Lee, Shinyi and Yigitcanlar, Tan and Egodawatta, Prasanna K. and Goonetilleke, Ashantha (2010) ***Sustainable water provision : challenges, alternative strategies and sources in the era of climate change.*** In: Yigitcanlar, Tan (Ed) Sustainable Urban and Regional Infrastructure Development : Technologies, Applications and Management. Premier Reference Source. IGI Global, Information Science Reference, Hershey, PA, pp. 17-30.

CHAPTER 2
Sustainable water provision: challenges, alternative strategies and sources in the era of climate change

Shinyi Lee, Tan Yigitcanlar, Prasanna Egodawatta and Ashantha Goonetilleke
School of Urban Development, Queensland University Of Technology, Brisbane, Australia
shinyi.lee@qut.edu.au; tan.yigitcanlar@qut.edu.au; p.egodawatta@qut.edu.au; a.goonetilleke@qut.edu.au

Abstract: *As a result of rapid urbanisation, population growth, changes in lifestyle, pollution and the impacts of climate change, water provision has become a critical challenge for planners and policy-makers. In the wake of increasingly difficult water provision and drought, the notion that freshwater is a finite and vulnerable resource is increasingly being realised. Many city administrations around the world are struggling to provide water security for their residents to maintain lifestyle and economic growth. This chapter reviews the global challenge of providing freshwater to sustain lifestyles and economic growth, and the contributing challenges of climate change, urbanisation, population growth and problems in rainfall distribution. The chapter proceeds to evaluate major alternatives to current water sources such as conservation, recycling and reclamation, and desalination. Integrated water resource management is briefly looked at to explore its role in complementing water provision. A comparative study on alternative resources is undertaken to evaluate their strengths, weaknesses, opportunities and constraints, and the results are discussed.*

Keywords: climate change, water provision, water conservation, water scarcity, infrastructure

Introduction

Is the world running out of water? Climate change induced drought, patterns of urbanisation and unsustainable withdrawal from natural aquifers are only some of the problems faced today when trying to source freshwater to sustain population and economic growth, while at the same time maintaining the integrity of the environment (Mitchell et al., 2004). Aquifers are overdrawn to the extent that groundwater is becoming increasingly saline, while in some parts of the world, there are months where deltaic rivers such as the Colorado, the Yangtze, and soon the Nile, do not reach the sea (Boutkan & Stikker, 2004). In Europe, countries on the coast of the Atlantic Ocean are facing increasing droughts, while water intensive tourism and agricultural practices are compounding water problems on the Mediterranean (Dickie, 2006). In the US, groundwater is already being extracted to a point where it is no longer replenished, while other surface water sources are increasingly threatened by contamination (Dickie, 2006). Even in Asia, where rainfall has been historically high, growing population and unevenness of rainfall can mean that there are surprisingly low levels of water available per capita, such as in Japan (Dickie, 2006).

Australia is suffering from the worst drought in decades. In a country where all the capital cities have been well served by surface water supply for the past century, there is currently a large gap between the supply of freshwater and its urban demand (PMSEIC, 2007). In the summer of 2007, all capital cities, with the exception of tropical Darwin, were under some form of water restrictions due to low rainfall in catchment areas, leading to dangerously low levels in reservoirs (Marks, 2005).

Sustainability in water provision

The concept of sustainability was first raised by the Brundtland Report in 1987 (WCED, 1987). In recent years, sustainability has been made one of the most vital issues. This follows the increasingly concrete evidence that the impacts of climate change and the effects of the modern urban lifestyle will threaten both manmade and natural water supply systems, with long term consequences which may be irreversible (Jabareen, 2006). Although vague, with its definition varying depending on its source, sustainability is a useful concept, forcing everyone to consider where development is heading environmentally, economically and socially. It has been widely stated that current practices and lifestyle cannot continue if we are to leave a living planet for the generations beyond the next (Granault, 2008). To achieve this, there are difficult and drastic measures that must be undertaken. Cities must be redesigned and habits reformed, and the concept of conserving and reusing our natural resources are keys to achieving sustainability (Jabareen, 2006). For this reason, the current open looped, single purpose design of infrastructure is not sustainable and cannot be maintained; the provision of water can no longer be linear, flowing from the tap to the sea. It is vital that society, policy-makers and planners introduce and incorporate sustainable features into energy intensive, but 'invisible' facilities. It is easy for the public to ignore or not realise the extent of the ecological footprint of the infrastructure due to its size and the fact that it is usually 'hidden' or located far away. There is also a need to recognise that the concept of 'sustainability' is not purely about environmental concerns; it also incorporates economic and social elements (Davidson, 2007).

The freshwater challenge

The 1992 Dublin-Rio Principle highlights that freshwater is a finite and vulnerable resource, and that its provision is integral to sustain life, economic development and the wellbeing of the environment (Thomas & Durham, 2003). While 71% of the earth's surface is covered by water, freshwater only makes up 2.5% of this amount. The remainder is essentially salty or brackish water locked up in oceans, salt lakes and saline groundwater reservoirs (Bidlack, 2004). Of this 2.5%, only 0.8% is accessible, as the rest are sequestered as glaciers and ice packs. Even this 0.8% is subjected to seasonal variation and dictated by the weather (Bidlack, 2004).

Although 0.8% of the world's water is available for human use, its extraction often requires an extraordinary engineering effort. As demand rises due to increased population and economic growth, water has to be harvested from increasingly remote sources. This requires a sophisticated engineering effort such as the construction of reservoirs and long pipelines. The use of engineering efforts to satisfy the increasing demand has worked well in the recent past (Chanan & Woods, 2006). However, the engineering based approach to water provision has brought about a range of adverse consequences to the environment. Lack of recharge and environmental flows in rivers, lakes and wetlands is one consequence that not only restricts water harvesting, but also endangers the integrity of the ecosystem. With continuing population growth into the 21st century, the solution to the challenge of water provision becomes more of a management, rather than an engineering solution.

Effective management solutions are only possible if there is a detailed understanding of the scenarios that create water deficiencies. Changes to rainfall patterns, which are direct consequence of climate change, are the most critical reason for water deficiencies. On the other hand, population growth has increased water demand significantly. In Australia, populations in capital cities are projected to increase by 35% by the year 2030. At the same time, annual rainfall in the catchments serving these cities is predicted to fall by as much as 25% (Henderson, 2004). Furthermore, problems of water provisions have worsened due to unsustainable water usage and uneven water distribution.

Climate change

Global temperature has risen 0.74°C since the last century, and is likely to climb by 5.8°C by the end of this century (NRM, 2004; IPCC, 2007). This increase in temperature will, in turn, alter precipitation patterns and increase evaporation from surface water, escalating its scarcity even further. Based on the most reliable models yet, the forefront global body on climate change – the Intergovernmental Panel on Climate Change (IPCC) – has stated that climate change will see a growth in extreme weather and rainfall events such as longer droughts and cyclonic events, as well as a decrease in annual rainfall (IPCC, 2007).

The principal characteristics of climate change for the Australian continent will be the same, but to different degrees (CSIRO, 2007). Climate change scenarios applicable to Australia are mostly influenced by its surrounding oceans. As predicted in the recent Commonwealth Scientific and Industrial Research Organisation (CSIRO) report (2007), tropical cyclones and monsoonal rains will be predominant in Northern Australia, while climate in the south will be affected by mid-latitude storm systems. The consequences of these climate change scenarios will be extreme flood events, prolonged droughts and bushfires.

The recently released Garnault report (2008) concurs, indicating that the regions that house most of Australia's population (the eastern, south western and the southern regions of the country) are likely to receive less rainfall and higher evaporation rates due to rising temperatures, reducing water supplies, thus confounding the longstanding problem of strong population growth in an arid country. Australia is currently experiencing the worst drought in a decade (Marks, 2005), and with climate change forcing rainfall years to be further apart, it will be increasingly difficult for water managers to extract maximum use of the available rainfall due to the limitations in storage capacity in water supply reservoirs. Furthermore, the changes to spatial distribution of rainfall may isolate the existing water infrastructure, thus creating reduced recharge. Consequently, these factors lead to concerns about the sustainability of traditional water resources.

Patterns of urbanisation

In the early part of the 20th century only a relatively small percentage of the population lived in city regions of the world; however, as the population has grown, so has the trend in urbanisation (UNESCO, 2003). Urbanisation exerts one of the most important impacts on water use, as the congregation of many people from a diversity of backgrounds, lifestyles and expectations have different demands on water (UNESCO, 2003). With world population likely to increase (Al Radif, 1999), water use will undeniably increase.

Research has shown that urbanisation, sprawl and low density housing encourages higher water usage due to lifestyle demand; low density residence and sprawl is usually associated with outdoor areas such as yards, gardens and swimming pools, which increases outdoor water use due to watering (Al Radif, 1999; Western Resource Advocates, 2003; Domene & Saurí, 2006). This change has also fuelled a competition of usage between agriculture and industrial water uses, causing tension between urban and rural areas (UNESCO, 2006). Rises in population naturally equals a rise in water demand and use, which is traditionally met by tapping available ground or surface water. If such sources are not sufficient, authorities often resort to transferring water from great distances to feed growing, thirsty cities, such as in China and Spain, where water is siphoned from the Yellow River and the Tagus River respectively, to the detriment of the ecological health of the waterways (Dickie, 2006; Postel, 2007).

The clearing of land for agriculture, housing, recreation and other anthropogenic activities also affects the aquatic ecosystem and its ability to retain and purify water, creating water stress (UNESCO, 2003). Low density development around dry coastal areas is also a driver for water demand, as are changes in patterns of consumption due to industrialisation, migration and public attitude towards water (Al Radif, 1999). As economic standards in the world rise, so does the demand for manufactured goods, instant gratification and food consumption. This has lead to the overexploitation of water resources, a problem which is discussed next.

Unsustainable usage

Current resource consumption is unsustainable, with oil being the first casualty, and water coming in a close second (Henderson, 2004). World water use has increased almost four times since the 1940s (Bidlack et al., 2004), while in Queensland, Australia, water use has increased 'significantly' over the last decade (CSIRO, 2000; DNR, 2000). In the future, UNEP (2008) predicts that annual global water withdrawal rates will increase by 10-12% every decade.

The increasing water use rates do not seem to be diminishing and are fuelled by population growth, unsustainable consumption and high demands for irrigated agriculture due to the continuation of the Green Revolution and the emergence of high intensity livestock farming (Al Radif, 1999; Bidlack et al., 2007). Two-thirds of global freshwater is used for irrigation (Brannan, 2008), which has increased seven fold since 1980 (Bidlack et al., 2004). In Queensland, 44% of all water is obtained from underground aquifers, a source which the government has recently admitted is now exhausted (DNR, 2000). The Queensland Water Commission (2008) concurs, stating that groundwater extraction in SEQ is currently developed to its full potential, or in some cases, already over developed.

The unsustainable extraction of these traditional resources has resulted in the ecosystem being unable to replenish, store and purify water, further compounding the freshwater crisis, as well as causing severe ecological damage such as land desertification (Dickie, 2007; Lattemann & Höpner, 2007).

Uneven distribution

Geographically, regions with high concentration of people and water are usually not coincidental. For example, in the Mediterranean, rain usually falls in winter; however, in summer months when water consumption is high, the weather is dry (Al Radif, 1999). To ensure that supply is constantly available, water needs to be stored, and subsequently drawn when needed. Current water schemes are already operating at or over their capacity, causing environmental degradation and water stress.

Within a region, areas with heavy rainfall do not necessarily coincide with areas with high population and water demand. While it is well known that Australia is the most arid continent in the world next to Antarctica, less widely known is the fact that, in terms of rainfall per capita, she is actually the wettest inhabited continent (Davidson, 1969, cited in Quiggin, 2006). Australia's problem is not the amount of rainfall, but rather the areas in which it falls (Quiggin, 2006). This, in effect, requires costly water transmission and distribution systems.

Alternative solutions to water provision and infrastructure

Due to the increasing scarcity of natural water sources, politicians, managers and policy-makers have turned their attention to non-traditional sources of water. There are three typical responses to the problem of water scarcity (Mitchell et al., 2004):

- increasing water use efficiency (e.g. installation of low flow showerheads)
- substituting water sources (e.g. reclamation or recycling)
- finding new water sources (e.g. new reservoirs or desalination).

From consolidating current water supplies, to providing new sources to managing demand, to better utilising available water, this section introduces major alternatives currently in use or under serious consideration. Table 1 below provides the findings of a SWOT analysis on these alternatives.

Table 1 SWOT Analysis of alternative water supplies

	Strengths	Weaknesses	Opportunities	Constraints
Conservation				
	• Easy to implement • Environmentally friendly • Requires no 'new' water • Cost effective	• May cause economic loss • Amenity of outdoor landscape affected • Some use—e.g. indoor use, during winter—inelastic to price • Generally unable to respond to acute situations e.g. drought • Need to implement significant institutional changes first	• Able to achieve savings quickly • Prices do not represent water's full value • Need more research & investigations to discover most effective way of pricing • Human behaviour is elastic & attitudes can change • Community more environmentally aware • Not yet fully utilised	• May be unpopular • Affects the availability of outdoor areas for recreation use • Current & prevalent public attitude towards water • Significant educational, political and social barriers
Recycling & Reclamation				
	• Environmentally friendly; requires no 'new' water • Technology is there and already successfully implemented • Can be used to augment reservoir supplies • Strong community support for non-potable use	• Potential for cross-contamination of pathogens or chemicals in water • Processing & redistribution costs can be high • Waste discharges can be highly concentrated—adverse environmental effects • Could be energy intensive	• Can counter negative perception using information campaigns • Cities produce large amounts of grey water • Lower quality water can be used for outdoor purposes • A diversification of water supply options • Installation of a 'third pipe system' in new developments for non-potable use	• Strong negative public perception (the 'yuck' factor) • Low community support for direct potable use
Integrated Water Resource Management				
	• Considers whole hydrological cycle • Environmentally friendly • Aesthetically pleasing while playing an important ecological role • Demand driven approach	• Relationship of chemical processes, runoff, aquifer recharge etc. is still unclear • The effectiveness of Water Sensitive Urban Design practices still debatable. • Heavily dependent upon public behaviour	• Assists in the collection of stormwater for reuse • Purification and filtering action keeps waterways healthy • Human behaviour elastic and can change	• Low understanding of the concept amongst the public

Desalination				
	• Conserves available freshwater for natural ecosystems • Vast amounts of brackish & saline water in the world • Reliable, independent of climate • Mostly positive public perception • Able to produce vast quantities of water	• High energy use, high emissions of greenhouse gasses • Adverse environmental affects • Expensive • High capital and recurrent costs • Gives less incentives to diversify or conserve water supply	• Advancement in technology o Cheaper o Improvements in efficiency • Able to support growing population • Utilisation of alternative energy sources can lower energy use	• High energy use in the face of peak oil & climate change • Strong negative perceptions by some • Likely to further increase the social divide as it is the wealthy who will benefit • Significant new infrastructure costs

Conservation

Previous attempts at solving water shortage problems have always been focussed on increasing the supply but not reducing the demand (Dickie, 2006; UNESCO, 2006). What remains to be explored are significant advantages that can be achieved from initiatives such as conservation and reclamation or recycling (White et al., 1999). Conservation has been termed the most environmentally friendly option because it places no additional demands on resources while providing 'new' water with lower resource consumption, and is cost effective (Mitchell et al., 2004; Schiffer, 2004; Hanak, 2007). Dam building and other large-scale water storage systems have come under increasing scrutiny due to their high costs and largely negative impacts both environmentally and socially (Girrard & Steward, 2007). For example, the Australian Capital Territory (ACT) government has indicated that no new reservoirs need to be built if savings of 12% and 25% per capita are achieved by 2013 and 2030 respectively (Turner et al., 2005). Conservation tools can be either 'hard' (regulations) or 'soft' (education) (Hanak, 2007); for example, improved public awareness, appropriate pricing and wastage reduction (Shiffer, 2004).

An important non-pricing technique is the 'command and control' method, where authorities impose regulations on certain types of water usage, such as car washing using potable water or hosing down paved areas (Byrnes et al., 2006). Currently, this is the most popular of all management policies, due to the ease with which it can be implemented (Byrnes et al., 2006). Other regulations currently in place are mandatory labelling of the efficiency of appliances, or laying in place planning mandates in relation to new development to reduce its water demand from the grid by installing water efficient facilities (Mitchell et al., 2004; Byrnes et al., 2006).

Conservation can also be achieved through economic incentives. Current water prices do not represent the actual cost. It has been advocated that the charges for water should change to reflect its quality and usage, mirroring the pricing system for electricity (Kaye, 2004; Garnaut, 2008). Users will be required to pay a lower tariff for lower quality water, but a higher price for better quality water for drinking (Kaye, 2004). In Australia, current water tariffs applied by State governments are called 'inclining block tariffs' and are in conjunction with the National Water Initiative, which relies on market forces to regulate demand (Byrnes et al., 2006). This simply means that, as usage increase, so does the price of water (Byrnes et al., 2006).

Water experts say that the key to managing water demand and facilitating conservation is to change how the public thinks about water (Gleick et al., 2003, cited in Hanak, 2007). However, this is difficult due to the common assumption that water is infinite and is, therefore, taken for granted (Kaye, 2004). The amount of available water should not be the only relevant parameter considered; it is not to be treated, used and then disposed of (Knights et al., 2007). There has to be a realisation that water cannot be a linear flow from the reservoir to the sea. Management policies are now more sharply focused on user behaviour which has previously received only a relatively modest scrutiny (Byrnes et al., 2006). There is an acknowledgement that there are significant 'educational, political, social barriers to achieving these savings' due to changing public attitude (Gleick et al., 2003, cited in Hanak, 2007). However, there are examples where conservation has been extremely successful with the cooperation of an informed community. For example, South East Queensland has managed to reduce its average water consumption from 340L/day to 123L/day as the public realised the severity of the drought via a strong media campaign (QWC, 2007); and industry in the region of Central Queensland reduced their consumption by 10% via changes in practice alone, with almost no external investment (Mitchell et al., 2003, cited in Mitchell et al., 2004).

Recycling and reclamation

The concept of recycling is not new; all water on earth has been used previously and recycled through the natural water cycle (CSIRO, 2000). The focus on recycling is generally on indirect potable reuse or non-potable use where wastewater is treated and then mixed with existing potable water sources such as reservoirs, or when wastewater is treated to a standard where it is able to be used for irrigation (Marks, 2007). Internationally, Singapore has demonstrated that potential risks can be successfully managed and that this water can contribute significantly to a limited freshwater source (PMSIEC, 2007). Israel also recycles around 65% of its municipal wastewater and aims to increase this to 90% (Friedler, 2000).

Recycling is an environmentally friendly option due to the utilisation of water which has already been used or the reclamation of urban stormwater (CSIRO, 2000). In cities with subtropical climates such as Brisbane which experience periodic heavy summer storms, a potential supply of water runs straight into thousands of kilometres of storm drains; this is unharnessed and represents a flood risk to lower reaches of the city's catchments (Rahman & Weber, 2003). In the current climate of water scarcity, treated wastewater, stormwater and rainwater should be seen not as waste, but a resource. Reclamation also has the dual use of reducing the amount of effluent and pollutants being discharged into the environment (and therefore lowering its environmental impacts), and of augmenting current water supplies (White & Howe, 1998; Friedler, 2000).

One of the biggest impediments to recycled water usage for personal and domestic use is the negative public perception, termed the 'yuck' factor (Hartley, 2006; Hanak, 2007). Marks (2007) suggests that mindset and perceptions are improved if the public trusts the body that carries out the schemes, and that stakeholder involvement is vital in order to secure support from the community. Financially, installing facilities for the recycling of water is usually more costly than taking the route of 'business as usual' (BCC, 2008). However, the true value of the utilization of recycled water needs to be evaluated over the long run; the cost of water security and the avoidance of dam building, for example, is expected to be much greater than the savings made by not uptaking recycling (BCC, 2008). There is also evidence from New South Wales that the price of non-potable use of recycled water can actually be lower than that of potable water (ATSE, 2004). The biggest challenge for stormwater reclamation, however, is that of storage space space – because of the intermittent nature of storm events, infrastructure required to capture, store and treat this water will not be used constantly, and could represent a high per capita cost (PMSIEC, 2007; QWC, 2008).

Desalination

Desalination has been established since the mid-20th century; sailors have been desalinating for well over 2000 years, while smaller communities with freshwater scarcity have been running micro-desalination plants for decades. The earth's natural water cycle also uses desalination; water evaporates from the land's surface water and leaves the salts behind to form vapour and clouds which eventually descend back to earth as fresh rainwater (Cooley et al., 2007). Using traditional energy sources of steam and electricity, the global desalination capacity at the time of writing is at about 25 million m^3/day, with two-thirds of this occurring in the Middle East where the situation of water scarcity meets the low cost of fuel (Mistra, 2007; Latemann & Höpner, 2008; Brannan, 2008).

While some large scale desalination plants have already gone forward (e.g. Kwinana in Perth, Ashkelon in Israel), there are still strong objections due to the need for high fuel and energy consumption in the wake of peak oil and climate change, as well as environmental concerns during construction and concentrated waste discharge during operation (Stikker, 2002). There are also economic concerns, with energy still accounting for 30% to 50% of total costs, and the high expense of building the plants themselves (Hairston, 2006; Nair & Clancy, 2007). However, the expected rise in the difficulty of obtaining water through traditional methods will fuel investment in the field, with investors scrambling to enter a market which will almost certainly yield profits in the future. The market for desalination is projected to grow up to $70 million annually (Martin-Lagardette, 2001; Hairston, 2006; Hanak, 2007). This investment in desalination technology will surely improve the technologies involved, and in time – as skills sets, equipment and efficiency improve – the costs will fall accordingly (Cooley et al., 2006). Desalination is often seen as a distraction to more sustainable water sources such as recycling and reclamation, despite its ability to provide large quantities of high quality freshwater independent of weather. This is because the price that is to be paid, economically, environmentally and socially may be too high to bear in the future.

Integrated water resource management

Integrated water resource management (IWRM) is a demand driven approach which seeks to redefine traditional boundaries (Al Radif, 1999; Knights et al., 2007). This is a response to the much criticised piecemeal approach to water management (e.g. looking at irrigation, treatment, energy etc. separately), highlighting instead, the benefits of a holistic approach to water management which integrates the management of all other resources to maximise sustainable and economic outcomes (UNESCO, 2006). The gist is to utilise skills of multi-disciplinary teams (incorporating as many stakeholders as possible) to produce sustainable use of water resources through diversification, policy and implementation of integrated management and protection of water sources, via integration of technological means, socioeconomic aspects, environmental concerns and health considerations (Al Radif, 1999; Thomas & Durham, 2003; Boutkan & Stikker, 2004; Brown & Farrelly, 2007; Knights et al., 2007). Barriers that prevent the implementation of IWRM are usually not technical, but often social, political or institutional; there has historically been inertia in embarking upon change (Brown & Farrelly, 2007).

Discussion

It is only in recent years that regulation and sustainability of infrastructure in general, and water in particular, have been subjected to much attention. On paper, the provision of water seems to be the simple process of estimating and balancing water demand and supply. Previous attempts at solving water shortage problems have always been focussed on increasing the supply but not reducing the demand. With dam building and other large-scale water storage systems coming under increasing scrutiny (due to their largely negative impacts environmentally and socially), alternative, 'renewable', more cost efficient sources have been pushed to consideration (Girrard & Steward, 2007). Water utilities and policy-makers can now choose between a wide array of alternatives – or a combination of them – to achieve water conservation, while at the same time increasing supply (Mitchell et al., 2004). For every policymaker and manager who concedes that water conservation is one of the 'been there, done that, did not work' options, there are others who argue that low cost demand management options – such as conservation and replacement and maintenance of water system networks – should be at the forefront of water supply augmentation due to their low demand on resources. Conservation will also enable water managers to 'buy time' for a more detailed assessment of demand and produce more accurate projections of how existing supplies will be affected by factors such as climate change, drought and population growth (Turner et al., 2005).

However, recycling and reclamation of wastewater or stormwater need to be managed in a much more sensitive manner, as there are strong negative feelings in the community towards it, with some factions referring to it as the 'toilet to tap' process (Hartley, 2006). Using recycled water for non-potable use such as for irrigation (or, more notably, such as its use at the Sydney Olympic Park) has generally been accepted or even welcomed. However, unless the process has been conducted with utmost transparency and with comprehensive community engagement, potable uses have still met with fierce resistance both at home and abroad (Marks, 2006). Even if its use is only currently primarily for non-potable use, it is still able to consolidate current water supplies, leaving higher quality water for uses which need such water. Cost can be a factor in selecting the uptake of this approach as the treatment process can be expensive. In New South Wales, Gregory (2000, as cited in ATSE, 2004), observed that it would be cheaper to attempt demand management and conservation before embarking on a recycling scheme. However, real-world cases have shown that utilising recycled water for non-potable use can be less expensive than using potable-quality water, as demonstrated by the Rouse Hill recycled water scheme in New South Wales (ATSE, 2004). The residential suburb's recycled water was priced at 28¢/kL, compared to 98¢/kL for potable water (ATSE, 2004). However, there is a need to be careful. As a consequence of the low price, the water consumption at Rouse Hill during the summers of January 2001 and December 2002 was at least 20% higher than the Sydney average (ATSE, 2004).

A more palatable option to the general public is that of desalination. However, this choice is fraught with difficulty and controversy because of its high resource consumption during construction and operation, as well as its environmental impacts. Supporters argue that there is almost an inexhaustible amount of salty and brackish water in the world that would be able to provide a stable supply of water independent of freshwater resources, and that this should be taken advantage of. However, critics point out that it is environmentally irresponsible to utilise desalination technology when there are better alternatives to be explored. The seas and oceans are not simply large basins of water; they are habitats for creatures and play important ecological roles (Dickie, 2007). There are also economic concerns, with energy still accounting for 30% to 50% of total costs, as well as the high expense of construction and operation

(Hairston, 2006; Nair & Clancy, 2007). However, the expected rise in difficulty in obtaining water through traditional methods will certainly fuel investment, and the market for desalination is projected to grow significantly in the near future (Hairston, 2006; Hanak, 2007). This investment in expertise will also improve the technologies involved and, as skills sets, equipment and efficiency improves, costs will fall accordingly (Cooley et al., 2007).

The options discussed in this chapter are not exhaustive and there are other alternatives which were not evaluated. To truly identify the best option or combination of options, there is a need to conduct a comprehensive comparison which will include social, environmental, political and economic elements; this is beyond the scope of this chapter.

Conclusions

This chapter has explored the current challenges of freshwater provision faced by politicians, policy-makers and planners, particularly in Australia. It has also examined major alternative strategies to address these challenges, focusing mainly on desalination and its strengths, weaknesses, opportunities and constraints in achieving water security for the region. While the main strength of desalination is in providing large quantities of high quality water regardless of precipitation, it may be concluded that such large scale infrastructure brings about too heavy a social and environmental cost. Compared to the alternatives of conservation, recycling and reclamation, it is expensive and difficult to implement, incurs high energy use in the face of human induced climate change, and creates numerous other environmental concerns. Other options presented here provide more environmentally friendly and economically viable solutions and should be explored further before embarking on an expensive desalination exercise.

Water is an unusual commodity: it is scarce, fragile and absolutely vital to life and development, yet so poorly understood and appreciated. Climate change and its subsequent impacts on water sources have come as almost an ambush strike; together with significant population growth, patterns of urbanisation and consumption, the natural hydrological cycle has been altered and its supply more and more difficult to obtain. There are several vital challenges to secure water provision; one of the most important is to provide a reliable water source for a rapidly expanding population and economy (QWC, 2008). With a hotter and drier climate predicted by both the IPCC and CSIRO, water provision must be diversified and the reliance on surface and groundwater reduced. It is undeniable that access to water is essential to economic growth, preservation of lifestyle and environmental health. While human needs are taken care of, so must those of the environment be, so that it can continue to play its oft forgotten role in filtering and replenishing increasingly dwindling water supplies (NRMW, 2006; QWC, 2008). Alternative sources of freshwater provision appear to be the norm of the future, as policy-makers realise that it is no longer feasible to rely on the extraction of rapidly diminishing ground and surface water resources.

The concept of 'sustainable urban development' is a complex issue. The social, economic and environmental processes are complicated not only from a scientific or conceptual point of view, but also from a management perspective (Rijsberman & van der Ven, 2000). How does one decide the tradeoffs between economic growth, social welfare and environmental protection? To further compound the problem, there are often numerous stakeholders involved, each with their own needs and interests, all of which are dynamic and fluid (Rijsberman & van der Ven, 2000). It is therefore important that all stakeholders be engaged as much as possible, as a single proposed solution is often acceptable to some but unpalatable to others due to different value systems and levels of knowledge. Therefore, there is no 'best' solution to this complex problem; there can only be one that is 'best achievable', because the 'best' solution to each person differs according to the values the particular stakeholder holds (Rijsberman & van de Ven, 2000). There is also the need to undertake a comprehensive economic, environmental and social study before deciding on the best course of action. The birth of a 'best achievable solution' ensures that the result produced is at least acceptable by most stakeholders, a vital component in ensuring the success of any program or policy (Rijsberman & van de Ven, 2000). Whilst one option may not be the complete solution to our water woes, an integration of hard infrastructure solutions and soft policy options may be part of the puzzle in resolving this problem.

References

Al Radif, A. (1999). Integrated water resource management (IWRM): an approach to face the challenges of the next century and to avert future crises. *Desalination*, *124*, 145-153.

Australian Academy of Technological Sciences and Technology (ATSE), (2004). *Water Recycling in Australia* [Online]. Available from: < http://www.atse.org.au/index.php?sectionid=597>, accessed 9th March 2009.

Bidlack et al. (2004). Water: The world's most precious resource. *Journal of Food Science, 69(2),* 55-60.

Boutkan, E. & Stikker, A. (2004). Enhanced water resource base for sustainable integrated water resource management. *Natural Resource Forum*, *28,* 150-154.

Brannan, P., (2008). Debunking desalination. *E: The Environmental Magazine*, *19(2),* 16-19.

Brisbane City Council (BCC), (2008). *Sustainability in action water recycling at Australia Trade Coast* [Online]. Available from: <http://www.brisbane.qld.gov.au/bccwr/environment/documents/case-study-atc-water-recycling_final.pdf>, accessed 8th March 2009.

Brown, R. and Farrelly, M. (2007). Institutional impediments to advancing sustainable urban water management: a typology. In the proceedings of the 13th International Rainwater Catchment Systems Conference and the 5th International Water Sensitive Urban Design Conference, Sydney, Australia, 21-23 August, 2007.

Byrnes, J., Crase, L. & Dollery, B. (2006). Regulation versus pricing in urban water policy: the case of the Australian National Water Incentive. *The Australian Journal of Agricultural and Resource Economics*, *50,* 437-449.

Chanan, A., Woods, P. (2006). Introducing total water cycle management in Sydney: a Kogarah Council initiative. *Desalination,* 187, 11-16

Commonwealth Scientific and Industrial Research Organisation (CSIRO). (2000). *Today's Water Recycling Issues for Queensland: Information paper*. Queensland Water Recycling Strategy, Australia.

Commonwealth Scientific and Industrial Research Organisation (CSIRO), (2007). *Climate change in Australia—Technical Report 2007*. CSIRO, Australia.

Cooley, H., Gleick, P.H. & Wolf, G. (2006). *Desalination, with a grain of salt: A California perspective* [Online]. Available from: <http://www.pacinst.org/reports/desalination/desalination_report.pdf>, accessed on 2nd April 2008.

Davidson, M. (2007). Searching for the socially sustainable city: Achieved through inducing the right mixture?. In the proceedings of the State of Australian Cities National Conference, Adelaide, Australia, 28-30 Nov 2007.

Department of Natural Resources and Mines (NRM). (2004). *Climate Change: The Challenge for Natural Resource Management*. Queensland Government, Brisbane.

Department of Water Resources (DWR), (2003). *Desalination: Findings and Recommendations* [Online]. Available from: <http://www.owue.water.ca.gov/recycle/desal/Docs/Findings-Recommendations.pdf>, accessed 2nd April 2008.

Dickie, P., (2007). *Making Water. Desalination: Option or distraction for a thirsty world?*, [Online]. Available from: < http://assets.panda.org/downloads/desalinationreportjune2007.pdf>, accessed on 2nd April 2008.

Domene, E., & Saurí, D. (2006). Urbanisation and Water Consumption: Influencing Factors in the Metropolitan Region of Barcelona. *Urban Studies, 43*, 1605-1623.

EPA, (2008). *Environmental Protection* Authority [Online]. Available from <www.epa.gov.au>, accessed on 6 Oct 2008.

Foran, B. & Poldy, F. (2002). *Future dilemmas: Options to 2050 for Australia's population, technology, resources and environment*. CSIRO Sustainable Ecosystems: Australian Capital Territory, Australia.

Friedler, E. (2000). Water reuse—an integral part of water resources management: Israel as a case study. *Water Policy, 3*, 29-39.

Girrard, M. & Steward, R.A. (2007). Implementation of Pressure and Leakage Management Strategies on the Gold Coast, Australia: Case Study. *Journal of Water Resources Planning and Management, 133(3)*, 210-218.

Garnault, R. (2008). *The Garnault climate change review: Final report*. Cambridge University Press: Victoria, Australia.

Hairston, D. (2006). The desalination challenge: Making water abundantly available, *Chemical Engineering Progress, 102(9)*, 6-8.

Hanak, E. (2007). Finding water for growth: New sources, new tools, new challenges. *Journal of the American Water Resource Association. 43(4)*, 1024-1035.

Hartley, T.W. (2006). Public perception and participation in water reuse. *Desalination, 187,* 115-126.

Henderson, H. (2007). 21st Century City Challenges. *Ecos, 135*, 14-17.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Working Group I: Climate Change 2007: The Physical Science Basis* [Online]. Available from: <http://ipcc-wg1.ucar.edu/wg1/wg1-report.html>, accessed on 17th September 2007.

Jabareen, Y.R. (2006). Sustainable urban forms: Their typologies, models and concepts. *Journal of Planning Education and Research*, *26,* 38-52.

Kaye, T. (2004). *Solving our water headache* [Online]. Available from: < http://www.solve.csiro.au/1104/article8.htm>, accessed on 5th April 2008.

Knights, D., MacGill, I & Passey, R. (2007). 'The sustainability of desalination plants in Australia: is renewable energy the answer?' in OzWater Conference, Sydney, March 2007.

Lattemann, S. & Höpner, T. (2007). Environmental impact and impact assessment of seawater desalination. *Desalination, 220*, 1-15.

Mahr, K. (2007). Making rain, *Time International (Asia ed.), 170(6)*, 47-52.

Marks, J.S. (2006). Taking the public seriously –The case of potable and non-potable reuse. *Desalination, 187,* 137-147.

Mitchell, C.A., Tuner, A., Cordell, D., Fane, S. & White, S. (2004). 'Water conservation is dead: long live water conservation'. In the proceedings of the 2nd IWA Leading Edge Conference on Sustainability: Sustainability in Water Limited Environments, Nov 2004, pp. 53.

Misra, B.M. (2007). Desalination of seawater using nuclear energy. *Desalination, 205(1-3),* 269-278.

Nair, A.K. & Clancy, B. (2007). Severe drought driving Australia towards seawater desalination for NSW coast. *Water & Wastewater International*, *22(1),* 12-14.

Postel, S. (2007). China's unquenchable thirst. *World Watch, 20(6),* 20-21.

Preston, B.L. & Jones, R.N. (2006). *Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions*. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.

Prime Minister's Science, Engineering and Innovation Council (PMSEIC). (2007). *Water for Our Cities: building resilience in a climate of uncertainty*. Available from: <http://www.dest.gov.au/sectors/science_innovation/publications_resources/profiles/water_for_our_cities.htm>, accessed on 4th April 2008.

Queensland Water Commission (QWC), (2007). *Our water: Urban water supply arrangements in South East Queensland, final report* [Online]. Available from: < www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban_Water_Supply_Arrangements_in_SEQ.pdf>, accessed on 21st March 2008.

Quiggin, J. (2006). Urban Water Supply in Australia: the option of diverting water from irrigation. *Public Policy, 1(1)*, 14-22.

Rahman, K. & Weber, T. (2003). Sustainable urban development in Brisbane City – the Holy Grail?. *Water Science and Technology, 47(7),* 73-79.

Rijsberman, M.A. & van der Ven, F.H.M. (2000). Different approaches to assessment of design and management of sustainable urban water systems. *Environmental Impact Assessment Review, 20*, 333-345.

Ryan, B. & Sadler, B. (1995). *Guidelines for the utilisation of cloud seeding as a tool for water management in Australia* [Online]. Available from: < http://www.cmar.csiro.au/e-print/open/cloud.htm>, accessed on 2nd September 2008.

Schiffler, M. (2004). Perspectives and challenges for desalination in the 21st century, *Desalination, 165*, 1-9.

Stikker, A. (2002). Desal technology can help quench the world's thirst. *Water Policy. 4,* 47-55.

Thomas, J-S. & Durham, B. (2003). Integrated water resource management: Looking at the whole picture. *Desalination, 156*, 21-28.

Turner, A., White, S. & Bickford, G. (2005). 'The Canberra least cost planning case study'. In the proceedings of the International Conference on the Efficient Use and Management of Urban Water, Santiago, Chile, 15-17 March 2005.

United Nations Educational Scientific and Cultural Organisation (UNESCO), (2003). *Water for People, Water for Life: The United Nations World Water Development Report* [Online] Available from <http://www.unesco.org/water/wwap/wwdr1/>, accessed on 16th June 2008.

United Nations Educational Scientific and Cultural Organisation (UNESCO), (2006). Water: A Shared Responsibility. Available from < http://www.unesco.org/water/wwap/wwdr/wwdr2/>, accessed 16th June 2008.

United Nations Environment Program (UNEP), (2008). *Vital Water Graphics: An overview of the state of the world's fresh and marine waters* [Online]. Available from: <http://www.unep.org/dewa/vitalwater/article42.html>, accessed 17th February 2009.

Western Resource Advocates, (2003). SMART Water A Comparative Study of Urban Water Use Efficiency Across the Southwest [Online]. Available from: < http://www.westernresourceadvocates.org/water/smartwater.php>, accessed 17th June 2008.

White, S. & Howe, C. (1998). 'Water efficiency and reuse: A least cost planning approach'. In the proceedings of the 6th NSW Recycled Water Seminar, Nov 1998.

World Commission on Environment and Development (WCED), (1987). *Our Common Future*. Oxford University Press: Oxford.