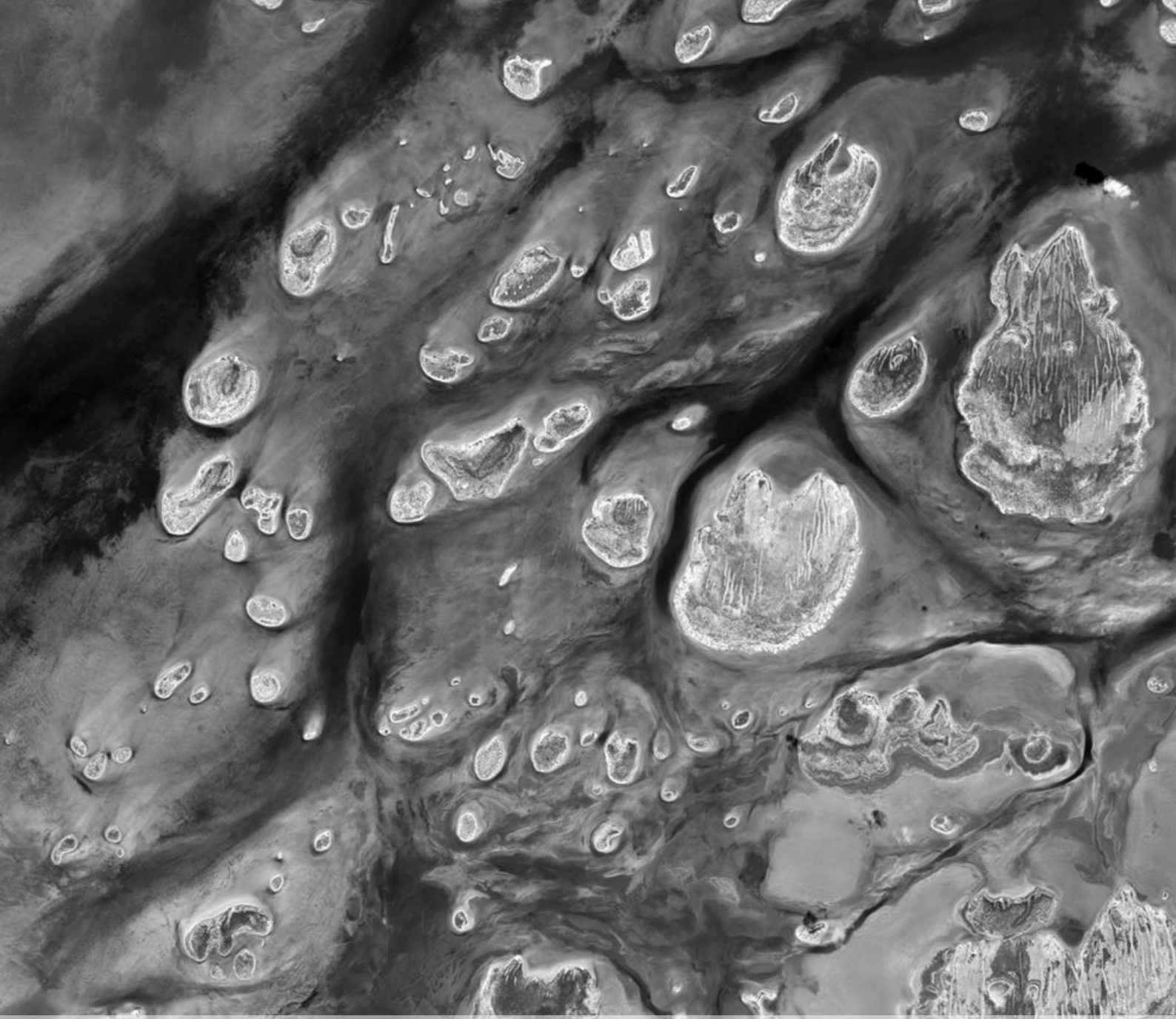

Australian freshwater study

Issues paper | **Water and Society** | Final | May 2019

The Ian Potter Foundation

THE MYER FOUNDATION

Point. Advisory

alluvium

Outline

This paper provides an overview of (non-indigenous) issues related to water in Australian society. The paper is one of six papers produced for the Ian Potter and Myer Foundations' Australian Freshwater Study.

About the Fresh Water Mapping Study

The Ian Potter Foundation and The Myer Foundation have funded a study of major issues affecting Australia's freshwater systems. The Foundations want to better understand the ways philanthropic investment might catalyse changes to the management of Australia's freshwater resources that will protect their ecological integrity, make access to them more equitable, and ensure Australia's long-term water security.

The consulting firms Point Advisory and Alluvium have been commissioned to undertake the study and have prepared a set of short issues papers covering water governance, economics, freshwater ecosystems, First Peoples' water rights, and social values. The issues papers are the first step in the project. They provide a "long list" of major issues facing the management of fresh water in Australia as well as a general indication of options for philanthropic intervention. In parallel, Point Advisory and Alluvium are working on identifying more detailed options for philanthropy to intervene to catalyse change. Both work streams will be consolidated into a final report that matches issues with options and recommends a short list of specific future interventions to the Foundations for more detailed review.

Acknowledgements

Point Advisory and Alluvium would like to thank the Expert Panel Members for the project who gave time to be interviewed and provided references and introductions for this paper:

- Jack Archer, Regional Australia Institute
- Professor Robert Vertessy, Global Change Advisory and the University of Melbourne
- Dr Guy Fitzhardinge, farmer, Northern Australian Indigenous Land and Sea Management Alliance (NAILSMA), World Wildlife Fund (WWF)
- Professor Sue Jackson, Griffith University
- Dr Anne Jensen, Environmental Consultant and Healthy Rivers Ambassador MDB
- A/Professor Darla Hatton MacDonald, University of Tasmania

We would also like to thank the respondents to the public consultation process who provided feedback, which has contributed to the final paper. While we are very grateful for all of the assistance provided, responsibility for the final product and any errors rests entirely with Point Advisory and Alluvium.

Citation: Point Advisory and Alluvium Consulting (2019) *Australian Freshwater Study – Water and Society Issues Paper*, report prepared for The Ian Potter Foundation and The Myer Foundation, Melbourne

Image credit: NASA Earth Observatory image by Jesse Allen, "Australia's Ephemeral Lake Mackay". Taken September 19, 2010 using data from NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team. Accessed via <https://earthobservatory.nasa.gov/images/84984/australias-ephemeral-lake-mackay>

Acknowledgement of First Peoples and Country

We acknowledge Australia's First Peoples and pay respect to the past, present and future Elders of Australia's First Peoples' communities. We honour the deep spiritual, cultural and customary connections of Australia's First Peoples to their lands and waters.

Context

Water supply and effective water management is essential for a functional urban society. Australian society has generally benefited from high reliability of water supply and water quality standards arising from our historical management of water. However, not all Australians have access to a safe, convenient and affordable source of water for drinking and other essential needs. And where we do have safe and reliable water supplies, these are coming under pressure from an increasing population and a changing climate. (see also Economics Issues Paper)

Further, there is a developing recognition across Australian society that water not only plays an indispensable role in the functioning of our towns and cities', but also their broader *liveability*. Liveability is generally understood to encompass those elements of home, neighbourhood, and metropolitan area that contribute to safety, economic opportunities and welfare, health, convenience, mobility, and recreation [1]. The availability of water in our built landscapes is increasingly linked with many elements of liveability. We know that water makes it possible to sustain green spaces and water features that cool our cities and towns, a function that will be increasingly important in the face of rising temperatures resulting from climate change [2]. Water also makes it possible to sustain parks and water features that provide amenity and opportunities for recreation that also contribute to our capacity to build and strengthen social connections [3].

This paper considers five key issues related to the supply and management of water for society in Australia. The first two relate to water supply and management for basic human needs (drinking, washing, ablution). The third concerns the involvement of society in the management of water resources and waterways. The fourth considers water for liveability in Australia's cities and towns and the final issue relates to water for recreation and sport, including mental and physical well-being.

This paper provides a discussion on these issues, why they are important, and potential manner in which philanthropic organisations may be able to contribute to their resolution.

Key issues

1 Australian and global standards for potable water quality are not always met, particularly in remote areas

A supply of water that is safe to drink is necessary to sustain life. Whilst most Australians enjoy a high level of water security and drinking water quality, this requirement is not always met in rural and regional Australia.

Overall, the security of Australia's water resources is excellent, second only to New Zealand in the water security index for the Asia Pacific region [4]. Because Australia is a wealthy, advanced nation [5], it is easy to assume that all Australians have access to potable water that meets global and Australian water quality standards [6] [7]. However, this is not always the case. Until recently, there were boil alerts for 18 communities in Tasmania [8] [9] and a recent audit criticised the regulation of pollution in the NSW Warragamba Dam drinking water catchment, the biggest single metropolitan water reservoir in Australia [10]. There were 23 boil water advisory notices issued by the NSW Health Department for towns across NSW between 2016 and 2018 [9]. The causes for such notices are diverse, ranging from high levels of E. coli, lead, or other contaminants being detected in the treated water supply, or treatment systems being unable to cope with low source water quality, usually following heavy rains, particularly in combination with bushfires.

In some rural communities in Western Australia, the water supply is tainted by contamination that is not managed by simply boiling it. High nitrate levels in tap water have been reported from some communities, such as Meekatharra, which relies on groundwater [11]. Western Australia's Water Corporation recommends bottled water for infants (under 3 months) in Cue, Meekatharra, Mt Magnet, Nabawa, New Norcia, Sandstone, Yalgoo, Laverton, Leonora, Menzies, and Wiluna as a consequence of nitrate levels in the town water supplies [12]. The Western Australian government has also reported that drinking water in some remote Aboriginal communities

is contaminated with uranium, faecal bacteria and nitrates well above the recommended levels [13]. Other enteric pathogens identified in contaminated water in remote Indigenous communities include Salmonella, Shigelea, Campylobacter, E. coli and Rotavirus [14] (see ***First Peoples' Water Rights issues Paper*** for further discussion).

High levels of nitrate in water cannot be easily treated and are particularly dangerous for infants. When consumed by babies high nitrate water can affect blood oxygen levels and cause a disease called blue baby syndrome. *E. coli* can cause diarrhea, abdominal pain and fever. More severe cases can lead to bloody diarrhea, dehydration, or even kidney failure. Naegleria infections typically lead to death within a week.

In the Northern Territory groundwater in Katherine has been contaminated by toxic and persistent chemicals used in firefighting. Many other communities across Australia have also been similarly affected [15]. Uranium has also been reported in some remote community water supplies from the Northern Territory. Alarmingly, uranium levels were above Australian drinking water guidelines in the community of Laramba, and there are no clear guidelines for managing the problem [16].

A study in 2017 by the University of Queensland's Global Change Institute on water, sanitation and hygiene in remote Indigenous Australian communities found that contamination of drinking water was a risk where monitoring regimes are not rigorous and consistent. Despite improvements, concerns also remained regarding self-certification of wastewater installations in the NT, irregular wastewater output monitoring regimes, and high turnover of wastewater management staff in communities [17] (see ***First Peoples' Water Rights issues Paper*** for further discussion).

The human right to water and sanitation was recognised by the United Nations in 2010 [18], based on the previously-established understanding that "The human right to water is indispensable for leading a life in human dignity. It is a prerequisite for the realisation of other human rights" [19]. Australia is one of the 193 UN member countries that formally agreed to the Sustainable Development Goals (SDGs) that stipulate that access to water should be convenient, reliable, and affordable [7]. SDG 6 targets include, among other things, that all countries, regardless of economic development status, should by 2030 achieve universal and equitable access to safe and affordable drinking water for all, achieve access to adequate and equitable sanitation and hygiene for all, improve water quality by reducing pollution, and support and strengthen the participation of local communities in improving water and sanitation management [7]. All Sustainable Development Goals apply domestically as well as internationally and while Australia has made substantial international aid contributions for SDG 6 purposes, it has not demonstrated a similar level of focus on improving water quality in parts of country domestically [17]. While there has been a strong focus on investing in water supply infrastructure and strategies which provide reliable, clean potable water to major urban centres such as Melbourne and Sydney, a high level of inequity remains, particularly when these urban centres are compared with many remote Indigenous communities.

What can be done

The examples above of water quality issues for drinking water in regional and remote communities reinforce the importance of preventing contamination from entering water supplies and of monitoring water quality at appropriate space and time scales. The NSW Auditor-General's report found serious issues in how the NSW EPA manages water pollution in Sydney's drinking water catchments [10]. Pollution watchdogs (such as the environment protection agencies) need to be strengthened and resourced properly so they can adequately protect this fundamental resource.

An Integrated Water Resources Management (IWRM) approach should be seen as the main target for achieving the UN SDG 6 (water, sanitation and hygiene), and should be a key focus in planning to attain all the elements of SDG 6. IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Ongoing programs to fund long-term and well-maintained water and wastewater treatment services are required and the removal of self-certification of wastewater installations. In doing so, IWRM involves applying insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems.

There may be a role for philanthropy to fund investigations of how monitoring regimes can be strengthened in remote locations with minimal staff and whether examples of successful models of water and wastewater service provision to remote communities in some parts of Australia could be replicated in other regions.

2 Providing water security for Australian cities and towns will be a challenge given population growth and a changing climate

The capacity to provide safe and affordable potable water of the quality and in the volumes expected by Australians is becoming increasingly difficult given global warming and population growth

The dual pressures of population growth and climate change impacts make it increasingly challenging to deliver secure and affordable water supplies from traditional sources, typically being surface and ground water (see also *Governance Issues Paper*). With respect to rainfall (and inflows to surface water storages and aquifers) in Sydney and Melbourne catchments, winter and spring rainfall is projected to decrease in the next few decades. In Perth and Adelaide, a continuation of the recent trend of decreasing winter rainfall is anticipated along with decreases in spring rainfall, while in Canberra, less rainfall in the cool season is predicted for later this century [20].

Climate change is also increasing the intensity and frequency of extreme events like flooding and bushfire [21]. Both can compromise water quality and supply reliability. In Brisbane, the Mount Crosby Water Treatment Plant, supplying most of Brisbane's water, was blocked by sediment and debris washed downstream after large storms in January 2013, leaving the city within six hours of running out of drinking water [22]. In Wangaratta in regional Victoria, high intensity storms following bushfires in 2003 and 2006/7 had similar impacts [23]. Fire within Melbourne's protected water supply catchments is a significant risk that would put the water supply for 5 million people at risk.

Issues around service provision to small regional and remote communities have been ignored in some states, resulting in unacceptable outcomes [24]. Effective governance has been missing, resulting in inadequate capital and operating revenue, and inadequate access to trained maintenance personnel [24].

In recent times, the response to water supply crises arising primarily as a consequence of the Millennium drought has been the construction of supply management solutions. Notably, the Victorian government reacted to the Millennium drought by building the $4 billion Victorian Desalination Plant at Wonthaggi and the $750 million, 70 km North-South pipeline to move water from the Goulburn River to the Sugarloaf Reservoir that services Melbourne. Whilst deemed appropriate to secure the water supply for the city, these measures were poorly planned and executed urgently, in the context of severely low dam levels. The North-South Pipeline has been idle since 2010 [24] and the desalination plant only received its first order for in 2017, almost five years after operations first began [25].

While these measures (and others like it elsewhere e.g. Adelaide and the Gold Coast) have undoubtedly improved the reliability of water supplies, they can increase both the cost and carbon emissions associated with water supply [25] [26]. These types of measure can also stifle potential innovation in the period of plenty, until the next emergency, when demand once again outweighs supply capacity. Emergency measures keep water managers stuck in a "hydro-illogical cycle" that does little to reduce long term societal vulnerability to floods and drought and may in fact make society more vulnerable by entrenching the status quo [25].

In crisis situations, governments have also adopted emergency demand management measures such as extreme water restrictions. While these have been effective at reducing demand in times of need, they have been found to be an "inequitable and inefficient way of balancing supply and demand" [26]. It can be argued that water restrictions are brought in when the water management system has failed to provide for the uncertainty and inevitable variability and scarcity that characterise water systems in Australia.

Demand for water continues to grow due to population growth along with a growing expectation and desire for our urban environments to be greener and cooler [27]. For example, forecasts of population growth within the Greater Melbourne area estimate that the population will reach 9 million by 2065 while total water use is

expected to increase from 400 GL to 600 GL [28] At the same time, the traditional approach of diverting or storing streamflows, or drawing from aquifers, has a diminishing level of resilience in the face of climate change effects. These convergent realities reflect a growing risk that conventional water management approaches will be insufficient to meet future urban water demands; from drinking and bathing, to industrial activities including food production and processing, to uses that make our cities liveable, namely environmental flows to support waterway ecology and the irrigation of parks and gardens [27]. This is particularly so for water systems that rely solely on rainfall and was prefaced during the Millennium drought with falling dam levels and expediated responses.

The hurried responses to that crisis highlight another risk: that planning and responding within the midst of a crisis runs a risk of sub-optimal outcomes where the best approaches may not be identified, and the community may pay too much. Planning and management approaches that accept and engage with the increased uncertainty caused by climate change are required. Risk-based, scenario planning approaches should be adopted to broaden the range of potential future outcomes as well as the timing and nature of responses available.

Over the past decade, state and regional water service organisations and government oversight departments have begun to change from being essentially engineering departments/companies delivering water and sewerage services, to much more complex organisations, attempting to retain the confidence of their consumers by working with them to maintain and enhance water security [29]. This process is far from complete, but an examination of recent annual reports and planning documents of water service providers illustrates that the process is well underway in most areas. See for example the Sydney Water Climate Change Adaptation Program [30]; Melbourne Water System Strategy [31]; South East Queensland's Water Security Program [32] and Western Australia's plan for drought-proofing Perth – Water Forever Whatever the Weather [33].

At the policy level in government and the planning level in water service organisations, the emphasis in the large capital cities has shifted from managing crises to managing the longer-term water security challenges. Many large urban water service providers have taken a wide portfolio of measures to improve water security per se, and to manage and reduce long-term risks [29]. Perth is an example, where the climate independent options of desalination and the recharging of aquifers with treated wastewater to replenish the potable water supply have been adopted in the face of diminishing dam levels. This did however require a substantial community engagement program to educate the public and change public perceptions of the trial [33].

Managing water security is an ongoing task. Key policy issues need to be kept under ongoing scrutiny. In Australia, climate change is likely to affect water security adversely in many ways. Population growth in key urban centres, coupled with a drying climate means that, without some other change, the current supply/demand surplus will disappear [29]. In addition, the enhanced resilience has come at a fiscal cost. Decisions made at all levels of government have on numerous occasions suggested little concern for delivering the most cost-effective solutions [24].

What can be done

Over the next 30 years, urban water managers will need to provide water supply, sewerage and liveability services for rapidly growing cities and towns in a much drier climate, while cutting carbon emissions and with their water prices under strict scrutiny [27]. Significant institutional and regulatory reform is needed to address barriers to integrated planning, taking into account objectives across multiple domains such as water security and housing affordability [27].

Water service delivery models need to be reformed to achieve the high level of water security that users are increasingly demanding. Governments need to explore new models when old ones fail [29]. Research is necessary to ensure that actions taken are able to reflect emerging risks within each city, particularly given the concentration of population and population growth in a small number of major cities. Going forward, all governments, but particularly state governments, which are responsible for many key urban infrastructure decisions, must look to delivering infrastructure that is more cost-effective to communities rather than focusing on what they perceive to be good politics [24]. An honest dialogue needs to occur with the community about the forecasted risk of running out of water, different solutions and their Willingness to Pay for water security.

Further work is also required to investigate how to increase the political and social acceptability of the reuse of wastewater, particularly in support of potable water supplies. While this source may not suit all situations, environments or communities, a critical issue is policy support. In Victoria, the current strategic framework [34] does not refer to the use of recycled water for indirect potable reuse, restricting the ability of agencies to begin that conversation within their communities. Alternately, in Western Australia that conversation is underway with a trial that replenishes groundwater with treated recycled water.

There is also a need to improve the community's literacy around water and specifically the range of potential water sources that could contribute to supply. This will serve to support and expediate social acceptance of non-conventional water sources particularly when considering them as part of the potable water supply solution. More needs to be done to identify and articulate the relative benefits of centralised and decentralised solutions in providing both stability and adaptability to water management in Australia. (see ***Issue 3*** for further discussion).

Finally, cost-effective solutions incorporating the cost of externalities where appropriate, need to be formalised into planning processes, so that water sensitive approaches are integrated into new greenfield development and re-development of existing urbanised areas. There is real potential to manage stormwater to more effectively provide green spaces and improved water environments. However, this is frequently a costly option and it is difficult to retrofit older urban areas. Stormwater management is also complicated by boundary issues between planning departments, local governments and water managers. (see ***Issue 4*** for further discussion).

Rather than broad-scale approaches, local recycled water systems can augment water supplies. As these schemes are developed, it will require governments to define roles and responsibilities in the new area of provision of "liveability" services, determining cost-effective and efficient mechanisms of augmenting water supplies, including being prepared to allow higher prices or higher rates to pay for them. Initiatives include the use of rainwater for laundry and toilet use, the capture and reuse of stormwater at precinct scale for the irrigation of open space and the investigation of opportunities to use treated stormwater and recycled water as part of the potable water supply mix. The approaches and practices associated with this are described in Water Sensitive Urban Design (WSUD) Guidelines produced in all States and Territories.

Philanthropic organisations may be able to contribute through sponsorship and/or investment in programs such as Water Sensitive South Australia (https://www.watersensitivesa.com/participate/funding-investment), a program for WSUD practitioners funded by organisations with a commitment to providing leadership in our transition to water sensitive communities.

While much of this future will be highly challenging, it will also create an environment for real innovation, which will see the emergence of new technologies and improved local integrated solutions to water and liveability issues [27].

3 Broader society has limited water literacy

The average Australian has limited knowledge of the character of our water resources and the health and sustainability issues these resources face [35]. Australians need to use water more sustainably and to have a greater appreciation of the management of their water resources.

The issues surrounding our water resources and water management are often complex. It is not surprising, therefore, that the average Australian displays a relatively low level of water literacy. This is illustrated by the results of a representative survey of Australian adults to assess knowledge about the impact of household activities on waterways, the urban water cycle, and water management. What the survey found was that although most respondents recognised that household activities can influence the health of waterways and reduce water use, less than one third knew that domestic wastewater is treated before entering waterways, that urban stormwater is not treated, and that these are carried through different pipes in Australia [35].

Australia's approach, as in much of the world, has been to develop large, centralised infrastructure such as dams, water treatment plants, piped water supply networks and irrigation channels, otherwise known as

supply-side management. In Australia, this has been historically associated with perceived public good and coupled with strategic objectives for national and regional development [36]. Because this approach has been very efficient at supplying water for people, it has contributed to the perception that we have an abundance of, and control over, water resources [37]. This has in turn led us to value forms of recreation and amenity that often require large quantities of water, whether these be swimming pools, water features, urban trees, parks and sporting grounds [38] The growing importance of such spaces and their benefits is part of the growing emphasis on 'liveability' discussed in Issue 4. Questions remain, however, about how such liveability benefits can continue to be provided and enhanced in ways that are water efficient. While it is important to recognise the amenity and recreation benefits that these features of our cities and towns provide [39] [40] [41], current water inefficiencies in the way we seek to provide these benefits have contributed to Australians becoming relatively high per capita users of water resources (21.3 ML/person/year when the world average is 6.4 ML/person/year) [4]. Fulfilling and expanding these benefits requires consistent and abundant water resources, neither of which Australia has.

Nevertheless, Australians have shown themselves capable of becoming more water literate in times of stress [42]. Events like the Millennium Drought that impacted much of the country in the 2000s and the floods that followed it made people more aware of the precariousness of water resources [43]. This shift was facilitated by demand-side management approaches that focused on efficiency and included the promotion of "education, water-efficient technologies, watering restrictions, regulatory regimes that promote reuse and recycling, and volume-based conservation pricing" [44]. Strategies such as the Target 155 campaign in Victoria and the Waterwise towns program in Western Australia fit within this category, and have helped to reduce household water consumption through increased awareness, water saving tips and advice and rebates for water efficient household appliances such as showerheads [45] [46] [47]. Improvements in water literacy during times of stress can be leveraged to continue engaging communities about our water resources. Interactive, visual tools such as the Climate Resilient Water Sources tool [48] and the Australian Landscape Water Balance [49] provide the opportunity for individuals to gain an understanding of water supply systems and the status of water resources before they reach crisis levels, in a format which is simple and easy to understand.

Other initiatives have gone even further by actively engaging individuals to develop greater awareness of the relationship between the health of waterways and their ongoing capacity to continue providing Australians with valued social benefits. The South-east Queensland Healthy Land and Water Report Cards (HLWRCs) [50] are such an example. One component of the HLWRCs is the annual community benefits survey of more than 3200 Southeast Queensland residents that Healthy Land and Water has been conducting since 2015, which assesses the social and economic benefits resulting from local waterways perceived by residents [50]. The data collected from this process results in the calculation of a Waterway Benefits Rating of 18 catchments, which becomes an effective tool to communicate the multiple values that local waterways provide to people. Another example is the Australian Conservation Foundation's (ACF) River Fellows program, which trains farmers, scientists, Traditional Owners, local businesses and leaders to run campaigns and empower their local communities to advocate for a healthy Murray-Darling Basin [51]. The training that Fellows have received has enabled them to foster community knowledge of and support for sustainable waterway management through participation in events such as the ACF's Healthy Rivers Roadshows that took place in September 2017 across the MDB [52].

These initiatives demonstrate some of the ways that Australians can be encouraged to become more 'water sensitive citizens' [53] and exhibit knowledge and informed attitudes about our water resources [54] [55], to change public behaviours such as seeking to impact political processes or engaging in waterway restoration [56], as well as individual behaviours such as making particular consumption choices based on their potential impact on waterway and broader environmental health [54]. These attitudes and behaviours make people more likely to base decisions with a potential impact on water resources on a more accurate understanding of the health and wellbeing benefits these resources provide Australian society and the fragility of these resources. Additionally, increased water literacy among the public will allow for higher levels of engagement with and appreciation for water resource management as well as opportunities to seek and champion innovative water management solutions.

What can be done

Entrenching water literacy is an ongoing process that requires the adoption of "the soft path" to water sustainability, comprising tools and strategies to alter people's perceptions and practices so that they are more attuned with the realities of the local ecological context [44].

Ultimately, there is no silver bullet to the lack of water literacy among the average Australian. However, philanthropic organisations can make a contribution towards the aim of Australia becoming a more water sensitive society by supporting the tools and strategies that have been shown to improve water literacy, such as:

- Funding the development of and promoting information and educational tools, such as healthy waterway scorecards and regional indices
- Lobbying for the integration of participatory initiatives, such as the ACF's River Fellows program, as permanent components of local, regional, state and national water management regimes
- Sponsor environmental education programs in schools to promote water literacy and general environmental stewardship ethos among young Australians
- advocating for public policy measures that facilitate the adoption of demand-side water-saving measures such as new pricing mechanisms that support sustainable uses, subsidies for water-efficient showerheads and taps and rebates offered for water-saving machines, among other similar measures known to foster greater water literacy among citizens.

4 Current approaches to stormwater planning and management are affecting the capacity to use these water resources to support liveable urban landscapes

Greening of urban landscapes is a fundamental element of liveability. The provision of healthy and green vegetation, including healthy tree canopies, appeals to urban communities, provides protection from heatwaves, improves air quality and water quality, improves physical and mental health, and supports urban ecosystems. Water is vital to support green and healthy vegetation in urban landscapes.

Redirection of stormwater and rainwater at source to irrigate lawns, garden beds and trees is an effective and low-cost approach to achieve green landscapes. Stormwater can be captured in constructed wetlands, stored and used to irrigate green spaces. However, current stormwater management is still too focused on directing stormwater runoff to pipes as quickly as possible.

The traditional approach to urban water management has essentially treated urban waterways as drains, often lining them in concrete or piping them underground to serve the singular objective of protecting people and property by moving water out of towns and cities. Although there have been significant advances in recent years towards water sensitive cities[1], there is an extensive legacy of hard, engineered drainage assets. This has led to a reduction in the visual amenity of waterways, reduced social connection to waterways (which are often hidden behind fences to protect people from deep, fast flows), diminished recreation value of water bodies and the decline and loss of unique ecological values [57]. From a water cycle perspective, the process of urbanisation and the associated paving of fields and farmland has fundamentally changed the hydrology of the landscape: disconnecting surface water from groundwater [58] and directing polluted and fast-moving stormwater directly to often sensitive receiving environments such as waterways, estuaries and bays [59] [60]. This approach to management has also led actors engaged in water management to dispose of water resources that could enhance the health of Australians and the liveability of urban centres.

[1] Water sensitive cities are cities that i) serve as a potential water supply catchment, providing a range of different water sources at a range of different scales, and for a range of different uses, ii) provide ecosystem services and a healthy natural environment, thereby offering a range of social, ecological, and economic benefits, and iii) consist of water sensitive communities where citizens have the knowledge and desire to make wise choices about water, are actively engaged in decision-making, and demonstrate positive behaviours such as conserving water at home and not tipping chemicals down the drain..

In recent years, this singular approach to stormwater management has been increasingly challenged so that built and natural assets, including urban waterways, are now managed to achieve multiple social and ecological objectives while also meeting flood mitigation and drainage functions. Notable global examples of this approach can be found in the re-integration of the San Francisco River in Bogotá, Colombia [61] and the Cheonggyecheon stream in Seoul, South Korea [62]. Both examples have been found to provide liveability benefits ranging from improved public transit and quality of life, to a reduction in the urban heat island effect and air pollution [62]. Increasingly, waterway naturalisation projects are emerging that remove concrete and 'daylight' drains (i.e. remove drainage from underground pipes and re-build waterways) This approach can rejuvenate drainage corridors, improving the amenity of waterways and inviting community connection. In Australia, councils and river management agencies are starting to 'naturalise' some urban waterways to improve their social and environmental values.

However, the evidence suggests that innovative water management interventions with benefits for both basic health and broader liveability are the exceptions, rather than the norm, in urban and regional planning approaches in Australia. Water management is often still treated as a 'silo', meaning that its complex and dynamic links with the multiple dimensions of liveability remain peripheral in urban and regional planners' thinking. Urban greening projects supported by innovative stormwater management plans and designs are often undertaken on a piecemeal basis, rather than looking at the open space and urban water systems as networks. In addition, the demand for water from different types of green infrastructure (which varies seasonally) are not well understood by practitioners, which limits the scope and scale of opportunities. The efforts are further constrained by the lack of an institutional mandate to normalise these approaches [63], the high cost of the projects, and the lack of availability people in the water industry with the requisite knowledge on how to design and deliver these complex projects.

Mainstreaming these approaches to the management and development of water resources for liveability outcomes requires a mature and co-ordinated approach to planning. Integrated planning approaches are required that consider both:

- the role of potable water, use of treated wastewater and stormwater, connection to open spaces and cycling and walking paths that are shaded by healthy trees, and
- the management of water for liveability outcomes including, recreation, health, affordability, social cohesion and safety.

Urban waterways are important green infrastructure assets, particularly in established urban areas where open space may be limited and opportunities to create new green space is constrained by existing urban development. Waterways provide opportunities for active and passive recreation, space for urban forests, connections for people to move through the city, opportunities for active commuting and interactions with other community members.

Capturing, treating and reusing urban stormwater runoff can reduce stormwater pollution in waterways and make ecosystems healthier [64]. These practices keep water in the urban landscape that can be used to irrigate and promote urban greening such as street trees, green roofs and walls, and urban parks [65]. In established urban centres and new greenfield developments, road runoff is directed toward street trees for 'passive' irrigation, accelerating their growth, reducing Council irrigation requirements, saving water, increasing the shade they cast and reducing micro-climate temperatures [66]. Many agencies across Australia are also developing Managed Aquifer Recharge Storage and Recovery projects to enhance urban irrigation, with notable examples in Adelaide.

There is a strong body of evidence that green, water sensitive cities support more healthy and productive communities in numerous ways [67]. There is a clear link in the literature between water sensitive design practices and mitigation of the urban heat island effect resulting in a cooler city [68]. Greener sports fields are cooler with a reduced risk of injury [69] [2], potentially inviting broader participation improving physical and mental health [70]. Equally important are 'passive' spaces that are used for relaxation and contemplation where proximity to water, greening and shade support improved mental health [70].

Numerous studies have indicated that urban greening can improve human thermal comfort, a measure of how physically stressed a person feels in the urban environment [71], resulting in improved public health outcomes

such as fewer hospital admissions for heat related illnesses. This is particularly pertinent during heatwaves where hospitals can become overrun with patients in a short period of time. Contact with nature can also be restorative for people's mental health with studies showing reduced depression, anxiety, stress and aggression, while an increase in happiness, wellbeing and life satisfaction is seen, further improving public health outcomes [72].

What can be done

The evidence suggests that enabling improved liveability through water cycle management that includes a restorative approach to urban waterway health, utilisation of a range of water resources and the provision of green and cool spaces demands a 'beyond current best practice' approach that may redefine the role of organisations and individuals managing water cycle services into the future. Comprehensively mainstreaming innovative urban catchment management ideas, including stormwater capture and use, also requires better understanding of the potential benefits among government treasury officials and a coordinated and consistent approach across urban and regional planning authorities.

Creating healthy, sustainable and resilient green-blue (i.e. considers both landscape and water planning) infrastructure across towns and cities requires integrated urban water management [73]. There have been significant advances in integrated water management through initiatives such as recent Victorian Integrated Water Management forums. However, there remain some gaps in our understanding of how water management can best support and secure urban liveability.

The degree to which such innovative and increasingly valuable elements of stormwater management can be applied is in part limited by our understanding of impacts on infrastructure and the development of effective guidelines to mitigate any impacts. Successful implementation of at source stormwater management infrastructure has been demonstrated at the internationally recognised Little Stringybark Creek project [74]. From the application of this pilot project, local government is taking actions to encourage land development to achieve best practice stormwater management and application of similar approach to other catchments [75]. However, to mainstream this approach, policy frameworks related to stormwater management and Integrated Water Management at the state and local government levels must be mandated and include guidelines to ensure that planners and engineers implement innovative stormwater management approaches with an understanding of what infrastructure impacts might be and the appropriate mitigation measures.

Philanthropic organisations could partner with research organisations to contribute to research efforts in this field including the compilation of evidence that links stormwater and urban waterway management to economic benefit beyond the lifecycle costs of the projects. This would assist to gain support for greater action from government treasury officials, regulators and the private sector beyond the water industry. For example, research projects that build on our established understanding that access to green and cool landscapes support improved physical and mental well-being (and perhaps reduced medical costs) could be supported to investigate exactly which water sensitive design and management interventions are best suited *in-situ* to fostering and maintaining such beneficial landscapes.

5 Poor water quality reducing recreational and sporting opportunities and enjoyment and consequently our socio-economic health

Sufficient good water quality is crucial for human health and the recreational value of waterways, wetlands and coastal waters. Unfortunately, water quality in a number of our recreational water bodies and catchments is poor and improving only slowly, if at all.

Although varying from catchment to catchment and over time, water quality in a number of Australian drainage divisions was deemed in the 2011 Australian State of the Environment report to be relatively poor (Table 1, [76]). By 2016, there had been some improvements in the Northeast Drainage Division and the Murray Darling Basin, but against a background of water quality parameter values exceeding guidelines [76]. In other drainage divisions with water quality concerns, there appeared to have been little improvement (Table 1).

Table 1: *State of inland waters by drainage division [76]*

Drainage division	Water quality	
Carpentaria coast	?	G
Lake Eyre Basin	?	G
Murray-Darling Basin	↗	VP
North East Coast	↗	P
North Western Plateau	*Not assessed*	*n/a*
Pilbara-Gascoyne	*Not assessed*	*n/a*

Drainage division	Water quality	
South Australian Gulf	?	P
South East Coast (NSW)	?	P
South East Coast (Vic)	—	P
South West Coast	—	VP
South Western Plateau	*Not assessed*	*n/a*
Tanami-Timor Sea Coast	—	G
Tasmania	—	G

Key:

Recent trends		*Grade*	
↗	Improving	VG	Very good
↙	Deteriorating	G	Good
—	Stable	P	Poor
?	Unclear	VP	Very poor

The causes of these water quality issues are varied and include inappropriate land management and climate change exacerbating existing risks such as bushfires, acid sulfate soils, blue green algae and salinity. In addition, cities and urban areas produce large volumes of runoff that needs to be appropriately managed. Pollutant concentration levels have increased with urbanisation. For example, the amount of phosphorus applications in a typical Perth residential area is estimated to be 40 kilograms per hectare per year [76]. The quality of urban stormwater can be significantly impacted by point and diffuse sources of contamination from industry and transport, water treatment facilities and residential homes. Urban water catchments tend to have large areas of impervious surfaces such as roads, rooftops and pavement which increase the velocity of water flow and inhibit ponding and the infiltration of water into soil.

Waterways provide vital opportunities for communities to engage with the natural environment and enjoy water-based recreational activities such as fishing, waterfowl hunting, swimming, canoeing, rowing, sailing and motor-boating [77]. There are also many recreational activities that occur beside waterways such as walking, hiking, cycling, picnics and viewing native plants and animals. Coastal river systems in particular attract large numbers of people during the summer months. Iconic waterways, and the recreational and tourism opportunities they provide, deliver significant benefits to the health and well-being of individuals and to regional economies [78].

Waterways in near natural areas provide opportunities for recreational fishers and bushwalkers to enjoy fishing, hiking and camping. Recreational activities (or access to waterways for recreational purposes) are also common on riparian land along waterways [78]. It is important that the condition of waterways is maintained or improved to ensure that valuable recreational opportunities persist into the future. People rate or value water quality very highly in determining their recreational destinations and experiences [77]. Studies have found that recreational anglers are responsive to the full set of water quality measures used by biologists [79].

In cities, urban streams are an important feature of our suburbs. While these streams tend to be modified or engineered, they are nonetheless a critical part of the urban landscape, providing valuable recreation, aesthetics and biodiversity conservation areas. During rainfall events, stormwater flows can rapidly enter urban streams carrying high levels of nutrients, sediment and heavy metals. This produces water with high biological oxygen demand (BOD) and low dissolved oxygen levels [80]. These rapid changes in water quality can also affect receiving aquatic environments, such as coastal waters, estuaries, rivers and wetlands. Adverse effects include: the closure of recreational access due to high levels of pathogens or toxic blue-green algae; and reduction in visual amenity [80]. A report for the ACT Government in 2011 demonstrated the substantial economic and social benefits of the sport, recreational, water and landscape values of Lake Burley Griffin to the ACT

community, and the serious potential for loss of these benefits as a result of declines in water quality of the lake [81].

Managing urban water quality will present an increasingly complex challenge for governments and the community as urban development in Australia grows.

What can be done

Awareness of the environmental conditions and human activities that influence water quality is an important part of effective water management. Strategies for managing these issues are developed by state and territory governments, local government councils and shires, or regional organisations such as natural resource management bodies, supported by national guidance contained in the National Water Quality Management Strategy [80]. Water managers and jurisdictional agencies can:

- use the nationally agreed guidelines for managing water quality to help develop water quality management strategies, plans and regulatory arrangements
- apply the guidance in characterising the relationship between water quality and water quantity to understand issues affecting water quality and assist managers in making informed decisions about how water is managed in the landscape to maintain and improve its quality.

Guidance is also available to help water and land managers identify and manage acid sulfate soil problems [80]. The guidance provides information to prevent, minimise, mitigate and remediate the harmful effects that disturbance of acid sulfate soils can have on water quality, aquatic ecosystems, farming and fishing, and built infrastructure.

Authorities also need to minimise the threat of intense bushfires and respond quickly after a major fire to stabilise the soils and facilitate natural recovery of the vegetation. A review of the water quality impacts of bushfires on various uses and values, including: drinking water, aquatic ecosystems and agriculture, was undertaken in 2009 [23].This review recommended management actions before, during, and after a fire to minimise impacts on water quality.

In urban areas, water sensitive design practice includes stormwater harvesting and wetland stormwater treatment systems, which can increase infiltration and remove unwanted pollutants (including nutrients) from downstream waterways, rivers and bays [82] and lead to improved urban waterway health due to improved water quality and baseflow. Many new urban developments across Australia, require that stormwater runoff is treated before being released to the environment within constructed wetlands or biofiltration systems that achieve the multiple objectives of removing pollutants, restoring pre-development hydrology, reconnecting surface and ground waters and providing a valuable natural asset to the surrounding community [83].

There may be a role for philanthropy in organising community groups to advocate for greater action on the rehabilitation of degraded recreational assets, such as the Yarra River, the Parramatta River, the Molonglo River and many others, including smaller urban systems Action programmes (such as those described in [84]) could possibly be organised as joint ventures between government, private enterprise and the community, potentially with publicity and other benefits going to commercial investors.

Works cited

[1] V. Vuchic, Transportation for Livable Cities, New York: Routledge, 1999.

[2] A. M. Coutts, N. J. Tapper, J. Beringer, M. Loughnan and M. Demuzere, "Watering our Cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context," Progress in Physical Geography, vol. 37, no. 1, p. 1027, 2012.

[3] R. Ashley, L. Lundy, S. Ward, P. Shaffer, L. Walker, C. Morgan, A. Saul, T. Wong and S. Moore, "Water sensitive urban design: opportunities for the UK," Proceeding of the Institution of Civil Engineers: Municipal Engineer, vol. 166, no. ME2, pp. 65-76, 2013.

[4] Asian Development Bank, “Asian Water Development Outlook 2016: Strengthening water security in Asia and the Pacific,” Asian Development Bank, Manila, 2016.
[5] Credit Suisse, “Global Wealth Report 2018,” Credit Suisse Research Institute, Zurich, 2018.
[6] N. Hall , E. Abal, S. Albert, S. Ali, D. Barrington, A. Dean, B. Head , P. Hill, K. Hussey, P. Jagals, G. Muriuki, M. Pascoe, S. Reid, R. Richards, J. Robinson, H. Ross, J. Torero Cullen and J. Willis, “The UN Sustainable Development Goals for water and sanitation: How should Australia respond within and beyond its borders?,” Global Change Institute , Brisbane, 2016.
[7] United Nations, “Sustainable Development Goals 6: Ensure avialability and sustainable management of water and sanitation for all,” 2018. [Online]. Available: https://sustainabledevelopment.un.org/sdg6. [Accessed 7 January 2019].
[8] L. Compton, TasWater declares Tasmania to be free of boil water alerts at last, ABC News, 2018.
[9] AWA, “Water Security for all Australians,” Australian Water Association, 2016.
[10] NSW Auditor-General, “Regulation of water pollution in drinking water catchments and illegal disposal of solid waste,” Audit Office of NSW, Sydney, 2018.
[11] Water and Rivers Commission, “Meekatharra Water Reserve: Water Source Protection Plan, Meekatharra Town Water Supply,” Water and Rivers Commission, Perth, 2001.
[12] Water Corporation, “Drinking water quality annual report,” Water Corporation, Perth, 2016-17.
[13] Western Australian Auditor General, “Delivering Essential Services to Remote Aboriginal Communities,” Office of the Auditor General of Western Australia, Perth, 2015.
[14] H. Clifford, G. Pearson, P. Franklin, R. Walker and G. Zosky, “Environmental health challenges in remote Aboriginal Australian communities: clean air, clean water and safe housing,” Australian Indigenous Health Bulletin , vol. 2, no. 15, pp. 1-13, 2015.
[15] L. Besser, “Contamination,” 10 October 2017. [Online]. Available: https://www.abc.net.au/4corners/contamination/9032140. [Accessed 18 January 2019].
[16] Power and Water Corporation, “Laramba Water Quality Factsheet,” 2019. [Online]. Available: https://www.powerwater.com.au/__data/assets/pdf_file/0020/34535/Laramba_Water_Quality.PDF. [Accessed 18 January 2019].
[17] N. Hall, M. Barbosa, D. Currie, A. Dean, B. Head, P. Hill, S. Naylor, S. Reid, L. Selvey and J. Willis, “Water, sanitation and hygiene in remote Indigenous Australian communities: A scan of priorities,” Global Change Institute , Brisbane, 2017.
[18] United Nations Department of Economic and Social Affairs (UNDESA), “Resolution 64/292: The human right to water and sanitation,” 2014. [Online]. Available: http://www.un.org/waterforlifedecade/human_right_to_water.shtml. [Accessed 18 December 2018].
[19] United Nations Economic and Social Council, “General Comment No. 15 (2002): The right to water (arts. 11 and 12 of the International Covenant on Economic, Social and Cultural Rights),” 20 January 2003. [Online]. Available: https://www2.ohchr.org/english/issues/water/docs/CESCR_GC_15.pdf. [Accessed 7 January 2019].
[20] CSIRO and the Bureau of Meteorology, “Climate change in Australia: information for Australia’s natural resource management regions,” CSIRO and the Bureau of Meteorology, 2015.
[21] Australian Government Department of the Environment and Energy, “Climate change impacts in Australia,” [Online]. Available: http://www.environment.gov.au/climate-change/climate-science-data/climate-science/impacts. [Accessed 8 January 2019].
[22] T. Moore, Brisbane waterways in poor health, Brisbane: Brisbane Times, 2014.
[23] H. Smith, J. Cawson, G. Sheridan and P. Lane, “Desktop review- impact of bushfires on water quality,” 2011.
[24] J. Horne, “Resilience in major Australian cities: assessing capacityand preparedness to respond to extreme weather events,” International Journal of Water Resources Development, vol. 4, no. 34, pp. 632-651, 2018.
[25] M. W. Shahzad, M. Burhan, L. Ang and K. C. Ng, “Energy-water-environment nexus underpinning future desalination sustainability,” Desalination, vol. 413, pp. 52-64, 2017.
[26] M. Kemp, Adelaide desalination plant too expensive to run, The Advertiser, 2015.
[27] B. Hart, J. Doolan, S. Bunn, J. Horne and C. Pollino, “Future Challenges,” in Decision Making in Water Resources Policy and Management: an Australian Perspective, 2nd ed, Elsevier, 2017, pp. 565-577.
[28] Melbourne Water, “Water for a future-thriving Malbourne: An overview of how Melbourne's metropolitan water industry is working together to secure water supplies for the next 50 years,” Melbourne Water, Melbourne, 2017.
[29] J. Horne, “Water Security in Australia,” in Global Water Security: Lessons Learnt and Long-Term Implications, Singapore, Springer, 2018.
[30] Sydney Water, “Climate Change Adaptation Program,” 2013. [Online]. Available: https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdy5/~edisp/dd_069672.pdf. [Accessed 21 January 2019].
[31] Melbourne Water, “Melbourne Water System Strategy,” 2017. [Online]. Available: https://www.melbournewater.com.au/sites/default/files/2017-09/Melbourne-Water-System-Strategy_0.pdf. [Accessed 21 January 2019].
[32] SEQWater, “Water for Life: South East Queensland’s Water Security Program 2016 - 2046,” 2017. [Online]. Available: https://www.seqwater.com.au/sites/default/files/PDF%20Documents/Water%20Security%20Program%20-%20Regulated%20Document%20-%20WEB%20version%20with%20clickable%20links.pdf. [Accessed 21 January 2019].

[33] Water Corporation, “Water Forever Whatever the Weather - drought proofing Perth,” November 2011. [Online]. Available: https://www.watercorporation.com.au/-/media/files/residential/about-us/planning-for-the-future/perth-10-year-water-supply-strategy.pdf. [Accessed 21 Januray 2019].
[34] Department of Environment, Land, Water and Planning, “Water for Victoria,” Department of Environment, Land, Water and Planning, East Melbourne, 2017.
[35] A. J. Dean, K. S. Fielding and F. J. Newton, “Community Knowledge about Water: Who Has Better Knowledge and Is This Associated with Water-Related Behaviours and Support for Water-Related Policies?,” PLoS ONE, vol. 11, no. 7, pp. 1-18, 2016.
[36] J. Tisdell, J. Ward and T. Grudzinski, “The development of water reform in Australia,” Cooperative Reserach Cetren for Catchment Hydrology, 2002.
[37] Z. Sofoulis, “Big Water, Everyday Water: A Sociotechnical Perspective,” Continuum: Journal of Media and Cultural Studies, vol. 19, no. 4, pp. 445-463, 2005.
[38] L. G. A. G. J. M. R. O. S. S. P. a. Y. P. Frost, “Water, history and the Australian city: urbanism, suburbanism and water in a dry continent, 1788-2015,” Cooperative Research Centre for Water Sensitive Cities, Melbourne, 2016.
[39] H. Corney, C. D. Ives and S. Bekessy, “Amenity and ecological management: A framework for policy and practice,” Ecological Management & Restoration, vol. 16, pp. 199-205, 2015.
[40] C. Dobbs, A. A. Eleuterio, J. D. Amaya, J. Montoya and D. Kendal, “The benefits of urban and peri-urban forestry,” Unasylva 250: Forests and sustainable cities, pp. 22-29, 18 May 2018.
[41] Government of Victoria, “Water for Victoria: Water Plan,” 2016. [Online]. Available: https://www.water.vic.gov.au/__data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf. [Accessed 14 November 2018].
[42] B. Head, “Managing urban water crises: adaptive policy responses to drought and flood in Southeast Queensland, Australia,” Ecology and Society, vol. 19, no. 2, 2015.
[43] J. Wei, Y. Wei and A. Western, “Evolution of the societal value of water resources for economic development versus environmental sustainability in Australia from 1843 to 2011,” Global Environmental Change, vol. 42, pp. 82-92, 2017.
[44] O. M. Brandes and L. Kriwoken, “Changing Perspectives — Changing Paradigms: Taking the "Soft Path"to Water Sustainability in the Okanagan Basin,” Canadian Water Resources Journal, vol. 31, no. 2, pp. 75-90, 2006.
[45] Department of Environment Land, Water and Planning, “Central Region Sustainable Water Strategy Review,” Department of Environment, Land, Water and Planning, East Melbourne, 2018.
[46] WA Water Corporation, “Waterwise towns program,” WA Water Corporation, 2018. [Online]. Available: https://www.watercorporation.com.au/save-water/water-saving-programs/community-water-saving-programs. [Accessed 5 December 2018].
[47] K. G. Low, S. B. Grant, A. J. Hamilton, K. Gan, J.-D. Saphores, M. Arora and D. L. Feldman, “Fighting drought with innovation: Melbourne's response to the Millennium Drought in Southeast Australia,” Wiley Interdisciplinary Reviews-Water, vol. 2, no. 4, pp. 315-328, 2015.
[48] BoM, “Climate Resilient Water Sources,” 2019. [Online]. Available: http://www.bom.gov.au/water/crews/. [Accessed 24 January 2019].
[49] BoM, “Australian Landscape Water Balance,” 2019. [Online]. Available: http://www.bom.gov.au/water/landscape/#/sm/Actual/day/-28.34/130.43/3/Point////2019/1/23/. [Accessed 24 January 2019].
[50] Healthy Land and Water, “Healthy Land and Water Report Cards,” [Online]. Available: hlw.org.au/reportcard. [Accessed 1 November 2018].
[51] Australian Conservation Foundation, “Apply for the Rivers Fellowship and get skilled up to speak out for our rivers,” 2018. [Online]. Available: https://www.acf.org.au/rivers_fellowship_20. [Accessed 12 December 2018].
[52] Australian Conservation Foundation, “Come to the Healthy Rivers Roadshow,” 2017. [Online]. Available: https://www.acf.org.au/healthy_rivers_roadshow. [Accessed 12 December 2018].
[53] A. J. Dean, J. Lindsay, K. S. Fielding and L. D. G. Smith, “Fostering water sensitive citizenship- Community profiles of engagement in water-related issues,” Environmental Science & Policy, vol. 55, pp. 238-247, 2016.
[54] A. Dobson, “Environmental Citizenship: Towards Sustainable Development,” Sustainable Development, vol. 15, pp. 276-285, 2007.
[55] M. Hawthorne and T. Alabaster, “Citizen 2000: development of a model of environmental citizenship,” Global Environmental Change, vol. 9, pp. 25-43, 1999.
[56] H. J. Aslin and S. Lockie, “Citizenship, engagement and the environment,” in Engaged environmental citizenship, H. J. Aslin and S. Lockie, Eds., Darwin, Charles Darwin Univeristy Press, 2013, pp. 1-18.
[57] V. G. Mitchell, “Applying integrated urban water management concepts: a review of Australian experience,” Environmental Management, vol. 37, pp. 589-605, 2006.
[58] C. R. Jacobson, “Identification and qunatification of the hydrological impacts of imperviousness in urban catchments: a review,” Journal of Environmental Management, vol. 92, pp. 1438-1448, 2011.
[59] S. Faulkner, “Urbanization impacts on the structure and function of forested wetlands,” Urban Ecosystems, vol. 7, no. 2, pp. 89-106, 2004.
[60] P. N. Owens and D. E. Walling, “The phosphorus content of fluvial sediment in rural and industrialized river basins,” Water Research, vol. 36, pp. 685-701, 2002.
[61] R. Davids, “Restoring Bogotá’s Waterscapes,” Berkeley Review of Latin American Studies, pp. 41-45, Fall 2012.

[62] Inhabitat, “How the Cheonggyecheon River Urban Design Restored the Green Heart of Seoul,” [Online]. Available: https://inhabitat.com/how-the-cheonggyecheon-river-urban-design-restored-the-green-heart-of-seoul/. [Accessed 10 January 2019].
[63] G. D. Mekala and D. Hatton MacDonald, “Lost in the transactions: analyzing the institutional design of green infrastructure delivery.,” Ecological Economics, vol. 147, pp. 399-409, 2018.
[64] T. Wong, R. Allen, R. Brown, A. Deletić, L. Gangadharan, W. Gernjak, C. Jakob, P. Johnstone, M. Reeder, N. Tapper, G. Vietz and W. C.J., “Blueprint2013: Stormwater Management in a Water Sensitive City,” Cooperative Research Centre for Water Sensitive Cities, Melbourne, 2013.
[65] A. Coutts, N. Tapper, J. Beringer, M. Loughnan and M. Demuzere, “Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context,” Progress in Physical Geography: Earth and Environment, pp. 2-28, 2013.
[66] V. Grey, S. J. Livesley, T. D. Fletcher and C. Szota, “Establishing street trees in stormwater control measures can double tree growth when extended waterlogging is avoided,” Landscape and Urban Planning, vol. 178, pp. 122-129, 2018.
[67] D. Kendal, K. Lee, C. Estima Ramalho, K. Bowen and J. Bush, “Benefits of urban green space in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub,” University of Western Australia, Perth, 2016.
[68] A. Broadbent, A. Coutts, N. Tapper, M. Demuzere and J. Beringer, “The microscale cooling effects of water sensitive urban design and irrigation in a suburban environment,” Theoretical and Applied Climatology, pp. 1-23, 2018.
[69] L. Lafortezza, G. Carrus, G. Sanesi and C. Davies, “Benefits and well-being perceived by people visiting green spaces in periods of heat stress,” Urban Forestry and Urban Greening, vol. 8, no. 2, pp. 97-108, 2009.
[70] J. Barton and J. Pretty, “What is the best does of nature and green exercise for improving mental health? A multi-study analysis,” Environmental Science and Technology, vol. 44, pp. 3947-3955, 2010.
[71] S. Jacobs, A. Gallant, N. Tapper and D. Li, “Use of cool roofs and vegetation to mitigate urban heat and improve human thermal stress in Melbourne, Australia,” Journal of Applied Meteorology and Climatology, pp. 1747-1764, 2018.
[72] K. A. M. S. E. G. P. &. B. J. DE JONG, “Perceived green qualities were associated with neighborhood satisfaction, physical activity, and general health: Results from a cross- sectional study in suburban and rural Scania, southern Sweden,” Health & Place, pp. 1374-1380, 2012.
[73] DELWP, “Planning a green-blue city: A how-to guide for plannign urban greenign and enhanced stormwater management in Victoria,” Department of Environment, Land, Water and Planning, Melbourne , 2017.
[74] The Waterway Ecosystem Research Group, “Little Stringybark Creek,” The Waterway Ecosystem Research Group, [Online]. Available: https://urbanstreams.net/lsc/. [Accessed 21 January 2019].
[75] G. D. Mekala, R. N. Jones and D. Hatton MacDonald, “Valuing the Benefits of Creek Rehabilitation: Building a Business Case for Public Investments in Urban Green Infrastructure,” Environmental Management, vol. 55, no. 6, pp. 1354-1365, 2015.
[76] R. M. Argent, “Inland water: State and trends of water quality. In: Australia state of the environment 2016,” Australian Government Department of the Environment and Energy, 2016. [Online]. Available: https://soe.environment.gov.au/assessment-summary/inland-water/state-and-trends-water-quality, DOI 10.4226/94/58b656cfc28d1. [Accessed 18 January 2019].
[77] Wimmera Development Association, “Wimmera Southern Mallee: Socio-economic value of recreational and environmental water 2017,” Wimmera Development Association, 2017.
[78] Victorian Department of Environment and Primary Industries, “Improving our Waterways: Victorian Waterway Management Strategy,” State Government of Victoria, Melbourne, 2013.
[79] K. Egan, J. Herriges, C. Kling and J. A. Downing, “Valuing Water Quality as a Function of Water Quality Measures,” American Journal of Agricultural Economics, vol. 1, no. 91, pp. 106-123, 2009.
[80] Water Quality Australia, “Issues affecting water quality,” 2019. [Online]. Available: http://www.waterquality.gov.au/issues. [Accessed 18 January 2019].
[81] I. Lawrence, “Investigation into the state of Lake Burley Griffin and catchment: Economic impact of water quality issues Report,” Office of the Commissioner for Sustainability and the Environment, Canberra, 2011.
[82] DELWP, “Using alternative water sources,” Department of Environment, Land, Water and Planning, 16 July 2018. [Online]. Available: https://www.water.vic.gov.au/liveable/using-alternative-water-sources. [Accessed 9 January 2019].
[83] T. H. F. Wong, “An Overview of Water Sensitive Urban Design Practices in Australia,” Water Practice and Technology, vol. 1, 2006.
[84] Australian Government 2012, “Improving water quality: Stories of progress and success from across Australia,” Department of Agriculture and Water Resources, Canberra, 2012.