Case study report
April 2018

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RMIT UNIVERSITY | Centre for Urban Research

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Casey Furlong[1*], Caroline Uittenbroek[2], Natalie Gulsrud[3], Montserrat Termes-Rife[4], Jago Dodson[1], Rob Skinner[5]

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1. Centre for Urban Research, RMIT University, Melbourne, Australia

2. Utrecht University, Utrecht, The Netherlands

3. University of Copenhagen, Copenhagen, Denmark

4. University of Barcelona, Barcelona, Spain

5. Monash Sustainable Development Institute, Melbourne, Australia

**Corresponding author: casey.furlong@rmit.edu.au*

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RMIT University acknowledges the Wurundjeri people of the Kulin Nations as the traditional owners of the land on which the University stands. RMIT University respectfully recognises Elders both past and present. We also acknowledge the traditional custodians of lands across Australia where we conduct business, their Elders, Ancestors, cultures and heritage.

Executive Summary

Across the world, the role and functionality of urban water utilities has evolved over time, in response to urban challenges. The role of the urban water sector in each region has generally begun with water supply, and then been followed by sewerage, drainage, environmental protection, and then water security efforts through the collection of alternative water sources, such as desalination and recycled water. Typically these services have been delivered through networks of underground pipes, and publicly inaccessible treatment facilities.

Increasing pressures from climate change, population growth, urban densification and urban sprawl require water utilities to adapt and innovate, in order to maintain service delivery standards. These pressures are contributing to a variety of challenges, particularly urban flooding, and sewage overflows (for cities that have combined stormwater and sewerage systems). Upgrading the capacity of existing underground pipe networks to accommodate for increasing stormwater and sewage flows is very expensive. Therefore water utilities are showing increased interest in a variety of multi-functional green infrastructures, across the public and the private realms, to treat, direct and retain water within urban landscapes.

Multi-functional green infrastructures, such as wetlands, swales, raingardens, water squares and green roofs, are associated with a number of different ideologies including: Nature-Based Solutions, Water Sensitive Urban Design, Climate Change Adaptation, Sustainable Urban Drainage Systems and Integrated Urban Water Management. Drivers and designs for multi-functional green infrastructure vary between regions, but a common theme between them is that they have the added benefit of also increasing amenity and greenery within urban landscapes.

In parallel with the evolution of these green infrastructure approaches within the water sector, there has also been a global shift, within the urban planning and public health fields, towards recognition of how built environments can affect community mental and physical health, often referred to as “liveability”. In particular there is increasing evidence that urban green space and vegetation can improve mental and physical health, through reducing the heat island effect, promoting exercise, and decreasing depression. As health expenditure is one of the largest on-going costs for governments around the world, the potential for all public institutions to contribute to reducing health expenditure by increasing green space and vegetation, is an issue worthy of serious consideration.

Water utilities are currently not clear on their role in this emerging liveability and urban greening agenda, and limited research has been done to compare how the actions of water utilities in different regions are contributing towards overall liveability and urban greening interventions.

The aims of the current research are to provide an initial exploration of the role that water sectors are currently playing in relation to liveability and urban greening interventions, and what potential role they can and should play in this agenda into the future.

This is approached through conducting descriptive case studies on Barcelona, Rotterdam, Amsterdam, Copenhagen and Melbourne. These cities were selected on the basis of the following criteria: a mix of drought and flooding concerns; a record of innovative projects and initiatives; presence in international literature; and participation in international city networks such as 100 Resilient Cities, C40, and Green Surge. Information was collected through interviews with 45 stakeholders.

Contributions to liveability and urban greening interventions in the case studies

Potential contributions of water utilities towards liveability and urban greening interventions have been organised into six categories. Water utilities in all of the case study cities are contributing to public health through improved liveability and urban greening outcomes. These interventions are summarised in Table i. It is important to recognise that contributing to more types of interventions (out of Actions 1 – 6 in the table), does not necessarily equate to a larger liveability and greening contribution overall.

In Barcelona, water utilities have been implementing recycled water projects to protect their groundwater aquifers from over-extraction; installing natural water features and butterfly gardens in parks and treatment plants to promote biodiversity; and developing a variety of multi-functional retarding basins and raingardens in the urban environment.

In Rotterdam, water utilities have been greening water utility and government buildings; implementing a variety of large capital intensive multi-functional green assets in public areas, such as "Dak Park" and "water squares"; and promoting green roofs on private buildings through incentives, education and public events, resulting in a total green roof area of 250,000m^2.

In Amsterdam, water utilities have been greening water utility and government buildings; developing a variety of multi-functional green assets in public areas, such as storage under tram tracks and in parks; promoting a variety of interventions by private citizens and public organisations through a high-profile and very successful public awareness and mainstreaming program (Amsterdam Rainproof); and have a related urban planning regulation to require new buildings to be "water neutral" (in terms of stormwater).

In Copenhagen, water utilities are implementing an approximately USD$2 Billion program of 300 multi-functional green infrastructures across the public realm of streets and parks; and complementing this program with the provision of free trees for residents to plant on their land.

In Melbourne, water utilities have been: implementing a variety of stormwater harvesting and recycled water projects to support greenery through water security; tree planting on water utility owned and managed land; naturalising and upgrading the amenity of waterways; constructing a variety of wetlands, swales and raingardens on public land; coordinating and facilitating interventions by other stakeholders (e.g. through the Greening the West group), supporting the planting of an additional one million trees; and implementing urban planning controls to require stormwater management infrastructures in new developments across public and private land.

Table i – Contributions to liveability and greening interventions by water sectors in the five case studies

Actions that water utilities are taking to contribute to urban liveability and greening interventions	Barcelona	Rotterdam	Amsterdam	Copenhagen	Melbourne
1. Water security measures to protect greenery	✓				✓
2. Greening of water sector owned and managed land and buildings	✓	✓	✓		✓
3. Waterway enhancement					✓
4. Multi-functional (green) stormwater infrastructure on public land	✓	✓	✓	✓	✓
5. Coordination, financing and incentives to promote greening actions by other stakeholders		✓	✓	✓	✓
6. Urban planning and regulation to protect and enhance greening across the public and private realm			✓		✓

Understanding the water sector's role in liveability in relation to water system challenges

All of these initiatives are likely to have an impact on some or all of the following public health outcomes: increasing exercise, decreasing depression, reducing chronic disease, reducing heat-related deaths etc. However, in general these initiatives have not been driven primarily by public health outcomes, but rather to address water system challenges, and contribute to public health outcomes as a secondary and sometimes unconsidered benefit.

Finding from the case studies suggest that the role of the water sector in liveability and urban greening interventions is dependent upon (a) climatic context, (b) infrastructure and physical context, and (c) governance context.

In cities that suffer from drought, such as Melbourne and Barcelona, the water utilities see their role in liveability and urban greening as being substantially tied to water security efforts. In Melbourne recent droughts, and associated water restrictions, have damaged parks and private gardens. In Barcelona, the groundwater aquifer which is used for irrigation (and other uses) is at risk of depletion. In such contexts, any efforts towards water security are indirectly contributing to protecting and enhancing greening, leading to improved liveability outcomes.

In cities that have secure water supplies, but suffer from flooding, the water sector generally directly contributes to urban greenery through green multi-functional infrastructure as a flood mitigation measure. This is particularly the case in Rotterdam and Copenhagen, where major multi-functional assets are constructed in the public realm, with projects in streets, parks and housing developments, substantially contributing to liveability and greening in these cities.

Infrastructure and physical contexts also have a significant effect on the role of the water sector in urban greening. Although Barcelona does not currently suffer from significant urban flooding, the fact that the city has combined sewers, and the damaging effects of sewer overflows along important city beaches, have driven their emphasis on raingardens and other multi-functional drainage assets. In Melbourne, the water sector has taken extensive efforts towards implementing green infrastructure throughout the city, with the aim to remove pollutants (nitrogen, phosphorous, litter etc.) in order to protect environmentally and socially significant waterways and bays.

The role of the water sector in urban greening also varies in accordance with the governance context of a city. In Barcelona, Rotterdam, Amsterdam and Copenhagen there is one unusually large municipality (in terms of geographical size, budget, and/or population) in charge of managing the core city, and in the case of Barcelona, there is also a metropolitan government. In contrast, in Melbourne there are 32 municipalities of relatively similar geographical size, and no metropolitan government. These specific circumstances have led to water utilities in Melbourne seeing a need to support urban greening through collaborative governance at a geographical scale that is larger than any one municipality, through the "Greening the West" group.

Melbourne is the only case study in which some water sector initiatives have been found which are primarily aimed at liveability and public health, rather than primarily aimed at addressing water system challenges such as flooding. Emphasis from Melbourne's water utilities on supporting tree planting and public green space initiatives have focused specifically on community health, through reducing heat, increasing exercise etc. Moreover, these efforts are supported by high-level government policy that specifically requires water authorities to work directly with local government and other stakeholders to achieve liveability outcomes.

Mechanisms through which contributions have been made

Although it is not the intention of this research to rank or quantify the contributions between the case study cities, it is possible to make some comparisons between the mechanisms through which liveability and greening contributions have been made. In particular a contrast can be drawn between: (a) a capital intensive approach that focuses on major projects in the public realm, (b) a low capital approach that focuses on public education, urban planning controls and incentives in the private realm, and (c) a mix of the two.

The most obvious contrast can be drawn between Copenhagen and Amsterdam. In Copenhagen authorities have focused on projects in the public realm, through 300 projects in streets and parks, with dedicated additional funding of approximately USD$2 billion. In Amsterdam authorities have predominantly focused on awareness and mainstreaming measures across the private and public realm, through community education, capacity building, incentives and urban planning regulations (requiring buildings to be "water neutral" when they are constructed), without extensive dedicated additional funding.

Rotterdam and Melbourne are examples of a mixed approach. In Rotterdam authorities have used a mix of large projects in the public realm, and education and incentives

to promote green roofs in the private realm. In Melbourne the focus has been primarily on using urban planning controls to compel private developers to fund projects in the public and private areas of new developments, as the city expands geographically, and also significant financial subsidies for projects by municipalities in existing suburbs.

Limitations of the research

This research has a number of limitations. As it utilises only five case studies, four European and one Australian, with no North American or Asian cities included, it is not possible to provide a representative sample of cities across the developed world. The level of detail provided on each of the case study cities is predominantly qualitative and so not all details are directly comparable across the cities. Also, to a certain extent the understanding of drivers in each city has been limited to the subjective opinions of consulted experts within each city.

Conclusions

Water utilities in the five case study cities are already involved in a wide variety of initiatives that contribute to liveability and urban greening, and thus to some extent improve public health. However in most cases these initiatives have been aimed at addressing water system challenges, and contribute to public health outcomes only as a secondary benefit.

This research highlights the potential mechanisms by which water utilities are able to have an impact on public health through interventions in the built form, either while addressing other water system drivers, or as an end in itself. In order to consider what mechanisms are appropriate in which city, it is recommended that water utilities be active participants in public health debates, and continue to explore (a) the benefits of urban greening interventions in the built form, and (b) compare the potential of different approaches (e.g. public projects, incentives for residents, planning controls), to contribute to these outcomes.

Contents

Introduction

1.1 Evolution of the urban water sector

The urban water sector includes any organisation that has a role in the management of water supply, sewerage or drainage services within an urban area. Depending on the city, these services can be managed by local, state or national governments, publicly owned utilities, privately owned utilities, or catchment management authorities. Collectively these organisations can be referred to as "Water Service Providers", or informally as "water utilities" (Marques & De Witte, 2011).

The mandate of the urban water sector has evolved over time to meet the challenges and needs of urban settlements (Marlow, et al., 2013). When initially created by governments, water utilities focused on the storage and transfer of clean water into cities. Later, the challenge shifted to removing dirty water from cities through sewerage and drainage systems (Mukhtarov, 2008; Furlong, et al., 2015). From the 1960s onwards, across the world, water utilities have increasingly concentrated on environmental protection of waterways and bays, which at the time primarily involved building and upgrading sewage treatment plants (Brown, et al., 2009).

From the 1990s water utilities in many countries have emphasised water security as populations have continued to increase but the total capacity of dams and rivers has largely either remained the same, or reduced due to climate change and pollution (Bell, 2015; Furlong, et al., 2016a). Water utilities in many parts of the world have thus looked towards alternative water supply options such as desalination and wastewater and stormwater reuse (Furlong, et al., 2017; Ghaffour, et al., 2013).

Since the beginning of the 21st century multi-functional green infrastructure, such as wetlands, swales and biofiltration systems has been increasingly popular across the world (Brown, et al., 2009; Mathews, et al., 2015). These systems treat, direct and retain stormwater within urban landscapes, and can provide a variety of benefits including: protection of waterways and bays, flood reduction, recreation, amenity, and cost savings in comparison to upgrading underground sewerage and drainage networks (Green Surge, 2015; Wong, 2006).

One of the most well-known examples of a green infrastructure approach to urban water management is in Philadelphia, which is "the first city in the United States to attempt an entirely green approach to meeting federal regulations". This approach was adopted because it is considered to have a lower cost than upgrading the aging underground pipes in the combined sewerage and stormwater system (Fitzgerald & Laufer, 2017; Uittenbroek, et al., 2016).

Green infrastructure approaches, such as the one used in Philadelphia, can be framed in many different ways. Some of the more popular terms are included in Figure 1. These terms vary in regards to their conceptualisation of drivers, and planning methods, but all are related to multi-functional green infrastructure.

The term "Green Infrastructure" implies that the green assets within a city provide valuable and tangible services, similar to dams, pipes, roads, electricity and telecommunications networks (Green Surge, 2015). Green infrastructure can be framed as a "Nature-Based Solution",

Figure 1 – Ways of framing multi-functional green infrastructure interventions by the urban water sector

because it replicates nature (Gulsrud, et al., 2018). The benefits they produce are therefore referred to by some in terms of the "Ecosystem Services" that nature provides (Frantzeskaki & Tilie, 2014). Many authors associate green infrastructure with "Climate Change Adaptation", because of its ability to address climate change impacts of heat and intense rainfall (Mathews, et al., 2015; Mees & Driessen, 2011).

Also any efforts by water utilities which involve holistic thinking about issues can be framed as "Integrated Urban Water Management" (Furlong, et al., 2017b), or alternatively "Water Sensitive Urban Design" because they involve altering the urban form to support water outcomes (Wong, 2006; Brown, et al., 2009). The idea that water management in general, and drainage systems in particular, need to become "sustainable", has also given rise to the terms of "Sustainable Urban Water Management" and "Sustainable Urban Drainage Systems" (Fletcher, et al., 2015).

The narrative provided up until this point, has covered the key points in the historical evolution of urban water management field. However the water sector does not exist in a vacuum and outcomes within the water sector will inevitably impact on other public sectors. The remainder of this report relates to the interconnectivity between urban water outcomes and the related fields of urban planning and public health, through the emerging "liveability agenda".

1.2 The emerging liveability agenda

In general, developed countries currently have, at least approximately, the level of hard infrastructure required to service their existing populations and climatic conditions (Infrastructure Australia, 2010; World Bank, 2016). As a result of this, the urban policy discourse within developed countries is increasingly focusing on not only what makes an area possible to live in, but also what makes an area pleasant and healthy to live in (Badland, et al., 2014; Arundel, et al., 2017).

At the same time as the shift towards green infrastructures has been taking place in the water sector, there has been a parallel shift in the fields of public health and urban planning towards recognising the impact of the built environment on human health and wellbeing (Alcock, et al., 2014). The

relationship between the built environment and human health is referred to using the concept of "liveability". Research is beginning to demonstrate that urban liveability can have significant impacts on public health outcomes, and therefore potential to impact on government health budgets (Arundel, et al., 2017).

"Liveability" is a broad term that can be used to describe anything that makes a city pleasant and healthy to live in (Holmes, 2013). Some authors and institutions define liveability even more broadly, basing the concept on Maslow's hierarchy of human needs and therefore including issues such as human connectedness and self-esteem (Johnstone, et al., 2012). For simplicity this paper focuses only on the biophysical aspects of liveability (i.e. the urban form).

Urban issues that are commonly considered to have an impact on liveability are shown in Figure 2 (Southworth, 2003; Arundel, et al., 2017). A preliminary sorting of these liveability considerations has been conducted to approximate which issues can be directly addressed by water utilities, and which cannot. In Figure 2, liveability issues that water utilities are considered to be able to have an impact on are shown in green, while areas they are unable to address are shown in red.

According to this preliminary analysis, all of the ways in which water utilities are able to have an impact on

Figure 2 – Urban issues considered to have an impact on liveability (green showing issues the water sector is able to address), derived from (Southworth, 2003; Arundel, et al., 2017)

urban liveability relate in some way to urban greenery. In recognition of this fact, many water utilities are now turning their attention to the concept of liveability, but particularly in relation to supporting urban greening (WSAA, 2014; Furlong, et al., 2017b). The extent of the water sector's role in urban liveability and greening is not yet well understood or defined (Catchlove & Ewert, 2012; Hodge, et al., 2014). However it is clear that the water sector's role in liveability and greening sits within the context of emerging threats to liveability posed by population growth and climate change.

1.3 Threats to urban liveability from urban densification, sprawl and climate change

The proportion of humanity that lives within cities is continually increasing. Between 1982 and 2015 the proportion of humanity living in cities increased from 40% to 54%, while the total number of people living in cities increased from 1.8 billion to 3.9 billion (World Bank, 2015). Such an increase in urban populations creates many challenges for public authorities who manage cities (Bjorvatn, 2000; Malekpour, et al., 2015). Increasing populations in cities lead to a combination of urban densification, where existing low density dwellings are replaced with higher density dwellings, and urban sprawl, where the geographical border of a city expands to allow for new development on the urban fringes (Furlong, et al., 2017c).

As urban areas densify and sprawl, they become increasingly impervious, reducing groundwater recharge, increasing flooding, and degrading waterways (James, et al., 2015). Densification and sprawl often leads to significant loss of trees and vegetation on both public and

private land (Hurley, et al., 2016; Brunner & Cozens, 2013). Loss of trees and vegetation can, in many cases, cause biodiversity loss for both flora and fauna (McDonald, et al., 2008; Guida-Johnson, et al., 2017). Loss of greenery and many other factors in urban areas, including number of cars, can contribute to poor air quality (Hasunuma, et al., 2014; Schindler & Caruso, 2014).

Urban surfaces such as roads, contribute to a "heat island effect" where urban areas may be as much as 10°C hotter than surrounding rural areas at certain times (Manteghi, et al., 2015). Temperature increases in urban areas are also added to by climate change, which is predicted to increase surface temperatures by 2-4°C by 2100, as well as increasing the frequency and intensity of heatwaves (National Oceanic and Atmospheric Administration, 2012).

These threats can result in negative impacts on human health and wellbeing. Degraded waterways, and loss of trees, can contribute to the following negative impacts:

- Reducing a population's likelihood to walk and cycle, increasing the occurrence of chronic diseases that are associated with sedentary lifestyles (Alcock, et al., 2014; Kendal, et al., 2016)
- Decreasing residents' sense of place and pride, and social interactions, affecting mental health (Donovan, 2017; Brooks, et al., 2016; Kendal, et al., 2016)
- Reducing connection to nature, increasing depression (Alcock, et al., 2014; Maller, et al., 2006; Donovan, 2017; Kendal, et al., 2016)
- Reducing air quality, resulting in decreased life expectancy (Correia, et al., 2013; Kendal, et al., 2016)
- Increasing heat, resulting in increased deaths from heat-waves (Kendal, et al., 2016). In some countries such as Australia, heat-waves now cause more deaths than any other natural disaster (Coates, 1996; PricewaterhouseCoopers, 2011).

Figure 3 summarises the benefits that urban greening provides to cities, which are being threatened by urban densification and sprawl.

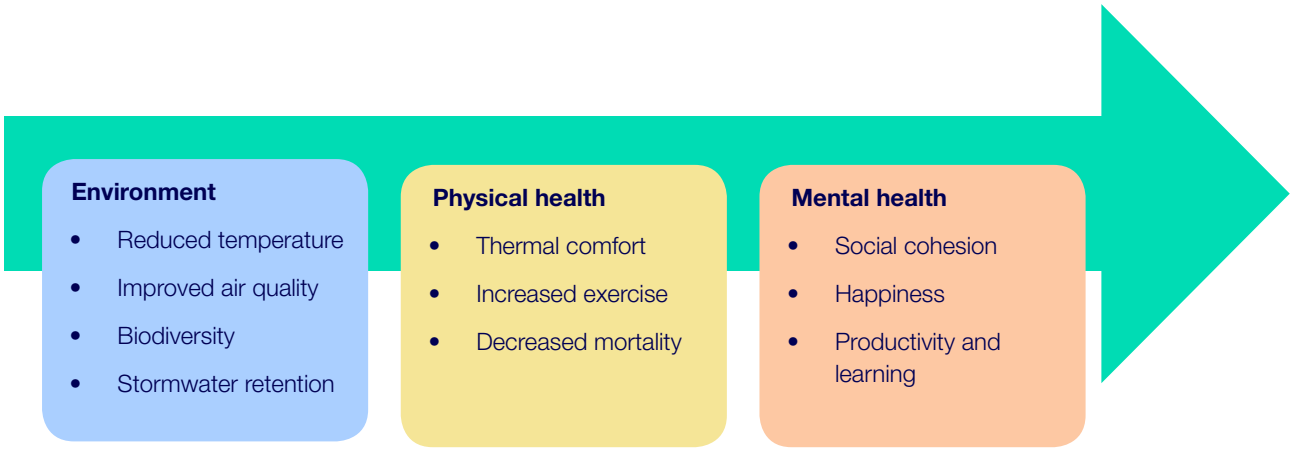

Figure 3 – Urban greening benefits being threatened by urban densification and sprawl (derived from Kendal, et al., 2016)

1.4 Role of the water sector in urban liveability and greening interventions

It is becoming increasingly recognised across the globe that urban greening can provide significant benefits to urban areas, and conversely, that the loss of urban greenery poses a significant threat to urban areas. For this reason there is a growing urgency for water utilities to begin to question and explore what role they may take in relation to protecting and enhancing urban greening in their regions, as a means of increasing liveability and supporting public health.

Table 1 provides an overview of potential actions that water utilities can take to support liveability through urban greening (Furlong, et al., 2017c). Actions 1 – 4 relate to intervention on public and water utility land and services, whereas 5 and 6 also include intervention on private land. This is particularly important because in some cities the majority of urban greenery is present on private land (Hurley, et al., 2016).

Table 1 – Potential actions that water utilities can take to support urban liveability and greening – derived from (Furlong, et al., 2017c)

Actions that water utilities can take to support urban liveability and greening	Public or private land?	Examples of interventions
1. Water security measures to protect greenery	N/A	• Wastewater and stormwater reuse projects • Protecting current irrigation sources through offsetting demands • Desalination plants, new dams, and water conservation measures
2. Greening of water sector owned and managed land and buildings	Utility land	• Planting trees on water sector owned land • Green roofs and walls on water sector buildings
3. Waterway enhancement	Public land	• Transforming concreted channels back into natural waterways • Improving vegetation and facilities along existing waterways
4. Multi-functional (green) stormwater infrastructure on public land	Public land	• Wetlands, Raingardens (biofiltration) and Swales • Water squares and parks that function as retarding basins
5. Coordination, financing and incentives to promote greening actions by other stakeholders	Public and private land	• Helping other stakeholders coordinate tree planting and construction of green infrastructures • Providing funding, or supporting funding applications by stakeholders • Providing incentives for actions by private landholders
6. Urban planning and regulation to protect and enhance greening across the public and private realm	Public and private land	• Developing/enforcing any urban planning regulation that protects and enhances liveability and greening, such as stormwater management controls to require raingardens, rainwater tanks, green roofs etc.

1.5 Aims of the research

Limited research has been conducted that compares how water utilities in different regions of the world are currently contributing to urban liveability and greening interventions. The current research begins to scope out:

a) What role does the water sector currently have in urban liveability and greening interventions?

b) What are the potential mechanisms that the water sector is able to utilise to contribute to urban liveability and greening interventions into the future?

These research questions are addressed through descriptive case studies on five cities in developed nations: (1) Barcelona, Spain, (2) Rotterdam, The Netherlands, (3) Amsterdam, The Netherlands, (4) Copenhagen, Denmark, and (5) Melbourne, Australia.

These cities were selected on the basis that: two (Barcelona and Melbourne) suffer primarily from drought, and the remaining three suffer primarily from flooding; all feature prominently in literature on water management and greening; and all participate in a variety of international networks (e.g. 100 Resilient Cities, C40, Green Surge) making for easier access to experts and documentation. Selected city case studies allow for a preliminary discussion of the research question, rather than a representative sample of cities in the developed world.

In order to answer the research questions, each case study is structured in relation to the following targeted questions:

1. What are the organisations involved in water management and urban greening?
2. What are the current contexts and emerging challenges which affect water and greening outcomes?
3. What are the main strategies and projects aimed at improving greening that relate to the water sector? (in relation to the potential actions listed in Table 1).

Methodology

In order to investigate this topic the authors have conducted a wide-ranging industry consultation to discuss the role that water sectors in each of the study locations currently has in relation to urban greening and liveability. Selection of these areas was made on the basis of a mix of drought and flooding issues within developed countries, and a preference for internationally recognised innovation and effectiveness. Part of this selection process involved developing a matrix of which European cities are involved in which international networks and research projects, such as 100 Resilient Cities, C40, and Green Surge.

Consultation has involved semi-structured interviews with 45 stakeholders from the 24 organisations listed in Table 2.

Table 2 – Organisations consulted

Country	Organisation
Australia	Brimbank City Council
	South East Water (Water/sewerage service provider)
	Melbourne Water (Bulk water/sewerage and drainage)
	RMIT University
	Department of Environment Land Water and Planning (State government)
	City West Water (Water/sewerage service provider)
	Port Phillip and Westernport Catchment Management Authority
	Wyndham City Council
Spain	Ajuntament de Barcelona (Barcelona City Council)
	Aigües de Barcelona (Public private water utility)
	University of Barcelona
	UNHabitat
	Barcelona Cicle de l'Aigua (Public sewerage and drainage utility)
	CETAQUA (Research group)
	Suez (Private organisation, major owner of Aigües De Barcelona)
Netherlands	Waternet (Water utility of Amsterdam)
	Amsterdam Municipality
	Utrecht University
	Rotterdam Municipality
	Resilient Rotterdam
Denmark	Copenhagen University
	Copenhagen Municipality
	HOFOR (Copenhagen water utility)

Meetings were semi-structured in the sense that researchers began interviews with a list of predefined questions, but then depending on the expertise of the individual and the mandate of the organisation, conversations did not always precisely follow this template. The predefined interview questions were as follows:

1. What does your organisation do?

2. How does your organisation have a role in urban greening?

Does anything you do increase greening? Do you: support others to do greening, provide water for greening, or use Nature Based Solutions?

3. What are the primary drivers behind your organisation's efforts towards greening?

Are they urban cooling, biodiversity, community health and wellbeing, or amenity?

4. How do you refer to these efforts?

Is it urban greening, Green Infrastructure, climate change adaptation, urban cooling, Nature Based Solutions, or stormwater management?

5. What is your opinion of the current level of greening in your city, and how do you measure it?

Do you measure it? How? Tree canopy coverage, or quantification of benefits? What is the general perception of current levels of greening?

6. What are you doing to increase greening?

Do you have a target/strategy or specific projects? How do you pay for projects? Are efforts working well?

7. How do/can local government, water utilities and other stakeholders work collaboratively?

Do you have any examples, or suggestions, for collaboration? Is there something that your organisation needs that another organisation can help with? What do you see as the links between "urban greening" and "urban water management"?

Notes from these meetings were used to put together a draft of the case study narratives. These narratives were then sent to stakeholders for review and validation. Minor corrections were addressed before publication of this paper.

Case Studies

3.1 City of Barcelona, Spain

3.1.1 Water management and urban greening organisations

Water supply infrastructure in the City of Barcelona is managed by a majority private company known to the public as Aigües de Barcelona (AB)[1]. This company is in charge of water security, catchment management, demand management, storage, treatment and distribution, as well as bulk sewage transfer, treatment and discharge in some areas. Barcelona Cicle de l'Aigua (BCASA) are a public utility owned by the municipality, in charge of sewerage and drainage services. As part of their drainage role, BCASA is involved in the implementation of some multi-functional retarding basins and raingardens (referred to as Sustainable Urban Drainage Systems (SUDs). BCASA are also in charge of watering public greenery, management of water features inside public parks, and management of coastline and beaches.

Aside from watering, the management of urban greenery, including tree planting, pruning, and monitoring, is the responsibility of the municipality (known as Ajuntament de Barcelona). Urban greening responsibilities are divided across several teams and departments within the municipality, including "urban planning" and "parks". The urban planning teams develop and implement policies which specify land use requirements, and allocation of public open space in the design of subdivisions and new developments. The parks department is responsible for an overarching Green Infrastructure Plan, which considers how to protect and increase greening at the municipal scale for public wellbeing and biodiversity.

3.1.2 Water management and urban greening context and emerging challenges

The City of Barcelona faces water and greening challenges that relate to (1) water security and groundwater depletion, (2) drainage and sewer overflows in the context of a steep catchment, intense rainfall, combined sewers, and popular beaches, and (3) protecting and enhancing urban greening under threat from climate change, pests and diseases.

The City of Barcelona's drinking water supply[2] predominantly comes from two major rivers which mark the North-West and South-East boundaries of the city, the Llobregat River and the Besos River respectively. Aigües de Barcelona (AB) sources municipal water supplies directly from the rivers, and also from groundwater extraction near the rivers. Both rivers have their own groundwater aquifers that mainly are linked to potable production, industrial and agricultural use.

Many industries source water directly from these groundwater aquifers. Outdated, excessive, and overly cheap private groundwater extraction licenses for industry are causing groundwater over-extraction. In the long-term there are serious risks to the area's groundwater supplies, and this means that the water source for all uses could be

[1] The corporate structure of this company is somewhat complex. This company is owned 70% by a private consortium named "Sociedad General de Aguas de Barcelona", integrated into Suez Environment, 15% by a financial entity named Criteria, integrated in La Caixa Bank, and 15% by the Metropolitan Area of Barcelona. This means that AB is predominantly owned and operated by Suez Environment.

[2] Aigües de Barcelona also supplies water to 22 other municipalities surrounding the City of Barcelona. Across the larger region water is sourced predominantly from the Llobregat basin and the Ter River basin. The Metropolitan Areas of Barcelona also has a desalination plant which can be used to supply 20% of the area's drinking water when necessary.

threatened.

Other than the drinking water system managed by AB, there is a separate 78km groundwater extraction and distribution system, as well as 3.4km of recycled water network, managed by BCASA. BCASA predominantly supplies this water for street tree and park irrigation directly from groundwater extraction within the city's area. This comes from an aquifer known as the "phreatic mantle", which is separated from the aquifers of the Llobregat and Besos Rivers, and therefore protected from industrial and agricultural over extraction. However for surrounding municipalities that do rely on the Llobregat and Besos aquifers for watering trees and parks, groundwater over-extraction poses a serious threat to the future of public greenery.

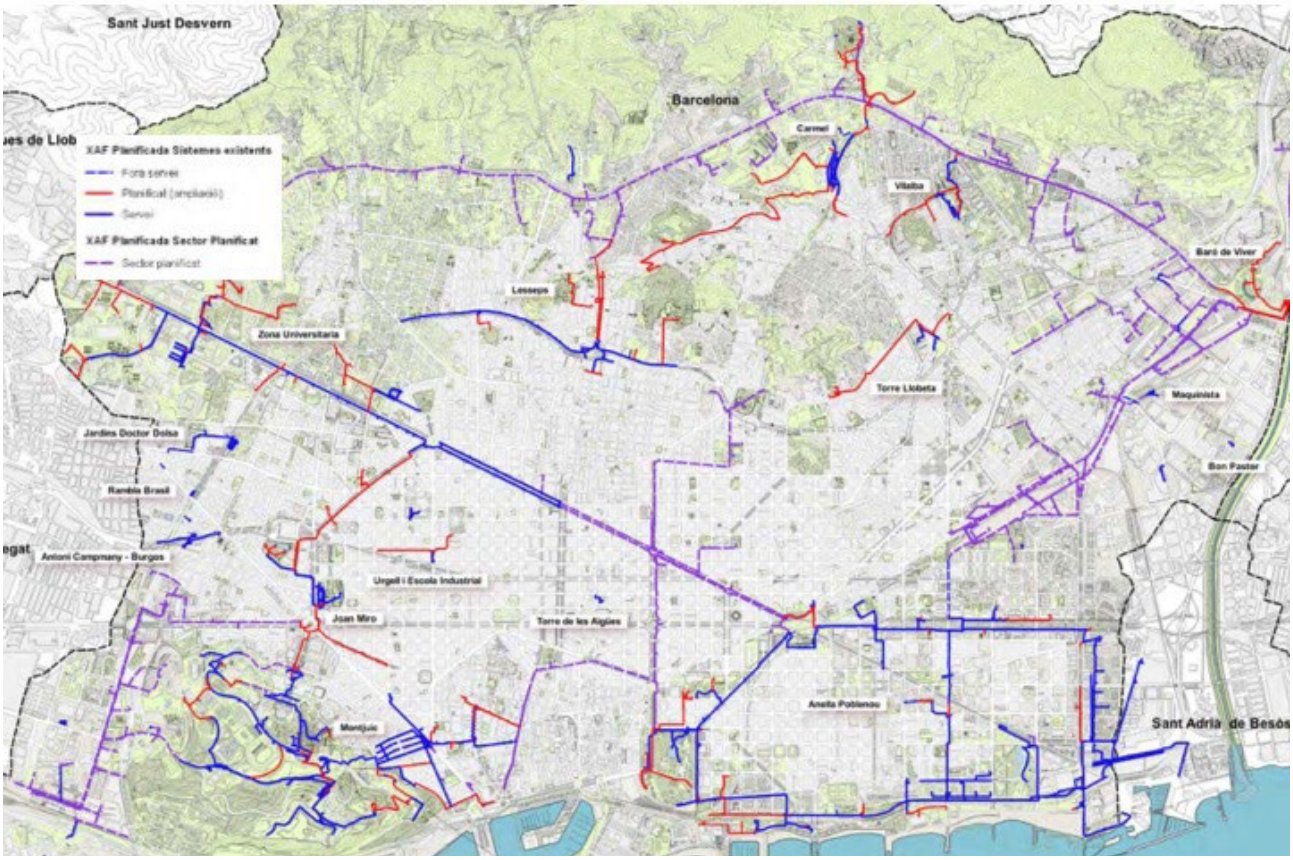

Figure 4 – Barcelona's existing and planned groundwater networks for tree and park irrigation (source: BCASA)

Barcelona also has serious drainage and sewer overflow issues due to intense rainfall and a steep catchment (500m elevation drop over 8km). Barcelona's average annual rainfall is 640mm spread across 55 rainy days. To draw contrast to this, Copenhagen has 613mm of average annual rainfall spread across 170 rainy days. This means that in Barcelona when it rains, the rainfall is generally very intense. In addition to this, Barcelona has a combined sewer and drainage network, which means that when it rains intensely the sewers overflow into the sea, directly along its popular beaches (see Figure 5). This is a major problem for the economy, as Barcelona's beaches and waterfront are important areas for tourism and recreation.

In terms of urban greening the consensus among the interviewed stakeholders is that the City of Barcelona has a lot of trees along streets (approximately 300,000), but does not have enough parks and green open space. A lot of open space in the city is either stone or clay with very little grass and shrubs. Currently urban planning controls specify for the creation of open space in new developments, but do not specify for any green elements within this space. This means that some public squares are being constructed without any trees or vegetation at all. The consensus among the consulted experts was that the major threats to Barcelona's trees are droughts, pests and diseases which can impact certain tree species.

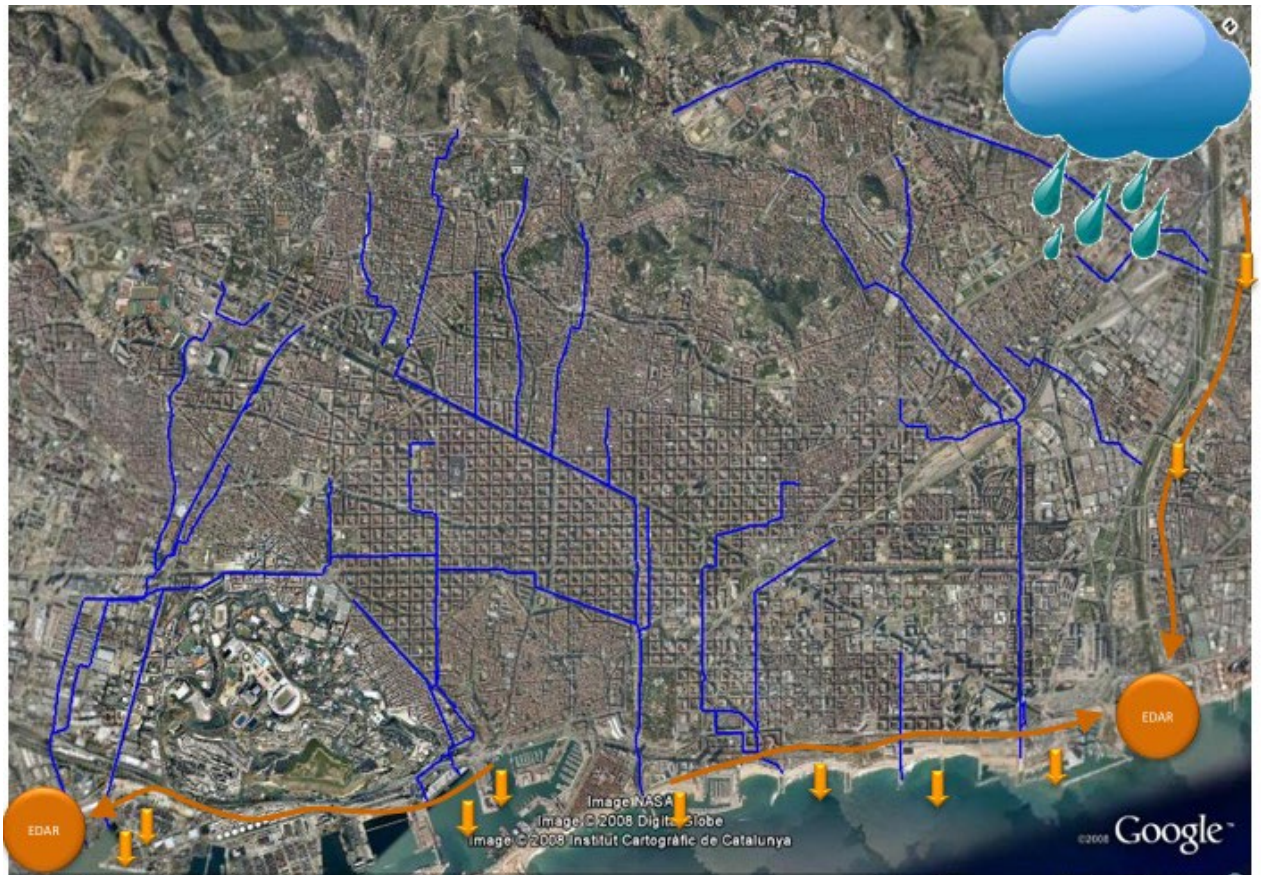

Figure 5 – Barcelona's drainage and sewerage network and overflow points (source: BCASA)

3.1.3 Strategies and projects aimed at improving greening that relate to the water sector

Currently Barcelona's water sector has a role in urban liveability and greening in the ways listed in Table 3. Water security measures such as water recycling to protect the Llobregat and Besos River aquifers relate to Action 1, biodiversity and greening initiatives on water utility managed land around the city relate to Action 2, and multifunctional drainage assets within the city to prevent sewer overflows relate to Action 4.

Table 3 – Contributions to liveability and greening interventions by Barcelona's water sector

Actions that water utilities can take to support urban liveability and greening	Major focus in Barcelona
1. Water security measures to protect greenery	✓
2. Greening of water sector owned and managed land and buildings	✓
3. Waterway enhancement	
4. Multi-functional (green) stormwater infrastructure on public land	✓
5. Coordination, financing and incentives to promote greening actions by other stakeholders	
6. Urban planning and regulation to protect and enhance greening across the public and private realm	

For cities that face risk of water shortage, any action to increase water security also supports urban greening. In Barcelona the Llobregat and Besos River groundwater aquifers are facing serious threat from over-extraction by industry, and therefore all water uses that source water from these aquifers are at risk, including the watering of parks and street trees in neighbouring municipalities. The main strategy for reducing groundwater extraction from

AB has been to provide recycled water for industrial and agricultural users, so that they do not have to rely on groundwater. Some parks and agricultural areas around the city are currently supplied with recycled water from a 3.4km recycled water network.

Implementation of recycled water projects in Barcelona has been somewhat challenging. An indirect potable recycling project was constructed in the previous drought to bring treated wastewater effluent from downstream end of the Llobregat River, back upstream so that it can be used again. For many years this project was not utilised due to a lack of political will, but an accord in January 2018 indicates that the project may soon become operational.

Other schemes to supply to industrial users and agricultural users have had limited success. This is because industrial and agricultural users have access to cheap groundwater. In order to force these users to reduce groundwater use, a unified regulatory approach by the various levels of government is necessary. However this is very difficult because Barcelona has five different levels of government: city, metropolitan area, region, state, national (and European Union). Fragmented government has been one of the major hurdles to solving the groundwater problem.

In contrast to the water recycling challenges faced in Barcelona, stakeholders made reference to extremely successful initiatives in the neighbouring city of Alicante. In Alicante the importance of recycled water to urban greening is so well acknowledged that a comprehensive urban greening strategy was completed in conjunction with a comprehensive water recycling strategy, and now 70% of parks within Alicante have a recycled water supply.

The water sector in and around Barcelona also engages in a variety of activities to support biodiversity and greening on water utility owned and managed land. Water utility land such as water treatment plants has recently had “butterfly gardens” and other biodiversity features installed, to help support local endangered species. In the City of Barcelona, BCASA and the municipality are working to replace decorative fountains within parks with semi-natural ponds to support local animals such as frogs.

Figure 6 – Raingarden in the City of Barcelona, managed by BCASA (source: author photo)

In order to address sewerage overflow issues, BCASA has been investigating and constructing some multi-functional drainage assets. These include retarding basins that also function as public open space when they are not full of water, and raingardens that support urban greening and biodiversity (see Figure 6). These efforts are concentrated

in the upper catchments of the City of Barcelona, as well as new infill developments, to retain stormwater before it enters the combined sewerage system.

In combination, protection of groundwater aquifers, installation of multi-functional parks, raingardens, water features and butterfly gardens demonstrate that actions by Barcelona's water sector are contributing significantly to liveability and greening outcomes within the City of Barcelona, and the broader metropolitan area.

3.2 Rotterdam, the Netherlands

3.2.1 Water management and urban greening organisations

In the Netherlands, water management responsibilities are divided between water supply companies, municipalities who manage sewers, and water boards who manage sewage treatment and the various rivers and canals that run across the country. This typical division of responsibilities is the case in Rotterdam. Urban greening is predominantly the responsibility of the municipality. However there are many examples of multi-functional assets, such as dykes that double as parks, and retarding basins that double as sporting facilities, that require integrated management from the municipality, the water board, and in some cases also the Port authority (Municipality of Rotterdam, 2017a).

3.2.2 Water management and urban greening context and emerging challenges

Rotterdam faces some water supply security issues, but the core water issue for Rotterdam is river flooding, from upstream rainfall, and downstream sea level rise. 80% of Rotterdam sits below sea level (Municipality of Rotterdam, 2017a). Before addressing the urban greening context within Rotterdam, it is first important to explore the flooding and flood infrastructure context for the region, as this has been the driving force behind water sector interventions which have affected liveability and urban greening within the city.

The responses to flooding threats within Rotterdam, with major funding and planning from the national government, have been using dykes that raise the height of the river bank and the coast. The river itself runs by gravity to the ocean, at a higher elevation than the city around it. Because the city sits not only below sea level, but also below the river, this means that the city's dykes are essential to its existence. Interestingly, in the event of a dyke failure and city flood, the safest and highest points in the city are along the river bank (see Figure 7).

Figure 7 – Elevation of Rotterdam (red indicating high, and blue low) showing the riverbank as the highest point (Source: City of Rotterdam)

The connection between the river and the sea is only blocked during storm surges. This is done using an innovative piece of infrastructure shown in Figure 8 below, also with major planning and investment from the national

government. This approach has been taken because Rotterdam is a very important port – the biggest port in Europe – so that it is imperative to have easy access between the sea and the river the majority of the time.

Rotterdam also has a combined sewer system, meaning that stormwater is directed into sewers. During storm events this inevitably leads to untreated sewerage overflows. This provides another incentive to reducing stormwater volumes (Geerse & Lobbrecht, 2002).

Rotterdam is one of the greenest cities in the Netherlands, with 19.7% of its area covered by green space, and a total of 747,000 trees on public land (Frantzeskaki & Tilie, 2014). During World War 2 Rotterdam was severely damaged by German bombing, and so the majority of the city had to be rebuilt with modern buildings. As a result of this, 75% of Rotterdam's roofs are flat, which has led to a facilitating environment for green roofs.

Figure 8 – How Rotterdam stops storm surges from raising the height of the river (Source: City of Rotterdam)

3.2.3 Strategies and projects aimed at improving greening that relate to the water sector

Currently Rotterdam's water sector has an impact on urban liveability and greening in the ways shown in Table 4, all of which are aimed at mitigating flooding. Greening of water utility and government buildings relates to Action 2; multi-functional drainage assets within the city, including water squares and dykes, relates to Action 4; and education and provision of incentives to promote roof gardens on private buildings relates to Action 5.

Table 4 – Contributions to liveability and greening interventions by Rotterdam's water sector

Actions that water utilities can take to support urban liveability and greening	Major focus in Rotterdam
1. Water security measures to protect greenery	
2. Greening of water sector owned and managed land and buildings	✓
3. Waterway enhancement	
4. Multi-functional (green) stormwater infrastructure on public land	✓
5. Coordination, financing and incentives to promote greening actions by other stakeholders	✓
6. Urban planning and regulation to protect and enhance greening across the public and private realm	

In 2001 Rotterdam's authorities developed their first "Water Plan", which involved 10 weeks of lectures and workshops with a variety of practitioners including engineers, architects and urban planners. Between 2005 and 2013 a lot more strategic work was done, and then

in 2013 Rotterdam released its "Climate Adaptation Strategy". Since then Rotterdam has had a systematic approach to dealing with flooding in the city through dykes, parks, greening, water sensitive designs such as increased permeability, and education.

Green roofs have been a particular focus for Rotterdam (Mees & Driessen, 2011; Municipality of Rotterdam, 2017b). Rotterdam currently has more than 500 green roofs, resulting in a total of 250,000m^2 area. 30,000m^2 of this area is present on "Dak Park", meaning "roof park" (see Figure 9). This has been achieved through (a) partnerships between public organisations, (b) incentives, and (c) education and public events. As it functions as a dyke, as well as reducing stormwater to the combined sewer system, Dak Park has been planned and completed as a collaboration between Rotterdam's water board, the municipality and the developer. To promote roof gardens on private buildings the municipality has since 2010 subsidised the construction of roof gardens to the amount of 25 Euro/m^2, for 10m^2 or more and over 15L/m^2 storage.

Figure 9 – Rotterdam's largest green roof known as "Dak Park" meaning "Roof Park" (source: City of Rotterdam)

There has also been a series of demonstration roofs, and events. In 2015 Rotterdam had its first green roof day, with 45 roofs open to the public. It has now become an annual tradition with up to 10,000 visitors per day. The green roof program assists with not only flooding, but also biodiversity, heat, noise reduction, and air pollution. Interviewed experts expressed the view that the culture of the city has adopted green roofs to the point where incentives are no longer necessary.

Rotterdam has also implemented a variety of multi-functional drainage assets, which store water during rainfall, but can otherwise be used for other purposes. Key examples of this are its "water squares" (see Figure 10), and a large car park which is divided into space for cars and space for water storage (see Figure 11). While water squares are not often particularly green or vegetated, they do however contribute to liveability and public health through the provision of recreation and sporting facilities. The underground car park does not contribute directly to amenity or greening, but provides important and interesting context to the integrated flood mitigation approach implemented by Rotterdam's municipality and local Water Board.

Taking all of these initiatives into account, it can be seen that water challenges, and initiatives to address them, have significantly influenced liveability and greening outcomes within Rotterdam, and contributed positively to public health outcomes through these changes to the built form.

Figure 10 – One of Rotterdam's many "water squares" which retain water during rainfall but are otherwise used for recreation (source: City of Rotterdam)

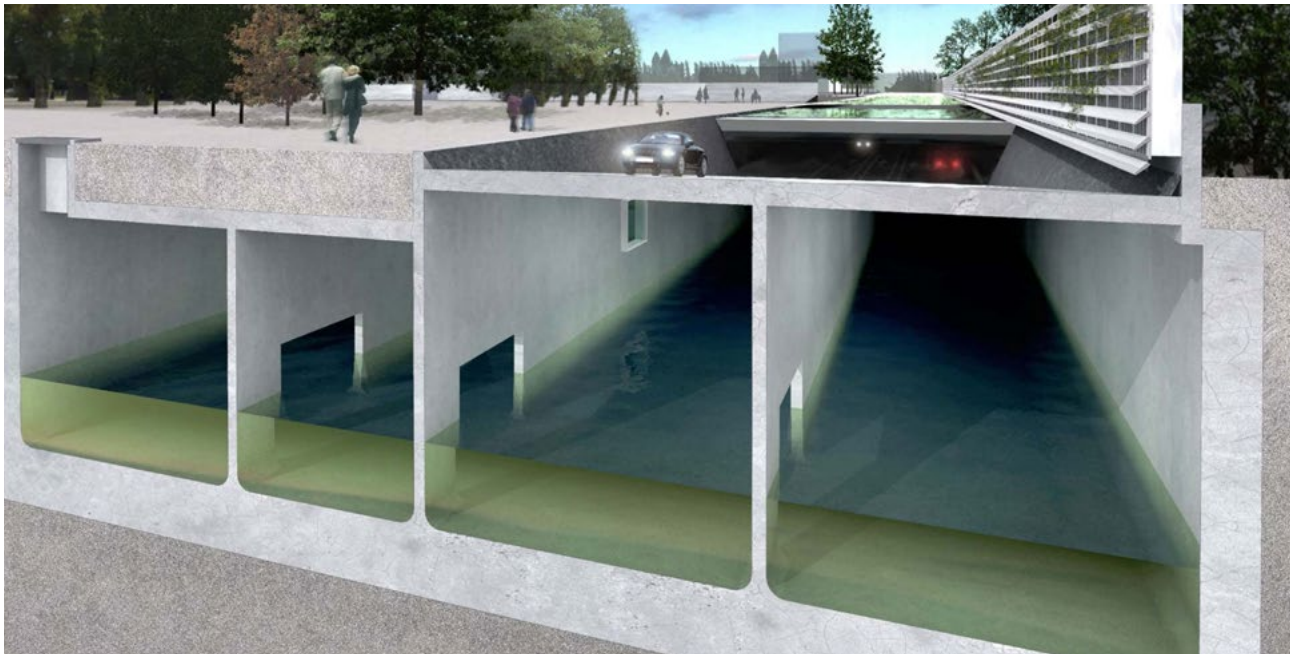

Figure 11 – Illustration of Rotterdam's multi-functional car park, of which half the volume is reserved for flood storage (source: City of Rotterdam)

3.3 Amsterdam, The Netherlands

3.3.1 Water management and urban greening organisations

As stated in section 3.2.1, water management responsibilities in the Netherlands are typically divided between water supply companies, municipalities who manage sewers, and water boards who manage sewage treatment and the various rivers and canals that run across the country. Amsterdam is unique in that the municipality and the water board have outsourced their tasks to a single public water services company named "Waternet", which makes it the country's first integrated water and sewerage service provider.

In Amsterdam, urban greening is predominantly the responsibility of the municipality. However there are various examples of multi-functional green infrastructure assets such as: "polderdaken" (a combination of water storage and a green roof); projects in which water storage is installed

below tram tracks; and nature-based solutions in parks or community gardens (Amsterdam Rainproof, 2017a). In such cases intense collaboration occurs between the municipality and Waternet. Also, a great emphasis is placed on citizen participation in stormwater management. For this, Waternet and the municipality have jointly created a platform called "Amsterdam Rainproof". The focus of this platform is to stimulate collaboration and development of rainproof measures by connecting citizens and businesses (Amsterdam Rainproof, 2017b). Waternet also becomes involved in some urban planning processes in collaboration with the municipality, which can require green stormwater measures on private land.

3.3.2 Water management and urban greening context and emerging challenges

In Amsterdam, there are no serious issues with water security. The city is below sea level, and intersected by a series of man-made canals and waterways which also sit below sea level. Waternet manages the height of these waterways through an intricate system of pumps and locks (Municiaplity of Amsterdam, 2013). Most of Amsterdam, other than the Central Business District has separated drainage and sewer systems, and sewers are built with enough storage capacity, meaning that sewer overflows from flooding are not a significant issue.

Amsterdam is also a green city, with many famous parks and 270,000 street trees. In total the municipality manages one million trees across streets, graveyards, sporting areas, and parks (Municipality of Amsterdam, 2017). However the municipality faces a number of challenges in regards to the management of urban greenery, and these challenges provide important context for exploring the strategies and projects the city is undertaking, which are discussed in the following section. These challenges relate to (a) population growth, (b) funding for maintenance, and (c) lack of resilience to diseases due to lack of species diversity.

Municipality staff consulted during this research expressed concerns with protecting and enhancing greenery in the context of population growth, expressing a view that trees should be increased as population increase, and green wedges around the city need to be protected through zoning. The municipality aims for a "lobbe stad" (green fingers) city design, which means radial linear green spaces extending out from the centre of the city.

Municipality staff expressed the view that public authorities (politicians at all levels of government) are generally able to find sufficient funds for new greening projects and trees (30M Euro has been allocated over 4 years). However according to these staff there is a chronic deficiency in funding for maintenance, because allocating funding for maintenance does not have the same public appeal as allocating funding for new projects. Consulted experts were also concerned about threats to tree health, and picking resilient species. Trees, such as the European Ash, are being affected by diseases (Harper, et al., 2016), and consulted staff expressed the view that no one has a clear strategy for dealing with this issue.

3.3.3 Strategies and projects aimed at improving greening that relate to the water sector

Currently Amsterdam's water sector has an impact on urban liveability and greening in the ways shown in Table 5. Greening of water utility and government buildings relates to Action 2; multi-functional drainage assets within the city, including green tram tracks and green infrastructures in parks, relates to Action 4; education, mainstreaming and provision of incentives to promote roof gardens on private and public buildings relates to Action 5; and urban planning controls to require water neutral developments relates to Action 6.

Table 5 – Contributions to liveability and greening interventions by Amsterdam's water sector

Actions that water utilities can take to support urban liveability and greening	Major focus in Amsterdam
1. Water security measures to protect greenery	
2. Greening of water sector owned and managed land and buildings	✓
3. Waterway enhancement	
4. Multi-functional (green) stormwater infrastructure on public land	✓
5. Coordination, financing and incentives to promote greening actions by other stakeholders	✓
6. Urban planning and regulation to protect and enhance greening across the public and private realm	✓

A variety of contextual factors in Amsterdam have resulted in a less capital intensive (expensive) approach to flood mitigation than that adopted in Rotterdam (see section 3.2.3). The threat of flooding was less serious, and while there was some political support for action, there was not enough support to enable the construction of large expensive infrastructure projects. As a result of this, Waternet and the municipality had to look to a variety of lower cost approaches to address the challenges of intense rainfall, such as public education and urban planning regulations.

The key example of efforts by the water sector towards supporting urban greening has been the "Amsterdam Rainproof" program, which involves community engagement, and mainstreaming green infrastructure measures in all public and private activities in streets, parks, gardens and roofs through working with all public and private stakeholders to influence outcomes. Cloud-bursts has been on the political agenda since July 2014, but already before this time Waternet was busy getting attention for the issue of urban flooding. The core principle behind the program is the idea that addressing extreme rainfall is the responsibility of all residents, businesses and public entities within the city. Public awareness and mainstreaming campaigns for the program were funded by Waternet, but conducted by a separate entity, using different branding. Consulted stakeholders consider the education program as being very successful; in general now "everyone knows" about this issue.

Figure 12 shows an example of imagery utilised by the Rainproof program. This image conveys the message that rainwater can be retained at various points in the catchment, including both public and private property.

Aside from the Rain-proof program, other examples of efforts to increase urban greening include: the greening of public buildings; providing funding subsidies for greening, including roofs, gardens and nature strips (predominantly arranged through the municipality, but Waternet also provides funding if the greening provides stormwater benefits, and especially if projects are within priority flood

Figure 12 – Example of marketing material from Waternet funded Rainproof program (source: Waternet)

areas); and an urban planning regulation that requires new buildings to be "water neutral" for rainfall of less than 60mm (in 48 hours), by retaining water on-lot. This planning regulation has been in place since 2015.

There are also some private initiatives such as "Rooftop Revolution" that support and implement green roof projects. Although not specifically related to urban greening, another interesting example of a private initiative is "Heaven's Water Beer", a private company that collect rainwater from private and public properties, such as hotels, and big roofs in parks, and use this water in their brewery to make beer. These types of private initiatives indicate a growing awareness of water issues within the community, and willingness to participate in contributing towards solutions.

In combination, the strategies and projects adopted in Amsterdam demonstrate a lower-cost approach to addressing flood-mitigation, and contributing towards urban liveability and greening through awareness raising and urban planning regulations.

3.4 Copenhagen, Denmark

3.4.1 Water management and urban greening organisations

In Copenhagen water supply, sewerage and drainage are all built and managed by HOFOR, a government owned corporation that was separated from municipalities in 2012. HOFOR also has a variety of other functions including district heating and cooling, gas supply, and wind power production. HOFOR is responsible for implementing green infrastructure throughout Copenhagen as part of works to make the city resilient to intense rainfall, known in Denmark as "Cloudburst" events.

The Copenhagen municipality is in charge of street trees and parks, and also developing overarching drainage and wastewater strategies for HOFOR to implement. Also the municipality is in charge of taking over ownership of green infrastructure after it is constructed by HOFOR, and in many cases is then in charge of the final stages of the projects, such as planting and beautifying, after the hydraulic works are completed. This makes the interface between the City of Copenhagen and HOFOR extremely challenging. In contrast to HOFOR's technocratic infrastructure planning approach, the municipality adopts a planning approach which incorporates more community engagement and environmental planning.

3.4.2 Water management and urban greening context and emerging challenges

The primary water challenge in Copenhagen is flooding. Two major flooding events in 2011 and 2014 ("1 in 1000 year" and "1 in 400 year" events respectively) resulted in significant damage to the city, particularly around flooding in basements and the ground floor of structures, across many areas of the city. These events are referred to in Copenhagen as "Cloudburst" events.

90% of Copenhagen has combined sewers, which mean that during heavy storms the sewers overflow. Although this does not occur very often, and there are warning systems in place to avoid public health issues around swimming.

Another challenge is that, according to the consulted experts, Copenhagen does not have as many trees as public authorities would like it to have. Currently Copenhagen has a tree canopy cover of approximately 10%, and authorities would like this to be increased to 20%. Consulted experts expressed a view that they believe Copenhagen's streets are not as green as the other cities considered in this study (e.g. Amsterdam, Rotterdam and Melbourne).

Historically the city always had an interest in being "green", but this referred to renewable energy, and reducing pollution. For these reasons the city was named the European Green Capital in 2014. However the municipality has only recently turned their attention towards the implementation of biophysical greenery (trees and vegetation) (Gulsrud, 2015). One of the major drivers for this growing attention towards trees and vegetation has been as part of a multi-functional green infrastructure approach to flood-mitigation, framed under climate change adaptation and resilience.

3.4.3 Strategies and projects aimed at improving greening that relate to the water sector

Currently Copenhagen's water sector has an impact on urban liveability and greening in the ways shown in Table 6. Development of 300 green stormwater management projects on public land relates to Action 4; and provision of free trees for residents to plant on private land relates to Action 5.

Actions that water utilities can take to support urban liveability and greening	Major focus in Copenhagen
1. Water security measures to protect greenery	
2. Greening of water sector owned and managed land and buildings	
3. Waterway enhancement	
4. Multi-functional (green) stormwater infrastructure on public land	✓
5. Coordination, financing and incentives to promote greening actions by other stakeholders	✓
6. Urban planning and regulation to protect and enhance greening across the public and private realm	

Table 6 – Contributions to liveability and greening interventions by Copenhagen's water sector

Copenhagen's approach to stormwater management and green infrastructure has involved a focus primarily on publicly funded projects in the streetscape and parks. This is in stark contrast to Amsterdam's approach of community education, mainstreaming, urban planning regulations and incentives for actions on private and public land.

Copenhagen's program has involved 11.5 Billion Danish Kroner (Approx. USD $2B) of HOFOR funding to build 300 projects (see Figure 13), with the aim of increasing the resilience of the city's drainage system from a 1 in 10 year rain event, to a 1 in 100 year rain event (with less than 10cm of water in streets).

Figure 13 – Map showing the location of the 300 projects across Copenhagen (source: City of Copenhagen, 2016)

The location of projects has been rigorously designed through world-leading city-wide flood modelling, and the separation of city neighbourhoods into connected sub-catchments. Each sub-catchment has flood-mitigation targets, which have then informed the number and design of stormwater management projects to be constructed in the area. This means that if, for any reason, a particular project is unable to be implemented, HOFOR and the municipality then have to adapt other projects, or add new ones, to meet the original flood-mitigation targets.

Figure 14 – Concept design for Copenhagen detention road (top image) which is designed to become an open water body during intense rain (bottom image) (source: City of Copenhagen)

These 300 projects can be divided into (1) stormwater roads, (2) detention roads, (3) green roads and (4) detention areas. Stormwater roads involve a re-profiling of roads so that they slope towards the middle of the road, allowing them to become canals during intense rainfall. Detention roads are larger roads that both convey and detain stormwater through a network and green and blue spaces (see Figure 14). Green roads are smaller and sometimes shared private roads which incorporate some green elements to retain water locally. Detention areas are constructed into public open space, so that during intense rainfall events they transform into open water bodies (see Figure 15). All of these projects other than stormwater roads, are likely to involve significantly increased greenery throughout Copenhagen, predominantly funded by HOFOR, the water utility.

As of mid-2017 approximately 40 of the 300 planned projects have begun construction. The biggest hurdle to the implementation of these projects is the collaboration between HOFOR and the municipality. Although there are no bad intentions on either side, there are a number of issues being experienced. Most importantly, the funding that HOFOR has been allowed to use is enough to cover the hydraulic works, but not enough to cover all of the greening and amenity works. Consulted stakeholders expressed that an additional 10% funding (~USD$200M) is needed for this amenity works, and stakeholders are unsure where this money will end up coming from. Either HOFOR or the municipality could potentially raise bills over time

Figure 15 – Concept design for detention area in Enghaveparken park in Copenhagen (top image) that turns into open water body during intense rainfall (bottom image) - (source: http://citiscope.org/story/2016/why-copenhagen-building-parks-can-turn-ponds)

to pay for this shortfall. In some rare cases philanthropic organisations have added additional funds to projects to increase amenity.

Other than this, the City of Copenhagen has also approved a plan for 100,000 more trees in streets and parks. Also there is a program called "the partnership tree program" run by the municipality to give citizens trees to plant on their private property. The citizens receive the tree for free and in return are tasked with planting and caring for the tree over 3 years. It is likely that over time the municipality will implement more incentives for greening of private properties.

These projects in combination will, when completed, have a major impact on the liveability of Copenhagen. Major increases to urban greenery will be associated with the 300 stormwater projects being implemented by HOFOR. These amenity improvements will have positive impacts on public health within the city.

3.5 Melbourne, Australia

3.5.1 Water management and urban greening organisations

Water infrastructure in Melbourne is managed by four water utilities and 32 municipalities. Melbourne Water is the bulk water, sewerage and drainage provider (managing the dams, and the large sewerage treatment plants and drainage pipes), as well as the waterways authority. City West Water, Yarra Valley Water and South East Water are the customer interfaces for the water supply and sewerage systems, managing the reticulation and collection systems which connect houses to dams and sewerage treatment plants (Furlong, et al., 2016b). Melbourne's 32 municipalities manage small scale drainage (from a catchment size of less than 60 hectares).

In Melbourne urban greening is primarily the responsibility of municipalities. Melbourne's 32 municipalities vary significantly in terms of socioeconomic and biophysical circumstances, with eastern suburbs being more affluent, than those in the west. Municipalities in Melbourne plant, water and maintain trees and vegetation in public streets and parks. They produce street tree plans to guide tree planting location and replacement. Some councils also undertake community education activities to encourage greening. Six of Melbourne's municipalities have produced "Urban Forest Strategies" which attempt to consider urban greening from a holistic perspective to protect and increase their urban forests and identify appropriate implementation mechanisms for protecting and increasing tree numbers. For example, several municipalities have amended their residential development regulation controls (approval processes for building new homes) to require developers to

retain and/or plant trees in private gardens in the front and back of properties (Phelan & Hurley, 2016).

3.5.2 Water management and urban greening context and emerging challenges

Major water and greening challenges for Melbourne include (1) drought, (2) stormwater and waterway health, and (3) inequality across the city in terms of access to urban greenery.

Melbourne sources the majority of its water supply from protected catchments in the hills to the north east of the city. These traditional supplies are threatened by reductions in long-term average rainfall due to climate change, and also dramatic population growth, from 4.5M people in 2017 to an estimated 8M people in 2050 (Victorian Government, 2017). In the recent Millennium Drought (2000 - 2008) water restrictions were required which resulted in intense damage to greenery in parks, sporting facilities as well as private gardens.

To address this, Melbourne has constructed a large (up to 150GL/year, which is one third of total demand) desalination plant as an insurance policy against drought, which is expected to ensure reliable water supplies up until somewhere between 2030 and 2065 depending on uncertainties. Melbourne has also constructed a variety of small scale stormwater harvesting schemes within parks, and also non-potable supply of recycled water to residences within new suburbs on the cities fringes for garden watering and toilet flushing, and also for nearby agriculture (Furlong, et al., 2017).

Melbourne has a number of factors that make stormwater and waterway health challenging. Melbourne is facing rapid geographical expansion due to population growth, which creates additional impervious areas and therefore more stormwater. It is also located on a bay with constrained inflow and outflow, which makes both wastewater and stormwater treatment a priority in order to avoid a build-up of pollution in the bay (see Figure 16 below). For these reasons Melbourne has been a focal point in the development of the "Integrated Urban Water Management" (IUWM) and related "Water Sensitive Urban Design" (WSUD) ideologies as ways to reduce reliance on dams for water supply, minimising the damage of city expansion to the environment, and also reducing nutrient loads from wastewater and stormwater into waterways and the bay (Brown & Clarke, 2007; Ferguson, et al., 2013).

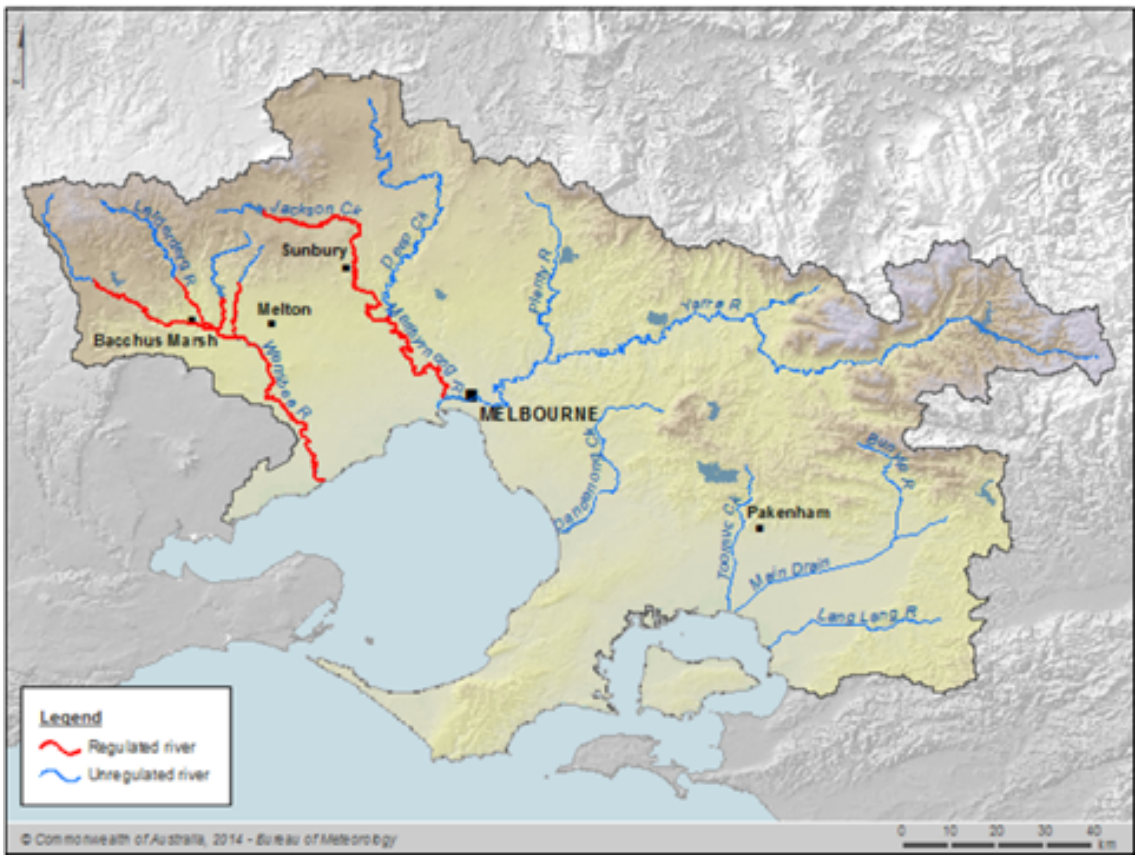

Figure 16 – Map showing Melbourne's major rivers discharging into Port Phillip Bay, which has constrained flow, making a build-up of pollution a serious concern (source: www.bom.gov.au)

In terms of conventional urban greening (trees and vegetation), in general central and inner-eastern Melbourne are far greener than western Melbourne. By comparison, Melbourne's western suburbs have less rainfall, fewer trees, poorer soils, and poorer mental and physical health (LeadWest, 2010). Recent research suggests that tree canopy cover increases, almost in a linear manner, from the western municipalities of Melbourne (e.g. Wyndham at 3.1% cover), to the centre (e.g. City of Melbourne at 12.9% cover), to the north eastern (e.g. the semi-rural area of Yarra Ranges at 77.2% cover) (Institute for Sustainable Futures, 2014), see Figure 17.

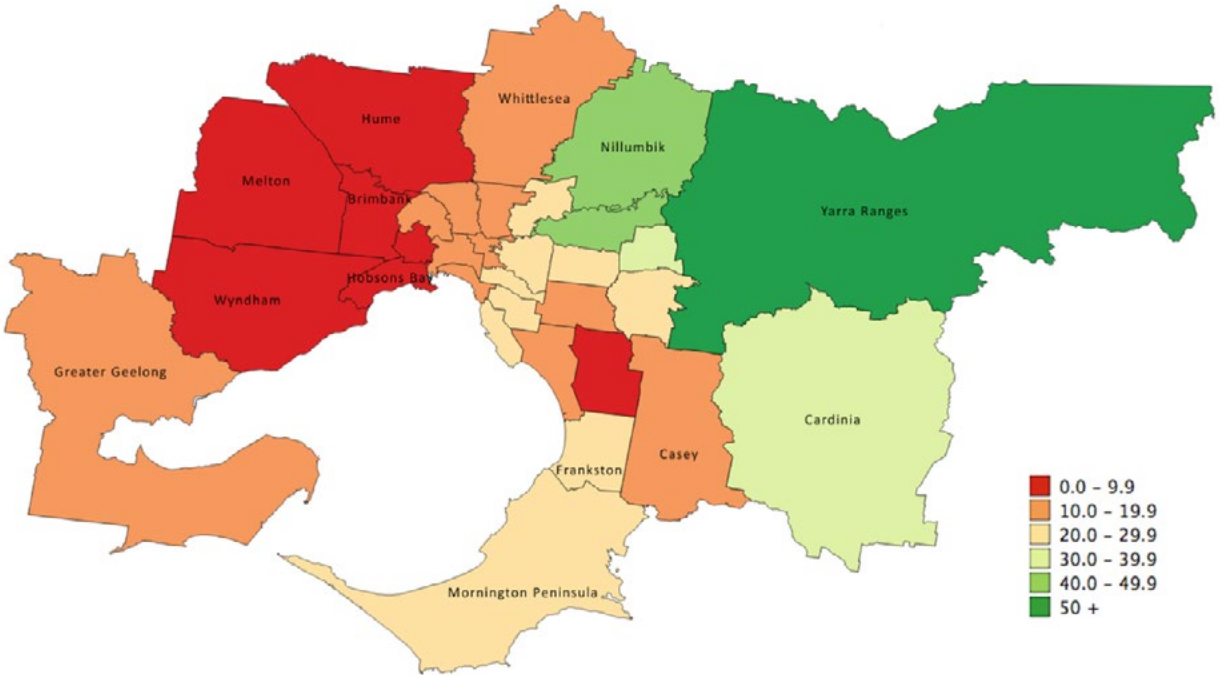

Figure 17 – Comparative levels of tree canopy cover (% of total area) in Melbourne's Local Government Areas (Institute for Sustainable Futures, 2014)

In the future Melbourne's urban greenery in public streets and parks is likely to remain relatively stable, but the level of greenery in private gardens will continue to decrease over time as urbanisation and densification continues. This is a major problem because research suggests that the majority of trees exist on privately owned land (Daniel, et al., 2016). Additional efforts are therefore needed to increase the level of greening on public land, and limit the reduction of greening on private land to prevent damaging impacts on public health and biodiversity.

3.5.3 Strategies and projects aimed at improving greening that relate to the water sector

Currently Melbourne's water sector has an impact on urban liveability and greening in the ways shown in Table 7. Recycled water, stormwater harvesting and desalination relates to Action 1; tree planting on water sector land relates to Action 2; drain naturalisation and stabilisation relates to Action 3; wetlands and raingarden construction relates to Action 4; coordination through the Greening the West initiative relates to Action 5; and urban planning regulations relate to Action 6.

Table 7 – Contributions to liveability and greening interventions by Melbourne's water sector

Actions that water utilities can take to support urban liveability and greening	Major focus in Melbourne
1. Water security measures to protect greenery	✓
2. Greening of water sector owned and managed land and buildings	✓
3. Waterway enhancement	✓
4. Multi-functional (green) stormwater infrastructure on public land	✓
5. Coordination, financing and incentives to promote greening actions by other stakeholders	✓
6. Urban planning and regulation to protect and enhance greening across the public and private realm	✓

Reliable water supplies are essential for urban greening. During Melbourne's Millennium Drought public green space suffered dramatically from water restrictions. Therefore any efforts by the water sector towards water security contribute to the protection and promotion of urban greening. In this regard the major desalination plant, and variety of wastewater and stormwater reuse projects provide an alternative water source which is available during times of drought and water scarcity. Currently it is common practice for Melbourne's water utilities to equip many new developments (on the fringes of the city near wastewater treatment plants) with a source of reuse water which is plumbed into houses, businesses and parks, for gardening purposes and some indoor uses such as toilets and laundry. While it is difficult to determine exactly how many lots will eventually have recycled water connected, strategic documents suggest it could be in the region of 150-300 thousand properties, across the west, north and eastern fringes of the city.

In comparison to the other case studies in this research, Melbourne is unusual in terms of how much land the water sector owns and manages. Melbourne Water is considered to be the second biggest landholder in the State of Victoria, after public land. For this reason Melbourne Water has recently begun an "Urban Cooling" program which aims to plant trees across 30ha of its land, and it is hoped that these direct greening works will increase into the future.

One example of a major greening project on water utility owned land is "Greening the Pipeline". Melbourne Water, Wyndham City Council, City West Water and VicRoads are currently investigating the feasibility of transforming a decommissioned 27km sewerage transfer asset ("Main Outfall Sewer") into a linear park and high quality bike-path connecting the western suburbs to the Central Business District (see Figure 18).

Figure 18 – Greening the Pipeline pilot park on a small section of the 27km pipeline (Source: Melbourne Water)

Melbourne's water sector directly protects and enhances urban waterways. On the remaining natural waterways, Melbourne Water conducts tree and vegetation planting to stabilise river banks and improve water quality. However, over the past 100 years, water authorities transformed many natural waterways into concreted

channels, to transfer stormwater out of the city faster. Now Melbourne's water sector is actively pursuing an agenda of returning concrete channels back into natural waterways. This process is expensive, but creates significant liveability, greening and cooling benefits. In Melbourne, the naturalisation of Upper Stony Creek (1.2km of currently concrete channel) is the most well-known of these projects, although Melbourne Water is currently considering a broad spread of naturalisation works (known as the "Reimagining Your Creek" project).

In order to address environmental impacts on Melbourne's waterways and bays mentioned in the previous section, the water sector has installed a variety of green stormwater management infrastructures such as wetlands, raingardens and swales (see Figure 19 for example).

Melbourne currently has more than 200 wetlands and more than 1000 raingardens (biofiltration systems).[3]

These stormwater management devices contribute to public greenery, biodiversity and amenity. Because Melbourne has separate sewerage and drainage systems, these stormwater management devices are not related to preventing sewer overflows, but rather focus on waterway and bay health.

These vegetated stormwater assets are implemented via two major mechanisms. The first is through planning controls which require new developments to include green stormwater management assets (funded by developers). The second is through providing financial grants to municipalities to construct stormwater assets in existing suburbs (e.g. raingardens within streets).

Figure 19 – Wetland in the central suburb of Docklands, Melbourne, Australia (source: https://www.australiaun-limited.com/science/water-for-sustainable-cities)

[3] Precise numbers are difficult to quantify, as they are recorded differently in different databases. The provided numbers are conservative.

In 2011 City West Water established a multi-organisation committee named "Greening the West" to help coordinate and facilitate liveability and greening interventions by other public organisations, particularly municipalities. This committee has 23 partner organisations including all municipalities and water utilities operating in Melbourne's west, as well as community groups, state government departments, and a number of other public organisations such as VicRoads (roads authority) and Parks Victoria (manager of large parks, reserves and forests). This group has a broad scope, including government and developer advocacy, joint funding submissions, capacity building and community engagement. Due to the diverse capability of the committee, in 2014 the Australian government awarded the group $5 million in funding. Greening the West was then able to leverage this funding to plant an additional one million trees in the parks, waterways, and drainage corridors in and around Melbourne's west (see Figure 20 for example).

Figure 20 – Recent tree planting as part of Greening the West's 1 Million Trees project (source: Greening the West)

In combination these activities undertaken by the water sector in Melbourne will have a major impact on the liveability and overall level of greenery within the city, and have positive impacts on public health.

It is also worthy of noting that in order to coordinate future projects, the Victorian State Government has released a high-level policy document named "Water for Victoria", accompanied by an "Integrated Water Management Framework", which requires the creation of "Integrated Water Management Forums" (Department of Environment, Land, Water and Planning, 2016). In Melbourne, as of late 2017, there are now five catchment-based forums which bring together senior water utility staff, the CEOs of municipalities as well as other stakeholders, to collaboratively identify and prioritise water-related liveability and resilience initiatives, including urban greening.

Discussion

4.1 Contributions from water utilities towards liveability, urban greening and public health

From the case studies considered in this research, it is clear water sectors in all of these cities are making significant contributions towards liveability and greening interventions. The types of interventions have varied across the cases studies, as shown in Table 8. It is important to recognise that contributing to more types of interventions (out of Actions 1 – 6 in the table), does not equate to a larger liveability and greening contribution overall.

In Barcelona, water utilities have been taking strong efforts to protect their groundwater aquifers through water recycling; installing natural water features and butterfly gardens in parks and treatment plants to protect biodiversity; and developing a variety of multi-functional retarding basins and raingardens.

In Rotterdam, water utilities have been greening water utility and government buildings; developing a variety of large capital intensive multi-functional green assets in public areas, such as “Dak Park” and “water squares”; and promoting green roofs on private buildings through incentives, education and public events, resulting in 250,000m^2 of green roofs.

In Amsterdam, water utilities have been greening water utility and government buildings; developing a variety of multi-functional green assets in public areas, such as storage under tram tracks and in parks; promoting a variety of interventions by private citizens and public entities through a high-profile and very successful public awareness and mainstreaming program (Amsterdam Rainproof); and have a related urban planning regulation to require “water neutral” buildings (in terms of stormwater).

In Copenhagen, water utilities have been implementing a ~USD$2B program of 300 multi-functional green infrastructure across the public realm of streets and parks; and complementing this program with the provision of free trees for residents to plant on their land.

Table 8 – Contributions to liveability and greening interventions by water sectors in the five case studies

Actions that water utilities can take to support urban liveability and greening	Barcelona	Rotterdam	Amsterdam	Copenhagen	Melbourne
1. Water security measures to protect greenery	✓				✓
2. Greening of water sector owned and managed land and buildings	✓	✓	✓		✓
3. Waterway enhancement					✓
4. Multi-functional (green) stormwater infrastructure on public land	✓	✓	✓	✓	✓
5. Coordination, financing and incentives to promote greening actions by other stakeholders		✓	✓	✓	✓
6. Urban planning and regulation to protect and enhance greening across the public and private realm			✓		✓

In Melbourne, water utilities have been:

- Implementing a variety of stormwater harvesting and recycled water projects to support greenery through water security
- Tree planting on water utility owned and managed land (e.g. Melbourne Water's Urban Cooling program)
- Naturalising and upgrading the amenity of waterways (e.g. the Reimagining Your Creek program)
- Constructing a variety of wetlands, swales and raingardens on public land through collaboration between water utilities and municipalities
- Coordinating and facilitating interventions by other stakeholders (e.g. through the Greening the West group), supporting the planting of an additional 1 million trees
- Implementing urban planning controls to require multi-functional infrastructures and trees in new developments across public and private land (funded by developers)

It is clear that all of these contributions towards liveability and greening will provide some contribution towards increasing the public health of their communities. These contributions are likely to include some combination of (actual contributions will vary between cities):

- Increased exercise, due to the increase in greenery and quality of open space, resulting in decreased chronic disease (Alcock, et al., 2014; Kendal, et al., 2016)
- Increased happiness (or conversely decreased depression), through improved connection with nature, increased pride in their neighbourhood, and increased social connections (Donovan, 2017; Brooks, et al., 2016; Kendal, et al., 2016)
- Decreased temperatures, and reduced mortality, during heat-waves (Coates, 1996; PricewaterhouseCoopers, 2011; Kendal, et al., 2016)
- Increased biodiversity, for both flora and fauna (Alcock, et al., 2014; Maller, et al., 2006; Donovan, 2017; Kendal, et al., 2016)

Importantly, water sectors do not often seriously consider or calculate public health impacts of these interventions. Almost all of these projects have been developed with the primary aim of addressing water system challenges, and have contributed to public health as an indirect benefit. The following section summarises the water system drivers that have led to these initiatives occurring.

However the authors propose that, while the public health benefits are difficult to quantify, they are neither negligible nor inconsequential. Due to the increasing recognition worldwide of links between built form and public health outcomes (Arundel, et al., 2017), and the immense amount of government budgets that are allocated to health, water utilities should pay increased attention to the public health outcomes of their initiatives, as an important end in itself, rather than only a secondary consequence.

4.2 Drivers behind liveability and greening contributions

This research has found that the drivers which have led to water sector intervention in urban liveability and greening outcomes vary depending on (a) climatic context, (b) infrastructure and physical context, and (c) governance context, of each city.

Table 9 – Drivers leading to liveability and greening interventions by water sectors in the five case studies

Drivers for water sector projects affecting urban liveability and greening	Barcelona	Rotterdam	Amsterdam	Copenhagen	Melbourne
Water scarcity	✓				✓
Flooding		✓	✓	✓	
Sewer overflows	✓				
Protection of waterways and bays					✓
Fragmented governance of greening					✓
Public health (cooling, exercise, mental health)					✓

In cities that suffer from drought such as Melbourne and Barcelona, the water utilities understand their role in urban greening as being substantially tied to water security efforts. In Melbourne recent droughts, and associated water restrictions, have damaged parks and private gardens. In Barcelona, the groundwater aquifer is at risk of depletion. In such contexts, any efforts towards water security are indirectly contributing to protecting and enhancing greening, leading to improved liveability and greening outcomes. Therefore in these cases a major driver behind action is "water scarcity".

In cities that have secure water supplies but suffer from flooding, the water sector generally directly contributes to urban greenery through green multi-functional infrastructure as a flood mitigation measure. This was the case in Rotterdam and Copenhagen, where major multi-functional assets are constructed in the public realm, with projects in streets, parks and housing developments, substantially contributing to liveability and greening in these cities. Therefore in these cases a major driver behind action is "flooding".

Infrastructure and physical contexts also have a significant effect on the role of the water sector in urban greening. Although Barcelona does not currently suffer majorly from urban flooding, the fact that the city has combined sewers, and the damaging effects of sewer overflows near the popular city beaches, has led to their efforts towards raingardens and other multi-functional drainage assets, meaning that a major driver is "sewer overflows". In Melbourne also, the water sector has taken extensive efforts towards implementing green infrastructure throughout the city, with the aim to remove pollutants (nitrogen, phosphorous, litter etc.), meaning that a major driver is "protection of waterways and bays".

The role of the water sector in urban greening also varies in accordance with the governance context of a city. In Barcelona, Rotterdam, Amsterdam and Copenhagen there is one unusually large municipality (in terms of geographical size, population and/or budget), in charge of managing the core city, and in the case of Barcelona, there is also a metropolitan government. In contrast, in Melbourne there are 32 municipalities of relatively similar geographical size, and no metropolitan government. These specific circumstances have led to water utilities in Melbourne seeing the need to support urban greening through collaborative governance at a geographical scale that is larger than any one municipality, through the "Greening the West" group, meaning that major driver include both "fragmented governance", as well as a desire to contribute to "public health" (as a primary rather than secondary aim) through increasing urban greenery and cooling.

Understanding of these drivers is important because it may help identify other cities around the world which can utilise the findings from this research, and help cities to develop responses to their drivers which are mindful of their potential role in liveability and public health outcomes.

4.3 Mechanisms through which contributions have been made

Although it is not the intention of this research to rank or quantify the contributions between the case study cities, it is possible to make some comparisons between the mechanisms through which these contributions have been made. In particular a contrast can be drawn between: (a) a capital intensive approach that focuses on major projects in the public realm, (b) a low capital approach that focuses on public education, urban planning controls and incentives in the private realm, and (c) a mix of the two.

The most obvious contrast can be drawn between Copenhagen and Amsterdam. In Copenhagen authorities have focused on projects in the public realm, through 300 projects in streets and parks, with dedicated additional funding of approximately USD$2 billion. In Amsterdam authorities have predominantly focused on mainstreaming and awareness measures across the private and public realm, through community education, capacity building, incentives and urban planning regulations (i.e. requiring "water neutral" buildings when they are constructed), but without extensive dedicated additional funding.

In Rotterdam and Melbourne a more mixed approach can be seen. In Rotterdam authorities have used a mix of large projects in the public realm, and education and incentives to promote green roofs in the private realm. In Melbourne the focus has been primarily on using urban planning controls to compel private developers to fund projects in the public areas of new developments, as the city expands geographically, and significant financial subsidies for smaller projects by municipalities.

4.4 Limitations of the research

This research has a number of limitations. Through utilising only five case studies, particularly because four

European and one Australian city is used, but no American or Asian cities are considered, it is not possible to provide a representative sample of cities across the developed world. Additionally, the level of detail provided on each of the case study cities is not quantitative, nor directly comparable across initiatives. For example in Copenhagen it is possible to provide the capital cost of projects, while in other cases this is not possible. Also, to a certain extent the understanding of drivers in each city has been limited to the subjective opinions of consulted experts within each city.

For these reasons the authors make no claims towards providing conclusive data around the role of water utilities in liveability and greening interventions across the world. These limitations do not however prevent the initial exploration of the research questions, nor negate the contribution that this research makes towards progressing policy debates across the world around what potential role water utilities can adopt within the emerging liveability agenda, and the potential mechanisms through which this can be done.

Conclusion

The research questions for this paper have been:

a) What role does the water sector currently have in urban liveability and greening interventions?

b) What are the potential mechanisms that the water sector is able to utilise to contribute to urban liveability and greening interventions into the future?

In order to answer this question the authors have developed descriptive case studies on five cities, two cities dealing with water scarcity (Barcelona and Melbourne), and three dealing with flooding (Rotterdam, Amsterdam and Copenhagen). These case studies provide interesting insights on (a) the extent of contributions by water utilities towards liveability and greening interventions, (b) the drivers behind these interventions, and (c) the methods and processes through which these contributions have been made.

All of the case study cities have shown that water utility projects are contributing to liveability and public health, through a combination of protecting or increasing urban greenery, amenity, biodiversity, and access to recreation. All of the considered initiatives will affect liveability and public health in some way, with the potential to increase exercise, decrease disease, decrease depression etc., having potentially a significant impact on government health expenditure.

However public health was generally not the primary driver behind any of these projects (other than some tree planting and green space improvements in Melbourne). The main drivers have been to address water scarcity, flooding, sewer overflows and the protection of waterways and bays. For this reason, the research has found the role of water sector in urban liveability and greening interventions vary between cities depending on (a) climatic context, (b) infrastructure and physical context, and (c) governance context.

It is therefore found that, in general, the current role of the water sector across the globe appears to be to contribute to liveability and greening interventions only as a secondary aim, while addressing other water system challenges. Although the Melbourne case indicates that in specific circumstances water sectors may be going beyond their traditional mandate of water service delivery, and considering liveability and public health improvements to be a primary, rather than secondary aim.

This research highlights the potential mechanisms by which water utilities are able to have an impact on public health through interventions in the built form, either while addressing other water system drivers, or as an end in itself. In order to consider what mechanisms are appropriate in which city, it is recommended that water utilities be active participants in public health debates, and continue to explore (a) the benefits of urban greening interventions in the built form, and (b) compare the potential of different approaches (e.g. public projects, incentives for residents, planning controls), to contribute to these outcomes.

5.1 Further research required

Through conducting this research the authors have noted a number of worthwhile future research agendas:

1. Conducting case studies on more cities, particularly in North America and Asia, to further explore the current role of the water sector in relation to urban liveability and greening interventions
2. Additional dimensions that warrant consideration in future city comparison research

   a. Quantification of public health benefits from water utility-led projects

   b. Optimisation of financial mechanisms for water utility projects that affect liveability (e.g. potential for innovative partnerships with the private sector)

   c. Design of governance, decision making and approvals processes required to ensure urban greening and liveability interventions create net community benefits

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RMIT UNIVERSITY | Centre for Urban Research

Centre for Urban Research
Building 15, Level 4
RMIT University City campus
124 La Trobe Street
Melbourne VIC, 3000
Australia

T: +61 3 9925 0917
E: cur@rmit.edu.au

www.cur.org.au