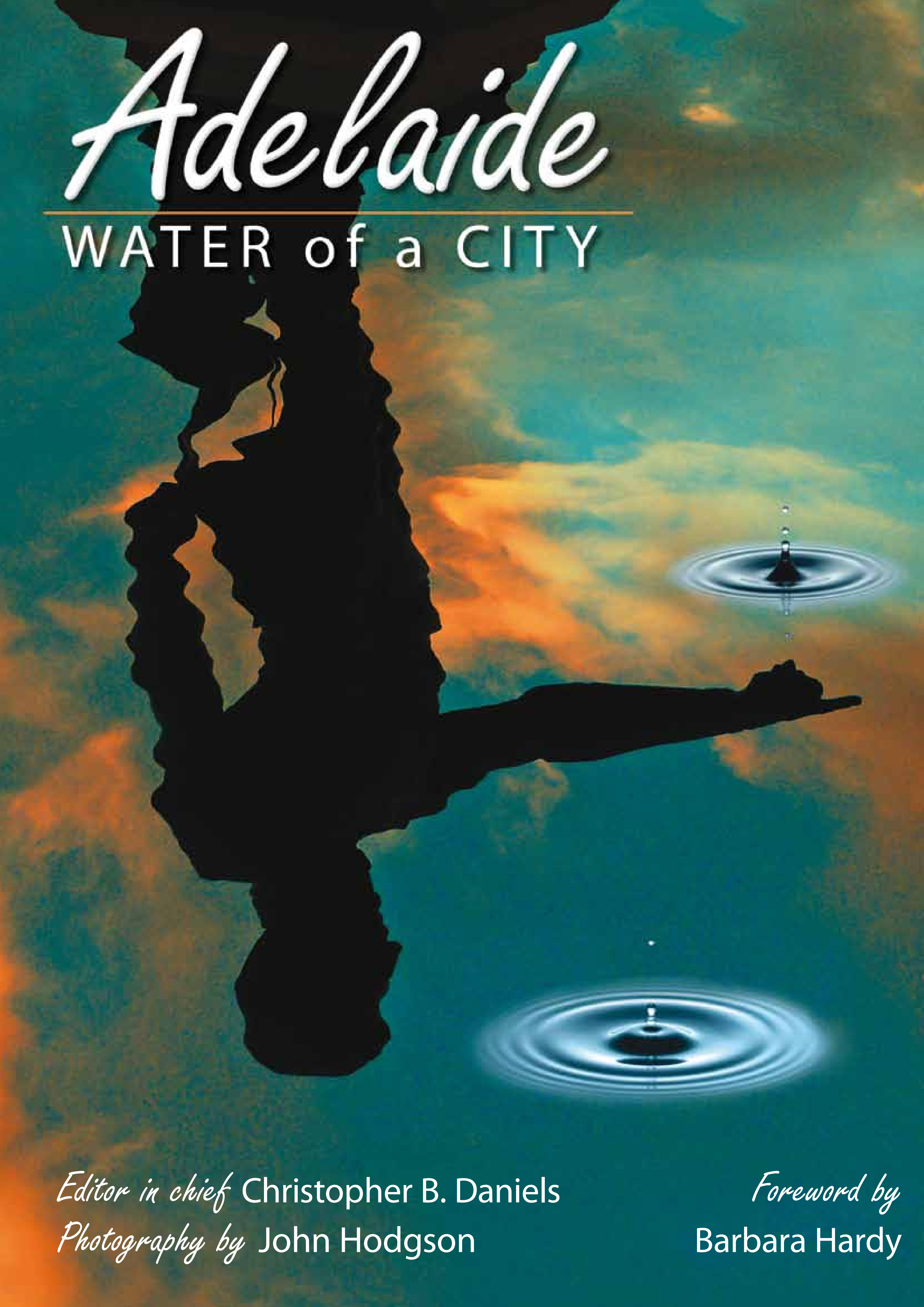

Adelaide

WATER of a CITY

Editor in chief Christopher B. Daniels

Photography by John Hodgson

Foreword by Barbara Hardy

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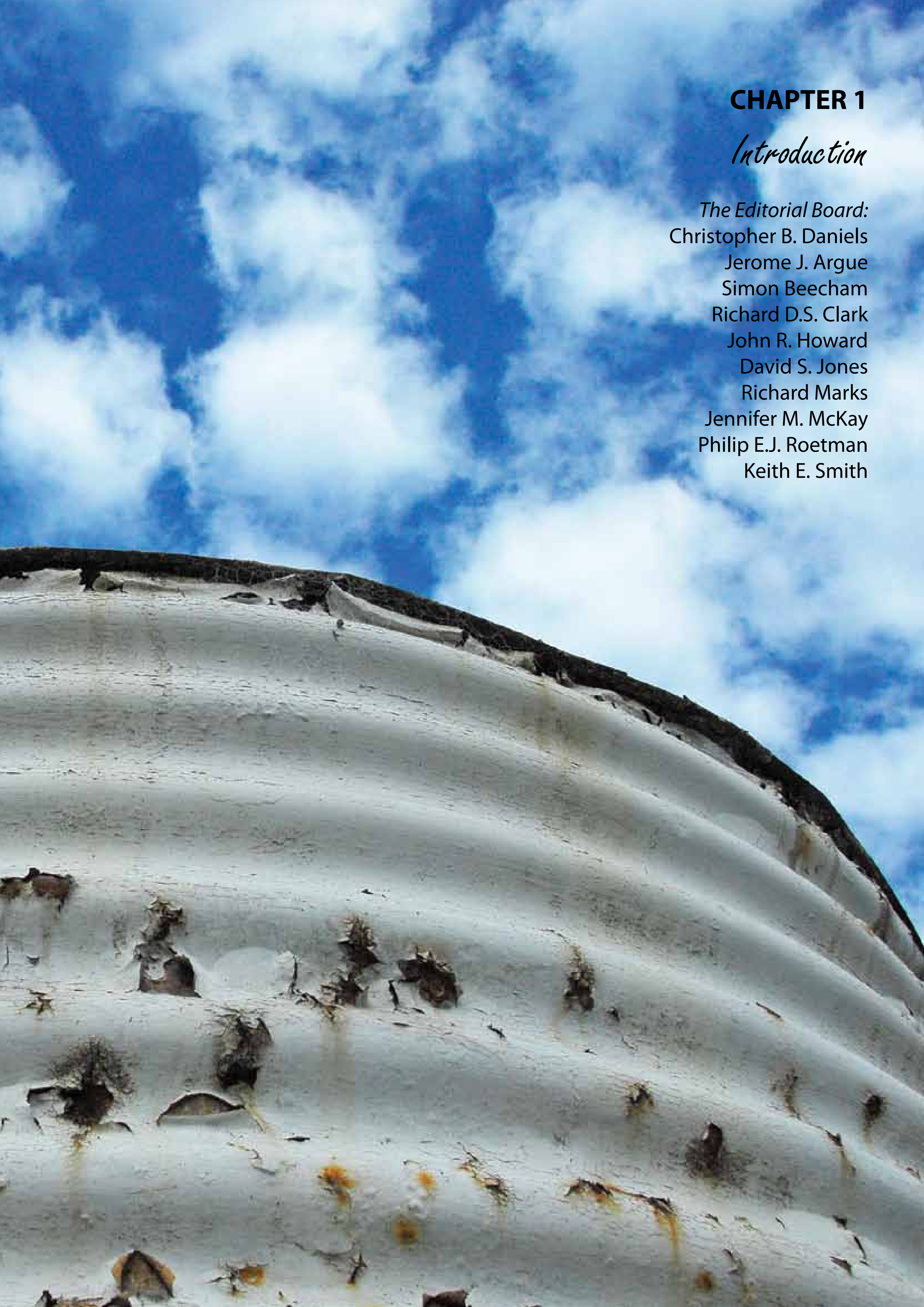

CHAPTER 1

Introduction

The Editorial Board:
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Simon Beecham
Richard D.S. Clark
John R. Howard
David S. Jones
Richard Marks
Jennifer M. McKay
Philip E.J. Roetman
Keith E. Smith

The Editorial Board

Christopher B. Daniels, Jerome J. Argue, Simon Beecham, Richard D.S. Clark, John R. Howard, David S. Jones, Richard Marks, Jennifer M. McKay, Philip E.J. Roetman and Keith E. Smith

It is raining outside today. It is late November and we are getting one of those infrequent but heavy showers that define spring in Adelaide. Unfortunately, the rain today is not enough. As with the last few years, our winter rains were less than average and we face a long, hot summer and the prospect of a longer, drier autumn. While Adelaide is in a dry year, and has been for the last few years, we are by no means alone as the drought extends over the eastern states of Australia. And that is our problem.

Adelaide, and in fact the state of South Australia, relies heavily on the Murray River system for its water. On average, 52% of all the water used in the state comes from the Murray; Adelaide receives on average 42% of its water from the Murray but our intake can be as high as 90% in drought years (see tables 1.1 and 1.2). The devastating drought in eastern Australia has massively decreased flows in the Murray-Darling System and revealed how reliant Adelaide has become on this source of water, and therefore how precariously we are perched, located as we are at the mouth of a drying system. Until recently, water has been an available and apparently easily renewable resource, but now, suddenly, the water shortage is the primary environmental issue in this era of significant changes in climate. Most climate change scenarios predict that annual temperatures for the Adelaide region will increase by 0.4–1.2°C by 2030 (with an increase in the number of hot days over 35°C and the annual number of hot spells over 35°C), with a reduction in annual rainfall of 1–10%, coupled with increases in extreme rainfall events. Potential impacts to riparian systems (medium impact), surfacewater resources (medium–high) and groundwater (medium–high) indicate that riparian systems have a limited capacity to adapt to these changes and are very vulnerable.[1, 2]

Despite the drought, however, floods will still be with us, even if occurring less frequently. Indeed, even in the midst of this general drought, we have experienced several flood events of unusual intensity. Even if things magically returned to 'normal' for a short time, the unpredictable recurrence of droughts and floods in southern Australia, and changes in the frequency and intensity of these events, should warn us that we need to continually revise our water plans to ensure they keep up with the changing climate, with the expectation of future change.

Yet, we should not be in this situation. Enough rain falls to suit the needs of the approximately 1.2 million people living in the Adelaide and Mount Lofty Ranges region. Further, as Clark and Argue demonstrate in chapter 21, our catchments could potentially support a population of 2 million people in Adelaide, as targeted by the state government, without requiring water from the River Murray. However, Planning SA's (renamed the Department of Planning and Local Government in October 2008) recent review for growth to 2036 – *Directions for creating a new plan for Greater Adelaide* (2008)[3] with its prediction of up to 537,000 new residents (potentially requiring 247,000 additional dwellings) – does not address water sustainability. Water sustainability is overridden in this document, which is driven by conventional theories for the planning of growth corridors to accommodate traditional forms of dwelling and their spatial locations. This plan compromises the inherent productive landscape, its natural resource qualities, water catchment and harvesting, and the scenic landscape imperatives of the peri-urban regions surrounding the Adelaide metropolitan area.

So how did we get ourselves into this mess, and how will we get out of it? This book describes the nature of the Adelaide Mount Lofty Catchment and its climate – to better understand the environment we inhabit. It takes multiple perspectives in viewing the range of issues of water management past and present. At the broadest level, this is a book about plans and planning for a 'brave new world', in which we, as individuals, communities and nations, will have embraced sustainability.

Table 1.1 Water use in an average year

Supplies		Uses	
Source	Amount supplied (GL)	Rural consumption (GL)	Adelaide consumption (GL)
River Murray	88	8	80
Adelaide Hills catchments	137	16	121
Rural groundwater	53	53	0
Metro groundwater	9	0	9
Metro rainwater tanks	1	0	1
Stormwater, recycled water	22	17	5
Total	**310**	**94**	**216**

Table 1.1 Sources of water and amount consumed (in GL) by the city of Adelaide compared to rural consumption during a year with average rainfall. Source: adapted from Government of South Australia, 'Water proofing Adelaide: a thirst for change 2005–2025', 2005.

Table 1.2 Water use in a dry year

Supplies		Uses	
Source	Amount supplied (GL)	Rural consumption (GL)	Adelaide consumption (GL)
River Murray	179	8	171
Adelaide Hills catchments	43	13	30
Rural groundwater	72	72	0
Metro groundwater	9	0	9
Metro rainwater tanks	1	0	1
Stormwater, recycled water	22	17	5
Total	**326**	**110**	**216**

Table 1.2 Sources of water and amount consumed (in GL) by the city of Adelaide compared to rural consumption during a year with below average rainfall. Source: adapted from Government of South Australia, 'Water proofing Adelaide', 2005.

At the local level, this book concentrates on water plans and planning for Adelaide, and therefore only addresses this one aspect of sustainability, albeit an important and vital component. The specific challenge of the Editorial Board was to reach a consensus definition of 'sustainability', as far as water within the Adelaide area is concerned.

The most general definition of sustainability is a system that:

> *Meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland 1987).*[4]

After much discussion, the board determined that the best identification of a sustainable system (that applied to urban water), can be gained by first reviewing the desired outcomes for that system. These outcomes could then be analysed to determine whether they suggest a preferred management model. Listing the desired outcomes is relatively simple and non-controversial, using the general principle of 'water sustainability'.

Under future scenarios of most likely population growth, climate change, technological advances and social adaptations, the urban water system should continue to provide, or be readily adapted to provide, all of the following outcomes into the foreseeable future:

1. A reliable, affordable, equitable and healthy supply of water that supports the social and physical environment.
2. Efficient management of excess water and wastewater to avoid disease, inconvenience and harm to people, biota, and the built environment.
3. Minimisation of damages from floods (or sea storms) up to a risk level acceptable to the community, whilst also building into the system the ability to survive more infrequent but 'catastrophic' storm events.
4. Avoidance of damage to ecosystems caused by the excessive diversion of water from them, or to them, by the amount or quality of the water.
5. Minimum contributions to greenhouse gases involved with the construction and operation of water supply and management systems.
6. Water and wastewater systems that provide a maximum net benefit and consider full lifecycle costs.
7. Management of water and wastewater systems that encourage innovative responses to local conditions.
8. A community that embraces and contributes to water management in practice and in decision-making.
9. Sufficient access to water for recreation, amenity and aesthetic satisfaction.
10. Learning from our historical mistakes and policies to provide a more secure and sustainable urban habitat.

The first issue the board faced was to determine water usage. Calculating a city's water usage is very difficult because water usage and the fractional extractions from different sources can vary greatly from year to year. Adelaide's usage varies between wet, dry or average years. Moreover, the extent to which agriculture and industry are included, and where the boundaries for the city lie, influences the numbers. Throughout this book, different authors will use different numbers to support their various arguments, as they present specific discussions on specific situations. We have adopted the numbers presented in the 'Water Proofing Adelaide' (2005)[5] document (tables 1.1 and 1.2). We also use the SA Water figures[6] for water usage by different components of our community, and home usage from Planning SA's 'Directions for creating a new plan for Greater Adelaide' (2008)[3], which notes that present residential water use comprises gardens (40%), bath (20%), laundry (16%), kitchen (11%), toilet (11%), and other domestic use (2%), and that average water consumption tends to remain the same as housing density increases from 10 to 14 dwellings per hectare.

Secondly, what is Adelaide? In terms of its water and for the purposes of this study, Adelaide is defined as the region delineated by the urban growth boundary (although 'Directions for creating a new plan' allows for significant

BOX 1

The watercycle

Earth is often called the 'blue planet'. Indeed, viewed from space, earth is primarily blue – of water in oceans and lakes which cover around 71% of its surface. Water is also evident as white clouds in the atmosphere and as the solid ice and snow that cover the poles and mountaintops of the planet. Earth is a wet planet and the volume of water is virtually constant at an estimated 1.4 billion km^3. However, this water is not distributed evenly, nor is its distribution static. The movement of water around the planet is driven mostly by solar energy, known as the 'watercycle' (or the hydrologic cycle).

Water returns to the earth's surface as precipitation when clouds cool or become saturated. There are numerous forms of precipitation, including snowfall and rainfall. In cold locations, with regular snowfalls, icecaps and glaciers can form, which can store around 1.8% of the water on earth (about 69% of the global freshwater resource). Around Adelaide, snowfall occurs only occasionally in the upper parts of the Mount Lofty Ranges. More commonly, cloud is transported from the west and rainfall occurs as it lifts to pass the ranges ('orographic lift'). This water has often been transported from either the Southern or Indian Ocean.

Water is stored and moves through the oceans, the atmosphere, over land and underground. Around 97% of the water on earth is held within the saline seas and oceans The heating of these waterbodies by the sun causes evaporation, where water is vaporised and moves into the atmosphere.

When it rains, the water either infiltrates into the ground or flows as surface runoff. Infiltration replenishes groundwater aquifers. Globally, these bodies hold 1–2% of the planet's total volume of water. Much of this water is saline, but the freshwater fraction accounts for around 30% of the global freshwater resource. Water can percolate deep underground and be stored for many thousands of years. However, shallow groundwater flows interact with surfacewaters, and discharge into streams and rivers, lakes and oceans, and as natural springs.

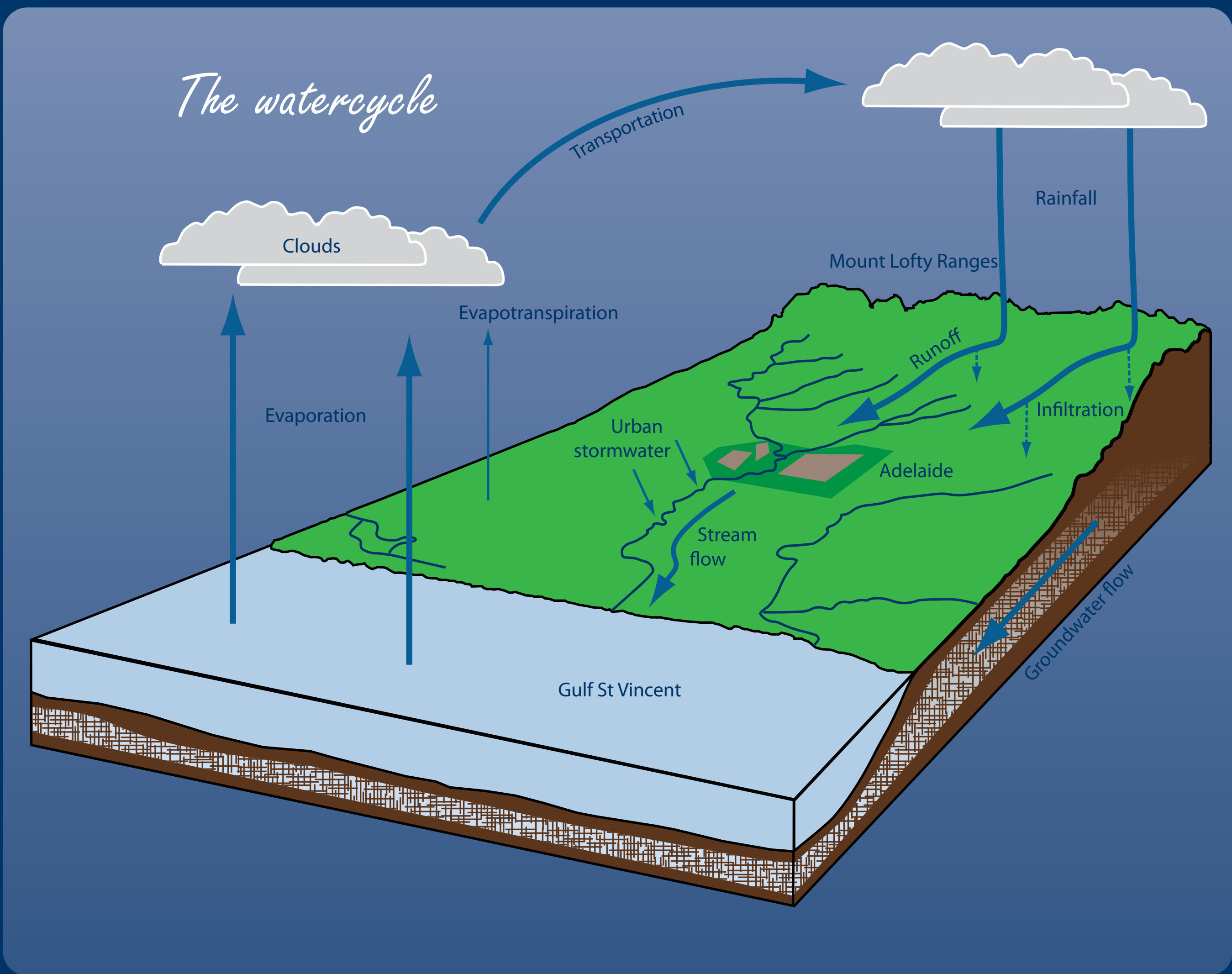
Additionally, around 10% of atmospheric water vapour is gained through evapotranspiration over land – a combination of the evaporation of water from the soil and the transpiration of water from plants In cooler climates, a comparatively small volume of atmospheric water vapour is also gained directly from ice and snow through subtion (a change of state that excludes the liquid phase). Water held in the atmosphere accounts for around 0.001% of the water on earth. As this water vapour cools, it condenses and forms clouds. Water vapour and clouds are transported through the atmosphere by wind.

Surface runoff flows into waterways such as streams and rivers, and wetlands such as lakes, marshes and swamps. This surface water accounts for only 0.02% of the water on earth, and less than 1% of the freshwater. In places with cool climates, streamflow is often fed by melting ice and snow during the warmer months of the year. Adelaide's reservoirs are replenished by native streamflows through the Mount Lofty Ranges (with additional waters pumped from the River Murray). Most of the streamflow on the Adelaide

Plains, including urban stormwater, is discharged into Gulf St Vincent.

The discharge of water into the gulf continues the cycling of water around the planet; however, it is not indicative of how water cycled through the Adelaide region prior to European settlement when the River Torrens drained into a marsh area before being deposited into the coastal dunes known as the Reedbeds. Water from the Reedbeds would have evaporated, seeped through the dunes to the gulf or into subterranean aquifers, or, at times, floodwaters would be discharged to the gulf via waterways to the north and south. We cannot re-establish the Reedbeds, but, with new aquifer management and water sensitive urban design practices we can mimic the groundwater recharge and reuse the freshwater rather than let it flow out to sea. For, although we live on the blue planet, readily available supplies of freshwater are limited, and we are remiss to waste them.

Philip Roetman



growth outside this boundary). Metropolitan/urban Adelaide therefore extends from the Gawler River in the north to Sellicks Beach in the south, bordered to the east by the Hills Face Zone of the Mount Lofty Ranges and to the west by Gulf St Vincent (Figure 1.1). As most of its catchments lie on or just outside this boundary, and those catchments also serve significant agricultural areas in the Mount Lofty Ranges, the Mount Lofty Ranges Catchment regions are included in the organisational discussions where appropriate. Figure 1.1 provides all the major water-related structures in the region covered by this book.

Using the criteria described on p. 36, we concluded, as a 'rule of thumb', that the Adelaide metropolitan area consumes just over 200 GL of water a year. The adjacent Mount Lofty Ranges agricultural area consumes another 100 GL (tables 1.1 and 1.2). In an average year, Adelaide uses about 80 GL of Murray River water, increasing to approximately 171 GL in drought years. If the dire situation arises where we can no long rely on water from the Murray, we must either find this water from elsewhere or cut our usage accordingly. We must also manage our water according to the principles of sustainable water systems outlined above. This is a tough ask but not an insurmountable one.

The aim of this book is to examine in detail the watercycle of Adelaide from a wide variety of perspectives. The definition of 'use' includes the sharing of the water with the supporting environments. In coming to grips with sustainability, it will become apparent through this book that it is the design of the city itself that is the main focus. In a nutshell, our core water challenge becomes our ability to progressively change our city to become more water sensitive, particularly as the city grows and the climate changes in response to past unsustainable practices.

The first chapters (in Part One) describe the geo- and biophysical environment of Adelaide. Part Two identifies the relationships between the form of the city and the movement of water into, through, and out of it, examining the development of water supply, sewerage and drainage systems. The manner and extent to which the present systems fail to meet many of the criteria listed on p. 37 (particularly the damage to ecosystems) will become apparent, as will the changes that will be required for systems to meet all the listed criteria in a comprehensive and integrated manner. To understand the complex relationships between the history, engineering, social, aesthetic, structural, economic, environmental, commercial, and political requirements for water, the Editorial Board asked the authors to take a personal approach. Therefore, in Part Two, the flow of information is not linear in that one chapter does not logically lead to the next; rather, when reading this section, imagine yourself in the centre of a circle with the chapter authors arranged around you. You listen to one, then move to the next. Each chapter is independent, each tells you its view. No chapter is worth more than another, and each is equally valid.

Please note that many places are mentioned in this book that have Aboriginal place names as well as names ascribed since European settlement. In some instances both names are included, but, in order to remain concise, in most cases authors have used only the post-settlement name. The Editorial Board recognises the need to celebrate and respect the knowledge, beliefs and heritage of both Indigenous and non-Indigenous inhabitants of our state. Our undertaking here is to include a representative view of the water systems in the area around the City of Adelaide; this book provides a detailed discussion of Kaurna place names and heritage values related to water in chapter 6.

Our aim is to provide the broad community with the information required to understand the issues around water in Adelaide. This book is not a policy document, but will inform policy makers by providing the information required to manage our water sustainably, now and into the future.

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Box 2: The four colours of freshwater

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BOX 5

Adelaide's water supply timeline

1836 • European settlement of South Australia.

1839 • River Torrens is the principal source of water for Adelaide, used for watering stock, bathing, disposing of rubbish and sewerage.
• Dysentery epidemic grips Adelaide – five children die in one day.

1848 • 36 water-carters operate in the city of Adelaide, earning an average of £3 per week.

1850 • Adelaide's population reaches 11,000; residents pay £8484 annually for impure water supplied by water-carters.

1856 • The Waterworks and Drainage Commission appointed.

1857 • Work commences on Thorndon Park Reservoir.

1860 • Adelaide receives its first supply of reticulated water when the valve house at Kent Town is turned on.

1862 • Thorndon Park Reservoir commissioned.

1869 • Work commences on Hope Valley Reservoir.

1872 • Hope Valley Reservoir commissioned.

1878 • establishment of Hydraulic Engineer's Department.

1881 • Deep Drainage System commissioned – Adelaide is the first city in Australia to enjoy the benefits of a water-borne sewerage system.

1883 • North Adelaide is connected to the sewerage system.

1888 • Hindmarsh, Thebarton and St Peters are connected to the sewerage system and the work of connecting Kensington and Norwood is well underway.

1892 • Work commences on Happy Valley Reservoir.

1897 • Happy Valley Reservoir commissioned.

1899 • Work commences on the Barossa Reservoir.

1902 • Barossa Reservoir commissioned.

1903 • Work commences on sewers for Glenelg.

1907 • Glenelg treatment plant commissioned.

1910 • Work commences on sewers for Port Adelaide.

1914 • Work commences on Millbrook Reservoir.
• Work commences on Warren Reservoir.

1914 to 1915 • Severe drought hits South Australia – the Murray River is reduced to a series of waterholes. River Murray Commission decides to regulate the river flow through construction of a series of locks, weirs and barrages.

1918 • Millbrook Reservoir commissioned.

1919 • Spanish influenza epidemic sweeps Australia. In the first half of 1919 normal life comes to a standstill. Desperate governments try to stem the spread of the disease and 12,000 Australian lives are lost.

1920 • Work commences on the construction of locks and weirs along the River Murray.

1929 • Engineering and Water Supply Department (E&WS) established.
• Sewerage Act empowers E&WS to construct and operate sewerage systems.
• A committee forms in South Australia to discuss bacteriological examinations of various water supplies.

1930 • Construction on locks and weirs along the Murray River completed.
• Adelaide's population reaches 315,000.

1931 • River Murray Commission recommends that barrages be built on the channels leading from Lake Alexandrina to the Murray Mouth at the Coorong.
• Government appoints an Advisory Committee on Water Supplies Examination to guide departmental actions on improving the protection of catchments and quality of water supplied to the public. The committee operates for two decades.

1932 • Waterworks Act introduced.
Work commences on Mount Bold Reservoir.

1933 • Glenelg sewerage treatment works commissioned.
• State Water Laboratory established by the E&WS.

1935 • Port Adelaide treatment plant commissioned.
• Work commences on the construction of barrages.

1938 • Mount Bold Reservoir commissioned.
• Most of Adelaide's suburbs are sewered.

1940 • Barrages on the River Murray completed.

1947 • 1000 miles of sewer have been laid in the metropolitan area – double the sewerage of 20 years previously.

1949 • Work commences on South Para Reservoir.
• Work begins on the construction of the Mannum–Adelaide Pipeline.

1950s • Chlorination stations installed at all metropolitan reservoirs.

1955 • Mannum–Adelaide Pipeline commissioned.

1956 • Work begins on the duplication of the Glenelg sewerage treatment works.
• Salisbury sewerage treatment works – constructed by the E&WS Department during World War II – is acquired from the Commonwealth.

1958 • South Para Reservoir commissioned.

1961 • Work commences on Bolivar treatment works. Caters for the sewerage and trade wastes of a population of 600,000. Can be expanded if necessary.

1962 • Doubling the size of the Glenelg sewerage works completed.

• Myponga Reservoir commissioned.

1965 • Partial operation of Bolivar treatment works begins with the diversion of sewage from Salisbury and Elizabeth. Additional stage of the scheme also underway.

• Adelaide is nearly 100% sewered; no other Australian city has more than 75% of its population served by sewerage.

1966 • Bolivar treatment works officially opened.

• Work commences on Kangaroo Creek Reservoir.

1968 • Work begins on the construction of the Murray Bridge–Onkaparinga Pipeline.

• The government announces its decision to fluoridate South Australia's water supplies.

1971 • Kangaroo Creek Reservoir commissioned. Fluoridation of metropolitan Adelaide water

1969 • supplies begins.

1973 • Murray Bridge–Onkaparinga Pipeline commissioned.

1974 • Work commences on the Hope Valley water treatment plant (WTP).

• Work commences on Little Para Reservoir.

1976 • Innovative Water Resources Act enacted. The Act enables water resources to be conserved, developed and managed for the benefit of the people of South Australia.

1977 • Hope Valley WTP commissioned.

• Work on Little Para Reservoir completed.

1978 • Six point River Murray Salinity Control Program is adopted. The main elements completed by 1984.

1979 • Little Para Reservoir commissioned.

1980 • Anstey Hill WTP commissioned.

1982 • Barossa WTP commissioned.

1984 • Little Para WTP commissioned.

1989 • Stage 1 Happy Valley WTP completed.

1991 • Happy Valley WTP commissioned.

1993 • Myponga WTP commissioned.

1995 • E&WS becomes SA Water.

1994 • First Council of Australian Governments (CoAG) reforms. Market will allocate water to improve efficiency: consumption based on 2-part tariffs (urban 1998, rural 2001); full cost recovery; separate identification and funding of community service obligations; trading in rural water entitlements; allocation of water for the environment; broader social values embraced.

• State Water Laboratory and the Australian Centre for Water Quality Research are combined. Renamed the Australian Water Quality Centre to recognise the significant expertise in water quality and treatment research at the Bolivar facilities.

1997 • *South Australia Water Resources Act* s 61 Catchment Management Boards Section 61 provides that a board must create a catchment management plan to manage the water resources of a region and ecosystems dependent in close cooperation with the community, local government and state and federal government the State Water Plan 2000 addresses statewide resource issues and all regional plans must be consistent with it.

1999 • Virginia Pipeline Scheme commissioned. The first and largest reclaimed water scheme of its type in Australia.

2000 • CoAG governments has also imposed a regional model for the delivery of NAP and NHT funding of environmental activities. The principle driver for regional delivery was to 'harness the capacity of those closest to the problem on the ground, building on local knowledge, experience and expertise, and enabling flexible and responsive solutions to local NRM challenges'.

• There are 56 NRM regions in Australia and these have been agreed by state and Commonwealth.

• *South Australia Natural Resource Management Act 2004* creates 11 NRM regional bodies with wider remit than Catchment Management Boards.

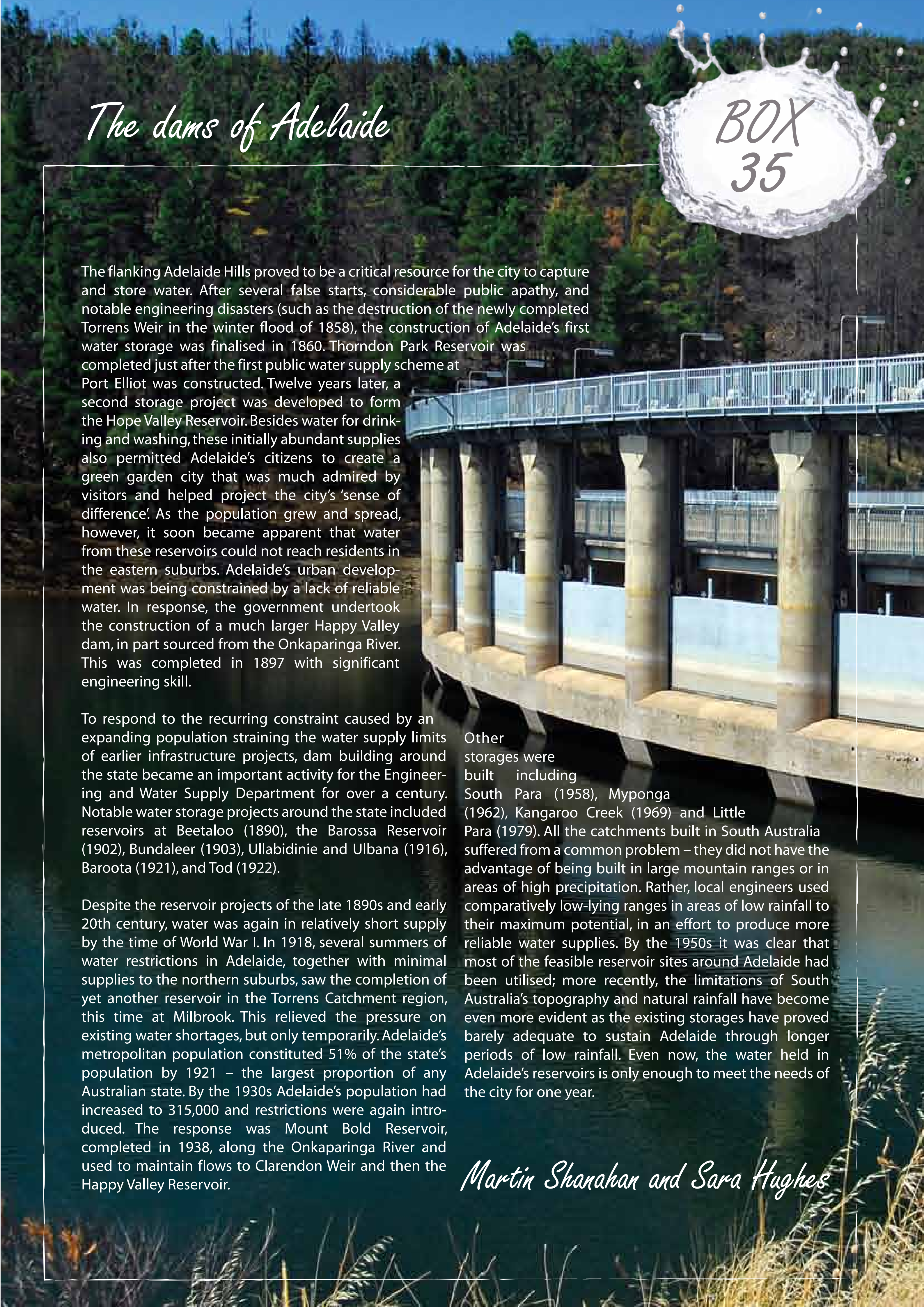
2003 • Permanent water conservation measures introduced in Adelaide.

2005 • Mawson Lakes Recycled Water Scheme launched.

• Water Proofing Adelaide strategy published.

[1] The role of regional bodies as per the Commonwealth is expressed as 'undertaking regional natural resource management planning, prioritising regional level investments, co-coordinating actions at the land-scape scale, getting community ownership in decision making and reporting on progress.'

Thorsten Mosisch



The dams of Adelaide

BOX 35

The flanking Adelaide Hills proved to be a critical resource for the city to capture and store water. After several false starts, considerable public apathy, and notable engineering disasters (such as the destruction of the newly completed Torrens Weir in the winter flood of 1858), the construction of Adelaide's first water storage was finalised in 1860. Thorndon Park Reservoir was completed just after the first public water supply scheme at Port Elliot was constructed. Twelve years later, a second storage project was developed to form the Hope Valley Reservoir. Besides water for drinking and washing, these initially abundant supplies also permitted Adelaide's citizens to create a green garden city that was much admired by visitors and helped project the city's 'sense of difference'. As the population grew and spread, however, it soon became apparent that water from these reservoirs could not reach residents in the eastern suburbs. Adelaide's urban development was being constrained by a lack of reliable water. In response, the government undertook the construction of a much larger Happy Valley dam, in part sourced from the Onkaparinga River. This was completed in 1897 with significant engineering skill.

To respond to the recurring constraint caused by an expanding population straining the water supply limits of earlier infrastructure projects, dam building around the state became an important activity for the Engineering and Water Supply Department for over a century. Notable water storage projects around the state included reservoirs at Beetaloo (1890), the Barossa Reservoir (1902), Bundaleer (1903), Ullabidinie and Ulbana (1916), Baroota (1921), and Tod (1922).

Despite the reservoir projects of the late 1890s and early 20th century, water was again in relatively short supply by the time of World War I. In 1918, several summers of water restrictions in Adelaide, together with minimal supplies to the northern suburbs, saw the completion of yet another reservoir in the Torrens Catchment region, this time at Milbrook. This relieved the pressure on existing water shortages, but only temporarily. Adelaide's metropolitan population constituted 51% of the state's population by 1921 – the largest proportion of any Australian state. By the 1930s Adelaide's population had increased to 315,000 and restrictions were again introduced. The response was Mount Bold Reservoir, completed in 1938, along the Onkaparinga River and used to maintain flows to Clarendon Weir and then the Happy Valley Reservoir.

Other storages were built including South Para (1958), Myponga (1962), Kangaroo Creek (1969) and Little Para (1979). All the catchments built in South Australia suffered from a common problem – they did not have the advantage of being built in large mountain ranges or in areas of high precipitation. Rather, local engineers used comparatively low-lying ranges in areas of low rainfall to their maximum potential, in an effort to produce more reliable water supplies. By the 1950s it was clear that most of the feasible reservoir sites around Adelaide had been utilised; more recently, the limitations of South Australia's topography and natural rainfall have become even more evident as the existing storages have proved barely adequate to sustain Adelaide through longer periods of low rainfall. Even now, the water held in Adelaide's reservoirs is only enough to meet the needs of the city for one year.

Martin Shanahan and Sara Hughes

What climate change means for Adelaide

BOX 55

The term 'global warming' says it all – a heating of the atmosphere right across the world. But that does not mean that the warming, or its impacts, will be the same everywhere. Regional and local differences can cause things to be worse, or better, depending on where you are.

One example of this unevenness is in the Arctic. Snow and ice melt over progressively larger areas and for longer periods as the temperature rises, causing the earth's surface to be duller. Bare rock, soil, vegetation and the open ocean are all much darker than bright ice, and so, just like the dark panels on solar hotwater systems, they absorb substantially more sunlight. This leads to greater heating, more melting, and so on – just one example of an amplifying feedback that can make global warming worse that it would otherwise be. There are many other such feedbacks, some of which remain poorly understood and could lead to more severe and more rapid warming than expected.

Perhaps the biggest regional impact of climate change that Adelaide faces is a shift in equatorial weather systems. Global warming causes the overturning tropical air masses that circulate in giant loops (called Hadley Cells and the Walker Circulation) to expand north and south. This has been recently shown to have happened already – up to 2° of latitudinal expansion over the last 30 years. Atmospheric heating also causes polar winds to whip around the Southern Ocean more rapidly. Together, these effects of global warming act to push rain-bearing mid-westerly weather systems further north and south. So, instead of being doused in rainfall brought in from the Indian and Southern oceans, progressively more of this rain will be dumped uselessly over the sea, below the Australian continental margin. This means less rainfall for Adelaide and South Australia's agricultural areas, as well as the south-west of Western Australia and other mid-latitude regions such as South Africa, southern Europe, Mexico and the western United States.

With less rain, the vegetation and soils around Adelaide and the Mount Lofty Ranges will dry. In combination with higher temperatures, the risk of bushfires intensifies. Heatwaves are the most dangerous culprits in this relationship. The 15 day March 2008 heatwave in Adelaide was, on the basis of the 20th-century temperature record, a staggering 1 in 3000 year event. Yet under a mid-range projection of global warming (should no action be taken to quickly curtail carbon emissions), such an event would be an expected part of an average summer. Such heatwaves, and regular intensive fires, also cause great stress to most species, leading to higher mortality, failed reproduction and reduced body condition. These synergies – between water availability, hotter temperatures and changed fire regimes – are some of the primary reasons why unrestrained climate change is anticipated to lead to the extinction of an appallingly large fraction of our biodiversity.

Sea level rise is a more universal threat. When salty sea-water mixes with fresh groundwater, the result is diluted seawater. A once useable water resource becomes worthless, with obvious impacts on coastal drinking and irrigation water supplies, as well as ecosystems that tap into aquifers. Severe storm surge events occasionally result in this exchange, but if these events are rare and do not encroach too far up the shoreline the impacts are generally minor and localised. But what if the frequency of flooding events from the sea were to increase dramatically, and do so across the entire coastline of South Australia? That ominous threat is just what is anticipated due to climate change, and should therefore be a major concern to coastal planners and beachside residents alike.

There is clear evidence that sea levels have risen over the past century. Long-term records from a globally distributed network of reference tidal gauges show that sea levels rose about 20 cm from 1870 to 2004, correlating with a globally averaged rise in temperature of about 0.8°C. Since 1992, a satellite monitoring system has made regular and precise measurements of sea level, and shows an accelerating rise over the last decade. If the Greenland and West Antarctic ice sheets hold together, the most recent estimates suggest another 50 to 140 cm of sea level rise this century. A worst-case scenario, now being predicted by some eminent scientists, is 3 to 5 m by 2100, should the polar melt accelerate. Yet 50 cm would be enough to make a 1 in 100 year storm surge event a yearly occurrence.

The need for action is urgent and our window of opportunity for avoiding severe impacts is rapidly closing. Yet the obstacles to change are not technical or economic, they are political and social.

Barry Brook

Cyanobacterial blooms

BOX 80

Over-use of super-phosphate based fertilisers, land clearing, runoff from roads, drains, urbanisation, and the loss of aquatic species' diversity has caused significant problems for water management in the City of Adelaide. Cyanobacterial blooms are a common occurrence during the warmer months, most visibly in the River Torrens in the heart of the city. The main contributing species are *Microcystis*, *Nodularia* and *Anabaena*, which produce the toxins microcystin, nodularin and saxitoxin respectively. In recent history, dense cyanobacterial blooms have produced toxin concentrations high enough to kill domestic animals and wildlife and pose significant health risks to human consumers. Potential health problems include hepatoenteritis, liver damage, tumor growth, gastroenteritis, hepatitis, renal malfunctioning and hemorrhaging. However, examples of these health problems occurring are uncommon due to management through monitoring programs and restrictions on the usage of affected waters for domestic and municipal purposes.

Adelaide's water supply comes from the Mount Bold and Happy Valley reservoirs (supplying the southern and central regions of the city up to Grand Junction Road), and the Murray River Pipeline, and the South Para, Kangaroo Creek and Warren reservoirs (supplying the north of the city).

Treatment with algicides, such as copper sulphate, is the most common method for killing blooms in the reservoirs supporting Adelaide's water supply. However, prevention of blooms can be approached in a number of ways.

External control measures include:

- protection of catchment areas by changing land usage and sewage treatment;
- reducing nutrient inflows to river water; and
- nutrient retention using wetlands and pre-dams.

Internal control measures include:

- mechanical mixing;
- artificial aeration;
- selective water withdrawal; and
- nutrient precipitation and sediment dredging.

Biological manipulations suitable for Adelaide in the future include:

- promotion of growth/harvesting of water plants; and
- promotion of algal grazing by herbivorous zooplankton through changes in fish community structure (biomanipulation).

These principles must be approached under the auspices of ecologically sustainable development to produce a suitable result. This requires consideration of all aquatic and associated terrestrial biota, water quality, commerce, and public amenity. Water quality managers are working to adhere to these principles to reverse some of the effects of agriculture, urbanisation and industrialisation.

Michael Sierp and Jian Qin

Porous and permeable paving

BOX 103

Paved, impervious surfaces have a significant impact on the water cycle by not allowing rainfall to soak through to the subsoil. Consequently, the volume and velocity of stormwater discharge is increased. This paving can be used to address these issues by allowing rainfall to soak through the pavement. Water is filtered by a coarse sub-base and may be allowed to infiltrate the underlying soil or be stored for later reuse. These systems also reduce the pavement's heat absorption and the reflection of heat into the surrounding atmosphere. Porous and permeable pavements can take numerous forms:

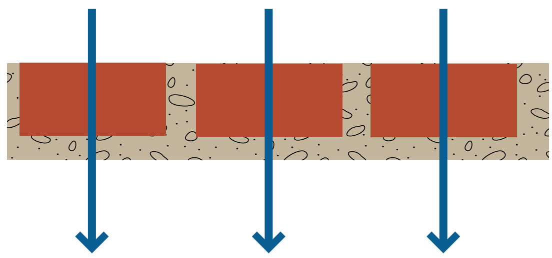
- porous asphalt or concrete (with no fines);
- concrete and clay modular pavers, installed with gaps between pavers;
- grid or lattice systems of concrete or plastic filled with soil or gravel (these systems may be vegetated); or
- gravel surfaces.

Porous and permeable pavements can be used for water reuse or storage. By introducing an impermeable membrane to the bottom and sides of the sub-base, a tank effect is created. This water can be gradually released or accessed for treatment and recycling.

Permeable paving is not suitable for use on land that slopes greater than 10% or 5 degrees, as water runoff may exceed infiltration and cause erosion. Additionally, it should not be used where there is a very high watertable, where there is a soil salinity hazard, where heavy clay soils are likely to collapse, or where the soil has a hydraulic conductivity of less than 0.36 mm/hour (unless using for a tanking storage system).

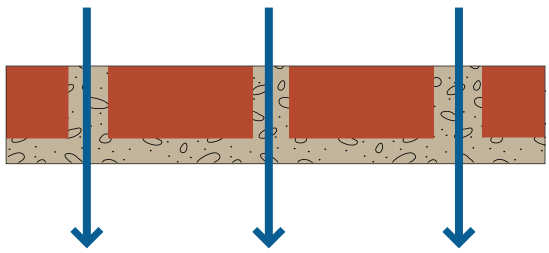
Porous and permeable pavements are well suited to public areas, including footpaths, carparks and plazas. In some instances, trafficable street surfaces are also suitable, particularly where there are low traffic volumes. Street parking lanes can use permeable paving and street trees will benefit from infiltrated water. Residential driveways are also suitable, and some of these systems can be visually softened with low vegetation growing within the pavement.

Porous



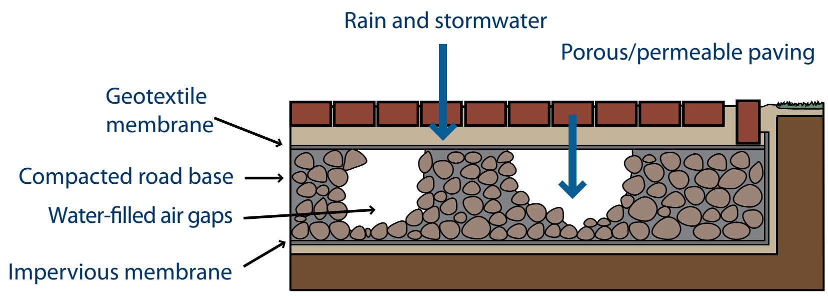
Water passes through pavers

Permeable



Water passes between pavers

Porous/permeable paving



Graeme Hopkins and Christine Goodwin

Breakout Creek Wetlands

BOX 118

Breakout Creek forms the last few kilometres of the River Torrens before it meets the sea. Prior to the development of Adelaide, the river terminated in a series of coastal wetlands and swamps associated with the coastline and dune system. During early settlement the area was cleared and drained for agriculture and flooding became a major problem. The existing channel, with high levee banks to provide flood protection, was constructed in 1937.

In 1996 the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLRNRM) Board identified Breakout Creek as a potential site for riparian and water quality improvement works. A concept plan, which involved works for the complete length of Breakout Creek from Henley Beach Road to the River Torrens outlet, was released for community comment in April 1997. In May 1998 the board approved a shorter 'demonstration project' as a precursor to the full-scale project.

The first stage of the Breakout Creek Wetlands project, a 500 m stretch of the River Torrens upstream of Henley Beach Road at Lockleys, was completed by the board in 1999. This demonstration site involved the widening of the existing waterway and deepening of sections to form wetlands with public access paths, viewing areas and riparian vegetation. During construction, the area was drained and a temporary weir was constructed upstream to prevent flows through the site.

The project was designed to recreate a viable ecosystem within the riparian zone, which could be be accessed and enjoyed by the local community. To ensure flood risks were managed, detailed computerised flood modelling was undertaken to simulate the behaviour of the wetland during a flood.

The first stage of the project has delivered many benefits for the environment and the community. Significant riparian improvements allow for increased use by the comunity, and a noticeable increase in the variety of native wildlife species has been reported.

Following the success of stage one of the project, the second stage of the wetland has been designed for a 700 m section between Henley Beach and Tapleys Hill roads. Before detailed planning commenced in 2005, the board commissioned a social impact assessment to ensure that proposed improvements were of the greatest possible benefit to the community, which involved a range of community consultation activities to identify, explore and document issues and ideas, in particular the impact of ceasing horse agistment in the area.

Stage two includes a number of habitat islands, reedbeds and deeper water pools, maximising opportunities for a variety of habitats to be formed in the river channel while maintaining flood protection.

Benefits of the project include:

- improved wetland and aquatic habitats in an urban environment;
- improved recreation opportunities for the local community;
- improved water treatment and quality, especially during low-flow periods;
- increased plantings of local native plants, including wetland species, following the removal of more than 30 weed species;
- improved public access to the site through the addition of viewing platforms and a network of paths within the wetland;
- improved native fish migration along the Torrens; and
- improved flood management.

Keith Smith

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