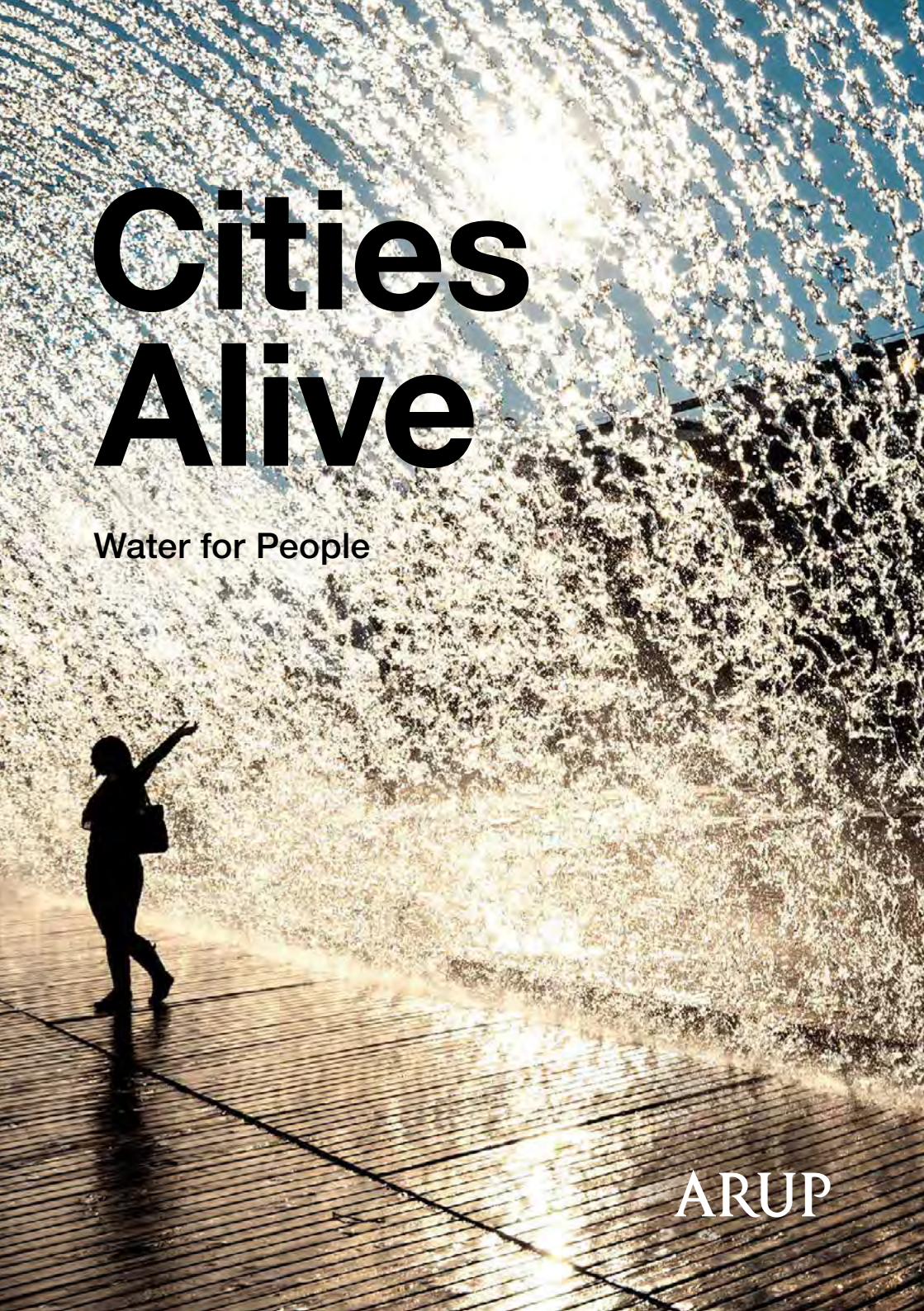
Cities Alive

Water for People



ARUP

“Saving our planet, lifting people out of poverty, advancing economic growth… these are one and the same fight. We must connect the dots between climate change, water scarcity, energy shortages, global health, food security and women’s empowerment. Solutions to one problem must be solutions for all.”

Ban Ki-moon, United Nations
Secretary General 2007-2016

This report was developed by Arup, with support from IWA, as part of the IWA's Water-Wise initiative. IWA is partnering with key members to drive change towards water-wise cities through influencing actors of change of the transition. Learn more on the initiative at: www.iwa-network.org/projects/water-wise-cities

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#CitiesAlive #IWAHQ

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Foreword

CORINNE TROMMSDORFF

'Cities of the Future' Program Manager, International Water Association (IWA)

Water keeps me alive every day. I have the luxury to live in a place where water enhances the quality of my urban living environment.

I can shower, enjoy clean urban spaces, parks and water features with ease. Given my background as a water systems engineer however, I understand just what it takes to provide these benefits. I see water as a precious resource that I should not waste, one I should reuse whenever possible so that it can be shared. I care that water is replenished, so that ecosystems and all downstream users can benefit from a pristine resource. In growing cities, where water becomes a limited resource, water can become either a community enhancer or a reason for unrest and conflict depending on our desire to share rather than cultivate self-interests.

At IWA, we strive for a world in which water is wisely managed to satisfy the needs of human activities and ecosystems in an equitable and sustainable way. Water-wise cities are an essential part of the water-wise world for which the IWA advocates because cities link utilities, industries, urban regions and their basins. Transitioning to water-wise cities relies on people taking responsibility in their respective roles, taking action towards basin-connected cities, water-sensitive urban design, and regenerative water services. This Cities Alive report Water for People will inspire urban leaders to build water-wise communities, redefining the problems that must be addressed and solved based on the needs of the people and what they can contribute.

▶ Urban drinking water fountain

Water systems are the lifeblood of cities, but they are increasingly coming under strain. One in four large cities are already facing water stress, and demand for water is only projected to increase.

Growing urban populations the world over are inexorably driving this rising demand for water. Concurrently, changing climate is driving extreme events in cities, from drought to floods, resulting in severe economic outcomes. As a result our urban water infrastructure requires extensive renewal and expansion. Whilst this is a significant challenge, it also provides a significant opportunity to revolutionise how urban water systems are designed and retrofitted, and how they can deliver greater benefits for all.

The challenge is to recognise and understand the complexity of urban water systems, relationship with the built environment, and interconnection with communities and stakeholders across the water cycle and its catchments. We must understand too the fundamental power of nature and the critical role it needs to play in complementing technological solutions. Water is a critical element in the drive to improve environmental conditions in cities and deliver resilience. Through this, and by focussing on well-being as an outcome, creating healthier city spaces with built-in resilience will also drive economic success. The defining feature of this age will be our response to the increasing shocks and stresses of these global challenges.

◀ World Water Day 2018 digital cards

DR MARK FLETCHER

FICE FCIWEM FGS, Arup Fellow and Global Water Business Leader

Executive Summary

Change is all around us. Climate change, population growth, urbanisation, and resource depletion are the major global challenges facing humankind, and these issues are all most prevalent in our cities.

Cities Alive presents an economic pathway of addressing the challenges of population growth and climate change in our cities, helping to deliver significant social and environmental benefits. To move towards a more sustainable future it is critical that cities adapt in order to address these contemporary challenges.

It is increasingly the case that cities, rather than governments, have the power to fuel the global economy, deliver prosperity to alleviate poverty and tackle climate change[1]. Access to clean, safe and reliable water promotes healthy and hygienic living that improves the quality of life in cities.

One in four large cities are already facing water stress, and demand for water is projected to increase by 55% by 2050[2]. As such, our urban water infrastructure requires extensive renewal and expansion to effectively manage water resources if we are to meet demands. Whilst this is a significant challenge, it also provides an opportunity to revolutionise how urban water systems are designed, or retrofitted, to better manage our water resources. Cities Alive - Water for People provides focus towards innovative 'blue' city thinking as a solution to current and future social and environmental challenges.

▲ Southbank, London

Pioneering blue approaches and interventions in cities across the globe have been explored, and five common themes for successfully reconnecting people with the water cycle (including fresh and salt water) have been identified. These approaches enable people to benefit from greater security, health and well-being as well as the resilience that sustainable water resource management provides.

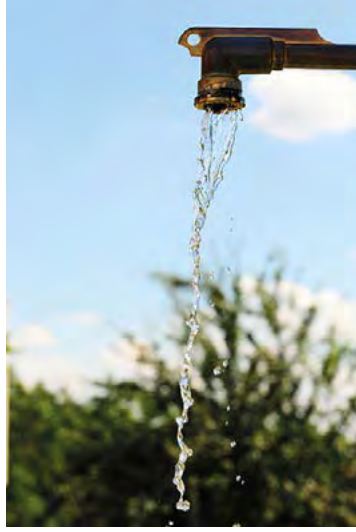
Rethinking water in cities as a connected network of 'blue infrastructure' (especially in combination with 'green infrastructure') offers environmental, social and economic benefits. This creates healthier more resilient and prosperous cities. The formation of new partnerships and ways of working are required in order to achieve this, as are new funding arrangements and increased collaboration. It will require strategic, long-term city planning and incremental working to achieve the aims of a common goal. This is complex and challenging, but critical if we are to meet current and future challenges in cities, and leave a legacy in changing times. That is why 'blue' cities are the only cities that can be truly sustainable.











Cities Alive – Water for People provides focus towards innovative 'blue' city thinking as a solution to current and future social and environmental challenges. Five common themes for successfully reconnecting people with the water cycle have been identified.

PUTTING PEOPLE FIRST

Placing people at the heart of sustainable city planning and design is crucial, and as a critical resource water has a central role to play. By harnessing opportunities across the full water cycle, people's needs can be better met now and in the future. A 'water-wise' approach to the planning and design of water in cities will create more reliable supplies, improvements in water quality, effective flood protection, reduction in drought conditions, more liveable cityscapes, which all contribute to the health and well-being of people.

BASIN SENSITIVE CITIES

Cities are located within river basins meaning that they both influence, and are influenced by, basins. The interactions of water, sediment, nutrients and ecology as they flow through basins offer benefits if embraced, but threats if ignored or misunderstood. Recognising these core concepts and considering the inevitable natural river basin processes is key in helping achieve successful design for cities that is focused on resilience, wise water use and sustainability.

INTEGRATED DESIGN

Urban infrastructure is traditionally designed with a singular function. This can restrict its usefulness and potential. By taking a more integrated and broader approach to design outcomes, infrastructure can be multifunctional. For example an infrastructure scheme can be designed to incorporate flood-risk management, water-harvesting and provide community and habitat benefits. Existing infrastructure can be retrofitted to equal effect. This design approach is a positive way forward in cities with land under pressure to allow inhabitants to better respond to future challenges.

CITY REGENERATION

Water can act as a powerful focal point for redevelopment, helping catalyse wider city regeneration. Cities that develop in a manner sensitive to natural processes are likely to be more efficient, resilient and sustainable. And 'blue' and 'green' environments, whether new or retrofitted, provide a robust foundation for economic success by maximising flood and drought resilience, and provision of ecosystem services. Such benefits, including improved aesthetics, natural treatment of air, water and temperature regulation, generate collective improvements to the health and well-being of inhabitants.

TRANSCENDING BARRIERS

Integrated working is the key to generate wider environmental, social and economic benefits to the planning and design of water in cities. This will involve breaking down barriers between communities, companies and organisations and forming new positive partnerships for the benefit of the complete water cycle. Siloed-thinking and fixed and restricted organisational responsibilities, within parts of the water cycle, are not conducive to achieving wider benefits. Greater engagement, integration and joint working across governments, education, industry and communities to gain mutual, city-wide benefits.

Challenges

"Water is the primary medium through which climate change influences the Earth's ecosystem and thus the livelihood and well-being of societies… climate change will affect the availability of water resources through changes in rainfall distribution, soil moisture, glacier and ice/snow melt, and river and groundwater flows"

United Nations World Water Development Report 4,
Background Information Brief

Thailand flood

Climate change

"Climate Change is no longer some far-off problem; it is happening here, it is happening now."

Barack Obama, 44th President of the United States of America

Too much water

Climate change is occurring at different rates across the world. For example, sea level rise in areas of the Pacific Ocean is four times greater than the global average. The low-lying nature of many Pacific Island Nations, many of which are less than 5m above sea level, means the thousands of people they home are at risk of flooding and significant changes to their communities, environment, customs and culture[3].

A World Resources Institute report in 2015 indicates that the number of people affected by river flooding could triple to 50 million between 2015 and 2030, costing approximately US$500bn. With seven of the ten most vulnerable cities Southeast Asia is generally considered the most flood-prone region in terms of magnitude, frequency and severity. Similarly, flooding is the most common extreme weather event facing Europe with increasing winter floods expected to impact an additional 1.6 million people every year.

Not enough water

Conversely, different areas of the world are expected to become increasingly arid due to climate change. Hyper-arid, arid and semi-arid zones currently cover 30% of land area on earth and house a third of its people. Arid cities are also expected to experience the highest rates of natural population increase in the next century while the frequency and intensity of rainfall is predicted to fall or become more unpredictable.

Appropriate blue infrastructure can improve the resilience of arid cities. In Riyadh, Wadi Hanifa has been transformed into an urban oasis by improving water quantity and quality. A sewage treatment facility and purification plant created a constant flow of improved-quality water, and a series of small lakes and dams regulate the flow of water to sustain trees and other vegetation. This created a place for recreation and improved biodiversity and resilience.

▶ Top: Water protest. Bottom: Thailand flood

Population Pressures

Increasing Populations

It is estimated that between 1.6 and 2.4 billion people live in river basins that experience water scarcity[4]. This is expected to almost double by 2050 to between 3.1 and 4.3 billion people from population increases alone, regardless of climate change exposing further basins to water scarcity[5].

Urbanisation (leading to densification) combined with overall population growth is a major component of the increase from 54% to 66% of the population living in cities between 2014 and 2050. These increases are primarily concentrated in Asia and Africa, with India, China and Nigeria accounting for 37% of the projected growth in urban population[6].

This spatial migration is altering the type of cities we live in. Of the 31 mega-cities (cities in excess of 10 million inhabitants) in 2016, 24 were located in less developed regions, or the 'global south'[7]. The number of mega-cities is also projected to increase to 41 by 2030, however, almost half of urban dwellers live in cities with only half a million people, and these comprise many of the fastest growing cities in the world.

◀ Top: Shamal Darfor, Sudan
Bottom: Water collection
▶ Rweru, Rwanda

▲ Water in agriculture

Increasing Demands

The projected global population of 8.3 billion by 2030 may cause an increase in food demand of 60%. Approximately 70% of global freshwater is used by the agricultural sector; almost a third goes into livestock production with the majority going into irrigation and the production of animal feed, fertiliser and pesticides. From 2013, almost a third of the world's water went to livestock production. Furthermore, there is a global shift towards diets containing more meat and dairy opposed to the less water-intensive vegetables and grain. Producing 0.5kg of beef uses 10,000 litres of water compared to 800 litres for 0.5kg of wheat[2].

As a result of population increases and densification, primarily developing regions will have to meet the increasing demands of its people for infrastructure, energy, housing, clean drinking water, and sanitation[8]. This represents a substantial challenge to cities across the globe, especially considering that the human right to water and sanitation was only explicitly recognised by the UN General Assembly as recently as 2010[9]. However, it also presents a great opportunity to promote blue infrastructure as the way forward for sustainable asset use.

Water challenges

1 in 4
large cities are already facing water stress

Global water consumption has
doubled every 20 years.
That's twice the rate of population growth.[11]

+55%
Water demand increase by 2050

Lost water through leaks or unbilled usage in 2013:

30%
Average American city

~53%
New Delhi

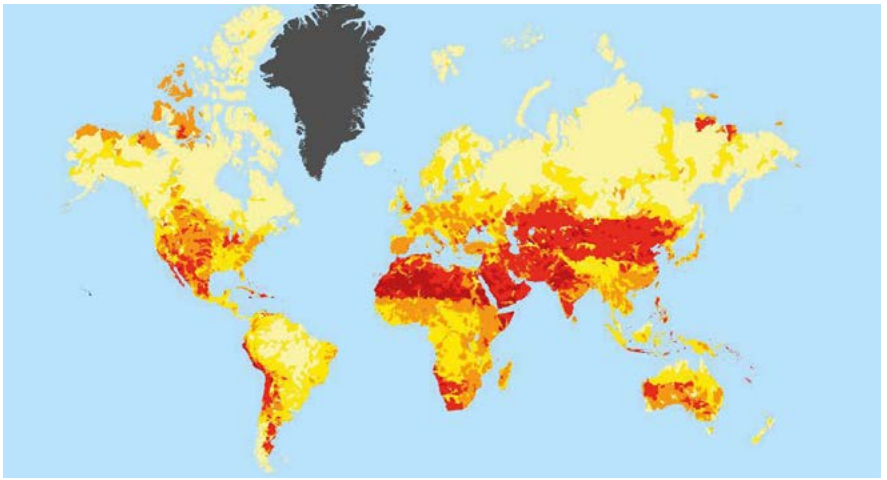
38%
Most developing nations

Many Pacific Island nations are
less than 5m above sea level
thousands of inhabitants are at risk

By 2030, If efficiency does not improve, worldwide water demand will outstrip supply by[10]
40%

It is estimated that between
1.6 and 2.4 billion
people live in river basins that experience water scarcity.[4]

3.2 million m^3
The amount of water the 100 largest cities in the world transfer approximately 5,700km through artificial channels per day.[2]



▲ World water scarcity map[12]

Water scarcity

As demand for water increases globally, the availability of freshwater is likely to decrease across parts of the world due to climate change[7]. The four main sources of water demand are from consumption, agricultural practices, energy production, and industrial use. Food production is especially water-intensive with agriculture alone accounting for 70% of the water withdrawn for municipal, agricultural and industrial sectors. This also leads to the inadvertent global trade of billions of gallons of water via 'Virtual Water': the volume of water required to produce goods and services that are subsequently traded and transported.

Based on analysis of climate and population change models, water availability per person will most likely diminish in many regions by 2080[8]. As a result of climate and population change, water scarcity will be exacerbated across the world, compromising cities' ability to produce a balanced diet and quality of life for their people. Given the transboundary nature of water, this will likely lead to acute water shortages and increasing tensions between nations, states and cities. Upstream and downstream users of a shared resource will also potentially come into conflict.

◀ Maua, Mozambique

Economic Development

The projected increase in population exhibited across the globe can be assumed to be accompanied by economic growth and development.

This in turn will further stress our water resources in terms of the development process itself, and the associated increase in industrial water use to supply the needs of a larger population.

"Of the approximately 7bn people in the world today, almost 6bn have access to a mobile phone, while only 4.5bn have access to working toilets"

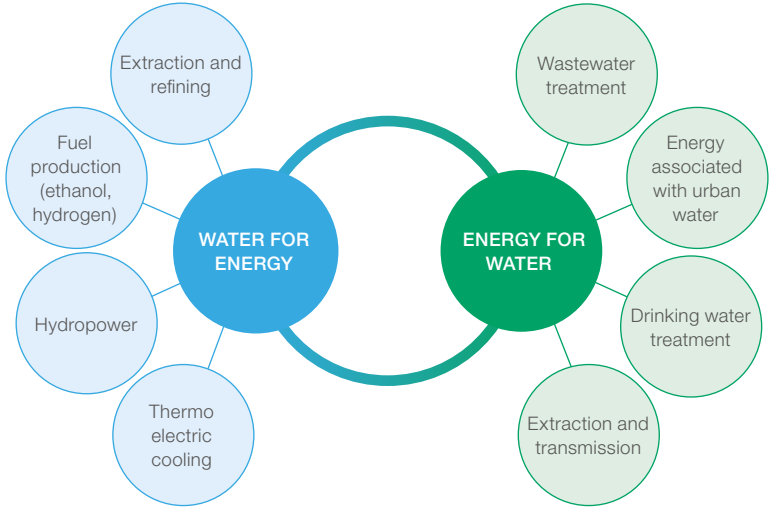
TIME Magazine Online (25 March 2013)

Uneven Development

The extent of a country's economic development is as unique and globally diverse as the water resource challenge they are facing. Generally, cities with higher GDP per capita import twice as much water as they source internally, while lower-income cities are more dependent on local water resources[13]. In the future, growing cities may be tempted to move larger volumes of water greater distances to meet demands. This is not sustainable. Development that sources water more locally and invests in nature to reduce the impact of land use on water quality and even quantity should be encouraged.

In 2013, the private sector controlled water and/or wastewater services to almost 15% of the population. The World Bank and International Monetary Fund believe privatisation helps to finance, develop and operate infrastructure. However, many members of the public believe privatisation transforms a low-return public utility into a for-profit venture. While privatisation may promote economic development, it can also lead to civil unrest and even war, as the Cochabamba water war, in Bolivia, highlights. Privatisation of Bolivian water assets in the late 1990s caused a 35% hike in water prices, prompting a public uprising in protest of the unaffordability of the vital resource.

If water is not easily accessible, treatable or distributed to meet demand, then it is not a usable supply. Since 2010, approximately 80% of the population lives in areas where water supply is insecure.



▲ The water/energy cycle, WUIM, 2012

Water-Energy Nexus

The energy sector accounts for 15% of total water use globally. This demand is expected to rise, meaning consideration of water will be increasingly important when assessing the sustainability of energy sources. The International Energy Agency has forecast a 35% growth in electricity demand by 2035, an increase in energy's water consumption of 85%[14].

The decarbonisation of energy systems as part of development is a must to contain climate change. In order to meet climate commitments, global hydropower capacity needs to increase 90% by 2040 (compared to 2012), with Asia seeing the greatest overall increase and Africa experiencing the greatest proportional increase[15].

Hydropower by Design can advise site selection, minimising environmental, social and financial costs. Globally, hydropower influenced basins comprise 660million people at risk of flooding in urban areas, equating to ~$30billion (USD) in flood management value[16].

Water for cities

Cities must now adapt to future global challenges, and as a critical infrastructure water is a fundamental consideration. Clean sustainable water supply and quality are key to healthy cities, as is the design and retrofitting of water infrastructure to build resilience to floods and droughts.

Madrid, Spain

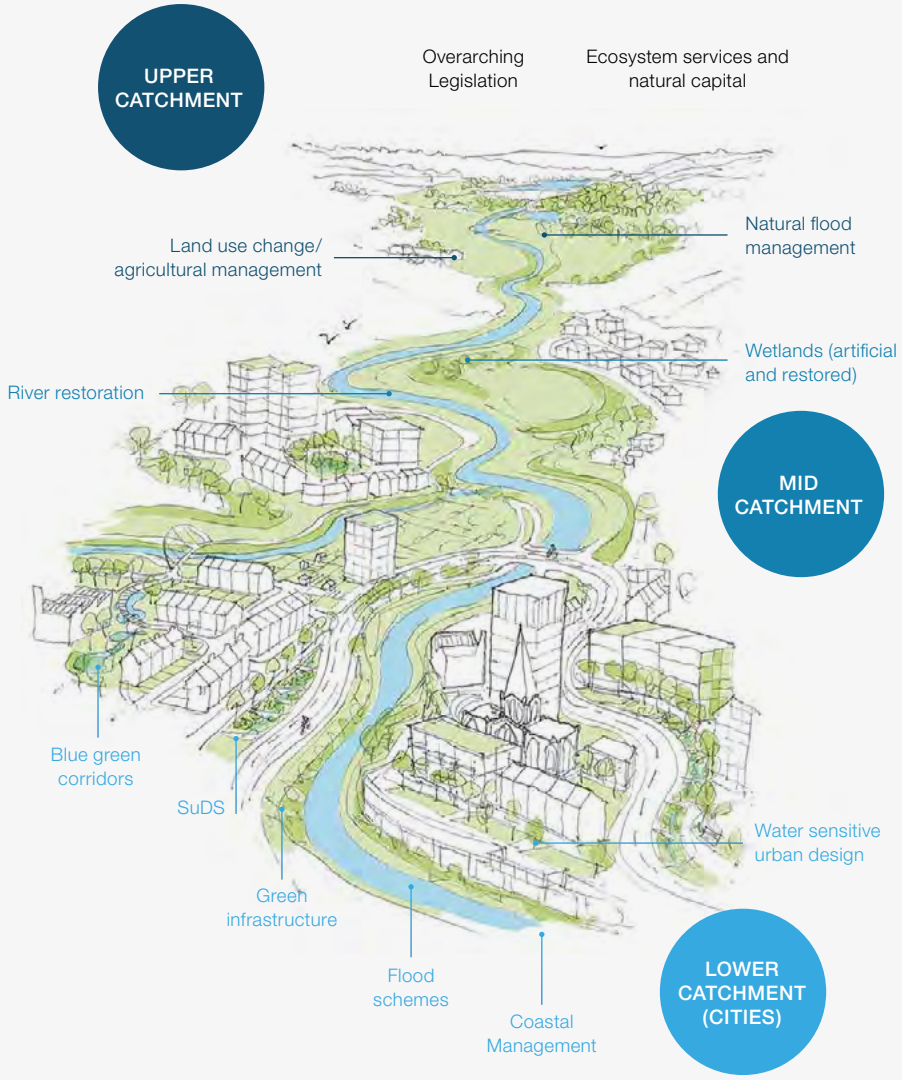
A blue approach

The world's 100 largest cities occupy less than 1% of the planet's land area whilst the basins that provide their water resource covers over 12% and serves almost a billion people.[17]

However, while basins are a vital urban resource, they receive little investment despite the fact that protecting water near the source is more cost-effective and efficient than treating polluted water. This is potentially due to the idea that restoring basin processes is difficult due to the myriad of potential barriers, in addition to the technical complexity. However, by considering restorative actions iteratively and as part of a larger and dynamic basin system, it is possible to move towards a more sustainable process state.

Cities dictate stewardship for hundreds of miles around by shaping the landscape and defining development options. Cities and their water managers need to expand what they consider 'their' water infrastructure to include the entire river basin on which they depend. Integrating those natural and engineered solutions will provide greater resilience and sustainability.

Urban resilience is not possible without rural resilience, so cities must be sensitive to their river basins to create a sustainable foundation.



▲ Catchment areas

Blue infrastructure

Blue infrastructure is closely related to green infrastructure and together they can be defined as follows: ‘Natural or semi-natural networks of green (soil covered or vegetated) and blue (water covered) spaces and corridors that maintain and enhance ecosystem services’[18]

Water-related investment in infrastructure, new technologies and management partnerships can positively affect land value and attract investment. By improving access to water, a city can create spaces with a stronger sense of well-being and identity through connectivity, collaboration, communication and facilitated partnerships. As part of this there is clear evidence that a city design incorporating blue infrastructure, especially when combined with green infrastructure, will lead to significant environmental, social and economic benefits.

Supported by global research and a growing realisation by policy makers of the importance of nature to society, the knowledge of how nature works and how it benefits all people can be used to turn challenges into positive actions. The research tells us that these benefits are not just environmental, but they drive social cohesion and economic opportunities in cities too. These range from the psychological and mental health benefits of connecting people to nature through to enhanced air quality and temperature regulation, as well as encouraging recreation and physical exercise. Healthier city environments will encourage social wellbeing, inward investment, tourism and will reduce the cost of healthcare.

▶ Blue infrastructure in cities

The answer is in nature[19]

We are living in a time of great opportunity for addressing global challenges.

The move towards ‘nature-based solutions’ for cities, encompassing blue and green infrastructure, is now reflected in the increasing number of international, national, regional and local policy initiatives. This includes the UN Sustainable Development Goals for the conservation, and sustainable use, of the natural environment.

Nature based solutions [can] offer more opportunities than ‘grey’ infrastructure, as they not only increase the resilience of society to external economic and environmental stresses, but contribute positively to human health and well-being.[20]

In times of fiscal austerity too, cost effective alternatives to traditional grey, or technology-based infrastructure are being sought. Nature-based solutions have demonstrated financial advantages due to a reduction in initial capital expense and lower on-going operational expenses.[21]

The City of Philadelphia found the net present value of green infrastructure benefits ranged from $1.94 - $4.45 billion, while grey infrastructure ranged from only $0.06 to $0.14 billion over a 40 year period.[22]

▲ Beavers can reduce the risk of floods and droughts by building wooden dams that store water

◀ Greenery in residential areas

Cities Alive: Water for People

There is a huge opportunity to retrofit existing grey infrastructure so that it better manages water in cities. Longer term, cities offer the potential to positively influence water management by ensuring that nature-based solutions are at the core of new development.

City Water Resilience Framework

Arup has recognised the factors that differentiate cities and, with the support of the Rockefeller Foundation, is developing a City Water Resilience Framework (CWRF).

This framework will help cities better prepare and respond to shocks and stresses to their water systems. Five cities from different continents have been selected to present the global variety of water challenges. Utilising field research, stakeholder engagement and qualitative and quantitative information, the level of city-wide water resilience will be determined and be applicable anywhere in the world. This pioneering research will enable cities to diagnose their water challenges and utilise that information to inform planning and investment decisions.

The cities that will shape the City Water Resilience Framework are Amman, Cape Town, Mexico City, Greater Miami and the Beaches and Hull.

The first four of these cities are also part of the Rockefeller Foundation's 100 Resilient Cities, helping cities around the world to cope in the face of physical, social and economic challenges.

"Of the more than 1,000 applications for the 100 Resilient Cities Network, more than 60% indicated challenges with water – too much or too little – as critical resilience risks. There is tremendous opportunity for the cities in this cohort to provide lessons and expertise to the many cities around the world grappling with water challenges."

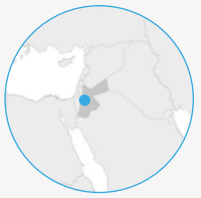
Andrew Salkin, Senior Vice President of City Solutions at 100 Resilient Cities

▲ Amman flood

Amman

Water challenge: located away from sources of water and regularly suffers drought. Experiences unusually heavy rain causing flash floods in low-lying areas of the city.

Jordan's water scarcity is largely seen as the foremost restriction on the country's sustainable economic growth, especially in consideration of the rapid population growth of approximately 3.22% a year.



LOCATION: Amman, Jordan
POPULATION: 4 million

▲ Theewaterskloof dam

LOCATION: Cape Town, South Africa

POPULATION: 3.7 million

Cape Town

Water challenge: Severe drought conditions, especially due to low rainfall since 2015. 'Day Zero', when household taps will run dry from lack of resources, was at one time predicted to occur on April 12th 2018 but was pushed back to 2019 as residents used less than 50 litres a day.

The city has previously been lauded for its environmental and sustainability practices and, in 2008, was voted one of 10 cities in the world most likely to become a global sustainability centre by 2020.

▲ Hull flood

Hull

Water challenge: 90% of Hull lies below the high-tide line. Consequently, the city is highly vulnerable to sea-level rise and has recently experienced extensive flooding. A recent study on the well-being benefits of a 'blue-green approach' to flood alleviation concluded that improved access to, and availability of, blue and green infrastructure could reduce NHS spending on mental health medication and therapies by between £12m and £61m in Hull over a 100 year period.[23]

LOCATION: Hull, UK

POPULATION: 323,000

▲ Mexico City

LOCATION: Mexico City, Mexico
POPULATION: 21.3 million

Mexico City

Water challenge: Historically a lake, Mexico City is prone to flooding. The rapidly growing city is also reliant on depleted underground aquifers for their water supply.

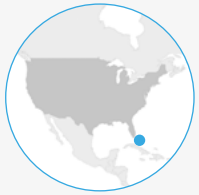
Large volumes of water are drawn from neighbouring states and virtually all its wastewater is discharged through an expensive drainage system into rivers. These rivers flow through arable land which in turn provides the city with its food.

▲ Miami flood

Miami

Water challenge: Its coastal location makes the city vulnerable to increasingly frequent tidal floods. Sea level rise is also a major threat, especially in conjunction with the high groundwater table and complex canal system.

A report by the National Wildlife Federation[24] estimated that Miami stands to lose US$3.5 trillion in financial assets from coastal flooding by 2070. This makes it the most vulnerable city in the world, beyond even Guangzhou and New York, and a prime candidate for coastal adaptation measures.



LOCATION: Miami, USA
POPULATION: 5.9 million

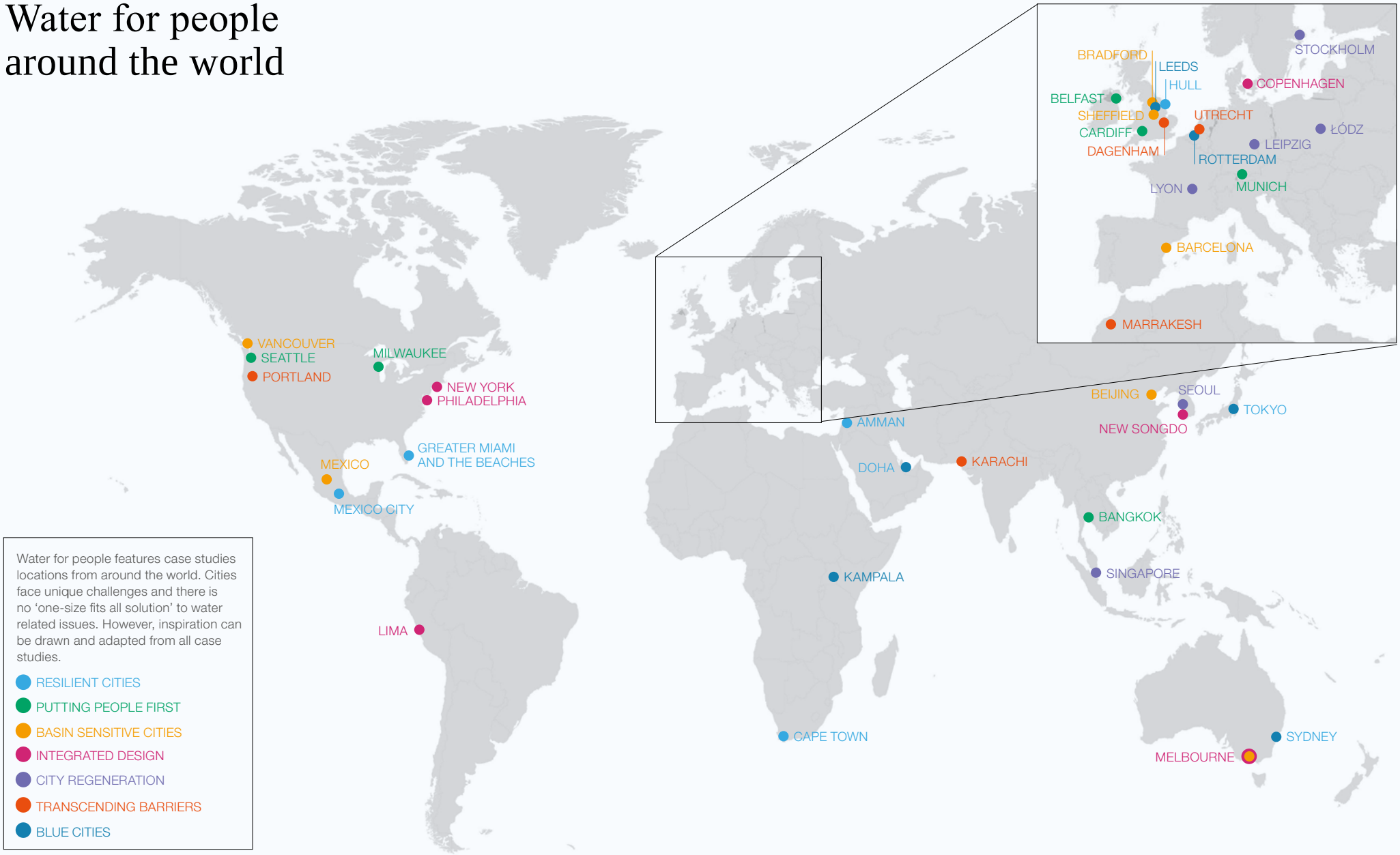
Water for people

Cities need to rethink water in order to meet the challenges ahead.

Wharf Recreation Pier, Washington DC

Cities Alive: Water for People

Water for people around the world



Water for people features case studies locations from around the world. Cities face unique challenges and there is no 'one-size fits all solution' to water related issues. However, inspiration can be drawn and adapted from all case studies.

- RESILIENT CITIES
- PUTTING PEOPLE FIRST
- BASIN SENSITIVE CITIES
- INTEGRATED DESIGN
- CITY REGENERATION
- TRANSCENDING BARRIERS
- BLUE CITIES

Putting People First

Cities are challenged by rapid population growth and intense climatic conditions.

These pressures have created poor social, economic, and environmental conditions for people in many cities around the world, directly contributing to global health problems. It is clear that conventional approaches to urban development planning and design are unable to meet current and future challenges.

By harnessing opportunities across the full water cycle, people's needs can be better met now and in the future. A 'water-wise' approach to the planning and design of water in cities will create more reliable supplies, improvements in water quality, effective flood protection, reduction in drought conditions, and more liveable city environments. In turn, this provides mental and physical health and wellbeing benefits that will boost the quality of life of people living and working throughout the city.

▶ Children in urban fountain

THOUGHTS

Interconnected nature of environmental challenges

We know that global environmental pressures including resource scarcity, climate change, nutrient pollution, and others are inextricably related, thereby hampering our efforts to truly address the challenges encountered in a single sector, such as water.

The key we should bear in mind is how (from a systems integration perspective) to address interconnected challenges encountered in our water sector, and to develop and promote the paradigm shift necessary to deliver sustainable and resilient water services at a global scale.

The 2018 World Water day slogan 'the answer is in nature' points the way forward. It further states "How can we reduce floods, droughts and water pollution? – By using the solutions we already find in nature". Global research describes clearly the environmental, social and economic benefits of nature-based solutions, and it is nature that can be used as the connecting and integrating factor in many projects, to bring together grey infrastructure with blue and green infrastructure solutions. This can be achieved by working in a more holistic way between disciplines and realising the fundamental importance of the environment as a key driver for solutions.

DR XU WANG

Associate Professor of Environmental Science and Engineering at the Research Center for Eco-Environmental Sciences of the Chinese Academy of Sciences (CAS)

◀ Turenscape, Tianjin Qiaoyuan Park

PUTTING PEOPLE FIRST

Sustainable drainage for urban areas

PROJECT
Greener Grangetown
LOCATION
Cardiff, Wales

131
new trees

1,700m²
new green space

Grangetown's Water Sensitive Urban Design provides sustainable drainage to an urban area of Cardiff, South Wales, by annually[25] removing over 40,000m³ of water from the sewer network.

This was achieved through integrated team working and rethinking traditional drainage design to deliver wider benefits for the community. The collaborative ethic of the design team extended to community and stakeholder engagement and education, involving the residents in the design of their own streets. 131 new trees and 1,700m² of new green space, provide climate change resilience and deliver enhanced public space.

▼ Grangetown visualisation

PUTTING PEOPLE FIRST

Transforming diseased flood water

The Thai Government has developed SOS - a device capable of transforming diseased flood water into a safe potable supply for its people.

In 2011, 65% of Thailand's provinces were submerged in flood waters for over 4 months. Flood water inundation causes a lack of safe drinking water due to water-borne disease and germs that quickly spread illness. The Solar Operating System (SOS) can be powered by the sun or batteries to filter 2,000 litres of water a day. Silver nanoparticles coat the ceramic filters and help to kill disease-causing microbes in the water.

PROJECT
SOS Water Purification
LOCATION
Thailand

2,000
litres of safe water produced per day

▼ Filtered drinking water

PUTTING PEOPLE FIRST

A world class ecocity

PROJECT
Milwaukee Water Centric City

LOCATION
Milwaukee, Wisconsin, USA

With three rivers and a Great Lake, water has shaped Milwaukee's history, identity and economy.

Milwaukee's Environmental Collaboration Office (ECO) 'Water Centric City' initiative aims to make the city a world class ecocity[26]. Nine principles have been developed to direct its water asset management strategy: water leadership, gathering place by the water, water technology, green infrastructure, applied water research and policy, fishable, swimmable rivers and waterbodies, sustainable water supply, healthy drinking water, on-site water reuse.

Milwaukee has also developed numerous initiatives to encourage public participation in water resource management. Milwaukee Riverkeeper is a volunteer program where people can help monitor rivers and keep them clean. Similarly, individuals can positively impact the health of rivers and Lake Michigan through the Respect Our Waters campaign, and prepare for flooding by being alerted to heavy rainfall via the Common Ground Watershed Initiative and Water Drop Alert system. Combined, these programs involve and inform the public at multiple levels of the water management process.

▶ Milkwaukee, Wisconsin

PUTTING PEOPLE FIRST

A visionary public green space

This visionary public green space has transformed East Belfast, combining flood protection with pedestrian and cycle routes to create a better connected community.

This flood alleviation scheme not only improves the quality, safety and vibrancy of the area, but also supports community cohesion and interactivity, economic development, public health improvements and cleaner rivers[27]. A 9km corridor of existing green space has been connected to form a park with improved biodiversity and water at its heart. The banks of the Connswater, Knock and Loop rivers have been softened, debris and refuse has been removed, stone revetments replaced with more natural solutions and native aquatic species have been planted. This supports the river's ecological status, helping to achieve the requirements of the EU Water Framework Directive, encourages a healthy dynamic and provides greater public access, appearance and protection. A 4.1km floodwall and 1.2km of embankments has effectively alleviated flooding in East Belfast with minimal disruption and cost to the environment and community. Nine new footbridges encourage sustainable transport and connects communities in areas where the rivers previously acted as a barrier.

PROJECT
Connswater Community Greenway

LOCATION
Belfast, Northern Ireland

9km
of connected green space

1.2km
embankments

4.1km
floodwall

◀ Connswater Community Greenway

PUTTING PEOPLE FIRST

Alpine character river restoration

PROJECT
River Isar

LOCATION
Munich, Germany

8km
restored river

A stretch of the Isar River has been restored to reflect the alpine character of its basin, providing flood protection and recreational space for the people of Munich[28].

The Isar River has experienced extreme hydraulic regulation since suffering repeat flooding in the 19th century. What was a typical wild alpine river with wide gravel islands, sandbanks and constantly evolving bedform was concreted over and canalised to protect the districts of Lehel, Au, and Thal, Munich from flooding. The Isar Plan revolutionised the river's flood risk management strategy by restoring 8km of the river and involving the community in the design process. The river banks were renaturalised, public beaches created, access routes improved and weirs replaced with natural rock ramps to promote fish passage and river continuity. The community is protected from flooding by reinforced vegetated embankments with a subterranean stone barrier, limiting extreme river migration. This is set back to promote a healthy river corridor and accompanying remediation works removed contamination and World War II debris to improve water quality and the overall aesthetic.

▶ River Isar public beach

PUTTING PEOPLE FIRST

Nature based solutions providing flood protection

Nature based solutions are providing flood protection, visual amenity, and community cohesion across Seattle.

Seattle Public Utilities constructed the Street Edge Alternative (SEA) project at 2nd Avenue NW in 2001[29]. This completely reconstructed the streetscape and drainage system, reducing the impervious area to 11% below the traditional street hardstanding. Using swales, 100 evergreen trees and 1,100 shrubs, the public is protected from the disruptive and costly effects of flooding. These natural and aesthetically pleasing solutions have also improved water quality, reducing 98% of pollutant transmission. Similarly, Seattle's seafront has been reinvigorated by a new eco-enhanced seawall[30]. The cantilevered footpath allows light to reach the water below, encouraging vegetative growth on the newly created shallow habitat benches and textured seawalls. This will alleviate Seattle from coastal flooding in Elliott Bay.

PROJECT
SEAttle – Street Edge Alternatives and Seafront regeneration

LOCATION
Seattle, USA

98%
reduction of pollutant transmission

100
evergreen trees

1,100
shrubs

◀ Street Edge Alternatives, Seattle

THOUGHTS

Water stress in Africa

NAJIB LUKOOYA BATEGANYA

Deputy Director of Environment and Sanitation and Directorate of Public Health and Environment at Kampala Capital City Authority.

Cities are growing rapidly worldwide as engines of the national economy and social transformation.

While Africa is currently the least urbanised, it has the highest urbanisation rate and projected increase in urban population. This offers both opportunities for social economic transformation, in terms of industrialisation, infrastructure improvement and improved access to key basic services (such as safe water and sanitation), and critical challenges due to the informal nature of urbanisation dynamics.

The rapid growth of informal settlements is ubiquitous across Africa at different rates with varying degrees of complexity regarding access to infrastructure and provision of basic services. This is a major driver of the urban water cycle, with significant implications to water security in terms of quantity and quality, made more uncertain due to climate change. With the urban poor in informal settlements contributing a greater percentage of the population, vulnerability to floods, water stress and associated public health risks is a critical challenge to urban authorities and utilities.

In East Africa, most cities around Lake Victoria such as Kampala, Kisumu and Mwanza rely on it for potable water supply. Unfortunately, unregulated informal urban expansion and inadequate planning of landscapes have resulted in extensive degradation of green space and wetlands which buffer the lake from rising levels of pollution. This has exposed these cities to increased costs of water treatment and flood risk.

▲ Africa floods

Such green infrastructure is also critical for coastal cities by providing a buffer against climate change impacts including floods and heat waves.

The provision of sustained water services is already uncertain in cities such as Cape Town, Lusaka, Kampala and Mombasa to name a few. Most of these cities are categorised as struggling economies with lack of investment and sustainable financing, large proportions of non-revenue water and inadequate institutional capacity and maintenance also influencing the efficiency and effectiveness of water provision. The social, economic and public health aspects of urban prosperity demand that African cities integrate water resources management in all dimensions of planning and development strategies. Strategic investment in urban green and blue infrastructure, institutional coordination and capacity building, waste management and pollution control, sustainable drainage systems and water production and distribution infrastructure need to be prioritised.

Basin Sensitive Cities

Cities lie within ‘basins’ (also known as catchments or watersheds) that they influence and are influenced by.

Benefits can be gained by embracing the flows of water, sediment, nutrients and ecology of basins, but ignoring or misunderstanding them can cause threats. Recognising these core concepts and considering the inevitable natural basin processes is key in helping achieve a successful design for cities that is focused on resilience, wise water use and sustainability.

“There is no urban resilience without rural resilience”

Rajendra Singh, Stockholm International Water Prize 2015 Winner, ‘The Water-man of India’

▶ Upper to lower catchment. Tyrol, Austria

THOUGHTS

The making of basin sensitive cities

PROFESSOR ALASTAIR DRIVER

Specialist Advisor for Arup and Rewilding Britain, Honorary Professor at University of Exeter and an environmental advisor pro bono to the UK Prime Minister

Rivers are the beating heart of most great cities around the world, but those cities which have understood the huge range of ecosystem services they can provide have become the places where this rings most true.

I doubt there is a city in the world that has all the answers but in many great cities there is certainly a growing understanding of the huge range of societal benefits that come from sustainable management of the entire basin within which the city is located.

Public authorities, academics and environmental NGOs have come a long way in recent years in their understanding of upstream thinking, but we are still yet to develop a marketplace where we have 'buyers' and 'sellers' of ecosystem services. The 'buyers' are the city communities, businesses, and infrastructure organisations which would benefit from reduced flood risk, better water quality, more reliable water resources, etc. The 'sellers' are the upstream land owners and land managers who would, under such an agreement, manage their land more sustainably and collaboratively than they currently do. We urgently need bold innovative cities around the world to trial this approach on the ground to help develop best practice.

▲ River and ecosystem

In the meantime, all cities must press on with interventions within their control – such as ensuring Sustainable Drainage Systems (SuDS) are part of are part of every new development, retrofitting SuDS in existing development, physically restoring rivers, floodplain connectivity and high quality urban greenspace whenever the opportunity arises, and establishing systematic litter removal from river corridors as routine. If they do this then steadily local communities and stakeholders will come to value their rivers more and more and become stronger advocates for further improvement, creating 'basin sensitive cities'.

BASIN SENSITIVE CITIES

The answer to serious urban flooding and water shortage

The Sponge City program was introduced by the Chinese Government in 2014 as an answer to serious urban flooding and water shortage.

"Urban drainage infrastructure... should make it a priority to retain valuable water resources and to utilise the natural system to achieve drainage, to establish natural retention, natural infiltration and natural purification- like a sponge city"

President Xi Jiping, 2013

The Sponge city programme promotes water security, environmental protection and ecological restoration. 16 cities were selected initially to pilot Sponge city interventions before national application. As an example of the success of this programme, Tongzhou in Beijing is now accommodating 70% of its rainwater on the surface[31]. In an area covering 19.36km^2, residential communities, parks, public buildings, municipal roads and watercourses have been water-optimised. This has been achieved using green belt, rainwater gardens, permeable paving, rainwater harvesting, and detention ponds. These provide flood protection, climate change resilience, water purification and public amenity all in one. The success of the scheme is only forecast to grow, with a further 40 pilot projects to be finished in 2018 boosting the region's rainwater absorption to 84%, creating a true sponge city and a notable legacy for the strategic planning of water.

◀ Top: Ningo Yinzhou Turne River.
Bottom: Houtan Park, Shanghai

PROJECT
Sponge City Program (SCP)

LOCATION
Various cities, China

14
completed pilot projects

19.36km^2
has been water-optimised

BASIN SENSITIVE CITIES

Flood interventions and wetland creation

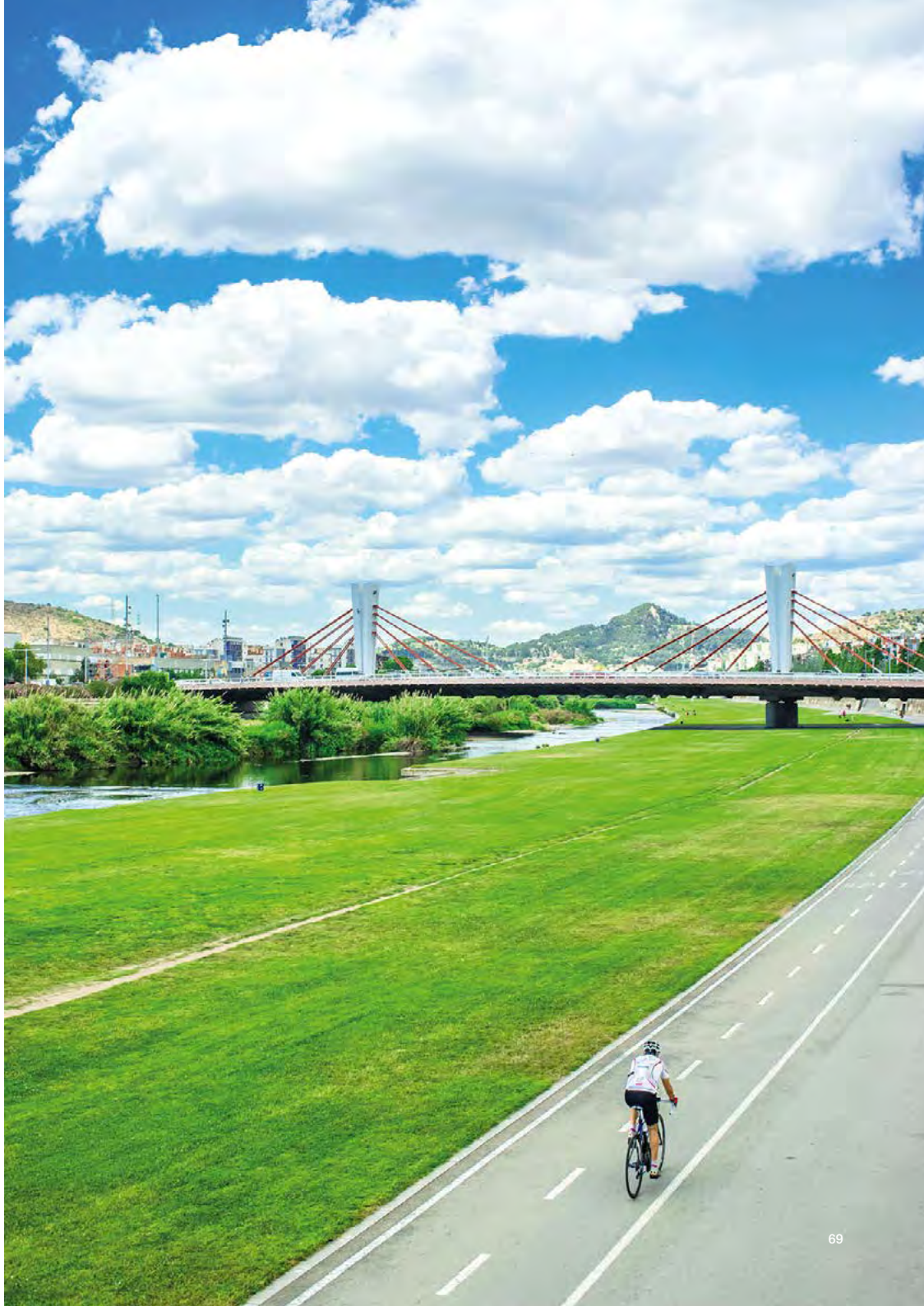
PROJECT
River Besòs
LOCATION
Barcelona, Spain

60
wetland biotopes were created

11
adjustable and inflatable dams

The flood risk and water quality of the River Besòs has been revolutionised by local flood interventions, basin-wide monitoring, and wetland creation.[28]

The River Besòs is characterised by the Mediterranean climate; for most of the year, the river carries very little water, but can transform into a raging torrent during intense rainfall. Following a flood disaster in 1962, a 4m high concrete wall in the river's lower reaches was constructed, effectively isolating a 130m wide channel from the city. In 1996, a EU project reopened riverside amenity to the public over the lower 5km of the river. Barcelona Regional developed a flood advanced warning system using upstream computer modelling to predict any rises in the water level: if a flood is predicted, the system links up to an access-control system which warns people within the floodplain to get to safety. Furthermore, 11 adjustable and inflatable dams have been installed within the active river channel. The dams are deflated during flood events to maximise the channel's capacity and inflated during drier periods to prevent the river bed drying out and becoming unsightly. In the upstream floodplains of Barcelona, 60 wetland biotopes have been created to naturally improve water quality, ecology and quality of life through improved odour and cleanliness.



▶ River Besòs floodplain

BASIN SENSITIVE CITIES

Aiming to become the greenest city in the world

PROJECT
Citywide Integrated Rainwater Management Plan

LOCATION
Vancouver, Canada

Vancouver is aiming to become the greenest city in the world by 2020, aided by their Greenest City Action Plan and Citywide Integrated Rainwater Management Plan.[32]

Embracing the ecological principles of rainwater and stormwater management. Vancouver had already implemented alternative permeable pavements and rain gardens, encouraging water to infiltrate across the city. Similarly, all new large buildings are legally required to manage stormwater as a resource through enhanced landscape, green roofs or rainwater harvesting tanks. The City of Vancouver has developed a best management practice toolkit to improve rainwater management and coastal adaptation. This includes infiltration swales, raingardens, pervious paving, daylighted streams, and constructed wetlands among others. When combined, these interventions treat Vancouver's stormwater as a resource. This reduces potable water demand by encouraging beneficial reuse and restores urban basins to support both urban and natural ecosystems.

▶ Vancouver UBC

BASIN SENSITIVE CITIES

Thinking like a lake

PROJECT
Water Forest

LOCATION
Mexico City, Mexico

ARTICLE AUTHOR
Dr Janice Astbury, Research Associate, Durham University, NATURVATION

Mexico City used to be a lake and now it is trying to think like one.

Mexico City sits in a virtually impermeable former lakebed that causes water to collect, unless it is retained higher up. Despite massive investment, both flooding and water shortages are common for the city's 20 million inhabitants. The new Bosque de Agua initiative seeks to change the way residents view Mexico City; not only as a megacity, but also as a forest upon which they depend for their water. The forest provides 70% of the city's water supply from across its 250 km² area, with an estimated economic value of US$30 billion[33].

▼ Mexico City

BASIN SENSITIVE CITIES

Total watermark

PROJECT
Total Watermark

LOCATION
Melbourne, Australia

ARTICLE AUTHOR
Dr Bernadett Kiss, Postdoctoral Research Associate, International Institute for Industrial Environmental Economics, Lund University, NATURVATION

Melbourne's Total Watermark is at the forefront of global Integrated Water Management.

This radical water plan was catalysed by recent weather events - a 13 year drought and infrequent and intense rainfall events. Integrated Water Management ensures that the right water is used for the right purposes, while minimising flood risk. Water-sensitive urban design is facilitating sustainable irrigation and combined grey and green solutions; large-scale green stormwater harvesting areas, parks, gardens and rain gardens with underground water tanks, have been created to reduce stormwater pollutants, decrease reliance on mains water (by 363 million litres, 2008-2017) and reduce energy use. Increased tree cover is also boosting well-being and reducing urban heat.

▼ Melbourne

BASIN SENSITIVE CITIES

Reconnecting people with watercourses

PROJECT
Stream Daylighting
LOCATION
Yorkshire, UK

50m
redundant culvert was daylighted

Reconnecting people with watercourses in Yorkshire has led to the creation of place.

Many rivers have historically been culverted to sanitise what had become used as open sewers by the 19th Century. However, there is a growing trend to uncover, or 'daylight', rivers from undersized culverts which are at risk of blockage and flooding.

The Porter Brook in Sheffield has been heavily modified and culverted for much of its length through the city centre. In 2015, 50m of redundant culvert was daylighted, restoring the channel and creating a 'pocket park' on the river bank. People can now sit and relax by the water, or even paddle in the stream. The channel's biodiversity has vastly improved with the re-emergence of brown trout. Local flood risk has also been reduced thanks to improved basin connectivity, which has in turn boosted the development appeal of the whole area.

Where it is not possible to physically daylight lost rivers, 'cultural daylighting' can still reconnect people with the history and value of culverted watercourses from source to mouth. A community-led action group called Friends of Bradford Beck has installed plaques along the course of Bradford Beck showing the direction of flow alongside evocative poetry about the beck. Similarly, numerous walks have been mapped and signposted allowing people to follow the becks.

▶ Matilda Street Park, Sheffield

THOUGHTS

Experiment with alternatives

PROFESSOR HARRIET BULKELEY

Principal Investigator of the NATURVATION project and Professor of Geography at Durham University

As cities increasingly confront climate changed futures, the importance of providing and managing water is rising to the fore.

Central to meeting this challenge is the capacity to experiment with alternatives. Experimentation allows cities to try out different approaches at a range of scales. Nature-based solutions are increasingly the focus, yet understanding their potential requires that we develop systems capable of learning from these experiments and integrating this knowledge and capacity into the mainstream.

Existing forms of monitoring and assessment may be of limited use, given their focus on a narrow range of metrics and the financial bottom-line. Instead, new approaches are needed that are capable of capturing the multiple contributions that such nature-based solutions can make to sustainability goals for the city as a whole. Interventions to make space for water in cities not only serve to support water management goals for public authorities and private utilities, but have wider public benefits. Finding the ways in which we can invest – in the broadest sense – in such solutions is a key challenge that cities will need to overcome if we are to see nature-based solutions come to play a significant role in the future of our urban worlds.

▶ Nature in cities

Integrated design

In the need to adopt new approaches to the design of cities there is a realisation that infrastructure can be designed to be multi-functional.

Conventionally, urban infrastructure has been designed to have a singular function. This can result in one-dimensional and segregated urban layouts, where infrastructure usefulness is restricted. For instance, a new road development can also have a flood risk management, water harvesting and habitat function, whilst containing easily accessible water and other utilities. Infrastructure can also be retrofitted to become more effective with greening existing grey infrastructure being an important part of the solution.

New development in cities provides an opportunity to manage water as part of the city and basin system. By upgrading and retrofitting existing systems, an interconnected and integrated city system can emerge. This helps cities become sustainable and benefit from water as an asset.

◀ Singapore

THOUGHTS

Water Security in Brazil

DILMA PENA

Consultant and Master, School of Business Administration of São Paulo, Fundação Getúlio Vargas

Most of the Brazilian Metropolitan Region (MR) depends on water infrastructure designed by elder generations that coexists with new and emergent demands. This leaves their water supply vulnerable.

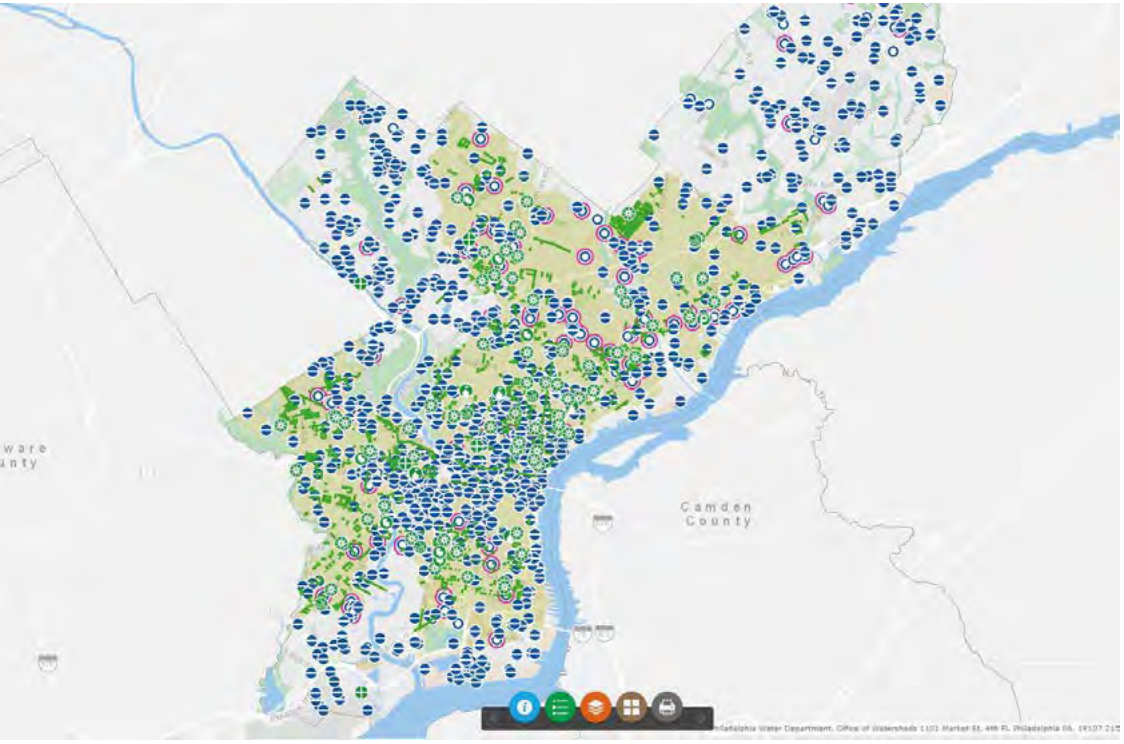
Brazilian MRs are faced with a deficit in wastewater collection and treatment, polluted urban watercourses, rapid growth of slums and a lack of urban renovation. A lack of legal regulation causes further challenges and leads to lack of synergy, resources, money, time, and hope. The negative impacts of this are disproportionally felt by the less affluent members of the community. Thus, a radical new approach is required to transform its polluted water into an available resource, reuse water and manage demand through rational and controlled use of groundwater.

São Paulo, is tackling this by adopting strategies that consider and utilise all water resources in a MR. The Paulista macro-metropolis comprises six MRs, supporting 27 million people, and is adopted as one integrated unit for water resource planning.

▲ São Paulo, Brazil

The Water Resource Use Plan for Paulista is indicative of progressive water resource governance. It provides a long-term vision for achieving self-sustainability and stakeholder consensus by outlining civil society initiatives and programs for progressing the depollution of rivers and Spring Recovery.

The best technical solution to each water challenge demands research and a governance structure to implement it, in a complementary and integrated way. Joining together the old and new.



INTEGRATED DESIGN

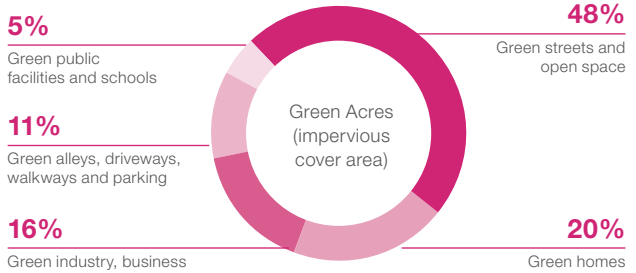
Using a blue approach

PROJECT
Green City, Clean Water
LOCATION
Philadelphia, USA

Philadelphia's Department of Water uses a blue approach to maximise environmental, social and economic returns within the most efficient timeframe.[34]

Philadelphia's Green City strategy adheres to four basic principles. Firstly, using recycling to utilise rainwater as a resource. Secondly, reusing and recharging groundwater aquifers. Thirdly, maintaining and upgrading water infrastructure. Finally, collaborating to achieve a sustainably revitalised City. Traditionally grey infrastructure will be given a water use to contribute towards the creation of Greened Acres, a metric for converting impervious landscapes into green stormwater infrastructure that reduces runoff.

These measures sustainably manage the first inch of runoff, preventing 80-90% of the 1 million gallons of annual rainfall from entering the sewer and becoming polluted.



◀ Green City, Clean Water projects and interactive map

INTEGRATED DESIGN

A multifunctional oasis

PROJECT
Central Park and Canal

LOCATION
New Songdo City,
South Korea

1,500 acres
reclaimed land

Central Park and its seawater canal provides a multifunctional oasis for the international business district.[35]

South Korea's first ever seawater canal has been created on 1,500 acres of land reclaimed from the Yellow Sea. The project involved an extensive remediation strategy to create a plantable landscape on the sea-dredged soils. The canal itself provides a natural cooling mechanism to tackle the urban heat island effect and increases biodiversity. The surrounding park offers a green retreat extending over 100 acres. The vegetation is supported on the reclaimed fill through a capillary break layer of growing medium fed by a sustainable irrigation system that conserves water and responds to the region's extreme weather patterns. Underground water storage captures the heavy summer rainfall and stores it throughout the dry winter for irrigation in the spring. This system is supported by carefully selected vegetated which favours dry conditions, saving energy by minimised pumping efforts.

▶ Songdo Central Park and Canal

INTEGRATED DESIGN

Tackling vulnerability through urban innovation

PROJECT
Cloudburst Excess Water Management Plan
LOCATION
Copenhagen, Denmark

10,000 people
participated in initiatives

Copenhagen is tackling vulnerability to increasing heavy rainfall through the 'Cloudburst' Masterplan and urban innovation.[36]

Tåsinge Plads hosts many cloudburst interventions to create a dynamic, multifunctional and resilient urban space[37]. Planting areas temporarily store water during storm events. Umbrella sculptures capture and store rainfall for irrigation. Stormwater is directed into underground storage tanks -hosting a sprung floor which generates energy to pump water away, as children play in the square. 10,000 people participated in 170 citizen-led initiatives to ensure the needs of the community would be met by this development. These blue approaches were also approximately half the combined price of traditional grey interventions.

▼ Tåsinge Plads

INTEGRATED DESIGN

Water from thin air

Lima have found a way to generate income and a potable water supply from thin air.[38]

Lima is one of the driest places on earth, frequently experiencing 90%+ humidity due to proximity to the Pacific Ocean. Lima University has developed a billboard with five condensers, cooler than the ambient temperature, causing water vapour in the air to condense. A reverse-osmosis purification system treats the water and stores it for use by local residents. The billboard produces 96 litres per day and cost just US$1,200 to install which is offset by advertising income.

PROJECT
Water from Air
LOCATION
Lima, Peru

96 litres
water produced daily

▼ Billboard purification, Lima

INTEGRATED DESIGN

An innovative rainwater harvesting system

New York's innovative rainwater harvesting system contributes to the East River Waterfront's sustainability goals, reduces potable water use and diverts stormwater from the East River[39]

The East River Waterfront is reducing its potable water consumption by reusing rainwater to irrigate the landscape. A rainwater harvesting system designed by Arup optimises the supply-demand balance by capturing, storing and treating surface water runoff. Stormwater runoff from the FDR Drive highway is collected, conveyed, treated to remove oils and sediments, stored and disinfected before being used to irrigate parks. A key aspect of the design was efficient use of space to fit amongst the many existing utilities and the groundwater table just two metres below the surface.

PROJECT
East River Waterfront

LOCATION
New York, USA

◀ East River Waterfront, New York

INTEGRATED DESIGN

Using ‘talking tanks’ to integrate water management

PROJECT
Aquarevo Stormwater Impact Model

LOCATION
Lyndhurst, Victoria, Australia

South East Water is using ‘talking tanks’ to integrate water management into new residential developments.

The new Aquarevo residential development will use rain water harvesting tanks to supply hot water to plots. The tanks will also act as a conglomerate of reservoirs controlled by ‘Tank Talk’. This smart control system is responsive to weather conditions to empty tanks in anticipation of heavy rainfall events. The empty tanks can then retain excess rainfall from roofs. Arup developed the hydraulic model to optimise the rainwater capture, usage and discharge of the tanks, and quantified the volumetric reduction in surface runoff both annually and during significant rainfall events.

▶ Rainfall from roofs

THOUGHTS

The synergies of the Sustainable Development Goals (SDGs)

PROFESSOR TONY WONG

Chief Executive of the Cooperative Research Center for Water Sensitive Cities

Cities and towns account for over 70% of global GDP and many are facing complex, interrelated challenges including population growth, resource constraints, degraded environments and increasing climate uncertainty.

Urban places concentrate and magnify many of the key challenges captured in the 17 Sustainable Development Goals (SDGs).

The interconnections between the goals may manifest differently in developed compared to developing countries. However, the challenges of climatic extremes of floods and droughts, and degrading environmental qualities of urban water systems are universal to almost all cities.

Urban water infrastructure and governance systems remain focused around 20th century solutions and experience, creating a fragmented, technologically-based approach to 21st century water challenges. Therefore, it is not surprising that the High Level Panel on Water identified the need for a more holistic social-technical approach 'in an inclusive, comprehensive and collaborative way'.

Ensuring availability and sustainable management of water and sanitation for all (SDG 6) is intrinsically linked to sustainable cities (SDG 11); targets explicitly reference the importance of environmental protection and restoration linked to life below water and on land (SDGs 14 and 15). Sustainable cities (SDG 11) aims to significantly reduce the number

▲ Sustainable Development Goals

of people, especially the poor and vulnerable, affected by disasters. Contemporary, integrated urban water management solutions that address drought, flood and pollution already exist and can simultaneously contribute to good health and well-being (SDG 3).

Specific regional context will always determine the relative significance of interconnections between the SDGs, but integrated spatial planning and urban design can provide context-specific solutions that capture these synergies. Achieving SDG 11 requires organisational partnerships (SDG 17) and integrated, multi-functional, nature-based solutions that support the development of contemporary industry, innovation and infrastructure (SDG 9).

City Regeneration

Water bodies including rivers, lakes, estuaries, canals and seas can become focal points for redevelopment, increasing land and property value and acting as catalysts for city-wide regeneration.

A city that develops in consideration of both its natural basin and good water design and management will be more efficient, resilient and sustainable. In turn, this provides a robust foundation for economic success, as resilience to floods and droughts can be maximised thanks to blue and (retrofitted) green systems. Benefits include a better quality of life thanks to improved biodiversity, aesthetics, bio-filtration, natural treatment of air and water, and temperature regulation.

An Oxfam report in 2014[40] suggests that every dollar invested in wetland restoration returns US$15 in net economic and social benefits, such as buffering storm surges, safeguarding coastal homes, creating nursery habitats for fish and supporting recreation.

▶ Gardens by the Bay, Singapore

THOUGHTS

The educational and environmental value of urban wetlands

FLORENCE GLOCK
Engineer, SIAAP's Energies resources service

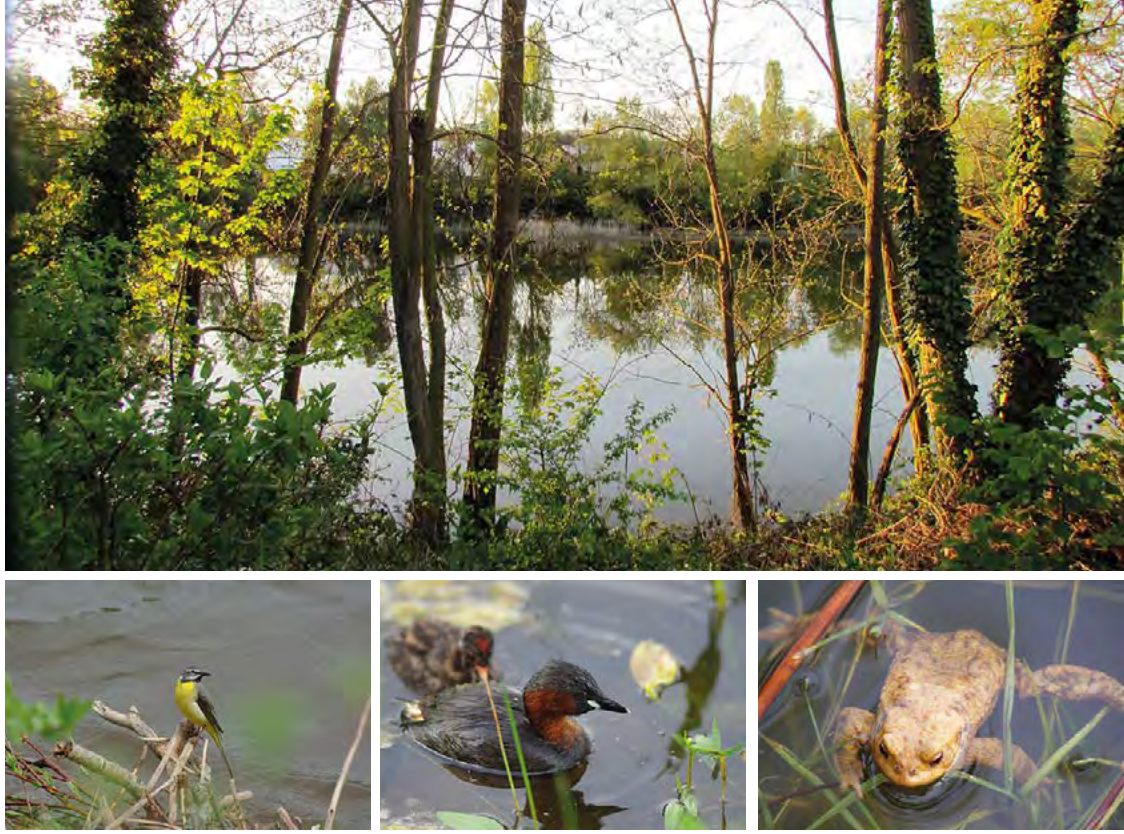
The Paris agglomeration has more than 10 million inhabitants. Within this agglomeration, the SIAAP (Greater Paris Sanitation Authority) provides sewage treatment for 9 million of them.

Its fundamental mission is to ensure wastewater treatment to reconcile urban development and protection of a natural resource: the River Seine. However, this central role for sustainable development of the region is challenged by the need to best manage this natural resource and adapt to the effects of climate change.

SIAAP promotes a policy of smart urban development, where water is present and at the service of users as an element of the landscape, source of amenity, and thermal regulator. In that purpose, it is necessary to develop a culture of exchanges between elected officials, urban planners, public services, and researchers, to create multifunctional assets.

One such example of this is the stormwater retention basin and natural reserve, the Bièvre Basin, a flood-control structure located in Antony and Verrières-le-Buisson, south of Paris. With an area of about 6 hectares, it is a wetland habitat of exceptional biodiversity in the heart of an urban area.

Nature surveys conducted since 1977 have identified over 650 various animal species living in the reserve, prompting the site to be classified as a Natural Area of Ecological, Faunistic and Floristic Interest in 1984, and a Regional Nature Reserve (RNR) in 2009.



▲ Bièvre Basin ecosystem

As co-managers of the reserve, SIAAP and League for the Protection of Birds, tackle the integrated challenges of hydraulic and landscape management, environmental conservation and ecological protection by:

1. Maintaining the refuge role of RNR's for Flora and Fauna.
2. Improving knowledge about the RNR's heritage.
3. Enhancing the natural heritage of the reserve.
4. Ensuring the management of the nature reserve.

All of this is achieved in conjunction with education and awareness building among the citizens on the wealth of benefits this wetland provides them. This is of great importance in ensuring the long-term sustainability of the reserve, which includes an observatory classroom and educational walking trails enabling children and adults alike to discover the biological richness of this site.

CITY REGENERATION

Restoration of a river to reinvigorate a city

PROJECT:
Cheonggyecheon River
LOCATION
Seoul, South Korea

639%
increase in biodiversity

Ambient temperature
3ºC
below city average

The regeneration of a critical three mile stretch of the River Cheonggyecheon has reduced the urban heat island effect and transformed the economic and cultural value of the area.[41]

For over 50 years, the Cheonggyecheon River in Seoul was trapped beneath a three-lane stretch of highway, creating a centre of congestion and pollution. Now the waterway has been transformed to unlock its potential, boasting three miles of fresh running water, accompanied by open space and tree-lined public walkways. The more natural landscape has reduced the local ambient temperature to 3ºC below that of the city average, boosted biodiversity by 639% and prompted land value to soar. The area has also developed into a tourist hotspot, drawing in 64,000 visitors daily. The restoration of the river has reinvigorated the city, bringing increased social, economic, and environmental value and boosting resilience to climate change.

▶ Cheonggyecheon River

CITY REGENERATION

Reconnecting the city to the Rhône

PROJECT
River Rhône
LOCATION
France

5km
regeneration scheme

Reconnecting the city to the River Rhône has created recreational space, boosted biodiversity and provided flood protection to the people and businesses of Lyon.[28]

This bold 5km regeneration scheme reconnected people with their river, which had become segregated by major highways. The scheme strengthened the presence of nature, and delivered new attractions including recreational space, playgrounds, restaurants and green space. These open onto a low promenade which doubles as temporary flood storage to accommodate the river's short, violent floods. Away from the city centre, the river banks become increasingly 'natural' whilst retaining their multifunctionality.

▼ River Rhône regeneration

CITY REGENERATION

Water as a catalyst for regeneration

PROJECT
Sokolowka River Valley
LOCATION
Łódz, Poland

The Polish city of Łódź has been regenerated by restoring its twin rivers and integrating urban water management throughout its basin.

Once the centre of a booming textiles industry, the city's two rivers Vistula and Odra were used as mixed stormwater drains and sewers creating severe environmental problems. The key to creating a more liveable and resilient city came through schemes to restore the natural functions of both rivers. The Sokolowka River Valley project supports flood management, increased water retention capacity and the recreation of wetland habitats boosted biodiversity and improved quality of life in the whole basin.

▼ Sokolowka River Valley

CITY REGENERATION

Water for quality of life

PROJECT
Active, Beautiful, Clean Waters (ABC Waters) program

LOCATION
Singapore

Improved water quality and life of

8,000km waterways

Singapore has transformed into a vibrant City of Gardens and Water by optimising reservoirs, rivers and canals.

The Active, Beautiful, Clean Waters (ABC Waters) programme[42] aims to improve the quality of water and life of the 8,000km of waterways and 17 reservoirs in the City's water supply network, reconnecting ecosystem services to people and the surrounding environment. At Bishan-Ang, the concrete channel has been re-naturalised into a living, functional river attracting wildlife back, the associated new park also provides community and recreational space, and doubles as floodplain storage during storms.

The Marina Barrage[43] separates the ocean and freshwater to create Singapore's first urban reservoir whilst mitigating floods and sea-level rise. The local water environment has improved in quality and diversity, exemplified by the return of the short haired otter and freshwater fish.

NEWater is a water reclamation programme currently providing 40% of the country's water needs by reducing reliance on unsustainable water imports. Wastewater is treated to create water for drinking, industrial processes and commerce. It is also mixed with natural freshwater in reservoirs to boost supply during dry periods.

▶ Gardens by the Bay, Singapore

CITY REGENERATION

From industrial estate to ecodistrict

The run-down port and industrial area surrounding Hammarby lake has been transformed into an Ecodistrict with its own environmental program integrating water, energy and waste.[44]

Stockholm's first ecocity district of the millennia, the Ecodistrict integrates traditionally segregated infrasystems including technical, mobility and communication, building and blue infrastructure to provide self-sufficient water, waste and energy services. Large-scale sustainable drainage systems harvest and filter wastewater and stormwater in an aesthetically pleasing way to enhance the neighbourhoods liveability. Water use is minimised using low-flow devices and stormwater is directed into Lake Hammarby or treated locally to optimise sewer capacity. Even wastewater is used as a resource with Hammarby thermal plant recovering waste heat from Henriksdal sewage treatment plant, ensuring all water assets are sustainably managed.

PROJECT
Hammarby Sjöstad

LOCATION
Stockholm, Sweden

◀ Hammarby Sjöstad, Stockholm

CITY REGENERATION

Reconnecting a city to water

PROJECT
Neue Ufer (New Shores) project

LOCATION
Leipzig, Germany

2.5km
millraces uncovered

The Neue Ufer (New Shores) project has effectively reconnected the city with the millraces since the late 1980s.[28]

In 1954, two rivers were redirected, canalised and culverted, effectively distancing people, nature and water. The New Shores program investigated a way to sustainably design these millraces to upgrade their authentic historical elements and create new green space to regenerate the millraces and wider city. Sections of the watercourses have been reconstructed, a water playground and access to the river have been constructed, and 2.5km of the millraces have been uncovered. New water-orientated open spaces with historico-cultural references provide recreational, cultural and social amenity in the heart of the city. A floating garden, Der Schwimmende Garten, celebrates the connection between art, nature and water to create an area of tranquillity and peace. New plant beds and streetscapes hover over the millraces in places, providing fluvial-urban continuity. These blue solutions have regenerated the whole town by creating space and place in an otherwise inconspicuous space.

▶ Leipzig New Shores project

THOUGHTS

Using urban catchment forestry to tackle flood risk

PAUL NOLAN
Director,
The Mersey Forest

Urban Watershed Forestry has developed in the United States over the last 15 years to improve water quality, manage flooding, and reduce stream erosion.

It is now embedded in how urban basins are managed, with engagement from a range of professionals, including engineers, planners, developers, and foresters.

In the UK, The Mersey Forest Team has worked with colleagues in the US to develop 'Urban Catchment Forestry'. This is an ambitious and long-term program, seeking to make a convincing business case to enable the strategic use of urban trees and woodlands to reduce flooding, improve water quality, and bring wider benefits.

As well as working on catchment-scale interventions to 'slow the flow' and hold water in the landscape, we can use green infrastructure to reduce flood risk in our towns and cities and reduce the level of pollutants flowing into our rivers or water treatment facilities. Urban Catchment Forestry starts by defining the new 'urban' catchment, made up of the installed drain network and, sometimes rivers.

Existing surface water flood risk maps and hydraulic models can inform flow direction and the planning of our Urban Catchment Forestry interventions. Developing tree pit designs to slow the flow, maximise water treatment and perhaps store water. As water passes through soil, nutrients can be recycled and pollutants reduced.

▲ Urban Catchment Forestry

The Urban GreenUP project, funded by Horizon 2020, will be the first large scale monitored Urban Catchment Forestry intervention in the UK. It will complement the work that is going on with Natural Flood Management in the wider Mersey Basin and be part of the integrated use of nature based solutions to help us tackle urban flood risk issues.

"We know from previous work and from experience that psychological damage from flooding is one of the worst because every time it rains, which is quite frequent… then the panic levels start to rise and by doing something like this (nature-based solutions to water management)… you're doing something towards reducing that risk of flood further down."

Clare Olver, The Mersey Forest[45]

Transcending Barriers

To gain the benefits of a ‘water-wise’ approach to the planning and design of water in cities will require new ways of working, and the design and planning of water.

It will require strategic city planning and thinking to focus effort and resources behind a common goal. It will require long term planning and incremental working to achieve the aims. This is of course complex and challenging, but it is critical that if we are to meet current and future challenges in cities and leave a legacy in changing times, we must all embrace change.

The key will be greater integration and joint working across governments, education, industry and communities to gain mutual benefits and larger city-scale goals. This will require the formation of new partnerships and ways of working, new funding arrangements and an atmosphere of collaboration. We must rethink water as an asset across the water cycle in cities, and as a means to face the future.

▶ Chicago

THOUGHTS

Fast recovering infrastructure

STEVE MODDEMEYER

Principal, CollinsWoerman.

We can no longer count on the weather of the past to design our infrastructure of the future.

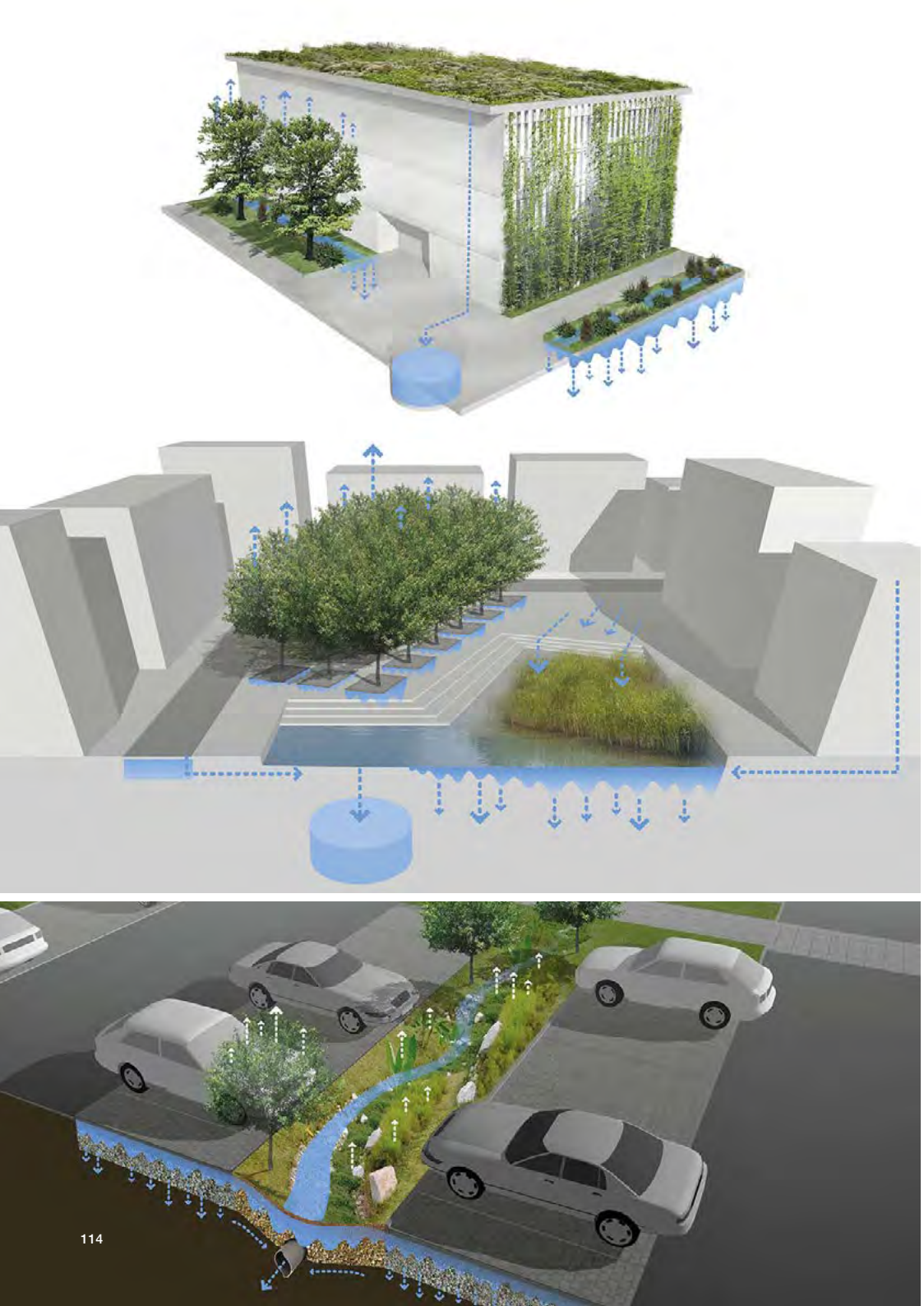
The ‘Death of Stationarity’ means that we need to hard-wire socio-ecological resilience thinking in how we design infrastructure. Instead of designing roads, bridges, sewers, and water supply systems to withstand extreme weather events, we should be focusing on designing infrastructure that recovers quickly. Likewise, the rate of technological change is stressing existing institutions to adapt. We need a new paradigm that helps communities to navigate change.

A first step is to stop externalising the cost and impact of recovery to the victims and survivors. Using a socio-ecological approach to resilience we can internalise recovery as part of the pre-planning and pre-design process for all infrastructure. We have been demonstrating this approach in the Puget Sound region of the United States. In the town of La Conner, Washington we worked with the community to identify flexible and adaptable solutions to sea level rise and urban flooding. Collaborating with the Puget Sound Regional Council of governments, we have developed resilience policies for regional planning to guide future growth management and transport funding. Working with the Washington State Departments of Transportation and Fish and Wildlife and local Indian Tribes, we have been developing a pilot process of design charrettes to help local communities identify priorities for recovery from flooding and other extreme events.

▲ La Conner, Washington

These efforts created new priorities for infrastructure design and new innovations required in the design of infrastructure to provide reliable service and quicker recovery. This leads to an emerging demand for modular culverts, replaceable bridges, and enhanced real-time sensing of performance for fish and vehicle mobility using computer vision and pattern recognition algorithms.

The future of resilient cities and infrastructure will be based on flexible, adaptable designs that internalise recovery while adapting to changes in climate and technological advancements using existing levels of spending.



TRANSCENDING BARRIERS

The ‘Green City by the Water’

This ‘Green City by the Water’ has decades of practice[46] and experience in sustainable urban development.

Hamburg is the second largest city in Germany, housing over 1.8 million people, but 8% of its area is open water. This urban water environment enabled industry to flourish around its large port, but also entails a host of challenges including flood risk mitigation, ecological conservation and maintaining a healthy water budget. Urban planners have been addressing these challenges through the implementation of blue infrastructure since 1984. More recently, the Rain InfraStructure Adaption (RISA) project has tackled rainwater management to avoid flooding and water pollution from combined sewer overflows and urban run-off. Flood risk from the River Elbe was analysed in 2009 and a structural plan was developed in 2012. Pilot projects successfully used an integrated approach involving relevant water, greenspace, transport and environmental authorities to develop comprehensive and holistic blue infrastructure interventions.

PROJECT
RISA

LOCATION
Hamburg, Germany

8%
of Hamburg is open water

◀ RISA water management plans

TRANSCENDING BARRIERS

Collaborative action for clean water

PROJECT
Karachi Water Partnership

LOCATION
Karachi, Pakistan

50m gallons
water needed in Karachi per day

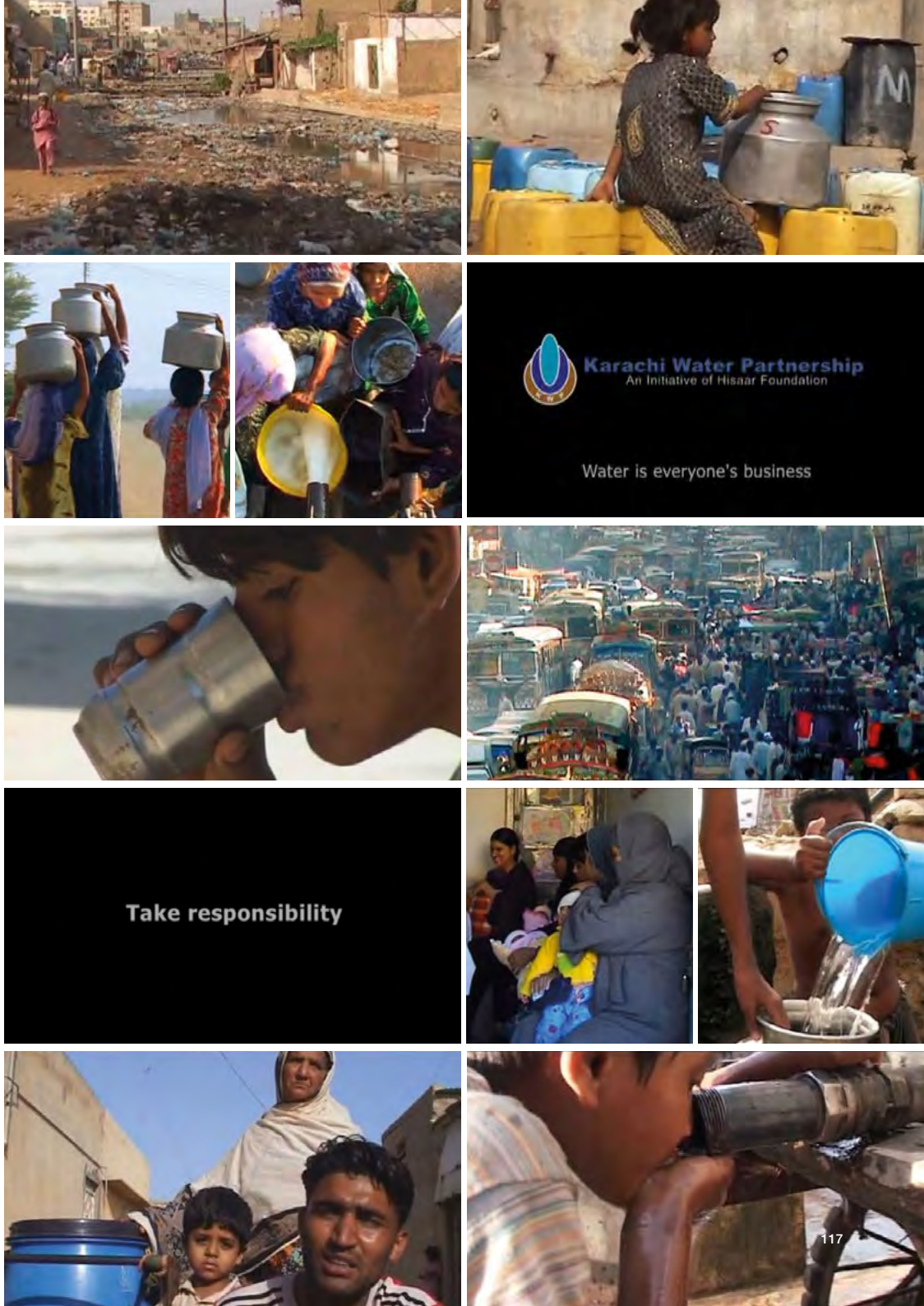
40%
of water is lost through leaky infrastructure

A group of concerned citizens have developed a water partnership to promote safe, sufficient, integrated water resource management.

The Karachi Water Partnership joins the civil and private sector, water professionals and members of the public to collectively drive better management of the city's water resources[47].

As one of the largest and most densely populated cities in the world, Karachi has a high water demand. Water resources and management are falling drastically short of the city's needs: water demand is 50 million gallons a day (MGD) greater than the supply, 250 MGD of wastewater goes untreated, 40% of water is lost through leaky infrastructure and 25% through wasteful consumption. Launched in 2007, the Karachi Water Partnership (KWP) comprises partners from the government, private sector, civil society, media, academia, water professionals and more, striving to build citizen ownership of water resources. They have signed numerous Memoranda of Understanding with institutions such as Karachi Water and Sewerage Board and have developed six Area Water Partnerships to facilitate partnership building, stakeholder engagement, training workshops and education on improved water management and conservation methods. Additionally, KWP has provided over 20 government schools with clean drinking water and sanitation.

▶ Karachi Water Partnership documentary



TRANSCENDING BARRIERS

Partnership working for success

PROJECT
Beam Parklands
LOCATION
Dagenham, UK

53 hectares
of wetland park

12 hectares
of UK Priority Biodiversity Action Plan habitat

The transformation of a flood prevention area into an award winning, multi-use community space and wetland park was achieved through partnership working.

The existing green area in Dagenham was a low quality public space on the floodplains of the River Beam and Wantz Stream. It attracted antisocial behaviour and did little to alleviate flood risk to over 600 properties. Working together, Arup along with the Environment Agency, The Land Trust, London Development Agency, and London Borough of Barking and Dagenham reinvigorated the space to create 53 hectares of wetland park for the local community. The park was developed through close engagement with the local community and schools. The park now integrates long-term flood protection and new wetland habitat, along with 12 hectares of UK Priority Biodiversity Action Plan habitat. The Land Trust now has long term ownership of the Parklands, ensuring that it provides significant community benefit, helping to regenerate a deprived area.

"The Beam Parklands project shows just what can be achieved when public, private and community groups truly work together. The project has demonstrated real multi-functional benefits - enhancing biodiversity, improving flood storage capacity and providing a community resource - for a truly winning combination. We hope other communities will follow their lead."

CIWEM Living Wetland Award Judges

▶ Dagenham Parklands

TRANSCENDING BARRIERS

Alternative sources for sustainable supplies

Marrakech is diversifying its water resources portfolio, reducing water demand by addressing leaky pipes and promoting participatory groundwater management.[48]

Through this initiative the city has curbed water losses from leaky infrastructure from 40% to 27% in 15 years, with a target of 20% by 2020. The city has engaged its rapidly expanding tourism industry too to sustainably manage water by treating and reusing wastewater on golf resorts. The city is further looking to diversify its water supply sources, through enhancing groundwater management and capturing stormwater for use in aquifer recharging.

All of these initiatives have been supported by the World Bank's Water Scarce Cities Initiative, which aims to deliver realistic solutions to deliver water security in cities. The initiative provides a toolbox to support water resilient strategies, creates connections and shares solutions between cities.

LOCATION
Marrakech, Morocco

13%
Reduction in water losses in 15 years

◀ Marrakech

TRANSCENDING BARRIERS

Natural solutions for the urban realm

A new Utrecht neighborhood is benefiting from a sustainable water system providing clear and clean surface water.

The Leidsche Rijn is the largest urban development project in the Netherlands, providing 30,000 new homes between 1997 and 2025. An integral component of the development is the sustainable, closed-circuit water system including natural wetlands, bioswales, pumping stations and permeable paving. The main goal of the project is to provide clean and clear surface water with benefits for neighbourhood quality, biodiversity and recreation. A dedicated Leidsche Rijn water system task force coordinated and implemented the infrastructure, involving Utrecht province, Utrecht municipality, Vleuten de Meern municipality and the water authority (De Stichtse Rijnlanden). This collaborative approach successfully delivered an attractive living environment, while also providing important biodiversity benefits and supporting urban climate change mitigation with minimum maintenance costs. The scale of Leidsche Rijn water system makes it a unique urban nature-based solution made possible by long-term partnership working, ambitious political targets, and experimentation.

PROJECT
Leidsche Rijn

LOCATION
Utrecht, The Netherlands

ARTICLE AUTHOR
Dr Sander van der Jagt, Copernicus Institute of Sustainable Development, Utrecht University, NATURVATION

30,000
new homes between 1997 and 2025

◀ Leidsche Rijn, Utrecht, The Netherlands

TRANSCENDING BARRIERS

Inspiring change in stormwater management

PROJECT
The Downspout Disconnection Program, Portland Ecoroof program, Innovative Wet Weather Program

LOCATION
Portland, Oregon

Portland's Bureau of Environmental Services leads the way in sustainable stormwater management, implementing regulatory compliant, educational and inclusive blue interventions.[49]

The Stormwater Policy Advisor Committee was created to ensure stormwater best management practices were implemented across the city. The committee brought together landscape architects, architects, engineers, institutional organisations and the stormwater treatment industry to create a city stormwater management manual, enabling users to easily identify, calculate and design best practice. Updated every two years, the manual details techniques that mimic natural systems.

The manual gives many options and can be used by all in the city to contribute to creating resilience. For example, the Downspout Disconnection Program successfully redirected almost a billion gallons of water from combined sewer overflows entering the Columbia Slough and Willamette River to private gardens. The implementation of large-scale tree planting, green street and green roof (Portland Ecoroof) programs combine to intercept and slow rainwater, reduce urban runoff and contribute to a more liveable, sustainable city. The Innovative Wet Weather Program utilises blue infrastructure techniques to provide stormwater retention and has uplifted communities around the city.

▶ Both: Portland Ecoroofs

THOUGHTS

The cost of water

ELAINE PANG

Senior Water Engineer and Practice Leader for Water Planning and Strategy, Australasia, Arup

What is the real cost of producing water, and who should pay?

This question is rooted in historical institutional arrangements and our cultural relationship with water; many perceive water as a freely available resource that we should not pay more than a nominal amount for, recently exemplified in Cape Town where people proclaimed: “Water is a human right!”

Governments have historically borne the cost of water supply as a societal benefit, with citizens paying only a portion of the true cost. However, potable water has become increasingly expensive to provide due to the rising costs of energy, aging infrastructure, resilience and safety measures and environmental stewardship. Local government and water service providers are also under increasing scrutiny for their spending; demanding they ‘do more with less’ and operate infrastructure with minimal investment. However, this approach is an ineffective short-term strategy which only defers expenditure.

Across all parts of the water cycle, there are win-win solutions if we can break down institutional barriers to achieve gains for multiple stakeholders. Possible opportunities can be found in almost any aspect of the water cycle, which some forward-thinking organisations are already discussing.

Major dams in Australia currently face recurring and increasing cost commitments to increase storage capacity as well as flood retention and structural safety, driven by population growth and the anticipated effects of climate change.

▲ Safe water kiosk, Chipata, Zambia

This can cost millions of dollars and require multi-agency conversations to agree the best solution. Relocating or raising vulnerable homes and infrastructure may be more cost-effective than upgrading dams, as with the Lockyer Valley after the devastating floods of 2011.

The Australian Water Outlook[50] found only 3% of community respondents had complete confidence in water security and the country’s ability to meet all social, environmental and economic needs.

Additionally, reshaping the rules around water reuse, drinking water standards and fitness for purpose could be utilised to improve drought resilience. Greywater could be used in place of potable water for toilet flushing and watering landscapes. The other half of the battle will be to ‘re-brand’ potable water reuse to support cultural acceptance. Perhaps the real question is: what is the real value of water, and how can we gain the most value from this resource?

Delivering water

For too long we have managed water by channelling it underground or out of sight, with only grey infrastructure visible to the world.

Stockholm, Sweden

▲ Multimedia Fountain Park, Warsaw

The rigid nature of grey infrastructure is not always conducive to the challenges of climate and population change.

The link between well-designed and implemented blue infrastructure and the operational performance of cities is increasingly acknowledged. Therefore it is clear that more best practice blue strategies must be implemented and communicated to the world. This will allow governments to make informed decisions on water infrastructure and deliver more holistic city planning.

A blue approach to planning offers a variety of processes and tools that help to identify strategic, low impact and financially competitive development and management options.

Communicating and celebrating these options will enable decision-makers to overcome any misconception that system scale planning is slow and expensive. Sustainably managing water resources with the involvement of its users can maximise health and well-being, and often for a fraction of the environmental, social and financial cost of grey infrastructure.

Water without borders

Water basins are natural systems that transcend political, economic and socio-cultural boundaries.

Water resources should be utilised and managed within the context of their entire basin in order to be sustainable and maximise co-benefits. Many water managers already strive to plan their water assets at the basin-scale, promoting integration with planning and management of other urban systems.

Inter-basin transfer (moving water from one river basin to another) is responsible for around 42% of water supplies globally.

The 100 largest cities in the world transfer 3.2 million m^3 of water, approximately 5,700km, on a daily basis through artificial channels[2], which highlights the need for integrated basin-scale water management. This requires engagement and collaboration between governments, environmental regulators, infrastructure providers. businesses and, perhaps most importantly, local communities.

▲ Urban river

Governance

The wider co-benefits of blue approaches to city planning and design are increasingly being recognised.

Blue infrastructure in cities delivers river basin-wide benefits. As the scale of blue infrastructure interventions increases, as does the potential complexity of the governmental considerations.

By involving a greater number of parties (decision-makers, authorities and asset providers), cities can use resources and various budgets more efficiently[51].

Inconsistent objectives between organisations can be a major reason for projects not achieving their goals. The Chartered Institute for Water and Environmental Management has also recognised that institutional arrangements do not always benefit decision-making between sectors. This recognition is an encouraging step in implementing positive environmental and social change through blue infrastructure.

Funding and delivery

New funding models are required for the correct implementation of blue approaches.

Once funding is secured there is an increased level of impetus, support and commitment to the delivery of blue infrastructure. The multifunctionality and associated benefits of blue infrastructure can strengthen business cases and stimulate and enhance cooperation, resulting in increased coordination of budgets between different groups.

The discussion on who benefits from, and who pays for, blue approaches in cities is ongoing. Longer term, the outcomes of this discussion and associated research will help to inform how blue approaches are funded at the city scale.

Government incentives such as tax cuts or reduced water rates are an effective way to reimburse and encourage private investors. A considerable opportunity lies with the involvement of insurance brokers, given that blue infrastructure mitigates flood risk (and other risks) and reduces damages claims. Implementation of blue infrastructure is in the insurers' best interests, so involving them in projects early on can be imperative.

▲ Philadelphia Green City, Clean Water art contest. Public involvement and support for scheme.

Blue cities

There are many good examples of blue cities around the world.

The following case studies highlight how nature-based design approaches to water infrastructure projects can be effective in tackling the key challenges of our time within city environments. These examples deliver both resilience and create sustainable water assets for cities promoting wider benefits and cover a range of scales from national strategy to more local blue infrastructure interventions.

These examples help illustrate that to be successful blue infrastructure needs to be planned at a strategic scale. By establishing a strategic masterplan, vision or road map, resources and funding can then be focussed behind a common goal. This will help the incremental delivery of blue infrastructure over time at regional and local levels.

Where possible blue infrastructure strategies should be combined with green infrastructure to create mutual benefits.

The focus for any blue infrastructure strategy should be on health and well-being of city populations:

"When we go out and talk to any of the communities in the area affected by flooding in the past, they are very clear on the amount of anxiety they've dealt with, and we have statistics in Hull about the mental health issues following the floods… there are a lot of people on [medication] to help them with that."

Rachel Glossop, Flood Risk Planning Manager, Hull City Council

▶ Midtown Garden, Roppongi, Tokyo

▲ Doha

LOCATION: Doha, Qatar
AREA: 132km^2
POPULATION: 800,000
AVERAGE ANNUAL RAINFALL: 75mm over 9 days

Doha

Qatar has developed an ambitious mega-reservoir project to meet water demand that is the first of its kind. A national plan will provide water-security in anticipation of economic growth and an expected population increase of 25% in Doha by 2030. The nation has historically relied on desalinated water due to its low freshwater reserves. The construction of five interconnected sites, each with four or five reservoirs will provide at least seven days of reserve water.

▲ Kampala street

Kampala

Rapid urbanisation in Kampala is causing management problems related to sanitation, water supply and flood protection. The Kampala Physical Development Plan aims to effectively deliver flood resilience and water security alongside sustainable water and sanitation. This is made possible through partnerships with the National Water and Sewerage Corporation, government ministries, NGOs and local communities. Kampala is developing new treatment plants and pre-paid meters to give people living in poverty access to clean water.

LOCATION:
Kampala, Uganda
AREA: 192km^2
POPULATION: 1.5m
AVERAGE ANNUAL RAINFALL: 1290mm over 152 days

▲ Leeds FAS weir

LOCATION: Leeds, UK
AREA: 552km²
POPULATION: 715,500
AVERAGE ANNUAL RAINFALL: 1025mm over 152 days

Leeds

Leeds experienced widespread flooding in 2015, from some of the highest river levels ever recorded. In response, the Leeds Flood Alleviation Scheme (FAS) is taking a basin-wide approach in planning resilience. In the city these innovative adjustable weirs can be lowered during flood events to minimise water levels, while landscaped flood defences promote fluvial continuity. Phase 1of the FAS protects 500 businesses and 3,000 homes, whilst also providing usable new city space for people.

▲ Benthemsquare, Rotterdam

Rotterdam

With 60% of the population living below sea level, The Rotterdam Climate Proof Programme has driven innovation. Benthemsquare was Rotterdam's first water plaza, combining flood protection with improved public space and vegetation cover. Comprising three rainwater detention basins, the plaza doubles as a sports park. Incentivised by the local government through subsidy schemes for private properties and mandatory implementation on municipal properties, Rotterdam's built environment is integrated with water storage wherever possible.

LOCATION:
Rotterdam, Netherlands
AREA: 320km²
POPULATION: 625,000
AVERAGE ANNUAL RAINFALL: 815mm over 152 days

▲ Sydney Park Wetlands

LOCATION:
Sydney, Australia
AREA: 12,400km^2
POPULATION: 4m
AVERAGE ANNUAL RAINFALL: 700-1,400mm over 144 days

Sydney

Sydney is committed to being a water sensitive city, implementing water efficient fixtures, swales, raingardens, wetlands and pollutant traps (such as at Sydney Park and the Drying Green Park wetland). The Decentralized Water Master Plan is reducing unnecessary water use by installing stormwater harvesting and water efficiency measures on existing and new developments and using recycled water wherever possible. Collaboration helps city-wide implementation of water-wise aspects, whilst asset monitoring with local research institutes increases awareness across the city.

▲ Chidorigafuchi, Tokyo

Tokyo

Tokyo is one of the most water-efficient cities in the world, with leakage rates of less than 3% (2016). The Tokyo Waterworks Environmental Plan also provides an effective strategy, laying out 34 targets around four policies; promotion of energy efficiency; conservation of a healthy water environment; effective use of resources; and promotion of environmental communication. This includes the management of a 23,000ha water conservation forest, the addition of green roofs on bureau's buildings and thorough infrastructure management.

LOCATION:
Tokyo, Japan
AREA: 2,188km^2
POPULATION: 9.27m
Average annual rainfall: 1,500mm

Conclusion

By pooling our expertise and understanding we can achieve healthy and sustainable blue cities that cater to the wants and needs of those who live in them.

Stockholm, Sweden

Closing messages

By applying five core principles when planning and designing ‘blue’ cities, we can shape a better world.

We can achieve a positive water management state that is considerate of the whole water cycle. This will boost cities’ resilience to the inevitable challenges of climate change, increasing global population and urbanisation. People-focused blue cities will be maximising their chance of long-term prosperity and economic health.

By celebrating existing success stories to raise awareness of blue infrastructure opportunities, offering financial incentives, and publicising collaborations and commissions, we can attract greater interest in blue infrastructure. Alongside inclusive and adaptive urban planning processes, this will ultimately deliver blue cities that embrace water as an asset.

PUTTING PEOPLE FIRST

The needs of communities and individuals should be at the heart of sustainable city planning and design. Real benefits can only be achieved by harnessing opportunities across the whole water cycle.

BASIN SENSITIVE CITIES

Recognising the relationship between cities and basins in which they exist to improve the sustainability of both the natural and built environment.

INTEGRATED DESIGN

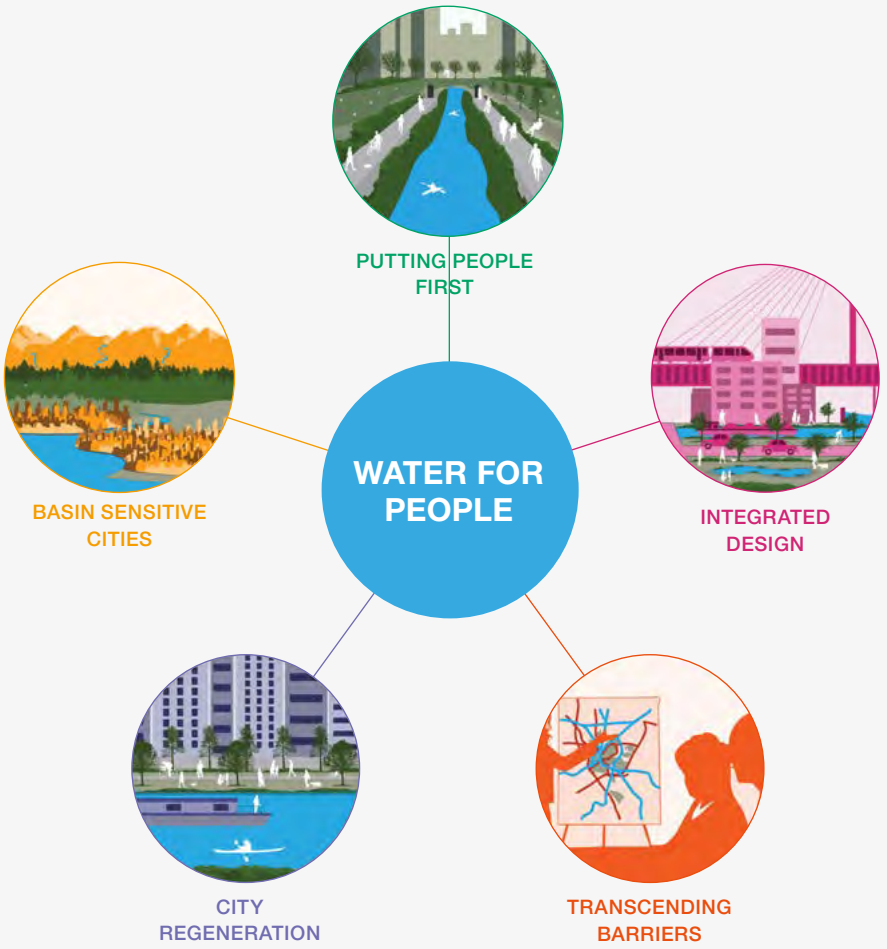
Multifunctionality can be designed into new, or retrofitted within existing, infrastructure to create interconnected cities that are better equipped to manage future challenges.

CITY REGENERATION

Cities that are developed to be sensitive to natural processes are more resilient, sustainable and efficient. Waterbodies can also be focal points for development and regeneration.

TRANSCENDING BARRIERS

New ways of working involving greater engagement, integration and collaboration across governments, industry and communities, in the context of the complete water cycle is the best way to gain mutual, city-wide benefits.



Cities Alive: Water for People

Cities Alive publications

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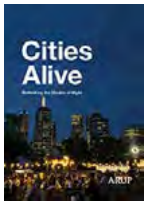
RETHINKING GREEN INFRASTRUCTURE

Cities Alive looks at how we can build nature into our urban systems at all scales through high quality landscape design, via new development or retrofitting through a green infrastructure design approach. The publication analyses existing research and trends in landscape design, drawing out key elements which can help deal with rapidly rising urban populations, mitigate climate change and produce integrated solutions.



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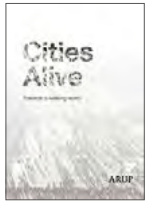
RETHINKING THE SHADES OF NIGHT

Rethinking the Shades of Night looks at the role of light in creating human-centered urban night-time environments. The report emphasizes a more context-sensitive design approach and a holistic integration of lighting infrastructure into the urban fabric. It focuses on the human factor and ways to enhance the experience and use of public space during the hours of darkness.



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TOWARDS A WALKING WORLD

Mobility is intrinsic to the quality of life experienced in cities. But for the past century, the car has dominated how we plan and grow our urban areas. With a growing desire to create more liveable streets, a light needs to be shone upon the benefits of walking as a catalyst for developing sustainable, healthy, prosperous and attractive cities.

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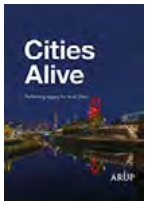
GREEN BUILDING ENVELOPE

In ever denser cities the space for green infrastructure, such as parks and green recreational spots, is being depleted. What is often considered as ‘green architectural decoration’ is, however, an important element in our built environment and should not be underestimated. The comprehensive research considers whether green building envelopes can have a special role to play in improving our cities for their inhabitants.



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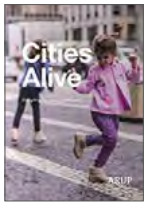
RETHINKING LEGACY FOR HOST CITIES

Major sporting and leisure events are under scrutiny like never before to deliver long term benefits for their host city, and the citizens within them. Arup is rethinking legacy. From venue optimisation, through to innovative finance models securing long term investment, we believe there are new ways to help cities achieve long term value and increased civic engagement through hosting.



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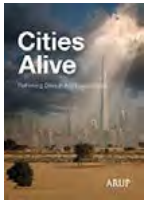
DESIGNING FOR URBAN CHILDHOODS

A child-friendly approach to urban planning is a vital part of creating inclusive cities that work better for everyone. Through 40 global case studies, 14 recommended interventions and 15 actions for city leaders, developers and investors and built environment professionals, the report shows how we can create healthier and more inclusive, resilient and competitive cities for us to live, work and grow up in.



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RETHINKING CITIES IN ARID ENVIRONMENTS

Cities Alive: Rethinking cities in arid environments proposes a strategic rethink of how we plan and design cities in arid regions. At the heart of the report sit three key recommendations to shape the next century of city building in arid regions. The report proposes 36 actions that local governments, planners, architects and investors can consider to support the development of more inclusive, resilient and competitive cities.

WATER FOR PEOPLE

Cities Alive: Water for People explores pioneering water approaches in cities around the world. It promotes five key ways forward for reconnecting people with the water cycle, delivering resilience and creating healthier city environments that help drive economic success.

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