdown of Australia’s urban water utilities by size. The breakdown shows that 200 (or 67%) of Australia’s urban water utilities fall within the ‘small’ category defined here as serving less than 10,000 connections (ie. 20,000 people or less) and about 13% of the Australian population.

Table 11 Breakdown of Australian Urban Water Utilities (AWA 2002)

| Source: AWA 2002 |
| Source: AWA 2002 Note: Equivalent number of people was determined loosely assuming and occupancy rate of 2.4 |

| NOTE: This table is included on page 54 of the print copy of the thesis held in the University of Adelaide Library. |
International comparisons and experience can provide useful insights for the Australian water industry. Australia’s ‘small’ water utilities can either appear small or large depending on whether the comparison made is between reported sizes of water utilities in the United Kingdom (UK) or the United States of America (USA). In the UK, 22 water utilities serve approximately 52.3 million people (Emery 2004); by Australian standards, a majority of UK water utilities fall into the ‘major urban’ category. In stark contrast, in the USA more than 4,700 utilities supplied water to around 180 million people; of which around 97% of the water systems serve ‘small’ communities of less than 10,000 people (AWWA 2004). It is also interesting that in USA, there is a move toward consolidation of existing small systems to help spread expenses over a larger number of customers (ACC 2004).

In Australia, sustainability of regional communities is linked to the long-term viability of numerous ‘small’ water utilities. The Federal government argued the NWI reform will benefit regional Australia, provided it is properly implemented by State governments with appropriate responses by local government, business and communities (COA 2004). All the same, community resistance will be encountered as cost reflective pricing is rolled out to regional areas. Fortunately, most Australian authorities also realise there are economic limits that prevent most small communities from entirely funding water infrastructure. All levels of government have an obligation to develop policies that will uphold regional communities.

3.2.3.2 Benchmarking Performance

The relative performance of a water utility and/or water supply system is sensitive to its size and context as a result of unavoidable cost drivers. Relative performance is primarily dependent on the relationship between capital and ongoing maintenance costs, which are a function of the size of the system, and its revenue customer base. Other influencing factors exist like the available water source(s) and associated treatment costs. For example, where groundwater is used, a utility can expect relatively consistent quality and quantity from year to year; however, the quality from each groundwater source may vary and require different methods of treatment. In contrast, surface water sources are subject to the vagaries of natural phenomena which can affect the quality, quantity and annual operating cost. Differences in cost drivers between individual utilities make comparison of the performance of utilities complex (Rabone 2004a).

Eggleton (1994) concluded that a systematic approach to performance benchmarking would benefit the Australian water industry because a shared language and a common set of relevant measures would be developed. To be successful selected performance measures need to be unambiguous and verifiable, consistent with long term incentives for compelling peak performance, and easy for the public to understand (Kingdom & Jagannathan 2001). As a general rule, trends of measures over time for a given utility or system provide the most reliable indicator of performance as differences in cost drivers are held constant (Rabone 2004a). However, the process of performance benchmarking remains subjective even where a systematic approach is adopted; for as Carrington (2004) points out customers (water users), utilities, and regulators have different perspectives and place different emphasis on certain performance measures.
Public performance reporting (as in regulated industries) makes service providers more accountable to the public and motivation for improvement is increased (Kingdom & Jagannathan 2001). The annual publication *WSAAfacts*, by Water Services Association of Australia, provides information to the Australian water industry. *WSAAfacts* reports on the performance of ‘major’ water utilities against a common set of measures for use by utilities, regulatory authorities and the public alike. A similar publication *Performance Monitoring Report for Australian ‘Non Major’ Water Utilities* was published by the Australian Water Association (AWA) between 1997/98 and 2000/01 (AWA 2002). Regrettably, after the fourth year, Commonwealth government funding support for the publication was withdrawn. The requirement to collect good quality data and analyse performance on a regular basis for this type of publication is a valuable discipline for the water utilities involved.

There is clear absence of published performance information for ‘non major’ and ‘small’ water utilities; a significant majority of the industry in terms of total numbers in Australia. Without this point of reference, selection of suitable benchmarking partners and determination of an overall ranking of their comparative performance is problematic. In addition, many ‘small’ water utilities would experience hardship in making resources available for collection and analysis of data. Despite these difficulties, where it can be implemented benchmarking can be a very powerful vehicle for driving peak performance of ‘small’ water utilities.

### 3.2.4 National Organisations and Industry Associations

There are a large number of organisations and associations that look after the interests of various segments of the water industry in Australia. The group of national bodies includes:

- **Australian Water Association (AWA)** was established in 1962 as a not-for-profit association for individuals and organisations interested in water resources. AWA plays an important role in the Australian and international water industry.

- **Water Industry Operators Association (WIOA)** was established in 1972 for persons involved in operations and maintenance of public and private water infrastructure.

- **Water Services Association of Australia (WSAA)**, represents ‘major’ urban water authorities.

- **Australian National Committee of Irrigation and Drainage (ANCID)** represents irrigation authorities and agencies.

- **Irrigation Association of Australia (IAA)** represents all sectors of the irrigation industry from water users to retailers.

- **Stormwater Industry Association of Australia (SIA)** represents the diverse and multi-disciplinary interests of stormwater stakeholders.
Part I Our Water Resources

• **Australasian Bottled Water Institute (ABWI)** represents water bottlers and promotes use of bottled water products.

• **Waterwatch Australia** is a network of individuals and community groups concerned with water quality protection of waterways and catchments. *Waterwatch* was established in 1993.

• **Australian Water Partnership (AWP)** was established in 2003 to link Australia to the Global Water Partnership (GWP).

• **Masters Plumbers of Australia (MPA)** represents installers of gas, water and irrigations systems, as well as fire, sanitation and drainage services.

• **Urban Development Institute of Australia (UDIA)** was established in 1972 to represent those involved in development (eg. developer, planners, and designers).

• **Australian Council for Infrastructure Development (AUSCID)** was established in 1993 to represent private sector development in public infrastructure.

• **Landcare Australia** is not-for-profit organisation established in 1989 to raise sponsorship for projects to care for Australia’s environment.

Despite the number of national organisations and industry associations, there is clear under-representation for the interests of ‘non major’ and ‘small’ water utilities in Australia. Apart from a special interest group of AWA for water recycling, no specific representation at the national level was identified for groundwater, rainwater or recycled water segments of the water industry. In addition, there is no mechanism for ensuring the established organisations act with the broad industry and community interest in mind. Gale (2000) reported that negotiations were being held to bring together the four major national players, being AWA, WSAA, ANCID and IAA, in a loose affiliation to coordinate the water advocacy and policy scene.

### 3.3 URBAN WATER USE SECTOR

At a national scale, the urban water sector consumes less than 20% of the total water use, with the majority (about 70%) being supplied to agriculture (AATSE 1999; Mitchell *et al.* 2002a; COA 2002; WSAA 2005). The urban water sector can be divided into two broad categories, with markedly different patterns water use, as follows; residential (household uses) and non-residential (ie. industrial, commercial and institutional uses). Overall, residential use in Australia accounts for less than 10% of total water used and is the dominant category in the urban water sector (COA 2002; WSAA 2005). The cost of urban water supply and competition for resources near towns and cities make this sector important. In addition, the intensity of competition is likely to increase as forecast reductions in rainfall connected to global climate change take effect. The obvious benefits to embracing water harvesting and reuse relate to being in a better position to deal with water shortages as well as boosting the environment and our economy.
3.3.1 Urban Water Services

3.3.1.1 Fundamental Management Philosophy

The supply of water to urban centres was one of the earliest concerns of governments in Australia, primarily by way of developing water resources to meet demand. Traditional patterns of urban water management were based on a simple ‘supply and disposal’ process - that is, water delivered to urban users in one pipe system and two separate pipe systems remove wastewater (‘used water’) and stormwater (‘unused’) for disposal. This approach dates back to the 19th century, when authorities found a positive correlation between poor sanitation and high mortality (Mitchell et al. 1999; Millis 2003). However, the simple ‘supply and disposal’ approach has caused serious - and unsustainable - impacts to water resources and the natural environment. Urban water infrastructure in all Australian cities has largely been based on this ‘separate system’ approach.

Increasing populations, particularly in capital cities, generate a steadily rising demand for water, and at the same time a rising demand for the disposal of wastewater (COA 2002). There was a focus on reliable supply and removal of urban wastewaters with little concern for the environmental impact and the sustainability of this pattern of water use. These pressures combined with ageing water infrastructure and general financial burdens have forced a review of traditional water management practices (Fleming 1999). Over time, a philosophical shift in the process of urban water management to the current ‘water cycle management’ view has occurred (Colebatch 2005). The transition from the traditional approach that prevailed between the 1880s and 1980s, and the contemporary focus (recently institutionalised in 2004 by the NWI) has spanned more than two decades in Australia.

Table 12 provides a summary of the primary water management focus for both the traditional and contemporary urban water supply frameworks. However, important traditional objectives of water infrastructure related to social and economic well-being of the community are preserved in each framework.

Table 12 Changing Focus in Urban Water Management Philosophy

<table>
<thead>
<tr>
<th>Water Management System</th>
<th>Traditional ‘Supply &amp; Disposal’</th>
<th>Contemporary ‘Water Cycle Management’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Supply</td>
<td>• reliable supply (security)</td>
<td>• efficient use (manage demand)</td>
</tr>
<tr>
<td></td>
<td>• economic development</td>
<td>• sustainable development</td>
</tr>
<tr>
<td></td>
<td>• ‘pure’ (drinking) water</td>
<td>• water ‘fit for use’ (eg. different qualities for different uses)</td>
</tr>
<tr>
<td>Wastewater</td>
<td>• public health concern</td>
<td>• public health concern</td>
</tr>
<tr>
<td></td>
<td>• water supply by-product</td>
<td>• reliable source of water (reuse)</td>
</tr>
<tr>
<td></td>
<td>• discharge to water body</td>
<td>• environment protection</td>
</tr>
<tr>
<td>Stormwater</td>
<td>• nuisance by-product of</td>
<td>• seasonal water source (eg. harvest for beneficial use)</td>
</tr>
<tr>
<td></td>
<td>development (eg. roads)</td>
<td>• flood protection</td>
</tr>
<tr>
<td></td>
<td>• flood protection</td>
<td>• environment protection</td>
</tr>
<tr>
<td></td>
<td>• ‘out of town’ disposal</td>
<td></td>
</tr>
</tbody>
</table>
New water supply systems developed in Australia must be planned and designed for long term sustainability. This is an obligatory responsibility, particularly for public infrastructure projects, where costs and benefits of development are distributed over long periods of time over the life of the asset (i.e. often between 50 and 100 years). The long life of the public infrastructure has been an impediment to rapid improvement of the sustainability of water services.

3.3.1.2 Security of Supply

Less than 1% of water supplied to Australian towns and cities is actually used for drinking or food preparation by households (COA 2002). That is, almost all water, generally treated to a potable (drinking) standard, is used for purposes that could be satisfied with non-potable water if available. In Australia, urban water systems are designed to provide a high level of security; that is, to maintain supply in all but the most severe drought years. It has been common practice to impose water restrictions every summer in many North American cities (Dandy 1989) but until very recently water restrictions have only been imposed in most Australian cities when prolonged drought conditions result in water shortages.

Application of water restrictions outside these times was considered an indicator of system failure (Hammerton 1986); something to be rectified to prevent repeat occurrences. For example, between 1960 and 1988, water restrictions were imposed in the cities of Perth and Melbourne for 35 months and 33 months respectively (Duncan & Kesari 1988 in Dandy 1989). Similarly, restrictions were imposed on Adelaide water consumers, either voluntarily or by decree, on occasions up to the last occurrence in 1967 (Clark 1989). Under pressure of the 1978-83 drought conditions, a number of small town water supply schemes failed completely in New South Wales leaving residents reliant on carted water (Samra 1989). Nevertheless, given the wide climate variation and arid nature of the Australian continent, it is surprising that water restrictions have not been imposed more often.

Reynolds et al. (1983) argued the practice of 'drought proofing' a water supply to support non-essential activities (i.e. irrigation of parks and gardens) is not in the public interest in the longer term. They maintained public infrastructure investment would be more efficient in situations where normal operation was not expected to cope with drought conditions. Residential gardens, public landscapes, golf courses, nurseries, and many industries all suffer losses when water use is restricted (Dandy 1989; Price 1990; WSAA 2005). During such times, separate contingency strategies would be engaged to minimise losses. Adjustments to allocation and charging systems could accommodate those prepared to pay a premium for reliability (Reynolds et al. 1983; Dandy 1989).

This approach allows water users to make informed decisions on their required security level (i.e. relative lack of water restrictions) by balancing individual resultant costs as rates and water charges with perceived benefits of their pattern of water use. While restrictions would still be necessary from time to time, the approach acts to limit them in frequency, duration and severity. Political support for this position was cemented in the 1994 COAG water reform framework and resultant pricing reform has stabilised per capita consumption in the Australian
urban water sector (AATSE 1999; WSAA 2005). However, except for the urban water sector, the degree of application has been limited to minimise the likely adverse social and economic impact of reforms on dependent sectors of the community.

After a period of drought there is renewed awareness in the value of water and communities are more inclined to support alternative water management strategies. Notably, the recent prolonged drought that afflicted much of Australia has exposed the fragile nature of the Murray-Darling Basin and focused attention on the water needs of the environment and the consequences of excessive water extraction (EPA 2003; Radcliffe 2004). In addition, during the 2003/04 summer, water restrictions were imposed in every Australian capital city, except Darwin (Radcliffe 2004; Marks 2005). Urban and rural communities alike are impacted as regulated use, water restrictions and water conservation measures come into force. The value of water to a user is the maximum amount the user is willing to pay for the use of the resource.

It is not possible to specify a single level of secure supply that would be appropriate for all Australian communities. The level of secure supply provided will depend on local circumstances including the availability of water resources, the cost of required works, the willingness of the community and the ability of the community to finance the works. Provision of high security water services to small rural towns is constrained by the need for water authorities to remain financially viable. Water harvesting and reuse represents a safe and reliable new water supply that can provide insurance against future droughts or shortages of water and as a foundation for maintaining and improving economic prosperity and quality of life in Australian communities.

### 3.3.2 Residential (Household) Water Use Category

Patterns of urban water use are subject to uncertainty, being influenced by many factors including population growth, consumer behaviour (culture), household formation rates, population density, business activity, and climate (Liang 1998; WRSCMA 2001). The *Australia State of the Environment Report 2001* found climate and consumer behaviour (ie. level of water conservation practices) to be the stronger determinants of household water use throughout Australia (COA 2001). The development and management of Australia’s water resources has entered a period of decisive change. The ‘easy’ options for augmenting water supplies have been taken up and prospects for future expansion are limited. The residential water use category accounts for about 50% of the total of the demand within the urban water use sector (COA 2004). Therefore, changes in the patterns of water use by Australian households can have a significant impact on the total urban water sector demand.

#### 3.3.2.1 Location of Household Water Use

Australian households use water for a range of purposes including washing (personal, clothes and dishes), cooking, toilet flushing, lifestyle (swimming pools) and watering gardens. Outdoor water use is an integral part of the Australian lifestyle where residential gardens are a common feature of urban development.
Residential water consumption is made up of several components, including essential uses (hygiene, health, washing of clothes, dishes); non-essential uses (washing the car, watering plants in the garden); and wastage (leaks, wasteful behaviour) (Roseberg 1994).

The division of household water use into components helps to understand how water is used in the domestic sector. Figure 16 illustrates the allocation of water use in Australian households. Nationally, the majority of household water use is for outdoor purposes and less than 10% of water is used in the kitchen (COA 2002; ABS 2005; WSAA 2005).

![Figure 16 Typical Pattern of Water Use in Australian Households (ABS 2005)](source: Water Account Australia 2000-01, cat.no. 4610.0)

Water use varies between houses depending upon the number of people as well as the type and frequency of particular household appliances. Nevertheless, the pattern of indoor water use for bathroom, toilet, laundry and kitchen purposes is relatively constant throughout the year. Water used for these purposes is considered as a basic (essential) requirement; however, Foley & Daniell (2002) found there is a significant difference between the amount traditionally used in Australia and the actual level required to satisfy these needs.

Gardens are cultural preferences; Australian gardening has significant historical roots and is heavily influenced by 19th Century British gardens (Murray-Leach 2003). This feature of Australian urban development makes Australian households heavy users of water compared their European counterparts. The pattern for outdoor (non-essential) use is seasonal, depends on the size and type of garden and influenced by the prevailing climate. Water required for gardening varies considerably between towns according to rainfall and evaporation. For instance, depending on the seasonal weather patterns, the outdoor water use component can fluctuate by plus or minus 8% in Melbourne (COA 2002) and rise or fall by 12% in Adelaide (GSA 2004).
Figure 17 presents the 5 year average household water use for 1998/99 to 2002/03 as well as the typical division of indoor and outdoor water use for selected Australian urban centres. The Köppen classification of world climates, as applied by the Bureau of Meteorology to Australia, is adopted to highlight the difference in patterns of household water use in relation to the prevailing climate. Australia is a big country, stretching from the tropics to the roaring forties, and it has a correspondingly wide range of climates. Under the climate classification system, Australia is divided into six major climatic regions on the basis of air temperature and humidity. The relative proportion of the average household outdoor water use varies from 30% in Sydney (temperate climate) to 70% in Alice Springs (grassland/desert climate) indicate that the Australian Garden has evolved with piped water and is not constrained by local climate. In the United Kingdom, a country with high rainfall and low evaporation, external water use is only 3% of the total residential water consumption (WSAA 2003). However, there is a low degree of confidence in such data because only very limited number of Australian studies have directly observed indoor/outdoor water use.

Nevertheless, these figures imply that current landscape and gardening practices are not well suited to the Australian arid or semi-arid environments and make residential outdoor water use an attractive target for consumption savings in the urban water use sector (Pigham 1986). The problem with outdoor water usage is that it is not amenable to easy general fixes for water efficiency. The answers lie in garden designs, paving rather than lawns, appropriate plants, responsible watering and urban planning. The solutions depend highly on the individual. Garden style can and has changed over the last hundred years, but influencing changes requires understanding of the current culture.

As residential customers use water more efficiently, patterns of water use will change and historic consumption information may no longer be reliable for long-term planning purposes.

On the basis of the pattern and location of household water use, it is possible to identify two distinct types of water quality requirements according to the end use. Potable (drinking) quality water, or water that is suitable for human consumption on a long-term basis, is needed for bathroom, laundry and kitchen purposes. The remainder of the household demand (non-potable uses) accounting for about 60% of the total water demand have less stringent quality requirements and do not require potable quality water. Given that a significant proportion of the potable water supplied to urban customers does not have to be of high quality; there is significant scope to use lower quality water for non-potable end uses. However, the established water system in most urban centres in Australia is designed to supply one quality of water to households. Even so, use of water in urban areas is to some extent discretionary and, at least for certain purposes such as garden watering should be sensitive to price changes.
Household Water Use for Selected Urban Centres

<table>
<thead>
<tr>
<th>City</th>
<th>Inhouse</th>
<th>Outdoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darwin</td>
<td></td>
<td></td>
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<tr>
<td>Hobart</td>
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<td>Adelaide</td>
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<td>Sydney</td>
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<td>Melbourne</td>
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<td>Canberra</td>
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<td>Canberra</td>
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</tbody>
</table>

Figure 17  Household Water Use in Selected Australian Cities (Rabone2004)
3.3.2.2 Level of Household Water Use

Water is essential to our health, our physical and spiritual needs, our comfort, our livelihoods, and our ecosystems (GTZ 2001). For these reasons, water demand by individuals has been of interest since ancient times for estimating water supply requirements. For example, analysis of the observations by Sextus Julius Frontinus, water commissioner of Rome, AD 97, indicate that the average water use of inhabitants of Rome, a city of one million people was 144 litres per capita per day (Hershel 1973 in McLellon 1991). In modern times, larger volumes of water are delivered by water supply systems because societal habits have changed; excessive water use is, in part, a cultural problem (WA WRC 1986; Fleming 1999; Murray-Leach 2003). Thus, effective water resource planning will increasingly rest on understanding the factors that shape society.

Figure 18 below provides a comparison of the 5 year average per capita use by the residential water use category (top graph) and the average annual household water use (bottom graph) for 1998/99 to 2002/03 for major urban centres around Australia. The top graph in Figure 18 shows the per capita residential water use (ie. excluding industry) in Australia ranges from 215 litres per person per day in Melbourne to more than 500 litres per person per day in Alice Springs. The bottom graph Figure 18 shows the 5 year average annual household water use in Australia ranges from 227 kilolitres per household per year in Melbourne to around 500 kilolitres per household per year in Alice Springs. The pattern of water use varies with seasons, with peak consumption in summer, except for Darwin which experiences peak consumption during its dry winter.

Demand management strategies introduced in the urban water use sector, as part of the national COAG water reform between 1994 and 2004 have been successful in relation to stabilising per capita consumption (AATSE 1999; WSAA 2003). For example, Sydney has been able to accommodate an additional 700,000 people without using more water (WSAA 2005). However, despite reductions the average household consumption in Australia remains approximately 30% higher than the 1997 OECD average of around 180 litres per person per day (COA 2004). When compared to the world standard for ‘optimal’ level of service of 100 to 200 litres per person per day the current level of water use in some Australian cities can be considered excessive.

While there has been a significant reduction over the last two decades in the per capita consumption of water in major urban centres, the total water consumption is increasing as populations grow (COA 2002). There is scope for reduced residential demand in Australia with per capita consumption in many urban centres well above the level required to meet essential drinking, cooking and sanitation needs. WSAA (2005) cautions that consumption savings cannot be achieved indefinitely, that most of the easy measures have already been taken and that further limitations will be highly intrusive and likely to encounter community resistance.
Average Per Capita Residential Water Use for Selected Cities in Australia

### Per Capita Water Use (Residential services only)

<table>
<thead>
<tr>
<th>City</th>
<th>2002/03</th>
<th>2003/04</th>
<th>2004/05</th>
<th>2005/06</th>
<th>2006/07</th>
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<td>337</td>
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<tr>
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<tr>
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Average Annual Household Use of Water for Selected Cities in Australia

### Average Annual Household Water Use

<table>
<thead>
<tr>
<th>City</th>
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<th>2004/05</th>
<th>2005/06</th>
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</tr>
</tbody>
</table>

* Hobart Water provide bulk water to retailers and do not report water consumed per residential property. Calculated from Bulk Water Supplied/Population receiving water, assuming 2.5 persons per residential property, and adjusting water consumed per property by 0.65 to equate water consumed per residential property.


Average Annual Household Water Use

Figure 18   Average Residential Water Use in Selected Australian Cities
3.3.3 Non-residential water use

The pattern of water use by the non-residential customer category (i.e. industry, business, and institutions) is markedly different from residential water use. Non-residential customers use larger volumes of water for a more diverse range of purposes. Businesses, industries, institutions, and other large non-residential water users often have the potential for significant contribution to conserving urban water supplies. However, potential water savings can only be achieved if these customers can be persuaded to change their usual ways of operation. If urban water utilities want to promote or require water conservation among non-residential customers efforts must be based on an understanding of how these customers use water and to address the needs of these customers.

3.3.3.1 Industrial and Commercial Purposes

Industrial and commercial users are generally manufacturers, retail traders and office buildings. Water is used by industrial customers for three fundamental purposes: heat transfer, materials transfer, and as an ingredient (Ploeser et al. 1992). Many industries use potable water when lower quality water would be adequate for their purposes; that is potable water could be substituted with recycled water or stormwater. Non-potable commercial and industrial end uses include toilet and urinal flushing in building complexes, industrial applications such as cooling, boiler feed and process water and heavy construction (Mitchell et al. 2002a). The demand curve for industrial consumers follows a more linear relationship than residential customers.

As the cost of water rises, substitutes and alternatives are found, such as the recycling of cooling waters or changes in the manufacturing process (Roseberg 1994). The introduction of water and wastewater (trade waste) tariffs has led industries to cut their unit production water consumption rates. For example, between 1990/91 and 1998/99, the industrial water use in Sydney declined from 5,200kL per year to current levels of 3,180 kL per year (COA 2002). However, owners of businesses and industries are reluctant to change their methods of operation except where the conservation program has a reasonable payback period of the order of 5 to 7 years and protects propriety information (Ploeser et al. 1992). Few businesses in Sydney committed to implement the free water audit findings even where the potential gains were clear (COA 2002).

From the limited data available, commercial consumption exhibits low seasonal variability. Depending on their operation, urinals can be extremely high users of water and can be the largest single water consuming device in a commercial organisation (COA 2002). In other countries, it is increasingly common for in high rise buildings to be designed to conserve potable water as described in Example 6.
Example 6  Onsite Water Reuse in High Rise Office Buildings

In highly populated urban areas, such as Tokyo, Japan and Seoul, Korea, individual building water reuse systems are being used for toilet and urinal flushing in high rise buildings to conserve potable water. These building are equipped with two separate wastewater lines to allow the water collected from the hand basin to be transferred to the treatment system that is usually located in the base of the building. The treated water is then used for toilet and urinal flushing before being discharged to the centralised municipal wastewater treatment plant.

Source: Anon (2003?)

This type of onsite water reuse is not commonly incorporated in the design of high rise buildings in Australia. Waterless urinals have been developed but their use to date is rare (COA 2002).

The impact of water use restrictions is not always an adverse one – there are many opportunities arising for industry and commerce to profit from water conservation programs and benefit from the provision of goods and services designed to improve water use efficiency. For example, several South Australian based companies are developing soil water monitoring technologies, scheduling and control systems for sale (GSA 2005). In the longer term, sustaining reduced consumption is heavily dependent in water efficient appliances and fittings becoming the accepted norm in the marketplace (COA 2002). There is evidence to suggest that industrial and commercial users can still cost effectively reduce overall water use by 10% through a number of efficiency measures (GSA 2005).

The economics of commercial and industrial reuse vary depending on the type of project being developed, the degree of treatment required, and the proximity of the water treatment plant to the location where the recycled water will be used. Some industries harvest and reuse water from their own site or use treated effluent from a local wastewater treatment plant in their manufacturing processes, but currently this is only a minor component of total industrial use.

3.3.3.2 Community (Institutional) Purposes

Water for community purposes includes water used by government agencies, universities, schools, local government, public parks and gardens, sporting grounds, places of worship and hospitals (GSA 2005). In some situations, potable water used for community purposes can be substituted with lower quality (non-potable) water such as recycled water, rainwater and stormwater. Non-potable community end uses include toilet and urinal flushing in institutional facilities, irrigation of sports fields, golf courses, parks and gardens, open spaces, and recreational and environmental uses such as ornamental water features, lakes and ponds, and stream flow augmentation (Mitchell et al. 2002a). Irrigation demand for water has high seasonal variability which is predominantly a function of the prevailing climate.
A great deal of community water use is not efficient, either through wasteful practices, poor design of landscapes, inefficient equipment or a combination of these. Water efficiency should be a primary consideration when irrigation systems are installed, renewed or undergoing significant maintenance (WSAA 1998). Adopting landscape designs and selection of drought resistant plants suited to the Australian environment would make reductions in community water consumption possible. Garden style can change but influencing changes requires understanding of the current culture (Murray-Leach 2003). Institutions and community organisations should be encouraged to replant with water-efficient vegetation. Through more efficient practices and installation of water efficient appliances in public and community buildings, there is the opportunity to reduce mains water use for public purposes by at least 12% (GSA 2005).

In addition to conservation measures, the use of non-potable water for landscape irrigation in Australian cities is also expected to increase in the future. The extent to which non-potable water is utilised depends on availability of suitable parks, sportsgrounds, golf courses, and cemeteries, in reasonable proximity to the sources of stormwater and wastewater. Irrigation requirements are seasonal and much of the stormwater and wastewater will not be utilised (ie. discharged to waste) unless large off-season storages are provided. Much of the focus on water harvesting and reuse has been on larger urban communities where the scale of engineering works is most likely to prove financially defensible (Cooper et al 2005).

Irrigation schemes for public and recreational purposes using local stormwater and wastewater resources is an attractive option for small communities as a means of improving their amenity at low cost. For example, trees and shrubs could be grown to create shelterbelts (windbreaks) that can deflect (or filter) hot drying winds around community facilities. Such initiatives may result in outdoor entertainment and play areas and enhancement of views for the town; however the benefits achieved will vary depending on local conditions (Zwar 1985). Strom (1985) estimated that water harvesting and reuse could be adopted benefiting more than 80 Australian towns.

### 3.4 LIMITATION OF SMALL SYSTEMS

Throughout the world, those responsible for supplying small towns with water have struggled to find ways to deliver good quality service at an affordable price. The small size of many regional towns in Australia, combined with small community budgets, has limited the delivery of mainstream services (ie. services comparable to urban centres). In general, rural communities are often disadvantaged in terms of their water supply, both in quantity and quality, and the smaller the town, the greater the disadvantage. Factors influencing the design and delivery of sustainable water services to small and remote communities might include affordability, technical appropriateness, current service delivery structures, and levels of skill and resources available in the community (HREOC 2001).
Many small towns have sufficient populations to benefit from the economies of scale offered by piped systems, but they are too small for conventional (mainstream) urban water utilities (WSP 2003). There is no common approach to delivering water services to small towns that meet the performance standards of good quality, affordability, sustainability and ability to expand to accommodate growth. The challenge is to undertake planning, management, and funding reform that will guarantee effective use of water resources, minimise adverse impact on the environment and provide long term sustainability of local economies. The degree of sustainability achieved is dependent upon the state of knowledge and therefore upon the evolution of appropriate technology (Fleming 1999).

3.4.1 Public Health Implications

3.4.1.1 Potential for Waterborne Disease Outbreak

Communities of all sizes are at risk of microbial infection without a safe water supply. In general, small water systems are more vulnerable to outbreaks of waterborne disease than larger systems. For example, in the United States, there have been nearly 600 reported outbreaks of waterborne diseases from water supply systems over the last 20 years (NAS 1998). The smallest systems, those serving less than 500 people (around 200 connections), violated drinking water standards more than twice as often as larger systems (US Water 1996; NAS 1998). In Australia, with the exception of the Giardia and Cryptosporidium scare in Sydney during 1998, ‘major urban’ water utilities are rarely confronted with large outbreaks of waterborne diseases. However, it is widely recognised by Australian health and water authorities that provision of safe water to small communities is an ongoing challenge.

Economic constraints often mean that only untreated water can be supplied, or that treatment is limited in extent, and monitoring may be infrequent or absent (ADWG 1996). Public health is protected by reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the water, and controlling specified chemical constituents in the water. Health problems can arise by drinking water from any source (ie. reticulated supply, rainwater tank, or bore) that is not properly treated if it contains disease-causing organisms or other contaminants. Without chlorination or other disinfection processes, communities are at risk of contracting waterborne diseases. Gastroenteritis is the most common disease derived from water and the causal agent may be bacterial, viral or protozoan from human or animal faeces (Millis 2003).

Example 7 outlines the consequences of a reported outbreak of gastroenteritis in three communities served by a ‘small’ Australian water utility.
Example 7  Public Health: Sunbury Outbreak 1987; Victoria, Australia

In October 1987, an outbreak of gastroenteritis occurred in the regional Victorian towns of Sunbury, Diggers Rest and Bulla, affecting over 5,000 residents (i.e. about 30% of the population). The three towns were supplied by a common drinking water supply, without treatment or disinfection of the source water. People of all age groups were affected (refer to Figure 19 below) and experienced symptoms of vomiting, abdominal cramps, diarrhoea, fever, and malaise.

![Figure 19](image-url)  
**Figure 19**  Attack Rates for Vomiting, October 1987 (Kirk et al. 1999)

Investigations identified contaminated drinking water supplied to the three towns as the likely source of the epidemic. The outbreak ceased shortly after the water authority turned off the suspected water source and issued a ‘boil water’ notice to residents in the affected areas on 9 October (see Figure 20).

![Figure 20](image-url)  
**Figure 20**  Residents Suffering Vomiting October 1987 (Kirk et al. 1999)

Source: Kirk et. al. 1999

When a waterborne disease outbreak occurs it causes considerable community disruption, illness and even death. Infants, elderly persons, and persons with illness are the most susceptible (Anon. 2003?; Millis 2003). The intense public and political pressure strains public confidence in the water supply itself and those concerned with its management. Therefore, it is critical that systems are in place to support water authorities and health agencies in managing such events (Kirk et al. 1999).
Disinfection is crucial to water system security, providing the 'front line' of defence against biological contamination (CCC 2003). Example 8 describes the extended health threat from waterborne disease in Peru where a major causative factor was inadequate disinfection.

**Example 8  Public Health: Cholera Epidemic 1991-1996: Peru**

> In 1991, an outbreak occurred in Peru that resulted in a five year epidemic of cholera where the major causative factor was determined to be inadequate drinking water disinfection. The epidemic spread to 19 Latin American countries, causing more than one million illnesses and 12,000 deaths. After the outbreak, international health officials criticised Peruvian water officials for inadequate chlorination the water supply. The water officials in Peru and other the Latin American countries confirmed the inadequate chlorination was the result, at least in part, of concern over disinfection by-products and clearly misinterpreted the risks the by-product posed.

*Sources: CCC (2003)*

In this case, the waterborne transmission of cholera was aided by the cessation of chlorination because the risk posed by chlorination by-products was misunderstood. Disinfection by-products (DBP) are compounds formed unintentionally when chlorine and other disinfectants react with matter in water. A report by the International Programme on Chemical Safety (2000 in CCC 2003) found

"the health risks from these by-products at the levels at which they occur in drinking water are extremely small in comparison with the risks associated with inadequate disinfection. Thus, it is important that disinfection not be compromised in attempting to control such by-products"

Nevertheless, cost effective methods to reduce DBP formation are available and should be adopted where possible.

While appropriate treatment and disinfection can control the bacterial pathogens, the oocysts of *Cryptosporidium* and some viruses are known to be resistant to chlorine (Millis 2003). In April 1993, breakthrough (ie. failure of the water filtration system) of cysts, not failure of the disinfection system, caused the major diaster in Milwaukee, United States. More than 400,000 people were affected and over 100 deaths were attributed to this outbreak (CCC 2003). The Milwaukee incident highlights the devastating impact that inadequate water treatment (barriers) can have on public health even where disinfection is maintained.

In Australia, public health falls within the jurisdiction of State and Territory governments and state-based health authorities are responsible for ensuring that state standards for water quality and water treatment are consistently met. Water supply managers and treatment plant operators may be held personally liable for non-compliance where established guidelines are not followed. Example 9 below illustrates how failure to respond to clear warning signals and to exercise diligence resulted in an extremely serious incident in Canada.
Example 9  Public Health: Walkerton Outbreak, May-June 2000: Canada

In May and June 2000, an outbreak of gastroenteritis occurred in the small town of Walkerton in Ontario. The source of drinking water for the town is groundwater that is chlorinated prior to distribution. The number of people affected by the outbreak was 2,300 and resulted in 65 people being admitted to hospital and 7 deaths, the largest multi-bacterial waterborne outbreak in Canada to date. Identification of the outbreak was initiated by the recognition of paediatric cases of bloody diarrhoea and severe abdominal cramps reported on 19 May. The onset for illness of the majority of reported cases occurred after 12 May and continued until late June 2000. Although most became ill between 16 and 26 May, several cases were identified with onset dates as early as 15 April 2000. The median age of reported cases was 29 years (range < 1 to 97 years); nearly 60% were female.

An enquiry after the incident into how the water supply was contaminated revealed that:

- heavy rainfall in early May and a well subject to surface water contamination was responsible for gross contamination of the water supply;
- coliform counts were often positive before the incident but no remedial action was taken by operators of the water supply;
- the chlorination plant for the contaminated well was unreliable (ie. not operating) due to inadequate maintenance and had been for months; and
- chlorine levels in the general water supply were overwhelmed by the influx of contaminated water from the well.

The water supply operators had failed to follow established guidelines on chlorine dosing, monitoring and recording chlorine residuals which could have prevented the outbreak. Alarmingly, it also found that despite the Boil Water Advisory and extensive publicity, some residents in Walkerton continued to expose themselves to the water through various routes, including brushing teeth and occasionally drinking it.

In March 2003, two former water supply managers were charged with public endangerment, fraud and breach of public duty (trust) for their part in the outbreak. In November 2004 both pleaded guilty. The Judge found them negligent in discharging their duties, although there was never any intent to harm anyone. The former utilities manager was sentenced to one year in jail and the water foreman was sentenced to nine month house arrest.

Sources: PHAC 2000; CCC 2003; Millis 2003; CBC 2004a, 2004b

The Walkerton incident sends a 'sharp and clear message’ that those employed in an occupation of any kind where public safety is affected and fail to perform their legal duties 'there’s a real risk you can be sentenced to jail' (CBC 2004b).

3.4.1.2 Level of Monitoring

The previous examples emphasise the importance of secure water sources, adequate water treatment and disinfection in ensuring a safe water supply to a community. Bacterial monitoring can only identify a contaminated source after the contamination has spread through the water system and put the public at risk (PHAC 2000; Millis 2003). Therefore, the first requirement for effective management of a water supply system is to understand the individual system, the
barriers in place to minimise the entry and transmission of contaminants, and the various processes and practices which can affect water quality within the system. The *Australian Drinking Water Guidelines* (1996) recommend that monitoring programs for public water supplies cover both the operational and system performance. Yet, for small communities the cost involved in carrying out all of the recommendations of the *Australian Drinking Water Guidelines* may not afford reasonable return on investment towards guaranteeing safe water supplies.

System performance monitoring is an assessment of the quality of water in the distribution system and as supplied to the customer. Table 13 sets out the minimum frequency, at which water samples should be collected and analysed for micro-organisms for systems serving different size populations. While public health considerations remain paramount, periodic sanitary surveys are likely to yield more information on the system performance than more frequent sampling for small water supply systems (ADWG 1996).

**Table 13 System Performance Monitoring Requirements (ADWG 1996)**

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<td>This table is included on page 74 of the print copy of the thesis held in the University of Adelaide Library.</td>
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Source: ADWG (1996)

A number of measures can be taken in order to reduce the risk of an unsafe supply such as maintaining plant and equipment in good condition, particularly the disinfection equipment. Disinfection is the most important single activity in providing a safe water supply and it is vital that this step is adequately carried out. If chlorine is used, a residual of between 0.2mg/L and 0.5mg/L (known to have good bacteriological quality) should be maintained (ADWG 1996). The residual level of disinfection of water in pipelines is to prevent microbial regrowth and help protect treated water throughout the distribution system. Operational monitoring is used to check that the processes and equipment that have been put in place to protect water quality are working properly.

As a minimum, small community supplies should be monitored for the characteristics which best establish the hygienic state of the water and the potential for other problems to occur. The *Australian Drinking Water Guidelines* recommend the monitoring program should be directed towards characteristics set out in Table 14 below for populations of less than 1000 people.
Table 14 Operational Monitoring for Small Water Supplies (ADWG 1996)

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<td>This table is included on page 75 of the print copy of the thesis held in the University of Adelaide Library.</td>
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</table>

Source: ADWG (1996)

Regardless of size of the system an annual report should be prepared to give an account of the system performance in relation to agreed water quality goals. The report should include a summary of monitoring information, indicate water quality trends and problems, and a statement of system failures over the past year and action taken to resolve them. Reporting on water quality should be open and comprehensive if the public is to have confidence in the water authority. Large water systems that serve a number of towns should be divided into regions for the purpose of annual performance reporting and made publicly available to the related communities.

3.4.2 Appropriateness of Technology

Appropriate technologies for water resource management and delivery should be available on an equitable basis to regions experiencing water related problems (GTZ 2001). Debate about appropriateness of technology has emerged in response to recognition that culture and other factors, such as prevailing socioeconomic and political conditions, are significant in the transfer of technology (Hazeltine & Bull 2003). Nevertheless, selection of appropriate technology can bring advantages to people living in small communities or remote locations. In the context of small communities, appropriate technology can be viewed as small-scale, energy efficient, environmentally sound, and self-sustaining. The degree of sustainability achieved is dependent upon the state of knowledge and therefore upon the evolution of appropriate technology (Fleming 1999). It should build on and strengthen existing local knowledge, cause little social disruption and be able to be maintained by people within the community (GTZ 2001). It is imperative that the design and implementation of systems that deliver water to Australia’s remote and indigenous communities reflects cooperative process of negotiation, community education, and cultural awareness (HREOC 2001).

3.4.3 Local Skill and Resources

Water utilities operating small systems cannot reliably deliver services unless their operators are adequately trained even where appropriate technologies have been adopted. Accordingly, training local people to operate the system and maintain associated equipment is as important as establishing the technology itself. Attention should be paid to whether the specified equipment, especially
sophisticated equipment, is in use elsewhere in the community. In addition to the
problem of learning to use complex equipment, having a unique piece of
equipment may mean that advice and spares will be difficult to find (ie. no local
serviceperson). It is recommended that a strategy be developed for debugging, for
training, for repairs, and for spare-parts and supplies when choosing any new
equipment. Safety is also an important issue. One needs to think carefully about
the ways a tool might be misused, especially by a careless or inexperienced
worker, and prevent as many ways as possible.

Operation is often simplified by automated features, particularly where
maintenance requirements are well documented in manuals provided by the
manufacturer. Common automated devices found in package plants are effluent
turbidimeters and chemical feed controls. Typical plant operation and
maintenance manuals should contain operating principles, methods of establishing
proper chemical dosages, operating instructions, and trouble shooting guides
(Clark et al. 1994). It is especially important to do the recommended maintenance
if the equipment is in a remote location where a breakdown cannot be repaired
easily. The advantage of doing preventative maintenance, rather than waiting for
a breakdown, is that it can be scheduled. Trained local personnel can carry out
routine maintenance activities; however, some maintenance, such as a full over
haul, needs to be done by a professional.

Periodic visits by the manufacturer should be scheduled to make adjustments to
the plant, inspect the equipment operation, and performance. The first visit should
be no more than 6 months after initial commissioning run-in period, the second
should follow in another 6 months, and then annual visits should be sufficient
(Clark et al. 1994). A final aspect of maintenance is preparing for an emergency
failure; a plan is needed covering such matters as whom to call and what to do
until the repairs are made. The number and kind of spare parts to be held in
inventory is affected by how important the machine is to overall operations and
how quickly spares can be sourced.

There is a need for the provision of technical support to small water supply
operators to ensure delivery of safe water to small communities when usual
situations arise and in the expansion of systems. In such situations, small water
utilities are likely to hire consultant services to supplement their in-house
technical capabilities. There may be an opportunity for several small water
utilities to join together to obtain needed specialists and thereby benefit from
economies of scale. Additionally, current training programs in Australia are
disjointed and often fail to meet the needs of small water supply operators. The
water industry should identify the knowledge and skills needed and work with
independent organisations, to develop and deliver training programs to system
owners and operators across the country. This might be achieved by the
organisations that support the water industry (as discussed in section 3.2.4).
3.4.4 Financial Viability

The provision of services to small towns is constrained by the need for water authorities to remain financially viable. A major constraint for towns and rural communities is the small static rate base, limited scope for economic development and restricted opportunities for resource sharing between communities. Without the benefit of economies of scale, small system managers often find it difficult to keep qualified staff and afford the professional technical and commercial support needed to properly maintain systems and improve efficiency. Differences in the operational environment faced by water utilities can have a significant impact on their cost recovery capability. The challenge into the future for small water utilities serving towns is to undertake pricing and funding reform which will guarantee their long term sustainability and cost effectiveness.

3.4.4.1 Capacity for Cost Recovery

Demand for water services is highly dependent on availability, price and a willingness to pay for water. The price paid by consumers generates obvious interest, but the structure under which the utility charges for services is more important. A key requirement of the national COAG water reforms was the introduction of a two tier pricing structure that includes separate fees for access (fixed) and usage (consumption). In general terms, utilities drawing most of their revenue from usage charges have comfortably achieved the COAG water reform requirements (AWA 2002a). Tariff structures around Australia have been changed to meet the COAG requirements, however governments may have retained a policy to set prices below those necessary to generate full cost recovery for water utilities operating in regional areas.

Most authorities realise that there are economic limits that prevent most small communities from funding such works in their entirety (ie. full cost recovery it is not feasible). For smaller water utilities to remain financially viable, revenue from community service obligation (CSO) payments is a necessary subsidy particularly where government provides water infrastructure to support development in regional Australia. About half of the ‘non major urban’ water utilities received some revenue from CSOs (AWA 2002a). Income derived from CSOs for WSAA members (ie. ‘major urban’ water utilities) was smaller as a proportion of total operational revenue (AWA 2002a). There is no publicly available comprehensive report for ‘small’ water utilities; however, income from CSO payments or other industry subsidises is also likely to be substantial.

The key objectives of an effective water pricing system are cost reflectivity, environment protection, and cost recovery (GWT 2003). The pricing system needs to generate revenues for the efficient operation (and debt service) of the present system and its future maintenance, modernisation and operation. A key condition is the government’s willingness to price water services at a financially sustainable level (see previous Example 2). Nevertheless, pricing adjustments should be applied selectively, gradually and with sensitivity to minimise the adverse social and economic impacts of such reforms on some sectors of the community in regional Australia.
3.4.4.2 Micro-Financing for Capital Investment

Lenders do not like to take financial risks. For example, if a significant proportion of the financing debt is variable, there is a risk that rising interest rates may jeopardise a community’s ability to service its debt. The payback period is the length of time in years until the initial investment is repaid and is a useful means to estimate of how long the utility and investor is at risk. To keep water prices affordable, the payback period for water infrastructure investments is usually amortised over 15 to 30 years (Figueres et al. 2003). Long-term financing is needed for water infrastructure projects, which is why the water sector is not very attractive for investors. Compared to international agencies, local Australian banking groups are relatively inexperienced in providing financing for small water supply infrastructure projects (ie. between $0.1m and $10m).

The perceived risks of the lender will be different from those of the infrastructure provider. Water supply projects can be considered low risk in terms of financing in that the business is a monopoly and the demand for water is always on the increase (Subramaniam 1993). Yet the current trend among most bankers is to assign the same risk and interest terms to water supply projects as housing (subject to the ups and downs of the market resulting in high financing risk) and other development projects. Furthermore, the financier requires the whole works, including the pipelines (which make up the greatest part of the project cost) to be insured against all risk (Subramaniam 1993). Matching water infrastructure projects and sources of finance is mainly a matter of identifying the right combination of risks for all parties.

Local small-scale financing can be used to support the development of water initiatives at the community level (Figueres et al. 2003). In developing countries, micro-financing is one of the driving forces behind economic development and an emerging industry throughout the world (Morse & Bell 2003). Micro-financing is the term used to describe a financial operation that provides small loans to struggling business people in order to expand their enterprises. Unlike commercial lenders, sustainability is the goal for this type of financial organisation rather than profit. Micro-financing operations provide various financial services similar to commercial banks but, due to the nature of the portfolio, loan procedures have been adjusted.

There is enough money in the world, just as there is enough water, but it is not always available at the right time and in the right place (Figueres et al. 2003). Observers still regularly call for donor agencies to support a larger number of smaller scale projects. With money, as with water, the challenge is to match resources with demand, taking into account both short and long term factors, social justice, politics and the needs of the environment (Figueres et al. 2003). It is obvious that funds to finance small-scale water projects in regional Australia must be increased in the coming years. Risks involved need to be better understood to improve the relationship between the financial world and the water industry sector.
3.5 MODELS FOR PROVISION OF INFRASTRUCTURE

Infrastructure has special characteristics that have traditionally justified or encouraged government involvement. There is a variety of alternative models for the delivery of water services ranging from public to private ownership with an array of public-private partnership (PPP) outsourcing and franchise models in between (Kopp 1997; Evans 2000). The continuum of models shown in Figure 21 represents the range of procurement processes for creation of infrastructure.

NOTE:
This figure is included on page 79 of the print copy of the thesis held in the University of Adelaide Library.

Adapted from Kessides 1993 in Kopp 1997

Figure 21 Models for Infrastructure Creation (Kessides 1993 in Kopp 1997)

Operations may wholly or partially contracted out to a private company under any of the above management arrangements. In Australia, the water supply industry is expected to remain predominantly publicly owned, but some privatisation through leasing out facilities and contracting out of services will occur (COA 2002). On the other hand, private sector involvement is expected to increase in wastewater treatment and recycling activities which will form a larger component of the Australian water industry in the future.

3.5.1 Public Enterprises

Infrastructure assets and the utility remains in public ownership. Government agencies are established through legislation and charged with the planning, construction and operation of water services to all or parts of a country. The agency and infrastructure created is owned and controlled by the government. Public utilities are formed as autonomous commercial enterprises with a board of directors. In recent decades, the traditional size of the public sector in Australia has significantly reduced due to contracting out of services. These changes are driven by a world wide trend for the reduction in size of government funded entities and increased sophistication of the private sector.
3.5.2 Public-Private Partnerships

Public-private partnerships (PPP) exist to create benefits for both the public and private partners. A key objective of a PPP is to allocate risk to the person best placed to manage and deal with the particular risk. Certain risks may be more effectively managed by the private sector rather than the public sector. The challenge for the public sector is to attract as much private capital as possible while ensuring that the facilities so produced create benefits for the public at least as great as those developed by traditional means (Kopp 1997). Importantly, PPP can also be viewed as a means of delivering services and not merely the asset enabling a service to be delivered. These types of agreements represent a potentially sustainable model based on private sector financing of water infrastructure.

3.5.2.1 Risk Management & Private Financing

Matching water infrastructure projects and sources of finance is mainly a matter of identifying the right combination of risks for all parties. The development of financing agreements depends upon a good risk assessment that identifies all of the possible risks (Figueres et al. 2003). There are various kinds of risk: completion risk, technological risk, risk relating to the supply of raw materials, economic risk, financial risk, currency risk, political risk, environmental risk and risk of catastrophe (Finnerty 1996 in Figueres et al. 2003). Figure 22 presents an overview of the possible risks involved.

NOTE:
This figure is included on page 80 of the print copy of the thesis held in the University of Adelaide Library.

Figure 22 Possible risks in water projects (Miller 2001 in Figueres et al. 2003)
Part I Our Water Resources

The risks will depend upon the type of water project under consideration, which could be an urban or rural water supply system, a sewage treatment plant, an irrigation, drainage, water harvesting or reuse project. The risks also depend upon the scale of the project, for example, the size of the population or area involved.

3.5.2.2 Outsourcing

In most jurisdictions in Australia, urban water authorities have been moved out of government departments and have become government enterprises (i.e. public corporations). At the same time, cities also began to contract with private companies to operate and maintain existing systems and to build and operate new sewage and drinking water treatment plants. For example, in South Australia, a management contract has been in place to operate large parts of the water and wastewater system since 1996. SA Water, a State Government Corporation, entered into a 15 year contract with United Water for the management and operation of the Adelaide water and wastewater systems. SA Water and the people of South Australia remain the owners of all of the metropolitan water and wastewater assets (SA Water 1999d).

Operating and maintenance contracts anticipate little or no private investment, although it is important to provide an incentive for the contractor to do routine or preventative maintenance. The private firm is paid a set fee or a fee plus a share of the profits. The shorter the contract, the easier it is to avoid disputes by anticipating problems and contingencies. And as Gomez-Ibanez (2003) noted shorter contracts make bad contracts more tolerable. Contractual approaches rely on the integrity of the legal systems (i.e. courts) used to enforce commercial contracts. Conventional contracts tend to be difficult for infrastructure monopolies because the lives of the investments tend to be long, and the longer the contract the harder it is to anticipate what will happen. Nevertheless, an explicit contract provides clearer protection against opportunism as long as the contract is complete.

3.5.2.3 Concessions

Natural monopolies make competition within a market impractical for many utilities; however, the government can introduce competition for the market by competitively awarding a concession of limited duration to the bidder who offered the lowest prices and best service. The fact that the concession was competitively bid would ensure that the prices and service standards were fair to both consumers and investors. Under a concession contract, the private company finances investments, operations and maintenance from its own revenue at its own risk, for the 20-30 year concession period.

In Australia, the private sector is involved in the provision of infrastructure through build-own-operate-and-transfer (BOOT) schemes where the private sector undertakes the risk, financing and the ownership of the infrastructure for a fixed period. Ownership of the asset will be transferred to the government at the end of the concession. Usually a government regulatory agency monitors compliance with a concession contract, but the agency can not change the terms once the contract is awarded (Gomez-Ibanez 2003).
Example 10 describes the BOOT concession agreement to provide infrastructure to serve a number of towns in South Australia. This is a useful study because of geographical spread of infrastructure involved - some 10 sites and 650km road distance.

**Example 10 Private-Public Partnership; Regional South Australia**

In August 1996, the South Australian government entered into the Water Treatment and Economic Development Agreement (WTEDA) with the private consortium Riverland Water Pty Ltd. The agreement delivered filtered water to parts of regional South Australia through a series of 10 privately financed small water treatment plants (see Figure 23).

Figure 23  Locations Served by Regional WTP (SA Water 1999d)

For the duration of the agreement, Riverland Water supplies treated water to SA Water at defined interface points downstream of each plant. Payment is based on two part tariff; an availability (fixed) and usage (variable) charge of approximately 84% to 16% respectively. The fixed component is set to cover 80% of the fixed operating and financing costs and provides Riverland Water with a predictable revenue stream. Riverland Water has virtually exclusive rights of supply to the 10 distribution areas.

Under the arrangement, SA Water is responsible for making raw water available and continues to be responsible for the distribution and customer relationships. To enable distribution of the filtered water into the existing supply systems SA Water financed to a value of $24M some pipelines, tanks, pumping station and associated works. Riverland Water assets are situated on land owned by SA Water and will transfer to SA Water control at the end of the term which is 25 years from the commissioning of the tenth plant.

The WTEDA enabled an economically justified infrastructure project to be successfully brought forward some five to ten years to benefit regional communities. At the same time, the level of financial, commercial and technical risks borne by SA Water was minimised. The last WTP was completed in 1999.

Source: Salkeld (1997) and SA Water (1999d)
BOOT projects require complicated risk allocation and sharing arrangements between the parties. There are many risks that may financially ruin the project including changes in law, exclusivity, adverse government (in)action, termination of concession, and payment failure by government. Inflation and interest are two significant finance risks that can impact on all parties. A significant legal risk is financial failure or insolvency of the concession company. Investors will only take these risks under the right kind of market conditions and incentives in smaller towns, such as the aggregation of a number of projects.

It is widely acknowledged that private sector participation in water supply can improve service and efficiency, yet there are few models suitable for small town water supply. A major challenge for concession contracts is how to ensure coverage of the smallest, poorest towns whose revenue base is too small to attract the private sector. For example, Geranium, a small township in South Australia, with a total of 39 water services of which 24 are residential has an annual revenue of less than $15,000 (based on average 2002/03 water use of 308 kL per service and State-wide residential water tariff). However, results of international research by Roche et al. (2001) has suggested that there is a possibility of building a successful business around small town water supply services if commercial methods are used and technological support is available.

3.5.2.4 Classic Franchising & Small Water Supply Systems

Franchising is arguably the most successful distribution strategy yet devised. In major western economies between 30% and 50% of all retail trade passes through franchised outlets in more than 60 different market sectors. Franchising also provides for replication between individual towns. Franchising is one model being investigated by the World Bank for application in small town water supply (WSP 2003). Roche et al. (2001) reviewed the potential of franchising in small town water supply as a means of providing incentives to local operators and introducing the type of professional support that is needed to improve service delivery, while keeping tariffs affordable. They argue the features that contribute to the economic impact of franchise operations are:

- Entrepreneurship;
- reputation of franchisor – quality and standardization; and
- joint advertising, purchasing power, training and management support.

Although composed of many independent units with relatively small revenue bases, a franchise network has the power and resources of a much larger enterprise (WSP 2003). By introducing an individual with entrepreneurial flair as the operator (franchisee), there is a built-in incentive to operate the water supply efficiently and in a business like way (Roche et al. 2001). Both parties commit to a long term relationship through a formal contract, the term of which is typically ten to twenty years and includes an exit strategy. Roche et al. (2001) also recommend the franchise be open to competition every five years for the franchisees. This would encourage them to perform well so that they are re-awarded their contract for a further term (WSP 2003). Clearly, it is in the interest of all parties to maintain continuity where possible, but the option to not renew the contract maintains healthy competition.
While franchising in small town water supply is an untested area, it has been successfully applied to the bottled water industry, in relation to the delivery of bottled water, coolers and associated products to residential homes and businesses. Under the franchising arrangement, the franchisee (operator) has access to a trusted brand, industry knowledge, and long term residual income. The franchisor (asset owner) develops an operating plan and procedures under a brand name (or logo) which become synonymous with quality service, and commits to ongoing support and guidance to small scale private operators in critical areas of management and operation and maintenance, in exchange for a share of the revenue.

There are no franchises currently operating in the small water supply sector and therefore no direct examples to follow (Roche et al. 2001). They recognised there will be obstacles to developing and operating a franchise system for delivering water supply services to small communities. For example, to attract competent franchisees a clear legal framework for contracting between the owner of assets and the franchisees would need to be established. Franchisees would not be permitted to raise tariffs without community consultation and franchisor (owner) sanction (WSP 2003). Therefore, a system of regulation would need to be in place to protect customers as well as to deal with contract compliance and performance monitoring.

3.5.3 Private Enterprises (Divesture)

Divesture is where the private sector undertakes the risk, financing and ownership of the infrastructure under a regulatory regime (Kopp 1997). This model is based around negotiation of private contracts between infrastructure companies and its customers. The British began privatising their utilities in the 1980s and found themselves forced to adopt a burdensome regulatory process in order to maintain political support for the efficiency incentives (Gomez-Ibanez 2003). Full private ownership in Australia will remain politically controversial particularly where some customers or sectors of the community remain vulnerable to opportunism.

3.6 REGULATING INFRASTRUCTURE

Concern over monopoly often leads the government either to provide infrastructure services itself or to regulate the prices and quality of service of private infrastructure (Gomez-Ibanez 2003). All markets are regulated in the sense that participants are constrained by private and public rules governing rights to act (Smith 1996; Baumol et al. 1988). Government regulation of, or intervention in, markets may range from social regulation (consumer protection, worker safety, environment protection, public health) to economic regulation (prices, profits). In Australia, government monopoly in delivering water services may have resulted in the low levels of sustainability and weak development of private sector. The challenge is to put in place principles of best practice regulation such that the decisions that emerge out of the regulatory process facilitate decisions in favour of sustainability outcomes (Harding 2005). Because regulation has an impact on everyone, it is important to decide both whether to regulate and how to regulate.
3.6.1 The Range of Solutions to Monopoly

Monopoly is defined as the lack of competition and the corrective implied is to make the market behave as if it were competitive. There are two basic reasons why a monopoly may exist - barriers to entry such as legal restrictions and patents, and cost advantages of large scale operation such as those that lead to natural monopoly (Baumol et al. 1988). The solutions to monopoly can be arrayed along a continuum according to the relative roles that markets and politics play in determining infrastructure prices and service quality as shown in Table 15. At one extreme prices and quality are determined largely by markets, at the other extreme largely by politics, and in between a mixture of the two. There are many variants along the continuum, but most can be assigned to one of four main groups or categories - private contracts, concession contracts, discretionary regulation, and public enterprise.

Table 15 The Range of Solutions to Monopoly (Gomez-Ibanez 2003)

NOTE:
This table is included on page 85 of the print copy of the thesis held in the University of Adelaide Library.

Source: Gomez-Ibanez (2003) Figure 1.1

Gomez-Ibanez (2003) assumes that private provision of infrastructure is generally desirable, particularly if the problems of regulating monopoly can be solved in a politically acceptable and economically sensible way. All things being equal (which they seldom are), private contracts are better than concession contracts and concession contracts are better than discretionary regulation. Gomez-Ibanez suggests one reason for this ranking is the stronger exposure to market forces, the greater the incentives to improve services and reduce costs. Another reason suggested for the ranking is that contracts enforced through the normal commercial courts usually provide a clearer and stronger form of commitment than specialised regulatory institutions.

Market-oriented solutions are more stable because they raise fewer concerns about the use of government powers and the fairness of regulatory proceedings, and thus are less likely to generate the kinds of political controversies that lead to intervention and broken commitments (WSP 2002). Nevertheless, it is important to choose the regulatory scheme carefully if private infrastructure is to survive
(Harding 2005). According to Gomez-Ibanez (2003) this means relying on private and contractual solutions where practical, since they generally increase the level of commitment and the chances that consumers will get the infrastructure services they value. But it also means being realistic about when private or contractual solutions will work, adopting discretionary schemes where necessary, or not privatising at all where no regulatory scheme seems workable.

### 3.6.2 Discretionary Regulation

Where there is little prospect for competition, specific controls are required to mimic the effects of competition and ensure that prices are minimised through; removal of abnormal profits and maximising efficiency improvements. The introduction of independent economic regulation poses a number of challenges in terms of designing a regulatory approach that delivers the desired outcomes. The best known examples of discretionary regulation are cost-of-service regulation as developed in the United States and price-cap regulation as developed in the United Kingdom. Both methods of regulation aim to provide regulated business with an adequate rate of return but the resulting risk/reward profile faced by the regulated business is different.

The cost-of-service methods focus on limiting abnormal profits, while price-cap regulation aims to maximise incentives for efficiency gains. A price cap control limits the year on year increases in prices to inflation plus or minus a predetermined X factor, applicable for a period of several years (the capping period). Under a cost-of-service system, the regulator establishes a permissible rate-of-return, which is enough to cover the company’s costs plus a reasonable profit. The need to estimate what the efficient market solution would have been in the absence of transaction costs makes discretionary regulation technically challenging. The tariff-setting task is complicated by the fact that the regulator inevitably has less information and analytic staff than the firm has.

Gomez-Ibanez (2003) observed that a lot has been learned about regulation in the last 150 years, the most fundamental lesson being that it is hard to regulate well. Therefore, Gomez-Ibanez recommends regulation only when it is essential and with the simplest and least intrusive scheme possible. Discretionary regulation has its shortcomings too, notably the risk of ‘capture’ by special interests, including the regulated firms, customers and others and misuse of regulatory powers. The future of private infrastructure depends on our ability to devise regulatory systems that treat both the consumers and the investors fairly. The perception of fairness is as important as the reality so that regulation is as much a political as a technical act.
3.7 SUMMARY

Water is one of Australia’s largest and most important industries. Provision of water is of integral importance to economic development and essential in protecting public health. Traditional patterns of urban water management were based on a simple ‘supply and disposal’ process, the remnants of which dominate our infrastructure and attitudes in the community today. There was a focus on reliable supply, with little concern about environmental impact and sustainability. A philosophical shift in the process of urban water management to the current ‘water cycle management’ view has occurred in Australia, and was institutionalised in 2004 by the NWI. New water supply systems developed in Australia must be planned and designed with a view towards sustainability.

Nationally, the majority of household water is used for outdoor purposes and less than 10% of water is used in the kitchen (COA 2002; ABS 2005; WSAA 2005). Less than 1% of water supplied to Australian towns and cities is actually used for drinking or food preparation (COA 2002). Urban water supply is the second most significant water consumption sector in Australia, exceeded only by irrigation for agriculture. The intensity of competition for water resources near towns and cities is likely to increase as forecast reductions in rainfall connected to global climate change take effect. Changing water supply practices in Australia has been and will continue to be difficult, with environmental, financial and political barriers delaying progress.

In Australia, all levels of government are responsible for different aspects of water management (LGA 2000). The water supply industry is predominantly publicly owned, but some privatisation through leasing of facilities and contracting out of services has occurred (COA 2002). Water services are provided by public or privately operated utilities and the Government (predominantly the State Government) is responsible for regulation and resource management. Private sector involvement is expected to increase in wastewater treatment and recycling activities. Natural monopolies make competition within a market impractical for utilities, however the government can introduce competition by competitively awarding financial concession with a limited duration to the bidder who offers the lowest price and best service.

Traditional water management practices have been reviewed over the past two decades in Australia as it has been recognised that they are not sustainable (Fleming 1999) leading to significant reform. Some consumption is highly price sensitive, and this has been used to regulate demand. Tariff structures around Australia have been changed to meet COAG requirements. Governments have, however, retained the power to set prices below a rate necessary for cost recovery for water utilities operating in regional areas. The pricing system needs to generate revenues for the efficient operation of the present system and its future maintenance. Pricing adjustments should always be applied selectively, gradually and with sensitivity to minimise potential social and economic impacts on the community. It is not easy for communities to accept the notion that higher prices can serve the public interest, especially for something as fundamental as water. Advocacy for higher prices for any service to communities in regional Australia is a mandate for political disaster. Reforms have started to correct the underpricing of water in Australia, but this is a slow and politically sensitive process.
Rural communities are often disadvantaged in terms of their water supply, both in quantity and quality. Factors influencing the delivery of water to small communities include affordability, technical appropriateness, levels of skilled workers, current infrastructure, and resource availability (HREOC 2001). Water utilities operating small systems cannot reliably deliver services unless their operators are adequately trained, even where appropriate technologies have been adopted. Operation is often simplified by automated features, particularly where maintenance requirements are well documented. There is a need for the provision of technical support to small water supply operators to ensure delivery of safe water.

The provision of services to small towns is constrained by the need for water authorities to remain financially viable. Most water authorities realise that there are economic limits which prevent most small communities from funding works in their entirety. Towns and rural communities have a small, static base of rate payers, limited scope for economic development and restricted opportunities for resource sharing between communities. These factors influencing regional water utilities can have a significant impact on their cost recovery capability. Additionally, many ‘small’ water utilities find it difficult to make accurate data available for analysis. This makes development of water resource management strategies more difficult and makes accurate risk management almost impossible.

Despite reductions, Australian consumption remains approximately 30% higher than the 1997 OECD average of around 180 Lpcd (COA 2004). Excessive water use is influenced by cultural factors (WA WRC 1986; Fleming 1999; Murray-Leach 2003) as well as policy and infrastructure. Popular garden designs in Australia encourage high levels of water consumption. Residential outdoor water use is an area where there is clear potential for consumption reduction. Much water use in urban areas is discretionary and is sensitive to price changes. Pricing structures have already taken advantage of this, but there is room to capitalise further. As the cost of water rises, substitutes and alternatives are usually found. The easy gains for consumption reduction have already been implemented. Further increases in efficiency and consumption reduction are going to require more radical social, political and infrastructure reform.

Water policy has changed significantly in Australia in the past two decades. During the decades of reform, a new understanding of water management with a view to sustainability has been adopted, improving urban water consumption by domestic and commercial users. The focus of the Australian water industry has moved away from increasing the quantity of water available towards more efficient water use. The improvement in efficiency was delivered through a combination of consumption based pricing structures, technological change and education campaigns. While there has been a significant reduction in per capita consumption of water in major urban centres, there is still a need for improvement as the total water consumption is increasing with population growth (COA 2002) and regional areas have significant room for improvement.
Chapter 4

More Sustainable Water Services

"We will only know the worth of water when the well is dry."

Benjamin Franklin (1785)

4.1 INTRODUCTION

The current generation in Australia enjoys the benefits associated with the provision of a reliable and safe water supply, adequate waste disposal system, improved health of communities and high standard of living by world standards. At the same time, this generation has inherited a range of problems associated with the form of the existing infrastructure not the least being degradation of a number of water dependent ecosystems. The growing population in Australia expects that sufficient water continues to be provided for its consumption, as well as implementation of alternative patterns of development that can act to mitigate acknowledged environmental problems. It is widely acknowledged that in order to be more sustainable, urban areas must alter the way in which water services are provided (Newman & Mouritz 1992; Fleming 1999; COA 2001). The complexity is increased by having an established system as a starting point.

Water supply will continue to be primarily about developing water resources to meet demand and systems will continue to be designed to obtain water from a source and deliver it to various users. The emphasis of water policies has shifted in most jurisdictions from infrastructure development to sustainability (AATSE 1999). Some aspects of sustainability have long been central to the development of water supply infrastructure, for example, water supply objectives traditionally related to social and economic well-being of the community being served. Nevertheless, explicitly incorporating sustainability into solving the traditional ‘supply-demand problem’ poses many challenges (Bell & Morse 2003; Figures et al. 2003; Hall et al. 2004). A key challenge in terms of provision of sustainable water infrastructure and services will be in transforming existing systems, often with an asset life between 50 and 100 years, into more sustainable forms while maintaining a high level of services to customers.

The introduction of alternative water management practices to achieve sustainability will require changes in deeply held attitudes in individuals, institutions, professionals and social organisations within society (Figueres et al. 2003; GWP 2003). Government can provide leadership and direction, however it is equally important that each Australian takes a collective responsibility for protecting and enhancing our environment (EPA 2003). Each person has a responsibility to reduce consumption of resources and protect the environment for our children and future generations.
Urban areas represent concentrated demands for water that compete with other demands, such as agriculture and environmental flows, as well as placing stress on the surrounding environment. Most urban areas have already fully exploited the readily available water resources and are now obliged to develop and treat sources of lower quality or travel long distances to develop new supplies, both options are costly. Invariably, there will come a point at which the demand for water cannot be met from the developed water resources. Fundamentally, water managers need to consider options of decreasing urban water demand, finding extra water supplies, or both. However, the ‘easy’ options for augmenting water supplies have been taken up and prospects for future expansion are limited.

‘Major’ urban water utilities in Australia are responding to the challenge by promoting greater efficiency in water use (ie. demand modification) and looking beyond improvement of conventional sources of supply (ie. considering alternative sources of water). For example, in 2001 the Water Resources Strategy for the Melbourne Area (WRSMA) summarised the key issues for public discussion around the four broad options (see Figure 24 below).

NOTE:
This figure is included on page 90 of the print copy of the thesis held in the University of Adelaide Library.

Figure 24  Future Options for the Melbourne Water Area (WRSMA 2001)

The first two options relate primarily to managing the demand for water within Melbourne and the remaining options relate to finding additional water supplies to meet growing demands. The options are not mutually exclusive and the strategy may well be based on a mix of different actions (WRSMA 2001). Another recent example in Australia is the 20 year Water Proofing Adelaide strategy published in 2005 by the South Australian Government. The three key issues identified by this study were; management of our existing resources, responsible water use, and additional water supplies. In addition to balancing the supply and demand, protection of quality of water resources for Adelaide was stressed to ensure that they remain healthy and sustainable well into the future.
The general conclusion is that achieving sustainable water use for Australia’s growing urban centres will require a mix of options that need to be complemented by responsible water use by individuals and businesses. These will include demand management (ie. water efficiency and conservation), water sensitive urban design and development (ie. policies and practices), and supply augmentation (ie. natural and recycled). The three key measures are discussed below.

4.2 DEMAND MANAGEMENT

Demand management focuses on improving the efficiency of water use and reducing per capita demand by changing the way our urban society uses water (Akkad 1990; Vickers 1990; Kinzelbach & Kuntsmann 1999; Langford 2003). For example, water efficient appliances in houses (ie. toilets, showers, clothes washers) and water efficient gardens. In Australia, there is a strong desire within the political and general public arena for water demand to be actively managed, and water use efficiency increased in all water use sectors, including irrigation, industry and domestic purposes. The more that demand for potable water can be reduced the more water will be available for future generations and to flow down our rivers and streams. More efficient use of water could be the cheapest, as well as the most environmentally benign means of augmenting and improving the quality of water supplies.

4.2.1 Benefits of Demand Management

Demand management is usually the first choice due to the cost effectiveness of these measures and that ability to influence the whole urban system. Demand management can be considered as a resource. Although it does not involve developing new sources of water, it does allow the developed water resources to support an increased population and economic development. Figure 25 below shows the potential contribution that a successful demand management strategy can make in delaying or eliminating the need to expand potable water supplies.

NOTE:
This figure is included on page 91 of the print copy of the thesis held in the University of Adelaide Library.

Figure 25 Benefit of Demand Management (Turcotte 1997)
Demand management measures can reduce water utility costs, primarily through avoiding or deferring the need for new capital works and also by reducing operating costs associated with pumping and water treatment. The benefits of demand management will be greatest in areas where the water supply system is constrained through growth in demand, the capital or environmental cost of new or increased supplies. Demand management may also reduce the volume of wastewater flow and defer augmentation of wastewater systems and treatment plants. Thus, as Figure 25 suggested efficient water use can provide an outcome equivalent to augmenting the water supply system and helps to balance supply with demand. However, Broad and Holroyde (1989) caution that savings achieved as a result of deferment of source amplification can render water supply systems more vulnerable under severe drought conditions.

4.2.2 Elements of Demand Management Strategy

The Australian urban water industry is committed to reducing per capita water consumption, reducing water wastage and ensuring that water-use is efficient. Variability in water usage patterns and geographic conditions across Australia means that no one strategy will be appropriate for all communities (COA 2002). This means understanding the constraints: analysing how much water is used, when, for what purpose and at what level of efficiency; determining the potential reduction in water use that can occur through improvements to water using equipment and behaviour; and developing programs to achieve these improvements (WSAA 1998). Strategic planning is the key aspect of a successful demand management strategy.

Demand management for urban water supply encompasses a range of possible measures and will typically include the following elements (McLaren et al. 1987; Akkad 1990; Gilbert et al. 1990; Fleming 1999):

- Economic instruments such as appropriate water pricing policies;
- Physical methods (voluntary and mandatory) such as water meters and water saving appliances, ie. toilets, showers, clothes washers, gardening systems; and
- Societal behaviour changes (customer advisory and education services).

All of these elements can be combined to reduce demand for urban water and to achieve more efficient water use. The sequence in which measures are implemented is also important. For example, it is not possible to establish a fair and efficient pricing system for water unless all customers are metered.

Example 11 below describes the water conservation effort undertaken by one town in the USA over three years from 1987 to 1989, and the importance of combining all of these elements. This example highlights that voluntary conservation was not as effective as regulated water use (ie. mandatory conservation). The sustained reduction in water use was a direct result of giving out water efficient appliances and the corresponding high level of up take. It also demonstrates changing behaviour is a fundamental factor in a successful demand management program.
Example 11 Demand Management: East Bay, USA

In March 1987, the East Bay Municipal Utility District (EBMUD) began a concerted effort to curtail water consumption after having experienced a dry winter with only 51% the normal rainfall average. A voluntary conservation program was begun to minimise demand with a goal of 12% reduction in case a second dry winter occurred. However, only a resulting decrease in consumption of 4% was achieved during this period. The voluntary program was heavily promoted to acquaint EBMUD's 340,000 accounts with methods of conservation that could be mandated if conditions did not improve.

A subsequent second dry winter was experienced in 1988 with only 56% of normal rainfall which lowered storage levels to a crisis trigger point. A full scale conservation program was then needed that would ensure compliance by all customers with a revised reduction in water consumption from 12% to 25% in 1988. An extensive advertising campaign was conducted, with conservation education programs in local schools, and additional publications including the use of a sympathetic press corps to provided daily reminders of shortage conditions. In addition, a drought ordinance was passed that included the following conditions:

- vehicles could not be washed without the use of a shutoff nozzle;
- new turfs could not be installed and only drought tolerant planting allowed;
- new service connections must adhere to a written drought compliance agreement;
- a waste watcher patrol established to identify violations; and
- flow restricting devices installed in the event of prolonged non-compliance.

More than 55,000 conservation kits containing low flow shower heads and toilet tank inserts were distributed to customers free of charge. A survey of recipients conducted by the municipal utility office indicated that 90% installed the devices, which should have a lasting effect on consumption. At the end of the 1988 summer period, the drought performance measurement actually decreased consumption by 30% (5% above the original goal of 25%). Through the following winter of 1989, there were signals that the drought had eased and a decision was made to reduce conservation effort to 15%, but the community actually achieved a reduction of 27%.

The resulting reduction in water consumption was arrived by using three major instruments, being a US$2.5m education and awareness campaign, changes in the pricing structure and mandatory regulation regarding water usage.

Source: Gilbert et. al. 1990

Sustained reduction in demand is equivalent to the addition of that amount of reliable yield to the supply system; however, there is debate about whether reductions can be sustained over the longer term. Demand management by the Australian urban water industry over the last 20 years has been very successful. However, despite reductions in individual consumption, as the population grows the total water consumption levels continue to increase and put pressure on water resources. WSAA (2005) caution that consumption savings cannot be achieved indefinitely, that most of the easy measures have been targeted and further limitations will be highly intrusive and likely to encounter community resistance.
4.2.3 Appropriate Water Pricing

One of the most effective methods to encourage consumers to conserve resources is through economic incentives. For example, if the price of water is set ‘too low’ water users will receive the ‘wrong’ signals and be encouraged to consume more water (ie. support inefficient water use practices). Paying for water makes people more responsible for their demand, as people often ask for more than they really need. The use of water in urban areas is discretionary at least for certain purposes such as garden watering. The price of water provides the clearest message to customers allowing them to achieve an appropriate balance between the benefits and costs of usage of water services (WSAA 1998). Naturally, consumers are concerned with keeping tariffs affordable and often fail to appreciate their long term interest in supporting the investments needed to maintain the capacity and quality of the services they enjoy.

Application of cost reflective pricing would generate revenue for the efficient operation (and servicing debts) of the present system, its maintenance, and future replacement. Costs should be determined and cost recovery implemented region by region. Increasing the cost of water too quickly, or with too little regard for possible social and economic repercussions, may cause unacceptable disruption to local economies and communities. Water pricing must recognise capacity to pay, and therefore users should not be required to meet full costs where this would be clearly beyond their capacity. Nevertheless, water prices should not be regarded as an instrument for modifying income distribution; this is a matter for social welfare policy (ie. rebates in appropriate circumstances). Government funds should be provided to meet the balance of costs in such cases.

Both willingness and capacity to pay can be surprisingly elastic, depending on what options are being offered, at what immediate and longer term costs, and how clearly this information is communicated to all potential consumers of services (WSP 2003). Appendix 3 discusses the impact of water pricing reform between 1990 and 2003 on residential water use in South Australia. Establishing an appropriate pricing structure for water supply is one of the most important tasks in a demand management strategy. In Australia, low price for potable water services has been an impediment to development of water harvesting and reuse projects.

4.2.4 Water Saving Appliances

Water conservation (efficient use of water) is an essential element in sustainable water resource management and should be practised at all times, not just during drought emergencies. Every new home or building equipped with water saving appliances (plumbing fixtures) can potentially provide additional water supply and wastewater capacity for future development without overburdening existing systems. The extent of water saving devices such as low flow shower roses can also have an impact on peak flow (Hoffrichter et al. 1999). By choosing water efficient products householders can conserve water as well as and save money through reduced water bills. In the past, an important barrier to water conservation was the lack of readily accessible and simple information for consumers (WA WRC 1986).
4.2.4.1 Indoor Household Products

In 1997, Water Services Association of Australia initiated a voluntary efficiency labelling for water using appliances (WSAA 1998). The National Water Conservation Rating and Labelling Scheme is a voluntary certification program that awards an appropriate A-rating to water efficient products that comply with the requirements of standard AS/NZS6400 *Water efficient products – Rating and labelling*. Products that can be covered by the voluntary scheme include:

- Shower heads;
- Dishwashers;
- Clothes washing machines;
- Urinal operating mechanisms;
- Taps and tap outlets;
- Toilet suites or matched cistern and pan sets; and
- Flow regulators.

Once a product is certified under the scheme, it is eligible to display the appropriate label to enable consumers to easily identify and select water efficient products. Until July 2006, products can be rated as indicated in the labels below.

![Water Efficiency Rating Labels]

In 2005, the Commonwealth Government, in collaboration with State and Territory governments, introduced the Water Efficiency Labelling and Standards (WELS) scheme. The WELS scheme draws on the experience of the mandatory energy efficiency labelling system which has been in place across Australia for over a decade. From July 2006, it will be applied as the mandatory national water efficiency labelling and minimum performance standard for household water using products (excluding domestic garden watering equipment). The mandatory WELS scheme will supersede the Water Services Association of Australia’s voluntary National Water Conservation Rating and Labelling Scheme. The WELS scheme will be overseen by a regulator located within the Commonwealth Department of the Environment and Heritage.

The WELS label (see Figure 26) features a six star rating that gives a quick comparative assessment of the products water efficiency and a water consumption figure for the product. These two features will assist purchasers of household water using products to compare the relative water efficiency. These WELS labels will begin to appear on water using products from July 2005, however until July 2006, the ‘AAAAA’ label may continue to appear on products for sale. It should be noted that the ‘As’ on the old label do not equate to the stars on the new label.
Figure 26 National WELS scheme label (www.waterrating.gov.au)

This information should be made available as part of an overall water strategy for country towns to help ensure their limited water supplies are used wisely.

4.2.4.2 Outdoor Products

In Australian cities, between 30 – 70% of household water is used outdoors and until recently there was no national program to provide advice to consumers on ways to save water used outdoors or to recognise services and organisations that are committed to saving water in this area. The Smart Approved WaterMark scheme is managed by a Steering Committee formed by the Water Services Association of Australía (WSAA), the Irrigation Association of Australia (IAA), the Nursery and Garden Industry Australia (NGIA) and the Australian Water Association (AWA).

The nationally endorsed Smart Approved WaterMark water conservation labelling scheme has emerged to meet this need.

The Smart Approved WaterMark label can be applied to:
- outdoor water using/saving products;
- outdoor water related services; and
- outdoor water related organisations

Estimates of the effectiveness of water conservation measures vary widely and are subject to considerable uncertainty due to limited reliable data. Social research is essential to ensure that technical conservation methods are taken up; including designing devices around people’s needs and marketing them (Murray-Leach 2003). Technical assistance should be offered with respect to the cost of installing and maintaining devices that reduce water use. Many conservation measures are already in place in country towns, particularly where there is poor quality supply, substantial reliance on roof water, or high water charges. Therefore, any survey conducted on community water usage habits to provide an indication of the potential benefit of a conservation program needs to include a review of the extent of water saving appliances currently in use.
4.2.5 Changing Water Use Behaviour

Changing water supply practices to achieve sustainable water resource management will require adjustment of deeply held attitudes in institutions, professionals and individuals alike. Education is widely recognised as the primary agent in driving generational change towards sustainable development practices (GTZ 2001; WSP 2003; EPA 2003). Yet, even with new understanding of environmental matters, individuals and organisations retain old habits, patterns and practices. These need to be removed and replaced by more sustainable practices. There are no instant habits so it is unrealistic to expect them to go away immediately (Warren 2002). There is only one way to re-develop water conscious habits in society – practice to unlearn wasteful habits – and it will take time. Learning-by-doing must be encouraged (World Bank 2002). Participatory approaches can be influential instruments for social change as they offer people the chance to claim rights and take on the consequent responsibilities. Building and sustaining a social connection is a key component of delivering a new culture. Primary education can make positive contributions towards combating the problems of environmental degradation and improvement of water use efficiency. Today's children are the custodians of tomorrow’s environment.

Another prerequisite for sustainable water management is strong research and easy access to the resulting information. An informed public can make a substantial difference in determining the behaviour of governments in response to sustainable developments (Fleming 1999). Progress depends upon the products of educated minds - research, invention, innovation and adaptation. Over time, education can affect cultures and societies, increasing their concern over unsustainable practices and their capacities to confront and master change. Education is a means for disseminating knowledge and developing skills to bring about desired changes in behaviours, values and lifestyles, and for promoting public support for the continuing and fundamental changes that will be required. The key to modifying urban water use behaviour in Australia is to change the mindset of water users; this will require education programs that target all levels of society. Combined with the current concern for the environment, public acceptance of water harvesting and reuse should increase.
4.3 SUPPLY AUGMENTATION

Supply management is primarily about developing water resources to meet demand. Imposition of restrictions in the form of water use or development embargos can impair community living standards and inhibit prospects for attracting industry (Pigram 1986). Nevertheless, population growth in Australia over the past 20 years has generally been serviced without the construction of new storages due to reductions in per capita demand through effective demand management measures (WSAA 2005). Invariably, there will come a point where, even with further demand management measures, developed water resources will not be able to satisfy the demands of Australia’s growing cities. Most cities and towns have exploited readily available water resources and will be obliged to develop lower quality water sources or travel long distances to develop new freshwater source to meet existing demand and accommodate future growth.

There are a number of potentially viable opportunities to provide additional water for urban centres and provide benefits to the environment at the same time. For example, one way of increasing water supplies and reducing the discharge of contaminants to the natural environment is to harvest and reuse stormwater and wastewater effluent, both commonly referred to as ‘urban wastewaters’. CSIRO (2003) estimated that 97% of urban stormwater runoff and 86% of wastewater effluent is being discharged directly into oceans or freshwater systems. Additionally, the volume of these ‘urban wastewaters’ grows in proportion to the size of the urban centre making them an important resource alongside current demand management measures. In general, undervalued or untapped water resources within urban centres in Australia include rainwater harvesting, treated wastewater, stormwater runoff, and seawater. The extent of use and potential of each of these resources is discussed below.

4.3.1 Rainwater

For millennia people have relied on rainwater harvesting to supply water for household and livestock uses. Harvesting rainwater simply involves the collection of water from surfaces on which rain falls, and subsequently storing this water for later use. This simple concept is shown in Figure 27. In rural Australia, it is common practice to capture rainwater from the roofs of buildings and direct the flow of rainwater into a rainwater storage tank.
In the absence of potable town water supplies, rainwater tanks are still a source of domestic water supply for isolated properties and small communities. For such locations, tanks need to be relatively large (and domestic water demand management a constant concern), so there is a security of supply even during prolonged periods of low rainfall (Lang et al. 2000?). The benefits of rainwater tanks are well understood in low density rural areas that have limited or no access to reticulated potable water supplies.

4.3.1.1 Extent of Use

In 2004, only 17% of households in Australia sourced water from a rainwater tank (ABS 2005). As there is no compulsion for householders in Australia to use this water this rainwater resource may not be fully utilised. Studies have shown that to maximise contribution of rainwater harvesting to meeting household demands requires plumbing the tank into toilet flushing, laundry or other uses (DWLBC 2005). Figure 28 shows that around 48% of households in South Australia already have rainwater tanks installed.

![Figure 28 Australian Households with Rainwater Tanks (ABS 2005)](image)

Substantial levels of public and private resources have been committed to provision of reticulated and domestic rainwater supplies in South Australian towns. Heyworth et al. (1998) found rainwater collected in domestic tanks to be an important source of potable water for rural South Australia, with 77 to 84% of households, depending upon the region, using rainwater from tanks as a source of water. They also found that 81.5% of consumers in country regions do not use mains water as their main source of drinking water, even where one is provided. The private facilities should not be overlooked (Hoffrichter et al. 1999). For example, private dams and rainwater tanks can act to increase the capacity of established water infrastructure. These supplementary storage facilities can have a significant impact on the ability of a community to endure during peak demand periods. The benefits of a rainwater tank include self-sufficiency, providing backup supply in case of water restrictions or water quality problems. It therefore seems appropriate to review the roles of rainwater storages as part of the overall water supply in Australian towns. The addition of a private rainwater harvesting system provides the household with a dual supply of water.
4.3.1.2 Potential in Urban Areas

The collection of rainwater from roofs of buildings can take place within cities and towns and replace a substantial proportion of a household’s potable water needs. In major urban centres, being largely self-sufficient in water supply is possible for a vast majority of Australian households and buildings (Coombes et al. 2002; Gardner 2003). Domestic rainwater tanks were standard in cities established in the nineteenth century, but once reticulated water supplies were developed, the need to secure and maintain an independent water supply diminished. Consequently, in many urban centres the traditional rainwater harvesting systems have been all but forgotten. However, when applied in the urban context, rainwater tanks can still provide an opportunity to significantly reduce demand on potable (drinking water) supplies in certain areas of use.

Studies have found that from a homeowner’s perspective rainwater tanks are not cost effective when compared with reticulated mains water, particularly, if the rainwater is used only for drinking purposes. Currently, this is the most common use of rainwater in Adelaide (Lang et al. 2000). In terms of efficient rainwater harvesting, it is better to maximise winter use, which is the predominant rainfall season in Southern Australia. This can be achieved by supplementing in-house water demand; that is, plumbing the rainwater for all in-house supply or selectively plumbing for toilet flushing, clothes washing or hot water supply. Other than the roof, which is an assumed cost in most building projects or a sunk cost in existing buildings, the storage tank represents the largest investment in the rainwater harvesting system. It is a common misconception that the larger the tank the greater the volume of water available for use. Of more importance are the rate of use, rainfall and the roof area connected to the tank. The smaller the roof area the higher the level of reliance on the town water especially, in years of below average rainfall.

Example 12 below describes operational experiences of a dual water supply system (rainwater and mains water) installed at an established house in Maryville, an inner city suburb of Newcastle in New South Wales.

Example 12 Dual Rainwater & Mains Supply: Newcastle, New South Wales

An old house in Maryville was fitted with an aboveground 9kL rainwater tank to supply hot water, toilet and outdoor uses to the household that consists of an average of three people. It has a galvanised iron roof with an area of 135m² and an allotment of 255m². Rainfall from a portion of the roof with an area of 115m² is directed to the rainwater tank and supplied via a small pump directly to the hot water service and the toilet cistern. Rainwater for outdoor uses is drawn either directly from the tank or from the mains supply. Mains water is supplied to the remainder of the house and is used to top up the rainwater tank when water levels are low. An air gap is used for backflow prevention in accordance with Australian standards.

The dual water supply system was installed during August 1999 and use of the system commenced during October 2000. The total cost to install the rainwater system was less than $2,000 including the tank, pump and pressure control, plumber, fitting, float system, concrete slab and electrician. The development approval process was delayed by the Council requiring approval from the Hunter Water Corporation to install the dual
system and until an undertaking was given to monitor the quality of water from the rainwater tank. A monitoring program was established to observe the water quality in the rainwater tank and at the household taps, and water use.

The automated monitoring program to measure rainfall and water levels in the tank commenced 15 December 2000. The majority of parameters tested (12 samples from the tank) complied with the Australian Drinking Water Guidelines although the average values for total coliform, pH and zinc in the water exceeded the recommended drinking water guideline. However, because the rainwater is not used directly for drinking, the quality may be acceptable provided water from the hot water service meets the drinking water guidelines (as it may find potable uses). The water quality results from 5 samples show that the hot water quality complied with the exception of pH and zinc.

After around 250 days in operation the rainwater tank significantly reduced the volumes of stormwater runoff discharging from the roof to the street drainage system. Stormwater runoff from the allotment was reduced by around 39% and reduced the peak stormwater discharge by 86%. The rainwater tank was also able to reliably meet water demand during the monitoring period with minimal top-up from the mains water supply, with a 52% reduction in mains water use observed. Analysis of the long-term performance revealed that the use of the rainwater tank was expected to provide a 63% reduction in mains water demand. The cost of rainwater has been found to be $0.30/kL which is less than the price of mains water.

Source: Coombes et al. 2002

The example demonstrates it is possible to replace at least a substantial portion of the freshwater requirements where rainwater is used before potable water. Generalising these results for the long term or for different locations, roof areas, and tank volumes requires water balance modelling. In the example the security of rainwater supply is not a critical concern, as mains water back-up is available if the tank is emptied. Rainwater tanks may be fed from the mains supply by use of a control valve and an approved air gap. Tank placement should also take into consideration the possible need to add water to the tank from an auxiliary source, such as the mains water system or a water truck, in the event your water supply is depleted due to over use or drought conditions.

4.3.1.3 Water Quality Issues

Wherever rainwater is used, there must be a long term commitment to its proper operation and maintenance to avoid endangering the health of users (EWS 1990; Liang 1998; Heyworth et al. 1998; Bowden 1999). This responsibility is particularly important in areas dominated by localised industrial emissions from heavy industry or in agricultural regions where crop dusting is prevalent. Where rainwater is to be used for human consumption (drinking, brushing teeth or cooking) filtration and some form of disinfection is the minimum recommended treatment (TWDB 1997). Table 16 sets outs some common methods of treatment units used in rainwater harvesting systems.
In the past, some homeowners have not always accepted this responsibility conscientiously. Consequently, there is a general reluctance by health authorities in Australia to endorse rainwater tanks for potable uses in urban areas because of concern from contaminants washing off the roof (Gardner 2003). As roofs collect debris, dust and bird droppings, it is desirable to have a device to discard the first run-off after a dry spell. However, first flush devices will reduce sludge accumulation in storage tanks but will not necessarily improve water quality.

For instance, despite the first flush device in the Healthy Home (refer Example 19 on page 116), frequent intervals when coliform levels in the rainwater tank exceeded the ADWG standard were observed, with peak values occurring after heavy rainfall events. Gardner (2003) reported this was rectified by fitting a small UV system to the rainwater tank. Coombes et al. (2000 in Gardner 2003) also reported similar high concentrations of coliform for rainwater tanks in cluster housing at Newcastle. Coombes et al. (2002) also reported coliform at the Maryville site (see Example 12 above) however in this case rainwater is not used for drinking purposes and the rainwater from the hot water service was compliant with Australian drinking water standards.

Rainwater tanks without proper management are subject to contamination and therefore a potential health risk exists. For example, if the rainwater is intended for use inside the household, either for potable uses such as drinking and cooking or for non-potable uses including showering and toilet flushing, appropriate filtration and disinfection practices should be employed. If the rainwater is to be used outside for landscape irrigation, where human consumption of the water is less likely, the presence of contaminants may not be of major concern and the treatment requirements can be less stringent or not required at all.

Source: TWDB (1997)
The reliability of rainwater supply systems in Australia is strongly affected by the prevailing climate, particularly where rainfall variability is high (COA 1989). Some costs and benefits will vary from region to region due to the differences in annual rainfall (hence tank yield), rainfall intensities (impacts on rainwater tank ability to reduce peak storm flow) and some other factors (Lang et al. c2000). However, the security of rainwater supply is not a critical concern, as mains water back-up is available.

4.3.2 Wastewater

Effluent reuse is not a new concept. Controlled wastewater irrigation has been practised on sewage farms in Europe, America and Australia since the turn of the 20th Century. Tougher environmental standards for discharging effluent into some waterways have led to improvements in the quality of that water to the point where those standards are on par with or better than the quality of the water required for many industrial, domestic and irrigation purposes. Once wastewater is treated it has many valuable uses. The value of wastewater for crop irrigation is becoming increasingly recognised in arid and semi-arid countries (Pescod 1985). In Australia, treated effluent is now being used to irrigate crops and pastures, vineyards, recreational areas, golf courses and woodlots.

The change in perceived value and wider acceptance of treated effluent as a resource in Australia has essentially occurred in a 30 year period. Polin (1977) observed that irrigation for tree growth was uncommon and the use of treated effluent for this purpose even more uncommon. Projects like that described in Example 13 show just how far we have come. Treated wastewater from the Gumeracha Wastewater Treatment Plant, which once flowed into the River Torrens, is now being used to grow high quality timber for housing and furniture (SA Water 1999d).

Example 13 Local Water Reuse for Commercial Irrigation: Gumeracha

Since 1996, the entire 25ML outflow from the Gumeracha wastewater treatment plant, which once flowed into the River Torrens, has been used to grow quality timber for housing and furniture. The treated wastewater is pumped just over a kilometre to irrigate a 15 hectare pine plantation (on land owned by SA Water) at Mount Crawford Forest. It involved construction of a new pumping station and rising main to the forest, a fully automated reticulation control system and 64 kilometres of dripper pipework. The $400,000 reuse scheme was the first of its type to be implemented in the Adelaide Hills, and incorporates an ongoing soil and water monitoring program.

The first logging is expected to take place in about 2010, providing a quicker than usual return, because of accelerated plantation growth resulting from increased irrigation and the nutrient rich nature of the water. In addition to removing a significant nutrient load from the River Torrens, the innovative project will provide premium logging for South Australia’s housing industry and timber for vineyard posts, plywood and packing cases.

Source: SA Water 1999d
Reuse of wastewater is an effective means of increasing total available water supply, particularly, where it can be used in preference to potable water. In addition, annual effluent production is relatively stable making treated wastewater a reliable source of water. An obvious benefit associated with reuse of treated effluent, as well as boosting the environment, is the reliability of supply and ability to deal with periods of water shortages.

4.3.2.1 Present Reuse Situation

Radcliffe (2004) estimates the proportion of treated effluent currently being reused in Australia to be about 9.1% with the majority of municipal wastewater produced disposed of to the ocean or other water courses or evaporation. This value may appear small nevertheless it demonstrates almost 200% increase in level of wastewater reuse in Australia over the last two decades. In 1982, wastewater reuse amounted to less than 5% of the total annual sewage flow in Australia (COA 1983). This excludes the land treatment at Melbourne's Werribee sewage farm which involves application of raw sewage to land to achieve treatment rather than the reuse of effluent (Strom 1985).

Table 17 presents the recycled water reuse from water utility treatment plants in states and capital cities expressed as a percentage of sewage effluent treated. South Australia has achieved the highest percentage of wastewater reuse, however considerable scope still exists to increase the level and conserve the State’s water resources.

<table>
<thead>
<tr>
<th>State</th>
<th>Wastewater Reuse (%)</th>
<th></th>
<th>Capital</th>
<th>Wastewater Reuse (%)</th>
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</thead>
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<tr>
<td></td>
<td>1982(1)</td>
<td>2004(4)</td>
<td></td>
<td>1982(1)</td>
</tr>
<tr>
<td>ACT</td>
<td>-</td>
<td>5.6</td>
<td>Canberra</td>
<td>-</td>
</tr>
<tr>
<td>NSW</td>
<td>2.5</td>
<td>8.9</td>
<td>Sydney</td>
<td>0.5</td>
</tr>
<tr>
<td>NT</td>
<td>33.3(2)</td>
<td>4.8</td>
<td>Darwin</td>
<td>-</td>
</tr>
<tr>
<td>QLD</td>
<td>2.5</td>
<td>11.2</td>
<td>Brisbane</td>
<td>-</td>
</tr>
<tr>
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<td>15.1</td>
<td>Adelaide</td>
<td>8.2</td>
</tr>
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<td>Hobart</td>
<td>0</td>
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<td>6.7</td>
<td>Melbourne</td>
<td>0.2(3)</td>
</tr>
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<td>10</td>
<td>Perth</td>
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</tr>
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<td>9.1%</td>
<td></td>
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</tr>
</tbody>
</table>

(1) Estimates of 1982 sewage flow reuse (%) as reported in COA 1983 & Strom 1985
(2) Estimate included projects in construction
(3) Estimate excludes Werribee Sewage Farm
(4) Radcliffe (2004), Tables 2 & 3
The amount of wastewater reused in Australia is low compared to water reuse overseas. For example, in Florida around 34% and in California 63% of treated effluent produced within these states is used (COA 2002). It should be noted that since 1928, the California State Constitution has prohibited waste or unreasonable use of water, encouraging water reuse wherever safe and practical (Price 1990). This legislation has served to encourage matching water quality to intended water use. Nevertheless, some regional Australian water authorities are doing well, for example, in Victoria, Goulburn Valley Water (centred around Shepparton) recycles 68% of its wastewater, and Coliban Water (centred around Bendigo) recycles 39% (WSAA 2001 in Farmhand 2004).

4.3.2.2 Potential for Further Development

The number of water reuse schemes in Australia is small and mainly restricted to market gardens, recreational spaces and some limited industrial processes (Tasman 1997). The cost of producing recycled water is frequently a deterrent to developing a successful project even for larger scale projects. Example 14 describes the findings of the feasibility investigation into the use of treated effluent (non-potable) supply to irrigate parks and gardens in the vicinity of the Subiaco WWTP in Perth, Western Australia. While the proposal was found to be technically feasible, based on the current economics, the public water authority would bear the bulk of the capital cost of the scheme unless other sources of funds (ie. Commonwealth programs or joint ventures) could be obtained.

Example 14 Evaluation of Effluent Reuse for Irrigation: Subiaco, Perth

The Subiaco Wastewater Treatment Plant (WWTP) discharges 52 ML/d of secondary treated wastewater to the ocean. The Western Australian Water Corporation commissioned a feasibility study to identify non-residential areas close to the Subiaco WWTP where treated effluent could be used (responsibly) for irrigation, determine the interest and demand for treated effluent, assess additional treatment requirements, estimate costs, and assess environmental and social issues.

A total of 85 local councils, golf courses and other major water users were identified as potential users of treated effluent to irrigate urban parks, gardens and golf courses within 15km from the Subiaco WWTP. All of these currently use groundwater for irrigation with operating and maintenance costs of about $0.20/kL.

Through meetings and questionnaires, current irrigation application rates were found to vary between 2 and 35 ML/ha/year, with the average being 10 ML/ha/year. Based on this application rate, the immediate demand for treated effluent (ie. users who expressed interest and a willingness to pay more than they pay for other water) is 4.5 ML/d (ie. <10% of treated effluent available). If the price was no greater than the cost of using groundwater, the potential demand for treated effluent increases to 65% of available treated effluent (or 35 ML/d).

Several options for distribution of the non-potable water to the potential users were examined. The most economical option was to store treated effluent in a 25ML lined and covered dam at the Subiaco WWTP and to supply it on demand over an 8 hour irrigation period (between 8pm and 4am). Based on a likely irrigation application rates, there was also a need...
to upgrade to meet nitrogen and phosphorus nutrient loading requirements. The capital cost for the WWTP upgrade, trunk and subsidiary mains, reclaimed water storage, power supply, and pumps to supply 35ML/d of reclaimed water was estimated to be $28M. Operation and maintenance costs including pumping, treatment chemical costs and monitoring were estimated to be about $900,000 per annum.

The unit cost to recover both capital and operating costs of supplying treated effluent to all potential users was determined to be $0.44/kL (based on a 30 year financial analysis and a discount rate of 8%). The unit cost to recover operating and maintenance costs alone was $0.12/kL. Compared to the public water supply charge of $0.61–0.68/kL the treated effluent unit costs are attractive. However, at double the cost of existing groundwater they are too high for substitution by most of the potential users.


The economics of reuse feasibility are site specific and depend on several factors including the cost of developing other sources of water, the costs to treat and dispose of wastewater, and the costs to treat, store and distribute water reuse. Other factors can include the distance of potential reclaimed water supplies, the availability of their alternative water supplies, and the type of reclaimed water available and needed. Regulators indicate support for treated effluent reuse, but the conditions imposed continue to make reuse complex, difficult and costly (Wajon et al. 1999). In addition, it can take as long as five to ten years to fully implement water reuse facilities (Turcotte 1997; Sickerdick & Desmier 2000).

Figure 29 shows the proportion of wastewater reuse in Australia is growing despite the challenges mentioned above. However, compared to water reuse overseas experience the amount reused is low.

![Effluent Reuse in Australia](image)

Figure 29 Growth of Wastewater Reuse in Australia
More extensive reuse of treated wastewater in Australia is feasible but dependent on a greater awareness of its value as a resource, and greater acceptance by the authorities and the public to its use. CSIRO researchers have predicted that the proportion of wastewater reuse will rise by a further 200% in the period 1994 to 2020 (Mitchell et al. 1999). This will translate to a rise in wastewater reuse from around 5% to nearly 15% of the total output (see Figure 29). Many agencies have been resourceful in obtaining federal, state and local grants and/or low cost loans that help to defray the cost of recycled water and make it more competitive with other sources. However, expansion of water reuse will require substantial investment and is likely to be constrained by the ability to raise capital. Sound evaluations are important to ensure that the community receives value for money, that is, the ‘right’ scheme is built and that it is neither too large nor too small to satisfy needs for a reasonable period of time.

4.3.2.3 Water Quality Concerns

There are still concerns about long-term safety of reclaimed water, despite development of advanced wastewater treatment technologies producing high quality water. As for any water source that is not properly treated, health problems could arise from drinking or being exposed to recycled water if it contains disease-causing organisms or other contaminants. National guidelines have been developed for the use of reclaimed water that sets standards for water quality, level of treatment, safeguard controls and monitoring. Figure 30 sets out the risk of a number of events including risk of infection from a properly operated recycled water system. According to Figure 30, there is a higher likelihood of contracting Hepatitis than a virus from recycled water.

NOTE:
This figure is included on page 107 of the print copy of the thesis held in the University of Adelaide Library.

Source: Ireland 2003 in Radcliffe 2004

Figure 30  Recycled Water Infection Risk (Ireland 2003 in Radcliffe 2004)
Public health is protected by reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the water, controlling specified chemical constituents in the water, or limiting public exposure to the water (Hickinbotham 1994). The occurrence of illness is the result of a series of complex interrelationships between the hosts and the infectious agents. The mere presence of an infectious agent in an effluent is not sufficient cause to declare the water unsafe. Even the most dreaded hazard poses no risk if people are not exposed to it. It is important, therefore, in assessing the health hazards of wastewater reuse to establish the relative importance of various routes of transmission from direct contact with the wastewater, through food or air, to indirect contact. State and Federal regulatory oversight has successfully provided a framework to ensure the safety of the many water recycling projects.

4.3.3 Stormwater

Harvesting and storing stormwater runoff can have many benefits for the local community and the environment. For example, replacing some freshwater use with stormwater can alleviate the need to extract more freshwater from rivers and aquifers as well as save the cost of treating and piping it long distances into towns and cities. The possible uses for stormwater are the same as those for any freshwater source, including potable water, irrigation and industrial uses. However, stormwater runoff is subject to pollution from a wide range of catchment activities and its management involves controlling both the quantity and quality of the runoff. Ownership and maintenance responsibility for most stormwater drainage systems in Australia is fragmented between local and state government organisations. This can inhibit implementation of catchment-based management strategies for urban stormwater.

4.3.3.1 Extent of Use

Stormwater is an obvious alternative source of water that has not been exploited to any large extent in Australia. Compared to wastewater flows, little is known about the quality or volume of stormwater flows from towns and cities or the percentage that is used for beneficial purposes (COA 2001). Gerges et al. (2002) reported that about 3% of the stormwater runoff generated in Adelaide is harvested for beneficial use and of the Australian state capitals Adelaide ranked second (after Perth) in stormwater harvesting. There appears to be considerable potential to better utilise stormwater resources to the benefit of present and future populations in Australia.

4.3.3.2 Characteristics of Flows

Traditionally, stormwater management focused on flood mitigation through the use of formal drainage systems to convey stormwater, and the pollutants therein, away from urban centres. The high level of paving (degree of imperviousness) in towns and cities has increased the amount and speed with which runoff enters nearby waterways. In addition, most of the current stormwater systems do not treat the water before it is discharged into riverine or marine environments (Farmhand 2004). Thus, runoff that can not be harvested for local purposes must be properly managed to reduce the pollutant loading on receiving waters. The
major difficulty in treatment of stormwater is the large discharges which occur for very short periods of time with long periods between flows. The issues in stormwater management vary from one urban centre to another, depending on climate, soil and the urban water environment. In large urban centres, a major challenge in maximising the use of stormwater is availability of space to capture, treat and store large volumes of water (Fleming 1999). Space is not generally a limiting factor in small towns. The management of stormwater quality is a different matter and some form of treatment will be required.

### 4.3.3.3 Pollution Control Practices

The quality of urban stormwater depends on factors that include population density, land use, sanitation and waste disposal practices, soil types, climate and hydrology (O'Loughlin et al. 1992). Materials transported typically include dust, soil, litter, garden rubbish, animal waste, paints, oil, fertilisers, pesticides and other street refuse. It is difficult to give typical pollutant concentrations for stormwater because of their high variability. This variability is caused by hydrological variability (rainfall duration and intensity) and pollutant availability. The high volume and variability of stormwater flows can make high-rate physical (structural) treatments more suitable than biological systems (Mitchell et al. 2002a). There is no uniform answer or system for effective urban stormwater management.

Stormwater may be managed using a combination of source control, mid pipe and end of pipe measures, depending on the circumstances and the management requirements of the catchment. Structural stormwater quality control practices targeting pollutants mobilised by runoff can be categorised as follows (Hunter 1998):

<table>
<thead>
<tr>
<th>Practice</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>ways of doing business to prevent pollutants releases.</td>
</tr>
<tr>
<td>Source control</td>
<td>specific actions taken at potential sources to prevent pollutants from entering runoff or removing them before they are conveyed into the natural drainage system.</td>
</tr>
<tr>
<td>Sediment control</td>
<td>methods used to control sediment being transported off-site. These are source controls utilised during the construction phase of development, and devices such as silt fences.</td>
</tr>
<tr>
<td>End of line treatment</td>
<td>facilities that remove pollutants at the terminal point of the formal drainage system.</td>
</tr>
</tbody>
</table>

One of the best ways to address the problems of urban water management is to use treatment trains, or the sequencing of best management practices. No one practice provides the solution to all pollution problems associated with stormwater runoff. The characteristics of a catchment or drainage system will dictate a design solution that is, in many cases, particular to that catchment (Hunter 1998; GSA 2002). For example, some sites are less suitable than others for detaining or retaining stormwater runoff because of topography or other constraints. Water
Part I Our Water Resources

Sensitive design and development (WSUDD) focus is on addressing pollution problems at the source rather than constructing expensive engineered add-ons further downstream and incorporates best practice in various combinations to suit the particular constraints and challenges of individual sites (COA 2002).

Pollutant traps come in various designs that provide a physical barrier to the pollutants while allowing water to flow through. These are designed to treat litter/gross pollutants, sediment and vegetation to varying degrees; however certain traps are promoted as having high capture rates for other stormwater pollutants including fine sediment material, suspended solids, nutrients, heavy metals, oil and grease. The appropriate type of trap depends on whereabouts in the catchment it is to be installed. Example 15 describes the combination of stormwater practices located just prior to discharge to sea (ie. end of line).

Example 15 End of Line Stormwater Treatment: Wellington St, Adelaide

At this site, the Port Adelaide-Enfield Council runs stormwater from a 150 hectare catchment into a detention basin before pumping the stormwater out over the sea wall. The ground level for much of the area is below sea level which has caused the council some difficulty in disposing of stormwater. These stormwater pumping units are protected by two trash racks that have been installed in parallel. In April 1998, a CDS unit was installed (4m by 8m deep) on the stormwater inlet at a cost of $230,000. The stormwater pumps are used to maintain a relatively constant water level in the detention basin to ensure there is a differential head across the CDS unit. The level of debris collected in the unit is monitored on a monthly basis and emptied when full or around four times a year (on average).

Source: Mr Peter Diprose, CDS Technologies pers comm. (1998)

The above example demonstrates how some large end of line treatments can have high installation costs and high maintenance costs for litter removal (ie labour and hire of specialised lifting equipment/trucks). At-source stormwater pollutant traps (ASPT) can provide an alternative to the end of line treatment practices the other end of the drainage system (Chrispijn 2003). Source controls can provide the opportunity to reduce costs by keeping structural controls small, unobtrusive and maintainable (Hunter 1998). These ASPT devices can be installed in roadside stormwater drains to trap sediment and floating pollutants. ASPT devices consist of a basket/filter bag insert that is installed into the individual drainage entrances. ASPT can provide treatment for the entire catchment area if fitted to all these drainage entrances.

The development of pollution control facilities can provide a source of treated water that can be attractive for use as a replacement for more conventional water supplies. The selection, placement and sequencing (ie. treatment train) of practices are important to optimise beneficial outcomes. Local communities could manage and control the use of stormwater (Farmhand 2004). This will enhance the sense of local ownership that is essential to increase the efficiency of water projects and small-scale projects make it easier to find local funds to finance them. In addition to capital costs, pollution control assets require funds in order to continue to operate as designed. Design solutions should therefore consider the most cost effective approach and seek to maximise the social and environmental
benefits (GSA 2002). Conventional drainage works also require ongoing maintenance for which local governments are required to set aside funds in their budgets.

The management of stormwater requires the use of a significant proportion of a community's financial resources. In some situations, the conjunctive use of stormwater and wastewater provides an approach that performs more successfully than the exclusive use of one or the other. In comparison with stormwater, treated wastewater is very consistent in quantity and quality but has higher salinity which can limit its use. This is due to several reasons, such as the increased quantity of water available, the balancing of fluctuations in the supply of stormwater, and the diluting effect of stormwater on the quality of some wastewater sources (Mitchell et al. 2002a). Blending stormwater with treated effluent can optimise applications for both water resources.

4.3.3.4 Performance Verification Trials

In Australia, a range of ASPTs are available; however, there is concern that claims made by various manufacturers of pollutant traps are not being evaluated (COA 2002). In Hobart, one local council undertook a trial of commercially available ASPTs to determine the performance of the units. The results of the trial are discussed in Example 16. The potential of benefits of independent verification of emerging technologies are discussed further in section 4.5.4.1.

Example 16 At-Source Pollution Control Unit Trial: Hobart, Tasmania

Site constraints in the Sullivan's Cove stormwater catchment and the Brooker Highway make them unsuitable for many of the end of line stormwater treatment methods currently available. An alternative option considered was at-source stormwater pollutant traps (ASPT). There are a total of 310 stormwater side entry pits (SEPs) in the Sullivan's Cove catchment and 30 SEPs on the Brooker Highway that drain into Cornelian Bay. The trial involved between 11 and 32 units from a number of proprietary businesses. These were installed in comparable locations and the pollutant retention performance (litter/gross pollutants, sediment, and vegetation) was monitored between January and August 2002. The traps were selected based on laboratory and/or field trials and the manufacturer's claims. On a monthly basis, the load captured in each installed trap was removed (on the same day) and weighed for gross wet weight. Capture loads are expressed as a mean kg/ha/year.

Sullivan's Cove

At a cost of $40,600, a total of 63 ASPTS were purchased and installed for the Sullivan's Cove trial comprising: 20 Enviropod Filter units with a cleanable 200 micron filter bag, 11 Ecosol RSF100 units with a removable 3mm filtration liner, and 32 side entry pit traps (SEPTs) with one-piece stainless steel baskets made of 33mm mesh (designed by Hobart City Council). Enviropod and Ecosol units had significantly higher capture loads (1,711 and 1,427 kg/ha/year) compared to the council's SEPTs at 878 kg/ha/year. The capture load for all types of trap was typically higher for catchment areas of less than 300m² than catchment areas between 600 and 2,000m² (39% lower). The polluted material was manually separated into litter and sediment/vegetation categories to determine retention performance. Sediment/vegetation represented 96% (wet mass) of all...
Brooker Highway

In this catchment, the comparison was between 18 SPIs (stormwater pollution interceptor) and 65 Enviropods units, in addition to the 20 Enviropod units installed for the Sullivans Cove trial, over four months from July to November 2003 (ongoing). The SPIs are specialised ASPT and heavy duty, disposable liners to collect fine sediments laden with heavy metals were purchased and installed at a total cost of $23,875. Enviropods had higher capture loads (3,800kg/ha/year) compared to SPIs with 2,340kg/ha/year. For both types the smaller catchment areas of less than 300m² had a higher capture load while larger catchments of 600 and 2,000m² had a reduced capture load (38-42% lower). The captured material was not separated as part of this trial.

Outcome

Based on the results:

- a further 45 Envirpods will be installed at Sullivans Cove by December 2003 and the 32 SEPTs will be removed and replaced; and
- The design of the SPIs may be modified to reduce the remobilisation of captured loads. After these changes the SPIs will be further monitored to assess if they have increased their retention of road runoff.

Source: Chrispijn (2003)

4.3.4 Seawater

4.3.4.1 Seawater (Dual) Supply Systems

Seawater can be used to provide a reliable water supply in places where conventional water resources, ie. surface water and groundwater is limited or unreliable. For example, in Hong Kong, seawater and treated effluent is used widely as a secondary source of water mainly in the flushing of toilets (Fleming 1999). Gibraltar also has a seawater supply system which is described below.

Example 17 Seawater Supply System: Gibraltar

Since around 1870, every household in Gibraltar has enjoyed a dual water supply system, one for potable water and the other seawater. Seawater is pumped from two intakes to various storages at different levels on the rock. The seawater distribution system parallels the potable water system providing the second supply for households. The seawater system is also used for fire fighting, street cleaning, sewer flushing and other purposes where the use of potable water is not essential. From a maintenance point of view, the seawater distribution system is problematic in comparison to the potable supply, especially since the older cast iron mains (up to 125 years) are badly corroded. These old mains are progressively being replaced as part of a mains replacement program. The use of better materials such as uPVC, plastic coating and sulphate resistant cement linings should alleviate the maintenance problems over time.

Source: Lyonnaise des Eaux (Gibraltar) Ltd (pers. comm. March 2003)
In addition, desalinated seawater is blended with Gibraltar’s limited surface water resources to provide the potable water supply. Theoretically, desalination of seawater could also be a reliable source of freshwater - at least for wealthy nations with access to seawater - but it falls far short of sustainability (PAI 1993).

4.3.4.2 Source of Freshwater

Desalination of brackish water for domestic and industrial use is employed in some sixty locations around Australia, mainly in small plants associated with isolated mining and tourist developments (AATCE 1998). High capital and energy requirements combine to make unit costs for desalinated water several times more than conventional water sources. Nevertheless, the cost of seawater desalination has significantly reduced over the past decade and can now be considered as a legitimate future supply option for Australia (WSAA 2003). Example 18 below describes a large scale desalination operation. A number of factors raise significant questions about the mainstreaming of desalination for general water-supply augmentation purposes. In addition to cost, two important environmental problems are associated with desalination technology, specifically carbon dioxide (CO₂) release from the energy it requires, and the production of concentrated brine with a host of management problems (Figueres et al. 2003).

Example 18 Seawater Desalination: Burrup Peninsula, Western Australia

The Western Australian government funded the $67M seawater desalination scheme to supply a number of industries on the Burrup Peninsula. It is the biggest seawater desalination scheme built in Australia in one of the hottest regions. Infrastructure planning in consultation with prospective customers took three years. The scheme consists of:

- a major pumping station;
- 4,400m seawater 280ML/d intake pipe of 1,422mm diameter;
- a 2ML storage tank;
- 4,000m brine return pipe and 1,400m ocean outfall;
- 3 by 1.2ML/d mechanical vapour compression (MVC) units; and
- 4,400m long 33kV transmission line.

Seawater will be collected in a storage tank 3km inland where it will be filtered and chlorinated. It will then be pumped to a holding tank in the desalination plant before being processed by the MVC units. The MVC process achieves distillate by evaporating seawater under vacuum conditions, which lowers the operating temperature of the process. The remaining concentrated seawater (brine) is then returned to the ocean.

Source: Cummings (2003)

4.3.5 Bottled Water

The origin of the bottled water market in Australia began with the supply of water to remote homesteads and even urban residential districts that were either not mains supplied or to which the quality was either poor or variable (Holloway 2000). Many consumers choose bottled water as their primary refreshment drink due to consistency of quality and taste, as compared to reticulated (tap) water supply where chlorine (used to disinfect it) and other products may leave...
aftertastes (ABWI n.d.). Heyworth et al (1998) report that the use of bottled water as a main source of drinking water was 14% and still growing.

4.3.5.1 Extent of Use

Figure 31 shows the rapid growth in consumption in bottled water over the 8 year period between 1992 and 1999. Holloway (2000) theorises that the 50% growth forecast for years 2000-2005 for the bottled water sector may be modest. By 2005, bottled water sales would be equivalent to around 45 litres per person per year (Holloway 2000), which exceeds the basic water requirements for drinking (previously discussed in section 2.2.2). A factor that has contributed to the advance of the bottled water industry in Australia has been the success of home and office delivery, especially home delivery. For a market of only 600 ML per year, Australia has a high bulk penetration (compared with other countries), with pack sizes over 10 litres accounting for 45% of the total (Holloway 2000).

**NOTE:**
This figure is included on page 114 of the print copy of the thesis held in the University of Adelaide Library.

*Holloway (2000)*

**Figure 31** Per Capita Consumption Bottled Water 1992-99 (Holloway (2000))

4.3.5.2 Affordability

Figure 32 provides a comparison of the cost (in 1998 dollars) of reticulated drinking water and other beverages.

**Figure 32** Comparison of the Cost of Drinks (Rabone 1998)
Clearly, people are willing to pay for water services that are perceived to be of high quality. Despite the cost of bulk (greater than 8 litres) packaged water being 42% lower than in 1993 it remains an expensive option for consumers. Appendix 5 contains additional information on the changes in consumers’ purchasing and the price of bottled water between 1993 and 1998. In communities where non-potable supplies are reticulated, the provision of bottled drinking water may be a realistic option to alleviating or deferring the need for capital expenditure for treatment facilities to achieve a potable water supply.

4.4 WATER SENSITIVE URBAN DESIGN & DEVELOPMENT

Water Sensitive Urban Design and Development (WSUDD) is about integration of water cycle management into urban planning and design. Water cycle management covers drinking water, stormwater runoff, waterway health, wastewater and reuse. Water cycle management is an important consideration for urban development that contributes to an ecologically sustainable city. Sustainability is about keeping the options open for the future (ie. precautionary principle). However, wide spread introduction of WSUDD principles is complicated by having an established system as a starting point.

4.4.1 The Approach

Water sensitive urban design & development (WSUDD) is an approach to urban planning and design that offers sustainable solutions for integrating the natural water cycle and land development (Lloyd 2002). WSUDD emerged in Australia during the 1990s out of a wider movement at an international level. It takes into account the whole water cycle from an urban perspective and attempts to maintain services and make best use of available resources, while minimising environmental impacts (WSAA 2003). There is growing enthusiasm and support for a fundamental change in the way urban water resources are managed.

A number of urban developments incorporating elements of WSUDD have been completed in Australia over the last decade. For example, two subdivisions in South Australia that incorporate local stormwater management and dual reticulation water supply are New Haven Village (62 allotments) and Mawson Lakes (3,400 allotments) commissioned in 1998 and 2005 respectively. There has been tension between introducing more sustainable water system and minimising the impact of change on the developer, council, owners and occupiers of allotments, and the wider community (Mitchell et al. 2002b).

Developers readily adopt features of WSUDD that have lower capital costs compared with traditional designs and are attractive to buyers (Lloyd 2002; COA 2003). However, some WSUDD infrastructure may have increased maintenance costs compared with traditional designs which may shift costs from the developer to local government. There is limited quantitative data on the long-term performance of WSUDD technology; however, over time WSUDD projects will provide information to enable assessment of their performance against traditional design from a sustainability perspective. Results from such assessments may change the shape of future urban water systems.
Physical attributes of a site such as climate, geology, drainage patterns and significant natural features (i.e., wetlands, low-lying areas, shallow groundwater) will impact the selection of appropriate WSUDD measures. For example, large urban centres seek measures to minimise stormwater runoff and wastewater discharge to the environment. On the other hand, regional townships often search for measures that maximise opportunities for water harvesting and reuse. Individual WSUDD principles may not be appropriate under all conditions.

WSUDD principles can also be applied to the design of a single building, a whole subdivision or township. Example 19 describes how the incorporation of WSUDD principles into the design of an average detached house on the Gold Coast can reduce demand on reticulated town water supply from 300kL to about 100kL.

Example 19 WSUDD Household Scale: Gold Coast, Queensland

The Healthy Home is a water and energy efficient home on a 420m² allotment in a high density beachside suburb in Queensland. It is a joint undertaking by the home owners, University of Queensland and Queensland Department of Natural Resources and Mines.

The plumbing in the home allows rainwater for potable use and treated grey water (excludes sewage) for toilet flushing and garden irrigation. Other water conserving strategies in use include low flow showers, dual flush toilets, permaculture garden, and simple soil water monitors to schedule and terminate irrigation.

The water use consumption of the residents (two adults and three children) was monitored for 24 months during 2000 and 2001, which were both years well below average rainfall (15 percentile & 26 percentile rainfall years respectively). Despite the low rainfall over the two year period, rainwater supplied 36% of the total water consumption by the household.

In an average rainfall year, the level of independence of town water is expected to be in the order of 65%. Further, the demand on town water reduces to near zero using the rainwater twice (the second time as grey water to flush the toilet and garden watering) in an average rainfall year. However the $5,500 grey water system at the Healthy Home has an infinite payback period and the $2,600 rainwater system has a 74 year payback, assuming that town water is purchased for the current price of $1.10 per kL.

Despite the installation of a first flush device to divert the first millimetre of roof runoff to waste, fortnightly water quality sampling showed there were frequent intervals when faecal and total coliform levels in the rainwater exceeded the NHMRC drinking water standard, with peak values as high as 500CFU/100ml occurring after heavy rainfall events. Following the installation of a 40W Trojan UV system to the rainwater tank in August 2001, all subsequent fortnightly samplings returned zero values for faecal and total coliform.

Source: Gardner (2003)
4.4.2 Matching Water Quality & Intended Use

In general, Australian households are provided with one water service and have access to a single quality of water for all purposes. However, urban water quality requirements can be divided into two main categories - potable and non-potable - according to the end use. Non-potable uses do not require such high quality water, and have less stringent quality requirements. Figure 33 shows the uses of water supplied to urban centres that could be satisfied with non-potable water if available.

![Figure 33 Matching Water Quality and Intended Use](image)

The degree of any water treatment prior to use varies according to the specific end use application and water quality (Polin 1977; ADWG 1996; Law 1999). Almost fifty years ago, Australia agreed in principle that “No higher quality water, unless there is surplus of it, should be used for a purpose that can tolerate a lower grade” (United Nations 1958 in NHMRC, ANZECC & ARMCANZ 1996). Nevertheless, with the exception of Western Australia, there is no requirement in Australia for lower grade waters to be preferentially substituted (where available) for freshwater. In Western Australia, towns can only use public water supplies on their parks or recreation grounds if all other avenues, including treated effluent, had been explored first. In 1972, Merridin was the first town to commence water reuse. Storm (1985) noted that some 35 country towns in Western Australia, representing most of the inland towns with central wastewater services, use locally derived non-potable water supplies to maintain public or school sportsgrounds.
The main output of the water supply system should be water in a condition that is compatible with its destined uses. Many observers suggest that water management practices be redirected towards water infrastructure systems that incorporate innovative technologies for water harvesting and reuse at the local or regional scale and can supply water at different qualities for different uses (Newman & Mourtiz 1992; Clark et al. 1997; Fleming 1999). From a public health standpoint, it is logical that a greater assurance of reliability is required for a system producing treated water for uses where direct human contact is likely (ie. bathing), compared to water treated by a scheme where the possibility of contact is remote (ie. toilet flushing).

4.4.3 Alternative Water Service Delivery Options

Moving towards a more sustainable approach will require adopting alternative or new configurations of water infrastructure systems. The manner in which water is treated, distributed and used in Australian urban centres is under constant review. A variety of potential models for delivery of water services can be considered. The number and applicability may be different under different circumstances (ie large urban, small town, or remote community). The attributes of some of the more familiar alternative delivery options are summarised in Table 18 (below).

Table 18 Variety of Alternative Water Delivery Options

<table>
<thead>
<tr>
<th>ATTRAIBUTES</th>
<th>POTENTIAL DELIVERY OPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAU</td>
</tr>
<tr>
<td>Water Use Applications</td>
<td></td>
</tr>
<tr>
<td>• Drinking</td>
<td>✓</td>
</tr>
<tr>
<td>• Personal Uses (Contact)</td>
<td>✓</td>
</tr>
<tr>
<td>• Non-potable</td>
<td>✓</td>
</tr>
<tr>
<td>Reticulation Infrastructure</td>
<td></td>
</tr>
<tr>
<td>• Existing water system</td>
<td>✓</td>
</tr>
<tr>
<td>• Dual water supply system</td>
<td></td>
</tr>
<tr>
<td>• Dedicated water pipeline</td>
<td>✓</td>
</tr>
<tr>
<td>• Existing wastewater network</td>
<td>✓</td>
</tr>
<tr>
<td>• Existing stormwater drains</td>
<td>✓</td>
</tr>
<tr>
<td>• Integrated stormwater mgt</td>
<td></td>
</tr>
<tr>
<td>Water Treatment</td>
<td></td>
</tr>
<tr>
<td>• Centralised WTP</td>
<td>✓</td>
</tr>
<tr>
<td>• Centralised WWTP</td>
<td>✓</td>
</tr>
<tr>
<td>• Decentralised WWTP/SWTP</td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes:
(1) Water used for drinking and cooking to be obtained from other sources, ie. rainwater tank or bottled water.
(2) More suitable for towns and other small communities
(3) May be more suitable for large urban centres to collect and treat wastewater and stormwater near demand points

KEY
BAU ‘Business as Usual’
SAFE ‘Safe Water’
URBAN ‘Urban Reuse’
LOCAL ‘Local Reuse’
DIRECT ‘Direct Potable Reuse’
### 4.4.3.1 Business as Usual

The ‘Business as Usual’ scenario is the term used to describe the traditional water delivery option. In Australia, this means the supply of a single quality of water (ie. potable) for all water uses. Figure 34 shows that potable water (drinking quality) is imported to the urban centre (township) in one pipe system and wastewater (effluent) and stormwater are removed using another two separate pipe systems. Figure 34 also shows that non-potable end use typically represents more than 65% of the total household demand with less than 35% requiring potable water quality (of which only around 5% is actually ingested).

![Figure 34 Traditional Water Infrastructure in Australia](image)

This approach dates back to the 19th Century, when authorities found a positive correlation between poor sanitation and high mortality, and prompted the development of piped water supply, drainage and sewers in towns and cities (Millis 2003). In addition, to the volume of stormwater generated from impervious surfaces within the urban centre, Mitchell et al. (1999) estimate that about 75% of the water imported into urban centres is eventually discharged as wastewater effluent. The sustainability of the traditional ‘Business as Usual’ approach of separating water supply and disposal systems is being questioned. Water supply engineers and urban planners are beginning to evaluate alternatives to traditional water supply and disposal methods.

### 4.4.3.2 Safe Water

The ‘Safe Water’ option is identical to the ‘Business as Usual’ with the exception that the single quality water supply is not suitable for drinking purposes (ie. deemed non-potable). Under rural conditions, treatment of potable (drinking) quality standards can be expensive and also requires trained supervision which may not be available if it is to be reliable. Under this scenario, householders make alternative arrangements (ie. rainwater, bottled water or bores) to meet their potable water demands. Traditionally, rainwater has been a source of drinking water for isolated properties and small communities in the absence of potable town water supplies. Currently, in South Australia 19 rural communities (ie small towns or locales) are supplied by SA Water with safe but non-potable reticulated water supplies (Sweet pers comm. 2005).
Rainwater is especially important to households and communities not connected to a potable water supply. Around 48% of South Australian households (ABS 2005) and about 80% of houses in rural South Australia have rainwater tanks, many of which also have access to potable water (Heyworth et al. 1998; Lang et al. 2000?). However, studies have concluded the resources (ie. private infrastructure and collected rainwater) may not be fully utilised. Studies have also shown that to maximise contribution of rainwater harvesting to meeting household demands requires plumbing the tank into toilet flushing, laundry or other uses. In many towns, the existing high level rainwater infrastructure as well as established water reticulation systems may provide an opportunity to shift the water service provided from potable to non-potable with minimal disruption to the quality of life or the local economy.

The viability and sustainability of shifting existing water supply infrastructure from delivering potable water to non-potable supplies in small townships should be investigated. The investigation would need to focus on the reliability of rainwater systems which is strongly affected by the prevailing climate, particularly in areas where rainfall variability is high. It would also be critical to determine locations where local industrial emissions or agricultural practices (ie. crop dusting activities) may adversely influence rainwater quality. Appropriate low skill level filtration and disinfection practices may need to be developed to combat potential public health hazards.

4.4.3.3 Urban Reuse

Under the ‘Urban Reuse’ scenario each household is supplied with two reticulated water products – potable and non-potable – that can be used according to the specific end use application (ie. matching water quality). The source of the non-potable water supply may be stormwater, treated wastewater or a blend (ie. stormwater/effluent or effluent/potable water). In addition to the traditional reticulated potable water supply, the ‘Urban Reuse’ service delivery scenario requires a dual (second) water reticulation system with lilac coloured water taps, pipes and plumbing fittings for easy identification in accordance with the WSAA code of practice. Figure 35 shows the concept of the ‘Urban Reuse’ approach with two separate supplies of water being imported to the urban centre (township).

![Figure 35 Alternative Water Harvesting and Reuse Water Infrastructure](image_url)
Technically, dual water supply systems are no more difficult to construct, operate and maintain than any other reticulation system. Over the last decade, a number of housing WSUD projects of varying sizes in Australia have incorporated ‘Urban Reuse’ infrastructure such as the small 62 allotment development on a 2 hectare site in the Adelaide suburb of New Haven Village commissioned in 1998 (more information is provided in the case study review in Part II). Household wastewater is treated by a local treatment plant located under the main reserve and returned to the dwellings for flushing toilets and irrigation of gardens and reserves. At the other end of the range, the Rouse Hill development commissioned in 1994 (extended in 2001) currently provides 15,000 allotments with dual water supplies where the non-potable supply is used for gardens and toilets. Infrastructure to supply an additional 10,000 allotments with dual water supply is expected to be completed in 2006. There are also a number of similar mid-sized developments around Australia.

These pioneering development sites reveal WSUDD principles to be practical from a technical and operational perspective; but construction and ongoing operation costs are higher cost than traditional supply systems. Most new urban subdivisions now incorporate some water reuse facilities, primarily for irrigation purposes, however the costs of re-plumbing, pumps and storages make ‘Urban Reuse’ an extremely costly as a retrofit exercise for large urban centres (Millis 2003). From a social perspective, there should be no major problems, associated with introducing this scenario due to its similarity to current water supply provision and usage. However, an increasing proportion of total investment funds are being devoted to maintenance and rehabilitation of existing water infrastructure systems in Australia (CSIRO 1999). As previously determined, the sustainability of urban centres depends on management and maintenance of semi-permanent infrastructure of society (ie. not just natural resources). The question then becomes can the community afford to sustain the established water infrastructure systems (water, wastewater and stormwater) as well as the capital expenditure and ongoing maintenance costs to introduce an additional non-potable (dual) water supply.

The provision of dual water distribution system in Adelaide could require construction of up to 8,600km of new parallel distribution lines. The very high capital investment of such an undertaking could mean that the non-potable water supply network may not become fully connected and operational for many years, ie. up to 100 years (Doherty in prep 2005). For Adelaide, Doherty (in prep 2005) estimated the level of expenditure to maintain the established water and wastewater systems to be between $10M and $20M per annum in the near term (ie. up to 2020) gradually increasing to $70M per annum (in current dollars) by the year 2100. The analysis by Doherty was confined to water and wastewater systems owned by the South Australian government (ie managed by SA Water). It does not include projected expenditure to maintain existing stormwater systems or septic tank effluent disposal systems managed by local government, community groups or the private sector. Consequently, the impact of adopting the ‘Urban Reuse’ approach must be reviewed from an ‘inter-generational equity’ perspective. Any improvement to the present lifestyle should not be at the price of the quality of life for future generations.
While, the costs may be prohibitive for large urban centres, it should be borne in mind that a number of western NSW towns already have a functional dual water supply system. In these towns, older large diameter mains have been retained for reticulating non-potable water for gardens and fire fighting purposes (Polin 1977). A new PVC reticulation system was constructed to deliver potable quality water for household uses only. The viability and sustainability of introducing dual water supply infrastructure for small townships should be investigated more closely. Obviously, retrofitting a non-potable water supply for a small town requires the existence of a suitable water resource that can be developed.

4.4.3.4 Local Reuse

Households continue to be provided with one quality of water through a conventional centralised reticulation system, ie. either the ‘Business as Usual’ or the ‘Safe Water’ approach. Industrial, commercial, and institutional consumers can represent a concentrated high demand for water within an urban centre compared with residential areas (Mitchell et al. 2002a). The presence of several large volume users – especially if they are in the same area – may dictate a geographically limited distribution pipeline. The ‘Local Reuse’ scenario involves the use of dedicated pipelines to supply individual customers with non-potable quality water for end uses that do not require water of potable quality. Alternatives in this category include landscape irrigation of parks, golf courses, and cemeteries, and makeup water for recreational ponds.

The ideal ‘Local Reuse’ project would use the greatest amount of non-potable water for needs that require little if any additional treatment, especially those that decrease the potable water demand (ie. to accommodate growth or other industries). The costs vary depending on the individual project being developed, the degree of treatment required, and the proximity to the location where the non-potable water will be used. As the additional infrastructure ‘Local Reuse’ infrastructure works alongside conventional water infrastructure already present in urban areas there should be no problems associated with introducing this scenario from a social perspective. This approach also gives locally based institutions the opportunity for more involvement in the delivery of water services.

Many benefits can be realised by adopting local water resource management practices. There are many country towns where the water distribution infrastructure is struggling to meet demand, particularly during peak periods. Greater use of our local sources of water has the potential to relieve pressure on our natural environment and support opportunities for economic development within communities. This type of scheme would serve parks, golf courses, agricultural areas and industry to reduce the demands on potable water during the hot and dry summers. In addition, the introduction of cost reflective pricing as part of COAG water reform has stimulated considerable demand by operations responsible for large areas of grass such as local council, sporting clubs, golf clubs, cemeteries and the like.

Rural towns are being driven to become increasingly water conscious with respect to the cost of maintaining community recreation areas. ‘Local Reuse’ projects have been beneficial in small towns as a means of improving their landscape amenity at competitive cost even though the quantity of stormwater runoff and/or...
effluent available may be small. For example, since the early 1980s, the small South Australian town of Snowtown has successfully harvested stormwater to irrigate community recreational areas (more information is provided in the case study review in Part II). Moore (1990) reported the pay back period for the capital cost of this project was 5 years. Moore also determined the unit cost of the harvested water to be about half the State-wide price of the potable water and speculated that this would be considerably lower than the actual unit cost incurred by SA Water to import water to Snowtown. A range of factors including regional climate, local water demands and the method of reuse determine the effectiveness of a stormwater and wastewater scheme in replacing potable water. Nevertheless, every independent water source which is developed reduces pressure on the State Government reticulated system.

4.4.3.5 Potable Reuse

The ‘Potable Reuse’ option is identical to the ‘Business as Usual’ scenario except that highly treated wastewater and stormwater are also used as sources for potable water. This option eliminates the need for an extra (dual) reticulation water supply system as required under the ‘Urban Reuse’ scenario, however the water treatment processes will be more complex and more energy intensive. The ‘Potable Reuse’ scenario also poses a number of technical and social challenges. While it is technically feasible to treat wastewater and stormwater to a potable (drinking) quality level, the ‘Potable Reuse’ approach completely reverses one of the major philosophies of current sanitary engineering practice, namely the separation of water supply from wastewater.

The first case history of direct domestic reuse was at Chanute, USA in 1956 (Metzler et al. 1958 in Law 1999). Example 20 describes the most famous case of Windhoek in Namibia. Here, despite initial public protest, public authorities won support for reuse of water in potable water supplies (Polin 1977).

Example 20 Pioneering Potable Reuse of Wastewater: Windhoek, Namibia

The 60,000 plus inhabitants of Windhoek - a city located at the edge of the Kalahari Desert in Namibia - have become used to drinking treated effluent. Since 1968, it has been an intermittent part of the city's drinking supplies. Because of a severe water shortage they drank treated effluent for 4 years between 1969 and 1972. Since that time the plant has been upgraded several times and is still operating to need. The wastewater is treated under a multiple barrier process designed to ensure that no single process is wholly responsible for the removal of any single contaminant.

Epidemiological studies carried out in Windhoek showed that 'within the limits of the epidemiological studies done, no adverse effects on health attributable to the consumption of reclaimed water should be established' (Isaacson et. al. 1987 in Law 1997). The water quality at Windhoek is measured against the WHO Guidelines. Water complying with the guidelines is predicted to have no health implications to a person consuming two litres of water per day over a 70 year period (van der Merwe and Menge 1996 in Law 1997). After more than 30 years of supply, there has been no known outbreak of water related disease and public trust has been built up.

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Potable reuse is a relatively new and somewhat controversial concept that has been successfully demonstrated in other parts of the world, but not yet implemented by any major water authority outside Namibia (Fink 1996). There are now many examples of advanced water reclamation plants that reliably produce treated wastewater effluent of a quality that is equal to or better than that of the local raw water supply or drinking water (Law 1997). Long standing monitoring of potable reuse experiments, similar to that described in Example 21 below, conclude that the potable reuse option was a viable alternative to using water (Law 1998; Fleming 1999; CMHC 2003).

Example 21 Potable Water Reuse Demonstration Project: Denver, Colorado

In the late 1960s, potable reuse was recognised as a potential resource to satisfy the future growing demands of the Denver, Colorado metropolitan area. The Successive Use Project (SUP) which investigated a number of possibilities for developing alternative water supplies for Denver included the operation of a pilot plant in operation from 1970-1979. Based on the results of the SUP, it was concluded that the potable reuse option was a viable alternative to using water from the Trans Mountain diversion. In 1979, plans were developed to initiate construction of a demonstration facility to study the costs and reliability of potable reuse.

The Denver Potable Water Demonstration Project began in 1985 with the operation of a potable reuse demonstration plant. The facility was designed to evaluate the feasibility of direct potable reuse of secondary-treated municipal wastewater. Influent to the demonstration plant was from the regional wastewater treatment facility (secondary treatment). The demonstration plant used multiple treatment processes to achieve the required water quality (drinking). Final effluent from the reuse demonstration plant met or exceeded Denver's drinking water standards (physical, microbiological, organic, metals and others) for almost every contaminant. These results indicate that the multiple-barrier used was able to produce a highly reliable process.

To further test the accuracy of the multiple-barrier system, an organic challenge study was conducted, in which 15 organic compounds were dosed at approximately 100 times the normal levels found in the reuse plant effluent. The results of the challenge study demonstrated that the multiple-barrier process can remove contaminants to non-detectable levels, even when the given organic compounds are present in high concentrations. An accompanying Health Effects Study concluded that no adverse health effects were detected from a lifetime exposure to any of the samples and during a two-generation reproductive sample. The Denver Potable Water Demonstration Plant project concluded in 1992.

Sources: CMHC 2003

Direct potable reuse has not been undertaken in Australia, although it is being investigated by Sydney Water as part of a water services strategy to protect water quality in the Hawkesbury-Nepean River (Clark et. al.1997). Sydney Water has installed an advanced treatment plant that would be suitable for indirect potable reuse at its Quakers Hill Water Factory, in Caboolture (Law, 1998). The technology for advanced treatment is available and epidemiological studies indicate that the risk is comparatively insignificant.
Some suggest planned potable water reuse by blending treated wastewater and stormwater to supplement the potable water supply systems represents the ultimate in the evolution of urban water resources technology (Pigram 1986; Fink 1996, Law 1997; Law 1999; CMHC 2003). A greater reduction in freshwater extractions from the environment would be expected if potable reuse were practiced. Law (1997) showed potable reuse can more than double the savings in freshwater, the estimated figure varying around the country and being dependent upon the local climatic data. For Adelaide, with an annual rainfall of 585mm the effect of the climate on reduction in potable water use for non-potable reuse is estimated to be 35% and for potable reuse 51% (Anderson 1995). It appears that economics and public acceptability are the only barriers to be overcome (Fleming 1999; Marks 2005). This situation is characteristic of ‘Potable Reuse’ plans and proposals worldwide. However, the complexity and high level of expertise required to ensure water quality suggests that ‘Potable Reuse’ will not be a viable alternative for small communities. An exception may be where the water is imported by major water pipelines from a central treatment facility.

4.5 THE PROMISE OF TECHNOLOGY

4.5.1 Introducing Innovative Technologies

Technology innovations are introduced within an organisational context of money, people, institutions and equipment. The question of which solution and hence intervention is appropriate in a particular situation is sometimes one not given enough attention when solution-driven benefactors interact with small communities. Hazeltine & Bull (2003) concluded that to be successful the new technology solution requires the following attributes:

- addressing an identified need;
- being technically sound;
- being suited to prevailing conditions;
- being culturally correct; and
- being introduced in an appropriate way so that it is received favourably.

Thus, organisational factors (systems and people related) as well as technical factors are involved in the introduction of technological change.

International experience is that finding personnel with appropriate training in community organisation and facilitation presents a significant challenge whereas recruiting sufficient numbers of qualified engineers to provide technical support has not (Davis & Iyer 2002). It is also apparent that services requiring high levels of technical and other specialisation may be less appropriate to meeting the long-term needs of small communities. Therefore it is widely accepted that new ideas are an integral part of developing small scale technologies and that a one size fits all approach is not always appropriate. Accordingly, a policy framework that is flexible and adaptive so that different arrangements may be developed to suit to differing regional needs is required. Policy should be strengthened to promote self-sustained and people oriented development with the ultimate goal is the creation of suitable local technology. Development of technology which has low
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maintenance requirements and utilises available local skills can be exported to rural communities throughout the world.

4.5.2 Constructed Wetlands

Wetlands may be defined as areas within the landscape that are permanently or temporarily covered by fresh, brackish or saline water. Accordingly, wetlands exhibit great diversity in terms of size, depth of water, still or flowing, duration of inundation, hydrologic connection with rivers, water quality, and vegetation. They provide essential breeding and feeding habitats for many kinds of organisms, waterbirds, fish, invertebrates, and plants. Both natural and constructed wetlands are known to remove pollutants from water by a complex range of physical, chemical, and biological processes. These processes include filtering and settling out of sediments and pollutants as the flow rates are slowed, the sterilising effect of sunlight and the uptake of nutrients by many species of wetland plants. In other words, wetlands are natural filters which can improve water quality. However, at the same time, excessive inflow of pollutants will degrade or destroy wetlands.

4.5.2.1 Water Quantity and Quality Control

Stormwater runoff from urban centres is subject to pollution from a wide range of catchment activities. Consequently, in large urban centres stormwater management now has to accommodate both water quantity and quality controls to combat the increased stormwater runoff, velocities and more frequent flood events. The use of constructed wetlands is a relatively common technique to reduce the pollutant load in stormwater runoff from large urban centres (O'Loughlin et al. 1992; Fleming 1999). In combination with other stormwater management measures (ie. trash racks, gross pollutant traps, swales) constructed wetlands can also act to slowdown runoff, create local site storage, and reduce flood peaks (Tomlinson et al. 1993; Hunter 1997). As a result of the storage within the wetland the peak stormwater outflows are less than the peak inflow. The result is a runoff hydrograph from an urbanised catchment that more closely resembles the hydrograph from the undisturbed catchment (Hunter 1998a).

The potential for wetlands to preserve or improve water quality is becoming widely recognised. Wetlands provide an efficient mechanism for the removal of a wide range of pollutants including suspended solids, nutrients, micro-organisms and heavy metals (Tomlinson 1993; Fleming 1999). Quantitative data on the performance of constructed wetland systems demonstrates they are most efficient if properly designed in terms of size, depth, configuration, biota and residence times (McIntosh 1992; Fleming 1999). The ability of ponds, marshes and wetlands to remove a wide range of pollutants from the water moving through them is an important dimension to the feasibility of using stormwater or sewage effluent as a source of supply (Clark 1992a; Hickinbotham 1997). Outflows from wetlands are usually of a quality suitable for aquifer storage and recovery for irrigation, commercial or industry processing uses (Chaudhary & Pitman 2002). Improved water quality is not the only potential benefit to be obtained from the use of wetlands.
4.5.2.2 Recreation Resource for the Community

Constructed wetlands can provide essential drainage functions such as control of flooding and water quality but can also provide a host of additional community benefits. Wetlands add to the diversity of the urban landscape and can provide a focus for recreational activities especially when bicycle paths, walking tracks and picnic areas are incorporated into the buffer surrounds. They can also form the centrepiece of public parklands and provide a source of water for irrigation and other uses (McIntosh 1992). Where wetlands are used to capture urban stormwater runoff, their size requirement can generally fit within the normal 12% allowance for open space in developments (Clark et. al. 1997). Figure 36 shows how constructed wetlands processes were able to be incorporated into the design of the urban development at Andrews Farm. This 1,300 allotment development is located 30km north of Adelaide.

Figure 36 Feature Wetlands at Andrews Farm, South Australia

At Andrews Farm, the developer helped finance trials to retain stormwater runoff in a three tier system wetlands where it was polished prior to being injected into the aquifer (Hickinbotham 1997). The wetlands at Andrews Farm have now developed into a valuable community asset, important habitat for birds and recreation resource for the community. The Hickinbotham Group also found that in addition to being environmentally desirable localised stormwater management systems were cost effective compared to traditional stormwater systems.

Example 22 below describes how wetland processes and urban drainage have been integrated to create a valuable community resource.

Example 22 Local Stormwater Wetlands: The Paddocks, Para Hills

The Paddocks is a 46ha community sport and recreation complex at Para Hills, a northern suburb of Adelaide. Before its development, stormwater from a number of drains which converge and discharge at the site presented a flood threat to proposed residential areas nearby. In the early 1970s, the City of Salisbury redesigned the site making use of the stormwater to create a feature of artificial wetlands to control flooding of adjacent urban areas. Since then the area has been progressively developed into an attractive landscape of both wetlands and formal sports fields.
Figure 37  Aerial Shot of the Paddocks (Tomlinson et. al. 1993)

The catchment of The Paddocks wetland is a mature, 60 ha, fully developed residential area. It is subdivided into about 500 building allotments with bitumen roads and concrete footpaths. The catchment is serviced by a fully underground piped stormwater drainage system. The runoff is therefore principally composed of street and roof drainage. Flow and water quality at The Paddocks have been monitored periodically since August 1990. Analysis of the data shows that the wetland provides the expected benefits in flood mitigation: flood peaks generally are reduced by more than 80% and there is a significant improvement in water quality. Levels of suspended solids are reduced by more than 80% after about 5 days residence time and those of total phosphorus by 60% after about 10 days residence time.

Source: Tomlinson et. al. 1993

Over the last 20 years the City of Salisbury has constructed more than 30 wetlands covering an area of 260 hectares for a total investment in excess of $18 million (Chaudhary & Pitman 2002). Surface wetland systems have visible standing water that supports wildlife habitats, particularly fish. Concerns are often raised in relation to surface drainage systems relating to ponds and wetlands. While there are some risks with lagoon systems, the design of wetland systems (shallow flows, low velocities, and sloping banks) often makes them safer than conventional (high flow) drainage systems (McIntosh 1992). Wetland basins are purposely designed to provide more of the characteristics of natural wetlands (Fleming 1999). In fact, because constructed wetlands are designed to be shallow (to imitate natural processes) they make inefficient over season storages.

Evaporation is a function of climate and the surface area of the storage and the losses are higher as a percentage of stored volume from shallow dams and wetlands. Thus, prevailing climate conditions can limit the potential constructed wetlands particularly where evaporation losses can be up to 3,000mm. To reduce evaporation losses many communities build deep and steep-sided open storages which often require fencing to minimise public safety hazards. Alternatively, appropriately selected bank vegetation (ie emergent macrophytes) can act as a barrier to the water edge. Construction of wetlands allows the natural processes to occur, provides the essential drainage functions and also provides a valuable resource for urban communities. Well designed and constructed wetlands imitate natural wetlands, resulting in an efficient biological treatment system. However, the functionality and effectiveness of wetlands depends very much on local conditions including climate, the development of land and its use.
4.5.3 **Aquifer Storage and Recovery (ASR)**

The idea of storing water in times of plenty (rainy days) for use when it is needed (dry days) is obvious, after all it is the basis of the anthropogenic manipulation of the water cycle. Conventional storage has been in the form of dams which are clearly visible and when full give a sense of security, even though considerable losses of water occur through evaporation and seepage (Armstrong 1992). However, the concept of storing excess surface waters in aquifers (underground) and extracting the stored water when needed is less obvious than traditional storage in dams or tanks.

Advantages of groundwater aquifer storage include the large capacity, low cost, and no loss from evaporation. The land above the stored water can be used for other purposes. Deliberate redirection of surface water into groundwater aquifers for later use to meet peak seasonal or long term demands has become known as ‘*aquifer storage and recovery*’ or ASR (Dillon & Pavelic 1996b; DNR QLD 1998). It is widely practised in some parts of the world including the United Kingdom, United States, Israel and the Netherlands.

4.5.3.1 **Methods for Artificial Recharge**

There are various methods for storing water in aquifers, collectively known as ‘*artificial recharge*’. The various methods include; injection wells, pond infiltration/soil aquifer treatment (SAT), induced infiltration (pumping groundwater adjacent streams), and irrigation (all forms can result in unintentional recharge. Figure 38 shows a basic schematic of the commonly adopted artificial groundwater recharge techniques. Artificial recharge ponds (basins) have been used extensively throughout the world including Australia. According to Fox (1999) percolation basins (infiltration ponds) are the most widely accepted low technology method. This method requires the presence of an unconfined aquifer and large areas of land. By comparison, direct injection wells that recharge directly to the saturated zone are expensive; they require more advanced pre-treatment and maintenance technologies (Fox 1999). Therefore, direct injection is not a viable option when low technology solutions are desired.

**NOTE:**
This figure is included on page 129 of the print copy of the thesis held in the University of Adelaide Library.

*Figure 38  Commonly Adopted Aquifer Recharge Methods (Fox 1999)*
In urban areas, the high cost of land has provided the motivation for the development of vadose zone injection wells. This recharge method is endowed with some of the advantages of both infiltration ponds and direct injection wells. For example, underlying unsaturated soil layer (vadose zone) may have capacity to remove contaminants from recharged (injected) water as it percolates through the vadose zone and enters the saturated zone. Improvements in water quality are expected but have not been well documented as compared to recharge basins (Fox 1999). Fox also notes that once a vadose zone injection well is clogged, it is very difficult to redevelop. Nevertheless, when land is expensive they can be more economical than either recharge basins or direct injection wells even when systems are designed with a life cycle of only five years (Fox 1999).

Depending on the site, storing water underground may be an appropriate option. ASR is very site specific and the technical advice is required before implementing this option (Fleming 1999; SA Water 1999b). Example 23 below provides a good study on the importance of site conditions for ASR. Estimating recharge rates is critical in any analysis of groundwater systems and the impacts of withdrawing water from them. The measurement of aquifer hydraulic parameters is performed by various types of pumping tests selected on the basis of the site and nature of the data required.

**Example 23 Aquifer Recharge & Storage Investigation: Enfield Cemetery**

The Enfield Cemetery Trust were interested in harvesting stormwater from a drain which passes through the undeveloped half of the cemetery for on site irrigation. Investigations by the Department of Mines and Energy revealed two possible options for aquifer recharge and storage at the site:

- a dry sand bed between 10-20 m depth, overlain with clay, and
- fractured rock aquifers below at about 30m.

The sand bed was found to be sloping towards the west slightly less than the slope of the land. Any water recharged at the cemetery site would migrate down slope and could eventually cause problems by surfacing near the Main North Road. Field experiments showed that the sand could be recharged but that the water stored would be lost by lateral seepage in the unsaturated sand. An underground storage could be created within the sand layer by constructing a wall of clay around the recharge site to provide the required storage. This was found to be expensive and of no greater benefit than an underground tank or surface storage.

A well was drilled to a depth of 117m which yielded a supply of 12l/s with a salinity of 500mg/L. A total of 0.78ML of mains water was recharged by gravity over 9 day period. However, during subsequent pumping the well yielded only aquifer water with little or no contribution from recharged mains water. The investigation and field experiments revealed that conditions at this site prevented aquifer recharge and storage being viable.

*Source: Armstrong 1992*

Potential problems with ASR systems can be categorised in two groups, those relating to the geology and hydrology of the aquifer and those relating to the quality of the water to be stored in the aquifer (Farmhand 2004). The best technique of artificial recharge depends on local conditions.
4.5.3.2 Benefits of Current ASR Systems

Groundwater aquifers can provide a means of storage and transmission of large volumes of water instead of large transfer pipelines. An unexploited aquifer underling or near an urban centre is latent water resources infrastructure which has a capacity to store, treat, and distribute water (Dillon 1999). Under natural conditions (pre-development), groundwater systems reach a state of sustainability (equilibrium) where recharge and discharge is balanced overtime. Pumping represents an additional withdrawal from the system which can be sustainable provided the volume extracted is balanced by total amount of natural recharge for the system. The rate at which infiltration takes place depends on the texture and porosity of the soil, which together determine the permeability of the soil. Excess water may be directed purposely into the ground to rebuild or augment groundwater supplies. Thus, estimating recharge rates and the impacts of withdrawing water is critical in any analysis of groundwater systems. At many places in the world, groundwater recharge has been a successful technique for augmenting water resources for more than half a century.

Over fifty years ago, Miles (1952 in Argue 1991) urged that 'serious consideration be given to the possibilities of enhancing the intake into aquifers under the Adelaide Plains by artificial recharge, using the excess runoff water which is now hustled out to sea.' Miles proposed a 'binary waters' concept in which the resource was divided according to its use: high quality water (fully treated and filtered if necessary) for domestic consumption, and non-potable water (untreated aquifer water with salinity 1500ppm or better) supplied by bores to manufacturing industries, councils, golf courses, schools for watering large open-space areas and playing fields. However, the 250 page report by Miles failed to attract the attention of decision-makers at an important stage in South Australia's water resource development (Argue 1991). At the time, the focus was on securing water supplies from the River Murray water for Adelaide and other parts of the state (discussed in section 5.5 and Appendix 6). Regrettably, fullest use of Adelaide’s local water resources (including brackish reserves) as Miles hoped has not been accomplished.

In fact since the 1990s, a number of ASR projects have been developed in South Australia for new urban developments at Regent Gardens, New Haven Village, Andrews Farm, New Brompton and Parfitt Square (Clark et. al.1997). These projects add value to under utilised urban water resources (ie. stormwater, wastewater and brackish groundwater) in a number of ways by blending and storing in times of excess supply until times of peak demand. Following successful trials at Andrews Farm and Regent Gardens, Guidelines on the Quality of Stormwater and Treated Wastewater for Injection into Aquifers for Storage and Reuse were published (Sibenalar 1996).

Most Australian ASR projects have been developed to meet non-potable water demands such as irrigation of community sporting facilities and open spaces. In addition, to reducing demand for potable water this approach can enable waters of varying quality to match intended uses. The exception is the potable water supply ASR project for the small holiday hamlet of Clayton in South Australia (more information is provided in the case study review in Part II).
The Clayton potable ASR has been operated within a challenging hydrogeological environment since 1996. Recovered water must be composed of at least 98% of lake water to be of an acceptable salinity for drinking water supply (Gerges et al. 2002a). Consequently, preparation to meet summer demand of between 40-70ML requires a significant volume of 200-300ML to be injected into the aquifer. However, the complex aquifer management and specialist expertise required has compelled the Department for Water, Land and Biodiversity Conservation (DWLBC) to operate the system on behalf of the local Alexandrina Council. In August 2005, representatives from the council and the community meet to discuss the future of the Clayton water supply scheme. Based on the information available and the price that customers are willing to pay it was agreed to maintain a safe but non-potable water supply to the community.

The fastest growing type of recharge is the direct injection well as shown in Figure 39. These wells are used to both store and recover water according to supply and demand.

**NOTE:**
This figure is included on page 132 of the print copy of the thesis held in the University of Adelaide Library.

![Aquifer Storage Phase Recovery Phase](Image)

**Figure 39  Cross-section of Direct Injection Well System (DWLBC 2005)**

The cost of storage is a function of depth of the bores, the depth of the aquifer and the rates at which water can be transferred into and out of the bores (Clark et al. 1997). The viability of an ASR scheme is significantly affected by the life of the injection/recovery wells and their clogging potential. The long-term sustainability of ASR sites requires the management of chemical, physical, and biological clogging in the near and far well zones (Buisine & Oemcke 2002). It remains to be seen if this practice can be extended (ie. scaled up) to assist with delivery of more sustainable water services to small towns in regional Australia.

4.5.3.3 Impact of Artificial Recharge on Water Quality

Artificial groundwater recharge can influence local gradients and groundwater flow patterns. For example, an artificial recharge system could displace or cause movement of contaminated groundwater towards a bore that supplies potable water. This may result in the loss of a potable water supply to a community and a contaminated groundwater plume that is more difficult to contain. Since ASR
systems can affect the quality of the adjacent groundwater resources, extensive water quality monitoring programs must be implemented.

Geochemical interactions between soils, aquifer materials and recharge waters can dictate final quality of recovered water (Fox 1999). ASR systems are generally designed for high recovery with minimum blending of stored water and native groundwater. However, improvements of water quality with successive operating cycles have been observed at several installations. The various ASR techniques are listed in Table 19 (below) along with their advantage and primary water quality improvement process.

Table 19 Storing Surface Water in Aquifers (Dillon & Martin 1999)

Since characteristics of injected water can change during storage in the aquifer, a prediction of change and need for additional treatment to meet requirement of intended uses upon recovery must be determined. Research indicates that, in most cases, ASR leads to water quality improvements and does not degrade groundwater quality (AWWA 2001). The ideal soil for soil-aquifer-treatment (SAT) system balances the need for high recharge rates (coarse textured soils) with the need for efficient contaminant removal (ie. fine textured soils). Investigations to characterise chemical, physical, and biological processes that contribute to water quality improvements during ASR is ongoing.

Source: Dillon & Martin (1999)
With adequate management and monitoring a SAT system may reduce pre-treatment and post-treatment costs. Experience with ASR technology continues to grow. At one time considered only applicable for recharge of potable quality water, ASR is being expanded to reclaimed water, groundwater and partially treated surface waters (Dillon & Pavelic 1996b; AWWA 2001). A combination of low cost technologies can be used to accomplish groundwater recharge with reclaimed water or other poor quality water sources. For example, stormwater or surface waters can be passed through stilling basins or a sequence of constructed wetlands to reduce the sediment and nutrient loading as pre-treatment to groundwater recharge.

4.5.3.4 The Potential of ASR Systems

In the USA, UK, Netherlands and Israel, aquifer storage and recovery with potable water or its equivalent is practiced. Dillon (1999) suggested artificial recharge of potable water could buffer seasonal peak demands that exceed the capacity of the existing infrastructure as well as a means of providing emergency or drought supplies of drinking water. In other words, the major transfer pipelines can be used in the off-peak season to transport water to recharge a suitable aquifer for subsequent recovery and return to the water distribution system. This approach could also be applied in situations where existing storage capacity within the distribution system is small. Investigation is required to assess the potential for incorporating ASR systems as a means of increasing the life and flexibility of existing water supply infrastructure supporting small towns in regional Australia.

As effluent and stormwater discharge requirements become more stringent, the difference between the quality for discharge to the environment and that for potable reuse will reduce, which in turn will reduce the costs of potable reuse (Law 1997; Fleming 1999). In the long term, the capital cost associated with the implementation of potable reuse is likely to be less than non-potable reuse (Anderson 1995) because the duplication in distribution system is not required. This flexibility presents opportunities for more holistic urban water management, recycling more water and reducing water imports and discharges of polluted water. ASR has been relied on for replenishing drinking water supplies with recycled water in multi-well and soil aquifer treatment systems as the following example demonstrates.

Example 24 Water Reuse for Aquifer Recharge: Orange County, USA

The Orange County Water District commenced pilot studies in 1965 to determine the feasibility of using treated wastewater as a hydraulic barrier to prevent saltwater encroachment into potable water supply aquifers. Construction of Water Factory 21, a tertiary treatment facility, started in 1972 and injection operations began in 1976. Water Factory 21 reliably produces high quality water. At this site up to 120 GL/yr recycled water has been injected for more than 20 years into an overexploited aquifer used for drinking supplies. Injection creates a groundwater ridge between the coast and the water supply wells to prevent saline intrusion.

Passage through the aquifer provides further treatment in addition to tertiary treatment, followed by reverse osmosis or granular activated carbon
filtration and chlorination. This is a highly regulated scheme and produces water of suitable quality at the recovery wells. It is a widely held view by operators and regulators that direct discharge of recycled water from the water factory to water supply pipelines would not be acceptable to the community at large. The entire treatment operation is expensive, but the cost is justified on the basis of the value of the groundwater which this protects, and the high costs of alternative supplies.

Source: US EPA 1992 and Dillon & Martin 1999

Fox (1999) found that public acceptance of groundwater recharge for indirect potable reuse has been more favourable compared with other forms of proposed potable reuse. Retention in an aquifer may provide the necessary contact with the natural environment to make recovery for potable use more acceptable for consumers (Dillon 1999). If emotional barriers to potable reuse can be overcome, it will provide a substantial opportunity to increase potable water supplies (Polin 1977; WSAA 1998). Alternatives, such as desalinated water, are preferred over potable reuse options (Marks 2005). In Australia, the main obstacle to water harvesting and reuse for potable purposes remains that of public acceptance.

Aquifer storage and recovery has emerged as a means of expanding urban water resources that would otherwise be lost. This underground water banking technique offers the flexibility of storing water from various sources such as surface water, stormwater or wastewater. Recovered water can be used to meet seasonal peak, emergency or long-term demands. The level of water quality treatment depends on the quality of the aquifer, the quality of the source and the quality of the recovered water. Among other things, ASR of potable (mains) water, stormwater, and treated wastewater effluent, can act to increase water supply flexibility, augment water resources, improve the efficiency of use of water infrastructure, and reduce adverse environmental impacts of urban water systems. However, ASR is not a universally applicable method for water supply and can only be applied if certain physical conditions are at hand. Potential problems with ASR systems can be categorised in two groups, those relating to the geology and hydrology of the aquifer and those relating to the quality of the water to be stored in the aquifer (Farmhand 2004). Depending on the site, storing water underground may be an appropriate option.

4.5.4 Package Plant Technologies

Although many small towns have sufficient populations to benefit from the economies of scale offered by piped systems, they are too small for conventional (mainstream) urban water utilities (WSP 2003). In addition, many small community water systems in Australia have a difficult time in complying with requirement of the Australian Drinking Water Guidelines. Pre-engineered package treatment technology offers an alternative (Polin 1977; NAS 1998). Included among these technologies are filtration systems, disinfection, organics control and inorganic treatment technologies (Clark et al. 1994). The treatment processes utilised in 'package technology' are essentially variations of coagulation and filtration treatment trains capable of treating a few kilolitres per day to many megalitres per day. These units are still 'central' in that a pipe distribution system is necessary for water to reach the consumers.
4.5.4.1 Application of Package Plants

Various aspects make this type of technology more appropriate for small community operations than conventional treatment plants. The most significant requirements for small water systems are low construction and operating costs, simple operation, adaptability to part-time operations, low maintenance, and no serious residual disposal problems (Clark et al. 1994). The major advantages and disadvantages of package technologies are summarised in Table 20.

Table 20 Advantages and Disadvantages of Package Plants

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Short construction time</td>
<td>• Difficult to validate claims made by suppliers</td>
</tr>
<tr>
<td>• Very compact (small footprint)</td>
<td>• Complexity of engineering and process solutions often require ongoing support from supplier (capture of project by supplier)</td>
</tr>
<tr>
<td>• Modularity (add to meet growth in demand, an effective way to distribute capital expenditure)</td>
<td></td>
</tr>
<tr>
<td>• Design for unattended operation</td>
<td></td>
</tr>
</tbody>
</table>

Performance data has demonstrated that package plants can meet traditional water treatment goals with regard to controlling microbiological contaminants and turbidity. Where package plants do not meet maximum contaminant levels, Clark et al. (1994) found that in general this was caused by failure to run for periods long enough to achieve stable operation (locations with highly transient populations) or lack of operator attention such as not varying chemical dosage to meet changing raw water quality. Highly variable influent water quality requires operator attention and tends to negate the package plant advantages of low cost and automation (Clark et al. 1994). While operation and maintenance is simplified by automated features, the operator needs to be well acquainted with water treatment principles and the plant manual, and should have attended a comprehensive training session.

Package plants can differ widely with regard to design criteria, and operating and maintenance conditions. Influent water quality is the most important consideration in determining the suitability of a package plant application (Clark et al. 1994). For example, in cases of consistently high levels of turbidity and colour, the package plant capacity should be down rated or a larger model selected. Fail-safe controls are built into many plants to ensure that the finished water does not exceed set turbidity levels. Complete influent water quality records should be examined to establish turbidity levels, seasonal temperature fluctuations, and colour levels and pilot plant tests may be necessary to select a package plant for more innovative designs. It is usually easier to repair and obtain spare parts for simple equipment. The complexity of the package plant usually increases with efficiency and production rate, but so does the need for skilled operators and maintenance people (Hazeltine & Bell 2003). A reasonable guideline is to acquire a machine no more sophisticated than is needed to meet product specifications, with due regard to future changes in those specifications.
4.5.4.2 Technology Verification

There are risks involved with using new or unfamiliar technology, particularly, where new boundaries of technology are being approached. In some cases, the advice of outside consultants may be sought with the overall objective to minimise the level of technical risk borne by the community. Example 25 below provides an overview of the verification program in the United States to provide independent verification of emerging technologies.

Example 25 Package Technology Verification Program: United States

The United States Environmental Protection Authority (US EPA) runs a group known as Environmental Technology Verification (ETV) that supports small communities to ensure compliance with the Safe Drinking Water Act. Support is provided in the form of government funded trials and evaluations to validate the manufacturer’s design and claims of packaged technology systems. It is a voluntary program designed to allow the performance claims of emerging technologies to be quickly given independent verification, thereby promoting their introduction into the market and minimising risk to the purchaser. While, neither the US EPA nor the ETV endorses a product, the program does provide a means for third party evaluation of systems that would not be cost feasible for many small water authorities, local governments and communities. Since the ETV program is operated at the Federal level, it is automatically valid for all the other states in USA. The ETV program is also actively involved with equivalent approval organisations from Europe and Canada, allowing the verification process to cross international boundaries.


Adopting a similar technology verification process within Australia would provide support to water utilities serving small communities by reducing repetitive, and potentially expensive, qualifying and verifying process. It may also minimise risk to the purchaser and facilitate more rapid up-take of new and innovative technologies (wherever generated). Another advantage would be the ability to bring new Australian technologies to the national and international market (AWA 1999). However problems may still arise when the technology is to be used at a significantly different location involving different environmental or operating practices, and a lapse of several years from the time of verification of the original technology may result in some components becoming unobtainable or obsolete.

4.5.5 Desalination

Desalination is achieved by distillation, electrodialysis, and reverse osmosis (the most popular technology for small plants). Reverse osmosis allows people throughout the world to convert undesirable water into water that is virtually free of health or aesthetic contaminants. Pantell (1993) estimated there are more than 7,500 desalination plants in operation worldwide with some 60% located in the Middle East. Desalination of brackish water for domestic and industrial use is employed in some 60 locations around Australia, mainly in small plants associated with isolated mining and tourist developments (AATCE 1998).
4.5.5.1 The Process of Reverse Osmosis (RO)

Reverse osmosis is the process whereby one component of a solution is separated from another (in this case salt is separated from the water) by the pressure exerted on semipermeable membranes. Figure 40 illustrates how the reverse osmosis process removes dissolved minerals (including but not limited to salt) from seawater, brackish water, or treated wastewater. Since brackish water has a lower salt concentration the cost of desalting is less than for seawater.

![Figure 40 Schematic of Reverse Osmosis Process](image)

Membrane-based processes do have associated waste streams. Reverse osmosis produces a continuous liquid waste stream, referred to as ‘concentrated brine’, which is low in suspended solids but elevated in total dissolved solids and organics. Desalination requires a place to dispose of the concentrated brine (salt solution). Disposal of the brine from desalination plants needs to be managed carefully to avoid creating environmental problems.

4.5.5.2 Reverse Osmosis to Treat Water

Reverse osmosis is the one treatment step capable of presenting a barrier to all contaminants in the production of potable quality water including Cryptosporidium and Giardia (Law 1999). Based on current knowledge, reverse osmosis will provide an additional 5 to 6 log reduction of pathogen bacteria and protozoa and a 3 to 4 log reduction in pathogenic viruses (Law 1999). It will also remove organic chemicals, heavy metals, and radionuclides and nearly all the dissolved solids, including nitrogen and phosphorous. A possible reverse osmosis water treatment train is shown in Figure 41 below.

![Figure 41 Possible Reverse Osmosis Water Treatment Train](image)
Before desalination, source (feed) water should pass through pre-treatment steps (ie. coagulation and filtration) to remove all suspended solids and other particles and reduce fouling of the membranes. Pre-treatment of the source water can extend the life of the membranes by 3 to 5 years (Pantell 1993).

The ratio of product water to feed water (recovery) for desalination plants is typically around 40% for seawater and up to 75% for brackish water. The recovery rate for a desalination plant is also influenced by the particulars of plant operations depending on site specific conditions. Operating the plant on a part-time, rather than full-time basis may be more expensive in the long run because maintenance and capital costs must be paid while the plant is shut down. Scaling is caused by the high salt concentration and can result in reduced plant efficiency (recovery) and corrosion of components. Components must be cleaned to reduce scaling, a condition where salts are deposited on plant surfaces such as pipes, tubing or membranes. Desalination is a high energy consumption process and also has a significant brine output.

In some cases, to reduce the overall energy consumption and costs the pressurised stream of concentrated brine can be sent through energy recovery units prior to disposal. The concentrated brine can be discharged to the ocean, to mechanical evaporators, to natural evaporation pans or via deep well injection (Law 1999). Metals in feed water are rejected along with the salts by the membranes and are discharged in the brine provided these remain dissolved. The metals present in the brine discharge, though concentrated by the reverse osmosis process, would not normally exceed discharge limits (Pantell 1993).

Desalinated water may be used in its pure form – that is, for make-up water in power plant boilers - or it may be blended with less pure water and used for drinking, irrigation or other uses. Pure desalinated product water is highly acidic and thus corrosive to pipes, consequently post-treatment processes are employed to ensure that product water for drinking meets the health standards (Pantell 1993). Post-treatment commonly includes adjustment for pH, hardness, and alkalinity. Finally, the cost of disinfection by ultra violet (UV) light, chlorine or chloramines is minimised because of the nearly demand-free nature of the reverse osmosis product water and its very high UV transmittance (Law 1999).

### 4.5.5.3 RO Treatment Costs

In South Australia, brackish groundwater has been desalinated for some time to provide potable water supplies for remote areas including Coober Pedy, Leigh Creek and Roxby Downs. There is one seawater desalination plant along the South Australian coast (commissioned in 1999) which serves the township of Penneshaw (permanent population less than 200) on Kangaroo Island (SA Water 1999d). A proposal for a second seawater treatment plant in South Australia at Cathedral Rocks on Eyre Peninsula where conventional water resources are limited was considered (Kilmore pers comm. 2004).

In November 2003, Dr Con Pelekani (water treatment process engineer) from the South Australian Water Corporation carried out a unit cost estimate analysis for treating brackish groundwater and seawater to specified product water salinity levels by blending (shandying) the product water with the source water. The analysis indicated a minimal difference in unit cost for treating low or medium
brackish groundwater to various salinity levels 500mg/L, 1000mg/L and 1500mg/L as shown in Figure 42 below. The difference was even less for the seawater analysis as the amount that can be bypassed (for blending) to achieve salinity target was very small (<5%).

Figure 42  Estimated Cost to Produce Water to Specified Salinity Targets

A summary of the cost of producing potable water from operational desalination plants operating in South Australia is provided in Table 21 below. The unit cost is for treatment by the reverse osmosis process and excludes the cost of accessing source water and distribution of product water.

Table 21 Summary of Reverse Osmosis Plants in South Australia

<table>
<thead>
<tr>
<th>Plant Capacity (kL/day)</th>
<th>Source</th>
<th>Raw Water TDS (mg/L)</th>
<th>Recovery Rate (%)</th>
<th>Product TDS (mg/L)</th>
<th>Unit Cost ($/kL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penneshaw (1)</td>
<td>Sea</td>
<td>37,000</td>
<td>28</td>
<td>&lt;400</td>
<td>$5.00</td>
</tr>
<tr>
<td>Coober Pedy (2)</td>
<td>Ground</td>
<td>4,500</td>
<td>74 -77</td>
<td>&lt;100</td>
<td>$1.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1400</td>
<td>&quot;</td>
<td>&quot;</td>
<td>$0.94</td>
</tr>
<tr>
<td>Leigh Creek (3)</td>
<td>Ground</td>
<td>3,000</td>
<td>75</td>
<td>&lt;150</td>
<td>$1.00</td>
</tr>
<tr>
<td>Roxby Downs (4)</td>
<td>Ground</td>
<td>1,000-4,500</td>
<td>75</td>
<td>&lt;150</td>
<td>$0.79</td>
</tr>
<tr>
<td>Adelaide (theoretical) (5)</td>
<td>Sea</td>
<td>37,000</td>
<td>80</td>
<td>&lt;400</td>
<td>$1.03</td>
</tr>
</tbody>
</table>

(3) NRG Flinders, Leigh Creek Operations per comm. Dion Robins (2005)

The costs depend on many local factors including the salinity of the source water, the technology being used, the energy requirements as well as economies of scale. Figure 43 below provides a comparison of the estimated unit cost to produce potable water with a target TDS 500mg/L determined by Pelekani (2003) and the
actual operating costs to produce potable water. The existing reverse osmosis plants consistently produce water better than the target TDS 500mg/L.

![Cost to Produce Water with TDS 500mg/L by Desalination](image)

**Figure 43  Comparison of Estimated & Operating Unit Cost of RO Plants**

While the cost of the water produced by these plants is higher than that provided through SA Water mains, it remains an attractive proposal for many remote communities or communities where conventional water resources are limited, particularly compared to the real cost of alternatives (i.e. taking externalities into account). The desalination process has high energy consumption with per kilolitre energy usage being in the order of three times that required to pump water from the River Murray to Adelaide (GSA 2004). The significant energy requirements of large-scale desalination could result in the need to expand the State’s power generation capability (EWS 1989). Unless the energy requirements can be met by clean renewable sources the associated contribution to greenhouse gas emissions would be significant (GSA 2004). Nevertheless, reverse osmosis can be expected to play an increasing role in water treatment in South Australia, particularly if the energy requirements can be met using sustainable power sources such as wind, hydro or geothermal.

### 4.5.5.4 Renewable Energy

Renewable energy can reduce dependence on fossil fuels and also provide affordable electricity. A major benefit of renewable energy is not subject to sharp price changes because it comes from sources such as sunshine, flowing water or wind. By comparison, fossil fuels are limited in their supply and their price will increase as they become scarcer. The general principle behind the drive to renewable energy is sustainability.
Part I Our Water Resources

Rottnest Island in Western Australia is leading the nation in wind energy desalination. The construction of a wind turbine in December 2004 was a definitive milestone in the journey towards a sustainable energy and water supply. Example 26 describes this innovative project.

Example 26 Wind Power & Water Desalination: Rottnest Island, WA

Rottnest Island is located 18 kilometres from the mainland west of Perth, Western Australia. The island is 10.5 kilometres long and 4.5 kilometres wide at its broadest point. The surface waters of Rottnest Island consist of a series of saltwater lakes, swamps and several freshwater pools and seeps. It has even been necessary to import additional water by barge from the mainland from time to time. The supply of drinking water in sufficient quantities and at a reasonable cost has always been an issue. Three main sources of water have been developed to meet the annual demand for freshwater on Rottnest Island;

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainwater runoff harvested from sealed catchment since 1939</th>
<th>Underground freshwater borefield recharged by seasonal winter rainfall since 1971, and</th>
<th>Desalination of saline groundwater since 1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>10%</td>
<td>70%</td>
<td>20%</td>
</tr>
<tr>
<td>2003</td>
<td>10%</td>
<td>20%</td>
<td>70%</td>
</tr>
</tbody>
</table>

Groundwater has played a major role as a source of potable water until recently. A reverse osmosis (RO) desalination plant with a capacity of 220kL/day was commissioned in 1995 to augment supplies. The use of desalination as a source of potable water on Rottnest Island is expensive (around $2.40/kL) with costs dominated by the electricity requirements of the plant. At the time, Rottnest Island was totally reliant on liquid petroleum fuels for power generation, at a great and ever-increasing cost.

With the depletion of underground freshwater supply, the Rottnest Island Authority produced an Integrated Water and Power Development Plan. The philosophy behind the plan was to deliberately shift from a predominantly rainfall dependant water source to a majority of potable water being supplied through desalination. The capacity of the plant was upgraded to 500kL/day in February 2002 and reduced the reliance on rainfall dependant water supplies from 80% to 30% on Rottnest Island. The project included the construction of a new wind turbine to supplement diesel-generated power in order to make the shift economically and environmentally acceptable.

In December 2004, a milestone was reached in the journey towards a sustainable energy and water supply for the island with the construction of the Rottnest Island wind turbine. It has also reduced dependence on fossil fuels by an estimated 40% and to have the potential to effect savings of around $1 million per year in fuel costs. The project received a high commendation in the environment category of the 2005 Premiers Award for Excellence in Public Sector Management.

Source: Playford (2000); www.rotnestisland.com/rotto accessed 08/04/05
4.6 TRANSITION CHALLENGES

Almost since the time of European settlement, land and water management practices in Australia have progressively been adapted to suit the environment. Social factors have a definitive say, thus it may take decades before new approaches are adopted and even longer to reap the benefits (Hammond 1998 in Figurese et al. 2003). However, recent widespread drought across the country has refocussed the Australian community to their dependence on the limited water resources (Radcliffe 2004). Under the pressure of water shortages, water harvesting and reuse practices offer the potential to increase the total available water supply, particularly, where potable (drinking quality) urban water supplies can be safely substituted with treated wastewater, stormwater or brackish groundwater. Nonetheless, as there is a degree of self perpetuation with the traditional ‘business as usual’ approach, the transition from the existing urban water supply infrastructure to any alternative supply system and the introduction of innovative technologies will be problematic.

The key challenges to be actively managed in order to move from the existing ‘business as usual’ approach to water services towards more sustainable forms include remaining asset life (financial dimension), community size (technical, institutional and financial dimensions), and community misgivings (social dimension). To ensure sustainability, these need to be managed within the carrying capacity of the local environment.

4.6.1 Remaining Asset Life (Established System)

The sustainability of urban centres and communities depends on management and maintenance of established semi-permanent infrastructure of society as well as natural resources. Infrastructure management and the need to replace existing assets could be seen as an opportunity to restructure water services and eliminate unsustainable water management practices (Clarke et al. 1997; Fleming 1999). This philosophy of moving from the established system to an alternative sustainable approach assumes that as the infrastructure ‘wears out’ it is replaced with the new system. Firstly, in reality the established system does not fail as one whole system – it tends to fail only in small segments (Doherty pers comm. 2005). Secondly, the cost to facilitate the transition would be dependent on how it is to be managed and over what timeframe. The critical question is not so much whether alternative water systems will work reliably, but how they can be integrated in a way that is acceptable to the community into the strategic planning effort.

New water infrastructure systems developed in Australia today must be planned and designed with regard to their long term sustainability. Naturally, it is important to know whether the alternatively configured systems will be successful in terms of achieving desired aspiration for sustainability. Over the last decade, a number of systems to supply new urban development in Australia have been designed to maximise water cycle management opportunities and minimise adverse impacts on the environment. These sites provide full-scale operational models that allow direct comparison over time without the need to compare with ‘imaginary’ systems. They can generate information for research on effectiveness of technologies, social, economic and environmental impacts.
4.6.2 Community Size

Global sector experience has established that services are better sustained when service delivery is done using approaches that seek to understand and respond to the demands of users of the service (WSP 2003). The processes for developing and managing a small local water supply are the same as the public system but carried out to a different level of service. Small communities are usually more flexible with respect to accepting lower level of service compared with larger urban centres. Small towns with limited potable supplies should be given the opportunity to have lesser standards for non-potable reuse water if it conserves their potable supplies. While small communities are not averse to accepting higher risk (lower standards), health authorities in generally impose conservative standards that do not account for possible less demanding local conditions or local integrated water, wastewater and reuse systems.

4.6.3 Managing Community Misgivings

Encouraging community involvement and acceptance is not always easy when introducing new ideas because people are wary of change, particularly, if the specific change is perceived to be detrimental to their interests. International research has identified significant community resistance to the introduction of recycled water systems, in some instances, resulting in the abandonment of such projects (Marks 2005). Several large scale water reuse projects including in Noosa, Australia, San Diego, USA, and Lichi Rijin, The Netherlands, have failed and been abandoned as a direct result of a lack of community confidence (Hurlimann & McKay 2005). In each case, community misgivings could be attributed in part to inadequate communication between the non-potable water supply organisations and their stakeholders. Yet, few authors draw conclusions from their studies with regard to optimal ways of increasing public acceptance. Learning to reconcile different perspectives is an important part of the process of introducing new technologies.

A sceptical community may be reassured if informed of the success that other communities are having with water harvesting and recycling projects similar to that being proposed (Khan & Gerrard 2005). When the community is involved in the planning process there is an increased likelihood of a project being accepted by the community and successfully implemented and sustained. In addition, acceptance of the selected option, which may incorporate lower standards associated with lower capital costs, will be more likely if the community has been engaged early in the development stage. In some circumstances, the community involvement process may be more important than the final detail of the selected scheme because people want to be involved and have an opportunity to complain (Sarkissian et al. 1986). It is recommended that planners involved with water harvesting and reuse projects in Australia learn from the experiences of recently implemented projects – both successful and abandoned. The primary goal of a sustainable community is to meet its basic resource needs in ways that can be continued in the future. Understanding that other communities practice water harvesting and reuse as a matter of choice can act as a powerful endorsement.
4.7 SUMMARY

There is increasing recognition that present development paths are not sustainable. In Australia, the manner in which water is harvested, treated, distributed and used in urban centres is under constant review. Fortunately, a number of viable strategies exist to meet future urban water demands and safeguard the environment. Initiatives to improve sustainability of urban centres may include a combination of demand management (ie. water efficiency and conservation), water sensitive urban development (ie. policies and alternative practices) and supply augmentation (ie. natural and recycled). All these strategies have strong community support in Australia, with the exception of further development of natural freshwater resources, particularly where they can be shown to be cost effective.

Despite the increase in emphasis placed on future water challenges, a major constraint continues to be how to establish an enabling environment that can accommodate the necessary shift from the present unacceptable state to a more sustainable future. Impediments to increasing the sustainability of water services include the long life of the public infrastructure (including financing), resistance to change (from institutions), time to effect cultural change (ie. businesses and individuals) and the difficulty in predicting the future (ie. impact of climate change). The key challenge will be in transforming established urban water systems, often with an asset life between 50 and 100 years, into more sustainable infrastructure forms while maintaining a high level of services to customers. Opportunities to deliver more sustainable water services will need to be balanced with the retention and use of existing water infrastructure investments.

The introduction of new ways of delivering water services to achieve sustainability requires an advanced understanding of the social and economic climate in which the alternative water systems will be implemented. Given the rainfall variability and wide range of climates across Australia, it is both physically and economically unrealistic to expect a single strategy to deliver the same result for all urban centres. The delivery of sustainable water services to growing urban centres will require selecting a diverse mix of strategies that are best suited to the prevailing conditions. Design solutions should consider the most cost effective approach and seek to maximise the social and environmental benefits.

Innovation and experimentation will remain important elements in the development work to improve the sustainability of water services. In Australia, undervalued (or untapped) water resources near urban centres can include rainwater, treated wastewater, stormwater runoff, seawater and bottled water. Sometimes, the question of which solution is appropriate in a particular situation is not given enough attention when benefactors driven by their own solutions interact with small towns or rural communities. The challenges and opportunities associated with harvesting stormwater and reusing treated effluent for towns in South Australia are examined in detail in the next chapter.