Political and sOcial awareness on Water EnviRonmental challenges
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Abstract	This report includes an analysis of best practices on urban water management for the following specific themes: 1) extreme weather events, 2) reduction of drinking water consumption, 3) variables related to water conservation, and 4) water quality. For each theme the best practices in the Key Demonstration Cities (KDC) are provided. Front-running cities have been identified based on the database of the City Blueprint Approach of more than 60 municipalities in regions in 30 different countries. An overview of promising concepts is provided together with interviews with key entities and associations in water management and governance.

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v.08	19/7/2017	Stef Koop	Further work on reviewer comments, methodology and link to previous work on best practices in cities based on the City Blueprint Approach
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v. 12	23/8/2017	Stef Koop	Final layout check and incorporating improved contributions from CASSA and Hagihon.

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Executive Summary

Rapid urbanization, climate change and inadequate maintenance of water and waste infrastructures in cities may lead to flooding, water scarcity, water pollution, adverse health effects and rehabilitation costs that may overwhelm the resilience of cities. These megatrends pose urgent challenges in cities as the cost of inaction is high.

The main objective of this Work Package (WP) 3 is to actively engage end users (donors, beneficiaries, facilitators, etc.) in the requirements phase in order to ensure the involvement, in a progressive way, of a POWER wide society knowledge community and to ensure social, technological, environmental and political uptake based on sound evidence knowledge. Cultural and legal differences affecting the needs of the communities will be addressed in this WP, to ensure that both requirements (functional and non-functional) and use cases produced here take under consideration a Pan-European coverage. To achieve the above, WP3 will focus on structuring the user community approach by collecting and analysing best practices at European and international level. Best practices are defined as: *"a procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread application"*. Best practices are by definition an optimal alignment of technical, social and administrative procedures and arrangements, and thus require an integrative approach. This overview of best practices may be the start of a database of best practices which can enhance the exchange of knowledge and experiences between cities. It is important that this database mostly consists of a growing number of best practices that are provided by the cities themselves in order to create ownership and provide meaningful interaction between citizens, professionals and decision-makers of different cities. Hence, this deliverable provides a valuable contribution as an example to initiate the build-up of this database and facilitate the interaction between cities that apply the Digital Social Platform (DSP).

Section 2 (methods) will start with a clear definition of best practices. Best practices are defined as "*a procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread application*". Consequently, best practices are by definition an optimal alignment of technical, social and administrative procedures and arrangements, and thus require an integrative approach. Next, the methodology consists of 1) in-depth interviews with key entities and associations in the area of water management; 2) the Key Demonstration Cities (KDCs) formulate their best practices by reflecting on their policies, strategies and progression; 3) based on an extensive literature review, a few promising concepts are identified that may serve as clear examples of best practices to be adopted by other cities. Finally, we identify frontrunner cities that may have best practices that can be adopted by other cities. This is done based on the Trends and Pressures Framework (TPF) and City Blueprint performance Framework (CBF) which are part of deliverable 4.5. Both frameworks provide an integrated overview of the city's management of Urban Water Cycle Services (UWCS). Cities that experience considerable environmental trends and pressures (e.g. flood risk, water scarcity and water pollution) while at the same time have a high score for its performance indicators, may be considered as front runners. Because best practices have an optimal alignment of both technical and social-political components, we also involve the results of the water Governance Capacity Framework (GCF) in a few follower cities. The GCF methodology is explained in deliverable 4.7 and the in-depth analysis of the KDCs and several follower cities will be part of deliverable 4.8. All three assessments are part of the City Blueprint Approach. Details of the methodology are provided in EIP Water (2017 a,b,c), deliverables 4.5 and 4.7, and milestone 4.4.

In section 3, the experiences, insights, and visions of key entities and associations in the area of water management are explored. This is done by interviewing important representatives of the European Innovation Platform on Water (EIP Water), International Water Association (IWA), Water Supply and Sanitation Technology Platform (WSSTP), the Organisation for Economic Cooperation and Development

(OECD), and Waternet International. The interviews focus on the question of how communities in general could improve effectiveness and enhance water management, taking into account the expenses involved as well as the likely effectiveness in the city/neighbourhood. The next sections (section 4, 5, 6 and 7) will explore best practices in three steps. First, by summarizing the best practices in the four KDCs. Second, identify front-runner cities that apply best practices based on the City Blueprint® Approach. Third, provide examples of promising concepts that can be considered best practices. These steps are repeated for respectively the themes of:

1. Extreme weather events (section 4),
2. Reduction of water consumption (section 5)
3. Variables related to water conservation (section 6)
4. Water quality (section 7).

For extreme weather events various best practices have been identified that are carefully incorporated in spatial planning. In particular, blue-green infrastructure solutions appear to be effective in adapting to more frequent and more extreme rainfall events. These solutions include several other benefits such as recreational value, combatting air pollution, increasing biodiversity etc., which make these measures an attractive option that is often supported the cities citizens, companies and other stakeholders as well. The city of Leicester is implementing many valuable best practices that can serve as useful examples for other cities in order to enhance to share their best practices. We found that there are many cities that have best practices to combat extreme weather events. In particular, Amsterdam (the Netherlands), Berlin (Germany), Bristol, (UK), Copenhagen (Denmark), Dordrecht (the Netherlands), Hamburg (Germany), Jerusalem (Israel), Melbourne (Australia), Milton Keynes (UK), New York (USA), Portland (USA), and Seoul (South Korea). These are all cities that could share their best practices within the DSP environment and contribute to the database. With respect to reduction of water consumption, we found key insights into strategies of communication, economic incentives, stakeholder engagement campaigns that can be considered best practices. The city of Milton Keynes has considerable experience in raising awareness about reducing water consumption which are useful examples of best practices. Follower cities that would be particularly interested in this theme are cities in regions of water scarcity. For Europe, this would be predominantly cities in the Mediterranean. There are several cities that have a particular low drinking water consumption and could be considered as front-runners. Examples are Kortrijk (Belgium), Milton Keynes (UK), Copenhagen (Denmark) and most Dutch cities. In addition, the city of Melbourne (Australia) has also much experience in this field as it had to adapt to the millennium droughts. Different techniques have been identified that can improve the variables related to water conservation. In particular, systematic monitoring techniques have been identified. The city of Jerusalem has good track record that has the potential facilitate a vivid interaction of best practices with follower cities in the DSP environment. The city of Berlin (Germany), is one city that would be interesting to include in the DSP environment as they also have many best practices with respect to variables related to water conservation. Finally, best practices of water quality have been identified. Water quality is a very broad theme; at this stage of the project we focus on the theme of the quality of water for reuse. The city of Sabadell is well-known for their recycling of wastewater for purposes that require less stringent water quality standards. Other cities such as have similar best practices such as for greenhouses in Torre Marimón (Spain), industrial purposes in Tarragona (Spain), for irrigation purposes in Shafdan (Israel) and urban and recreational purposes such as in Sabadell and El Port de la Seva (Spain).

We found five important lessons for the identification and exchange of best practices between cities which may explain successes of the identified best practices. Best practices in general have a multi-sector approach, have a long-term scope, are cohesive, are practices that can to some degree be adopted by other cities, and address the most urgent water-related issues at hand. We conclude with the main characteristics of best practices which provide an important basis for identifying best practices that can be exchanged and build upon in the Digital Social Platform (DSP) environment.

1 Introduction

Cities play a prominent role in our economic development as more than 80 % of the gross world product (GWP) comes from cities. Only 600 urban areas with just 20 % of the world population generate 60 % of the GWP (Dobbs et al. 2011).

The European Environmental Agency made a comprehensive overview of urban sensitivity to climate change and identified four major water-related challenges: (1) heat, (2) flooding, and (3) water scarcity and droughts (EEA 2012). The Urban Heat Island (UHI) effect described an increased temperature in cities compared to the urban surrounding that amplifies heat waves with 4 to even 10 degrees in cities. Besides southern Europe, UHI affects cities where extreme heat events have been rare, such as Belgium, Germany, the Netherlands, Switzerland and the United Kingdom. For example, the summer in 2003 was estimated to have caused up to 70,000 excess deaths (EEA 2012). For flooding, four important types are identified: river floods, coastal floods, surface water flooding (also referred to as urban drainage flooding), due to extreme rainfall, and groundwater flooding (EEA 2012). All three types of flooding are expected to increase both in frequency and severity due to climate change. Especially urban regions are often situated in flood prone areas. Moreover, the soil sealing by impermeable concrete, asphalt and rooftops leads to high rainfall runoff making cities vulnerable for urban drainage flooding. Finally, water urban demands are rising due to population growth, urbanization and increased economic activity. Increased dependency on limited freshwater resources lead to increase water prices and more severe competition between different applications and interests.

These challenges can be discussed globally by clustering cities into distinct categories of sustainability and by providing additional data and information from global regions. We have distinguished five categories of sustainability: (1) cities lacking basic water services, (2) wasteful cities, (3) water-efficient cities, (4) resource-efficient and adaptive cities and (5) water-wise cities (Koop and Van Leeuwen 2015a, b; 2017). Many cities in Western Europe belong to categories 3 and 4. Some cities in Eastern Europe and the few cities we have assessed in Latin America, Asia and Africa can be categorized as cities lacking basic water services. Lack of water infrastructures or obsolete infrastructures, solid waste management and climate adaptation are priorities. It is concluded that cities require a long-term framing of their sectorial challenges into a proactive and coherent Urban Agenda to maximize the co-benefits of adaptation and to minimize the cost. Furthermore, regional platforms of cities are needed to enhance city-to-city learning and to improve governance capacities necessary to accelerate effective and efficient transitions towards water-wise cities. Sharing best practices of cities is part of this strategy. These learning alliances are needed as the time window to solve the global water governance crisis is narrow and rapidly closing.

The best practices in this document provide insight in applied knowledge that has been shown by research and experience to produce optimal results and that can be proposed as a standard suitable for widespread adoption in the project's following cities and beyond. These best practices are all water related and focus on both technical and socio-political aspects. Furthermore, the summary of best practices provide a basic framing of the challenges and solutions that will be explored and identified by 1) analysing the socio-technical and legislative requirement and opportunities (deliverable 3.2), developing real-life situations and scenarios with respect to the end-users (deliverable 3.3), structuring visualizing of implicit knowledge of individuals and communities (deliverable 3.4) and exploration of the applicability of existing tools (deliverable 3.4). This report includes analysis of best practices in city water management. First, with regard to each issue of the Key Demonstration Cities (KDCs). The KDCs are Leicester (focus on extreme weather events), Milton Keynes (focus on reduction of water consumption), Jerusalem (focus on variables related to water conservation), and Sabadell (focus on water quality). Second, front-running cities will be identified for each theme and examples are provided as well. Third, an overview of promising examples for each theme are provided.

2 Methodology

2.1 Definition of best practices

Best practices in urban water management is widely acknowledged as complex, because it requires water management planning to protect, maintain and enhance multiple benefits and services of the total urban water cycle. This may include supply security, public health protection, flood protection, waterway health protection, recreation, intra and inter-generational equity, and demonstrable long-term environmental sustainability. It is therefore complex to identify and trade of multiple benefits across the urban water cycle. In the past, water managers have often reduced this complexity by focusing on optimising singular parts of the water cycle in isolation of reliable consideration to the other elements of the cycle. This has led to a compromise numerous well known social, ecological and economic costs which have increase the overall vulnerability of a cities. Hence, solutions that best protect and enhance the full suite of values and benefits from a total water cycle perspective are likely to result in more resilient solutions in the long-term (Wong and Brown 2009). We therefore define best practices as "*a procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread application*". Consequently, best practices are by definition an optimal alignment of technical, social and administrative procedures and arrangements, and thus require an integrative approach. Hence, best practices are by definition an integration of technical and social-political elements in order to address specific local water challenges. The POWER DSP aim to foster an optimal alignment of technical, social and administrative procedures and arrangements by increasing social interaction between citizens, professionals and decision-makers. Importantly, the exchange of best practices between cities can boost the learning process of adopting best practices and modify them in order to best fit the local demands and requirements. It is important that cities develop and share their best practices through the DSP. Therefore, this deliverable has aimed to facilitate this process by

1. Providing the best practices identified by the KDCs which form a start for the exchange of best practices for each theme.
2. Identifying front-running cities that show a high performance with respect to the theme related challenges they face. The focus will be on how communities in general could improve effectiveness and enhance water management.
3. Showcasing a few promising concepts for each theme.

2.2 Collection of best practices

The management of water supply can be split into five components, each of which is influenced by a wide range of factors in addition to the amount of rainfall a city receives (Philip 2011). These are:

1. Resource – The source of a city's water supply, for example rivers, aquifers and lakes.
2. Abstraction – The removal of water from the source through channels, pumps and boreholes.
3. Treatment – The application of treatment processes to produce water of potable quality.
4. Distribution – Pumping of the treated water to the points of use.
5. Demand – The use of water by people, industry, services, nature, etc.

Best practices in this section are defined much broader and include themes like climate adaptation and governance as well. The selection of best practices will be made based on three complementary data collection methodologies. First, we have carried out interviews with key entities and associations in the area of water management and with water managers in front-running cities. Key interviews have been held with members and representatives of: Watershare, IWA, EIP Water, OECD and WssTP. Here, matters such as the redistribution of resources across water services and sectors are covered. The interview are in accordance with the guidelines provided in deliverable 6.3 and the interview questionnaire is included in annex 1.

Second, the KDCs have formulated their best practices. Leicester City Council has identified their best practices with respect to the theme extreme weather events. Milton Keynes Council has formulated their best practices regarding the theme reduction of water consumption. Hagihon has identified their best practices in the city of Jerusalem with respect to variables related to water conservation. Finally, CASSA has collected their best practices with respect to water quality in the city of Sabadell. The four KDCs have collected their best practices by interviews, reflecting on their management practises and collecting knowledge regarding these best practices from their colleagues in the field.

Thirdly, frontrunner cities have been identified for each theme. This has been done by analysing data of over sixty municipalities and regions that have been analysed according to the City Blueprint Approach (Figure 1). The approach consists of three complementary frameworks. The main challenges of cities are assessed with the Trends and Pressure Framework (TPF; EIP water 2017a). How cities are managing their water cycle is done with the City Blueprint® Framework (CBF; EIP water 2017b). Both the TPF and CBF of the KDCs and follower cities are part of deliverable 4.5. An analysis about how cities can improve their water governance is done with the Governance Capacity Framework (GCF; EIP water 2017c). The GCF of the KDCs and follower cities is part of deliverable 4.7 and deliverable 4.8. All three assessment frameworks that are part of the City Blueprint Approach contain a systematic literature review and in-depth interviews with key stakeholders from various key actors involved in the integrated urban water cycle.

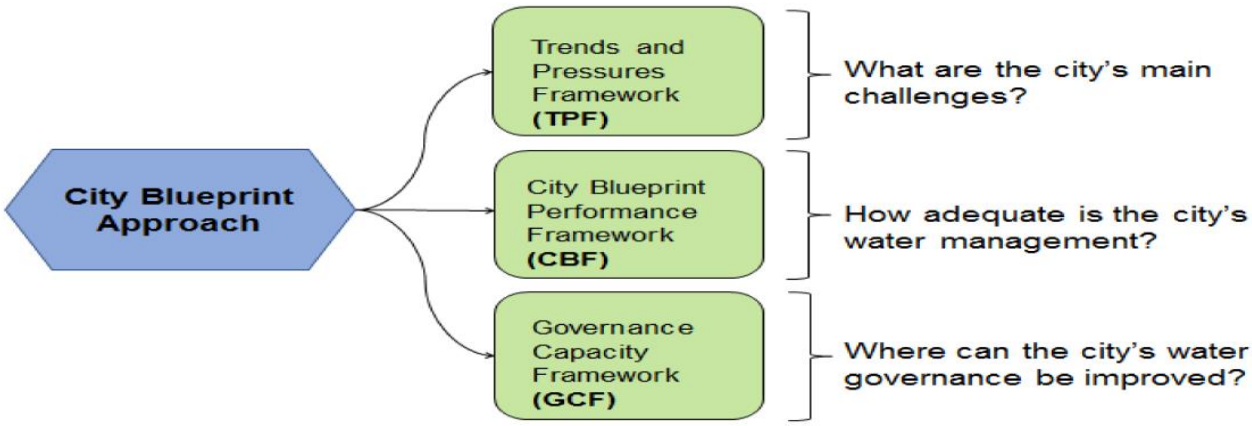


Figure 1 Overview or the City Blueprint Approach (EIP water 2017d).

The TPF summarizes the main social, environmental and financial aspects on which cities have hardly any influence but can affect urban water management. Table 1 show an overview of the TPF categories, indicators and sub-indicators. Indicators 5 and its associated sub-indicators have been used to identify cities that have challenges regarding the theme extreme weather events. Indicator 6 and its associated sub-indicators have been used to identify cities that have challenges regarding the themes water scarcity and variables related to water conservation. Indicator 7 and its associated sub-indicators have been used to identify cities that have challenges regarding water quality.

Table 1 Overview of the City Blueprint Trends and Pressures Framework (TPF). Indicators 5, 6 and 7 have been used to identify cities with challenges regarding the themes extreme weather events, water scarcity, variables related to water conservation, and water quality. When one of the indicators or sub-indicators score a concern or great concern the city has a challenge that might be addressed by best practices.

city blueprints		
	Social	1 Urbanization rate
		2 Burden of disease
		3 Education rate
		4 Political stability
	Environmental	5 Flood risk
		6 Water scarcity
		7 Water pollution
		8 Heat risk
	Financial	9 Economic pressure
		10 Unemployment rate
		11 Poverty rate
		12 Inflation rate

5 Flood riks	Urban drainage flood
	River peak discharges
	Sea level rise
	Land subsidence
6 Water scarcity	Freshwater scarcity
	Groundwater scarcity
	Salinization and seawater intrusion
7 Water pollution	Surface water quality
	Biodiversity
8 Heat risk	Heat island effect

0 No concern	1 Low concern	2 Medium concern	3 Concern	4 Great concern

The City Blueprint® performance Framework (CBF) provides an integrated overview of the urban water cycle management performance. The framework consists of twenty-five indicators divided over seven broad categories: water quality, solid waste treatment, basic water services, wastewater treatment, infrastructure, climate robustness and governance (Table 2). The indicators are scored based on an online questionnaire (EIP Water 2017b) together with key stakeholders such as the city council, water companies, water utilities etc. The twenty-five indicators are scored from 0 (concern) to 10 (no concern).

Table 2 Overview of the City Blueprint performance Framework (CBF).

Categories	**Indicators**
I Water quality	1. Secondary WWT 2. Tertiary WWT 3. Groundwater quality
II Solid waste treatment	4. Solid waste collected 5. Solid waste recycled 6. Solid waste energy recovered
III Basic water services	7. Access to drinking water 8. Access to sanitation 9. Drinking water quality
IV Wastewater treatment	10. Nutrient recovery 11. Energy recovery 12. Sewage sludge recycling 13. WWT energy efficiency
V Infrastructure	14. Stormwater separation 15. Average age sewer 16. Water system leakages 17. Operation cost recovery
VI Climate robustness	18. Green space 19. Climate adaptation 20. Drinking water consumption 21. Climate-robust buildings
VII Governance	22. Management and action plans 23. Public participation 24. Water efficiency measures 25. Attractiveness

Table 3 summarizes the indicators of both the TPF and CBF that are relevant to identify frontrunner cities for each theme. Both the TPF and the CBF provide an integrated overview of the management of urban water cycle services in sixty-two municipalities and regions in over thirty countries. The following indicator scores are used to select cities that front-runners with respect to *extreme weather events*: Indicator 14 *stormwater separation*; 15 *average age sewer*; 18 *green space*; 19 *climate adaptation*; 21 *climate-robust buildings*, and 22 *management and action plans*. For the themes *reduction of water consumption* and *variables related to water conservation* the following indicators scores are being assessed: 16 *water system leakages*; 20 *drinking water consumption*; and 24 *water efficiency measures*. Finally, the scores of indicator 1 *secondary WWT*; 2 *tertiary WWT*; 3 *groundwater quality*; and 9 *drinking water quality*, are being assess with respect to the theme *water quality*. Cities that experience considerable pressures regarding each theme (according to the TPF) and at the same time perform high (according to the CBF) with respect to this theme can be front-runners that apply best practices. Moreover, cities that have initiated considerable effort to address the water challenges related to each theme can already apply best practices as well.

The best practices are both technical and social-political and therefore also the water Governance Capacity Framework (GCF) has been applied to identify the best practices in the KDCs and several follower cities. The GCF methodology is explained in deliverable 4.7 and the in-depth analysis of the KDCs and several follower cities will be part of deliverable 4.8. The GCF consists of three dimensions, each with three conditions that are being analysed by three indicators (Table 4). For each of the twenty-seven indicators, a Likert-type scoring scale has been developed that ranges from very encouraging (++) to very limiting (--). The GCF has been further operationalized by developing specific questions linked with Likert-type scoring and has recently been applied for the city of Amsterdam (Koop et al. 2017). The details about the GCF methodology are provided in EIP Water (2017c). As part of deliverable 4.8, a few follower cities have already been analysed according to the GCF methodology. These results will be used to characterise best practices in these cities.

Table 3 Overview of indicators of the TPF and CBF that are relevant to select front-running cities for each theme.

Theme	**City Blueprint indicators**	
	Trends and Pressure indicators	**Performance indicators**
Extreme weather events	**5** *Flood risk*; **5.1** *Urban drainage flooding*; **5.2** *River peak discharges*; **5.3** *Sea level rise*; and **5.4** *Land subsidence*	**14** *Stormwater separation*; **15** *Average age sewer*; **18** *Green space*; **19** *Climate adaptation*; **21** *Climate-robust buildings*; and **22** *Management and action plans*
Reduction of water consumption	**6** *Water scarcity*; **6.1** *Freshwater scarcity*; **6.2** *Groundwater scarcity*; and **6.3** *Salinization and seawater intrusion*	**16** *Water system leakages;* **20** *Drinking water consumption*; and **24** *Water efficiency measures*
Variables related to water conservation		
Water quality	**7** *Water pollution*; **7.1** *Surface water quality*; and **7.2** *Biodiversity*	**1** *Secondary WWT*; **2** *Tertiary WWT*; **3** *Groundwater quality*; and **9** *Drinking water quality*

Table 4 Overview of the water Governance Capacity Framework (GCF) according to Koop et al. (2017).

Dimensions	Conditions	Indicators
Knowing	**1 Awareness**	1.1 Community knowledge 1.2 Local sense of urgency 1.3 Behavioral internalization
	2 Useful knowledge	2.1 Information availability 2.2 Information transparency 2.3 Knowledge cohesion
	3 Continuous learning	3.1 Smart monitoring 3.2 Evaluation 3.3 Cross-stakeholder learning
Wanting	**4 Stakeholder engagement process**	4.1 Stakeholder inclusiveness 4.2 Protection of core values 4.3 Progress and variety of options
	5 Policy ambition	5.1 Ambitious and realistic goals 5.2 Discourse embedding 5.3 Policy cohesion
	6 Agents of change	6.1 Entrepreneurial agents 6.2 Collaborative agents 6.3 Visionary agents
Enabling	**7 Multi-level network potential**	7.1 Room to manoeuver 7.2 Clear division of responsibilities 7.3 Authority
	8 Financial viability	8.1 Affordability 8.2 Consumer willingness-to-pay 8.3 Financial continuation
	9 Implementing capacity	9.1 Policy instruments 9.2 Statutory compliance 9.3 Preparedness

3 Results of interviews on best practices

3.1 Strategies that build resilience to floods

Our future water system will have to endure and be resilient to more and more extreme weather events including heavier precipitation, floods and droughts. Flood events already pose multiple health risks and cause widespread damage across Europe, and with more frequent and intense flood events expected, the damage costs of floods will likely increase even more. Based on the interviews (see annex 1), the following options were scored priorities:

- Using "soft" or non-structural approaches, such as "green" infrastructure, flexible options, etc.
- Adopting an integrated approach to manage water across different scales
- Prioritizing flood mitigation through infrastructure and planning

Furthermore, another option suggested was: A risk based approach to safety standards and safety management. In fact, this is a fact-based prioritization approach, that - when implemented – can lead to relevant cost-reduction. An appealing case is the Copenhagen climate adaptation plan. This is an inspiring example on how to think (and plan) out of the box about building resilience to floods http://en.klimatilpasning.dk/media/568851/copenhagen_adaption_plan.pdf.

Building resilience to floods is also highlighted on the following websites:

- https://watersensitivecities.org.au/
- https://www.watershare.eu/
- http://www.dutchwaterauthorities.com/projects/
- https://english.deltacommissaris.nl/

Climate adaptation refers to extreme weather events, both to flooding and droughts. **The European Climate Adaptation Platform** (CLIMATE-ADAPT) is a partnership between the European Commission (DG CLIMA, DG Joint Research Centre and other DGs) and the European Environment Agency. CLIMATE-ADAPT aims to support Europe in adapting to climate change. It is an initiative of the European Commission and helps users to access and share data and information on:

- Expected climate change in Europe
- Current and future vulnerability of regions and sectors
- EU, national and transnational adaptation strategies and actions
- Adaptation case studies and potential adaptation options
- Tools that support adaptation planning

CLIMATE-ADAPT organizes information under the following main entry points:

- Adaptation information (Observations and scenarios, Vulnerabilities and risks, Adaptation measures, National adaptation strategies, Research projects)
- EU sector policies (Agriculture and forestry, Biodiversity, Coastal areas, Disaster risk reduction, Financial, Health, Infrastructure, Marine and fisheries, Water management)
- Transnational regions, Countries and Urban areas
- Tools (Adaptation Support Tool, Case Study Search Tool, Map Viewer)
- The platform includes a database that contains quality checked information that can be easily searched.

The WssTP future-proof model and strategy for a water-smart society highlights that climate change affects many aspects of society and the European water system (flood defences, irrigation systems, drinking and wastewater networks). They have significant impacts on the natural water balance across the EU, impacting on the replenishment of water resources and reducing water availability. Our future water system will have to endure and be resilient to more and more extreme weather events including heavier precipitation, floods and droughts. Flood events already pose multiple health risks and cause widespread damage across Europe, and with more frequent and intense flood events expected, the damage costs of floods will likely increase even more. In addition, climate change, population growth and migration will disturb the balance between water supply and water demand, resulting in water scarcity and threatening natural water ecosystems. Apart from considerable water scarcity, our water quality will also be affected, because of seawater intrusion into coastal aquifers, faster depletion of dissolved oxygen because of higher water temperatures, and a higher content of pollutants that flow from urban and industrial sites into water bodies following extreme rain events. To cope with these challenges a robust, flexible and resilient water infrastructure is needed that takes into account the cross-border impacts of climate change events. Unfortunately, our current water infrastructure is often outdated and hence not able to cope with such problems. Add to that the impact that water losses caused by the deteriorating infrastructure have on our environment, and it is clear that change is needed through a manageable migration path. Furthermore, multi-stakeholder strategies must be strengthened for disaster preparedness, and interventions made to anticipate and mitigate their impact on the European water system and society. More information on this topic from WssTP can be downloaded here

3.2 Strategies that build resilience to drought

Climate change, population growth and migration will disturb the balance between water supply and water demand, resulting in water scarcity and threatening natural water ecosystems. Apart from considerable water scarcity, our water quality will also be affected, because of seawater intrusion into coastal aquifers, faster depletion of dissolved oxygen because of higher water temperatures, and a higher content of pollutants that flow from urban and industrial sites into water bodies following extreme rain events. To cope with these challenges a robust, flexible and resilient water infrastructure is needed that takes account of the cross-border impacts of climate change events. Unfortunately, our current water infrastructure is often outdated and hence not able to cope with such problems. Add to that the impact that water losses caused by the deteriorating infrastructure have on our environment, and it is clear that change is needed through a manageable migration path. Furthermore, multi-stakeholder policies and strategies must be strengthened for disaster preparedness, and interventions made to anticipate and mitigate their impact on the European water system and society. For more information: http://wsstp.eu/wp-content/uploads/sites/102/2017/05/WssTP-Water-Vision-Final_2edition.pdf

Based on the interviews, the following options were scored with ≥4:

- Diversifying sources of water supply
- Prioritizing demand management and water conservation
- Adapting by switching to less water intensive livelihoods
- Water recycling
- Imposing strict regulations on water withdrawals
- Utilizing natural or “green” infrastructure” (such as wetlands, streams, rivers)
- Implementing water resources management at the catchment scale
- Adopting integrated land and water use planning

Another suggestion of one of the interviewees was to include water trading or restrictions to major water users. Further strategies that are provided can be found on the following websites:

- https://watersensitivecities.org.au/
- http://www.dutchwaterauthorities.com/projects/
- https://english.deltacommissaris.nl/
- The EC website on water scarcity and drought includes some relevant studies from 2011 and 2012
- http://ec.europa.eu/environment/water/quantity/scarcity_en.htm

The focus on cities is probably the reason why the impacts of agriculture have not been brought up during the interviews. We have recently reviewed the role that agriculture (and consumer behavior) can play in solving the global water scarcity crisis (Koop and Van Leeuwen 2017). This is the summary: “Drinking water consumption in cities makes up a small fraction of the total water footprint. For example, people in the Netherlands use about 2300 m^3 of water per person per year of which 67 % is for agriculture, 31 % is used in industry, while only 2 % makes up household water (Van Oel et al. 2009). This means that water challenges in cities need to be solved predominantly by actors outside the traditional water sector. In fact, half of all cities with populations greater than 100,000 are located in water-scarce basins. In these basins, agricultural water consumption accounts for more than 90 % of all freshwater depletions (Hunger and Döll 2008; Richter et al. 2013). In a critical analysis, Richter et al. (2013) point out that nearly all water used for domestic and industrial purposes is eventually returned to a water body. For instance, toilets are flushed and purified wastewater as well as cooling water in power plants is often returned to rivers. Because much of this water is not consumed, efforts to reduce urban water use or to recycle water with the aim to alleviate water scarcity per se, hardly makes any difference. In total, the domestic, industrial and energy sectors account for less than 10 % of global water consumption (Richter et al. 2013; Hoekstra et al. 2012). Of course, proper urban use and reuse of water, as well as adequate sanitation, contribute significantly to pollution reduction, local water availability, as well as to energy efficiency, energy and nutrient recovery. Hoekstra et al. (2012) estimate that agriculture accounts for 92 % of the global blue water footprint. Land, energy and climate studies have shown that the livestock sector plays a substantial role in deforestation, biodiversity loss and climate change. Livestock also significantly contributes to humanity's water footprint, water pollution and water scarcity (Jalava et al. 2014; Hoekstra 2014). Furthermore, the Food and Agriculture Organization of the United Nations (FAO) estimates that 32 % of all food produced in the world was lost or wasted in 2009 (Lipinski et al. 2013; FAO 2011a).Therefore, consumers, i.e. citizens, can play a major role in the reduction in the global water footprint by both reducing the fraction of animal products in their diets and by curbing their food waste."

In another global modelling study (Van Vuuren et al. 2016) a reference scenario has been developed for 2050, in which the important role of agriculture was confirmed. Based on this scenario, it is projected that the production of food, energy and water will further increase mostly driven by increased demand in developing countries. The increase is 50-60% for food and energy and around 10% for water (literature ranges are around 50-60% for food, 50-80% for energy and 10-45% for water). The increased production is expected to lead to further pressure on natural resources and to climate change. For instance, land use is projected to increase by around 10% and greenhouse gas emissions are likely to lead to a warming of around 4°C by the end of the century. The latter is driven mostly by fossil fuel combustion, but the agriculture sector also contributes currently to around 25% of current emissions. At the same time, by 2050 a significant part of the global population will still be suffering from hunger, not have access to modern energy, or be living in water-scarce areas. Because the production and consumption chains of food, energy and water are tightly coupled, solutions need to be looked at from an integrative perspective. From the baseline trends, four, related, challenges can be derived:

- Providing access to modern energy for all while reducing greenhouse gas emissions.
- Increasing world food production significantly to feed a world of 9 billion people in 2050, without harming biodiversity.
- Increasing the efficiency of water use, in order to prevent water scarcity.
- In general, increasing resource efficiency while considering the linkages between food, modern
- energy and water use.

Agriculture is one of the core areas in the endeavour to bring the world onto a more sustainable development path. Globally, expansion of land-use driven by the increase in food production is the main cause of biodiversity loss in the baseline scenario. Agriculture is also responsible for about 25% of GHG emissions, can be strongly impacted by climate change but also be part of several solution strategies.

3.3 Strategies that build resilience to water conservation

In the context of dealing with water resilience, several strategies have been identified as potentially useful for building resilience. In the interviews (annex 1), the following options were scored with ≥4:

- Prioritizing demand management and water conservation
- Water reuse
- Public campaigns to demonstrate water conservation practices

Two other examples that have been provided by the interviewees are:

- **The Water Saving project** is a study on how eight small, dry European islands save fresh water. To become more sustainable, they have developed technologies and they are addressing people's attitudes and behavior regarding water. This set of good practices can be inspiring to the metropolitan environment.
- **Cape Town** has been internationally recognized for its efforts in water management. Over the past 15 years the city has managed to reduce water use by 30%, despite a population increase of 30% over the same period. **The city's water conservation programme** has a two-pronged approach: persuading people to use less water, and deploying the latest technology to use water efficiently. The city has adjusted the water pressure to reduce wastage, replaced old pipes, improved leak detection, carried out extensive repairs and improved the management of water meters.

3.4 Strategies that build resilience to water quality (water reuse schemes)

Drinking water can be produced from a variety of sources, i.e., surface water, groundwater, by rainwater harvesting, desalination, and by reuse. The Sabadell example (Spain) is about drinking water itself. In order to reduce drinking water consumption, water –reuse is proposed. The proposal is to supply piped water with two different qualities: (1) piped water that can be used as drinking water and (2) piped water used for other non-drinking water purposes. In the context of dealing with water reuse schemes, several strategies have been identified as potentially useful. In the interviews (annex 1), the following option was scored with ≥4: Diversifying sources of water supply. Two other options were score with values close to 4: (a) Public campaigns to stimulate the using of non-potable water resources and (b) Campaigns to explain health risks of non-potable water. Two other options were also suggested by the interviewees: (1) Digital water development and (2) other approaches to address the different users and sectors (and not just burden the urban water user), as urban citizens protest less. In the remainder of this section we summarize contributions of WssTP:

DIGITAL WATER is a key factor in water reuse schemes important concept underpinning the WssTP vision, based on the predicted development of a world where all people, "things" and processes are connected through the "Internet of Everything", leading to capillary networks and sensors, meters and monitoring of the water system all the way along to the individual user, as such generating large amounts of valuable data (big data) for innovative Decision Support and Governance systems. In this regard, WssTP promotes a future-proof European model for a water-smart society that entails a paradigm shift in the way our future society will be organized and managed with regard to water. It requires bold and courageous decisions, investments, changes and new types of collaboration for stakeholders at all levels of society, involving citizens, public authorities at all levels, industries and farmers, as well as representatives of our natural environment. Its advantage comes from dramatically higher levels of manageability enabled by the emerging cyber-physical society, "digital water" technologies and increased availability of "multiple waters" to complement freshwater sources, as well as much deeper levels of awareness, integration and collaboration between organizations and citizens. New digital technologies in an all-connected world (smart sensors, drones/robots, satellite technologies for earth observation and environmental monitoring) can provide detailed and capillary insights into water availability, use and quality, up to the level of each individual user. A holistic approach to digital systems applications at various scales (industrial, urban, rural, regional, international river basin) can be exploited by the joint stakeholders to manage the water system. For more information: http://wsstp.eu/wp-content/uploads/sites/102/2017/05/WssTP-Water-Vision-Final_2edition.pdf. ICT and water efficiency is a key policy issue with potential for new research area that includes decision supporting system for the measurement of water quality and quantity including the recycling and water reuse processes (**The ICT4Water Cluster**). This necessitates increased interoperability between water information systems at EU and national levels and efficiency of water resources management. The ICT4Water cluster is relevant and important source of information and an excellent network for improving knowledge and collaboration with stakeholders. In addition, the Cluster produced the ICT for Water Management roadmap that describes the main gaps and challenges that need to be addressed in the future of the ICT for water management sector, including water providers, customers and policy makers. The first roadmap was published in 2015 and after consulting the ict4water cluster members and other stakeholders an update has been prepared by the European Commission in August 2016. This latest edition of the roadmap will be presented at the Water Ideas conference to be held in Bologna (20-21 October) and can already be downloaded here or at the website of the European Commission https://ec.europa.eu/digital-single-market/en/news/emerging-topics-and-technology-roadmap-ict-water-management-august-2016

Multiple Waters is the important concept underpinning the WssTP water vision, picturing a future in which different alternative water sources and qualities (fresh ground and surface water, rainwater, brackish water, saline water, brines, grey water, black water, recycled water) will be available in our society, and employed for various purposes by multiple users. The WssTP vision paints a picture of a future European society that manages our precious multiple water sources from clean rivers, surface and ground water, but also alternative sources such as rainwater, brackish and saline water, brines and used water, as a holistically integrated system. In the future we will optimise water management and allocation by storing, treating and distributing the right water for the right purpose to the right users in a synergetic combination of centralised and decentralised water treatment. Water use will be optimised based on the circularity principle for water such as cascading, reuse, recycling, while enacting new economic mechanisms and models based on *the true value of water*.

The DEMOWARE project represents an excellent example for water reuse schemes. The DEMOWARE project brings together ten representative water reuse sites from across Europe and Israel. They are mostly located in water stressed areas or regions that suffer structural or seasonal water scarcity and have been selected to depict the range of water reuse applications: from different agricultural irrigation applications, industrial, urban and recreational uses through to indirect potable reuse. The sites also reflect the variety of water reclamation technologies used to achieve appropriate water quality, from extensive treatments to high-tech schemes.

3.5 Strategies that build resilience to water in general

In the context of *water planning and governance* in general, several strategies have been identified as potentially useful for building resilience. The interview question partly overlaps with the other questions resulting in new as well as other views and examples that have been raised before. In the interviews (annex 1), the following options were scored with ≥4:

- Polycentric governance (i.e., management or governance systems that have multiple centers of authority at different scales)
- Ability to quickly respond to changes, reorganize and adapt
- Openness to institutional change
- Strong integration of different water sectors (e.g., wastewater, bulk water, sanitation)
- Inclusive, fair and equitable governance
- Having diverse water resource options
- Restoring and maintaining healthy ecosystems

Another option that has been suggested by one of the interviewees is to focus on the regional level: in between national, provincial and the city level there is the regional catchment level. This might be a good alternative in some cases (like in NL).

Governance is an essential factor to build general resilience in the water sector, particularly in Europe. A good example is given by the DROP Project that ended in 2015 (http://www.nweurope.eu/about-the-programme/our-impact/challenge-5/the-drop-project/). The project focused on improving adaptation plans to drought and raising drought awareness. To do this, the project created a European governance toolkit, which defined regional drought adaptation, and improved the effectiveness of these measures for North West Europe. One success of the project was developing and maintaining a strong transnational collaboration between the partners. Each pilot of the project was designed around the collaboration of at least two partners, and these pairs enabled partners to gain new solutions and knowledge from their counterparts. As a result, the partners developed sustainable synergies that continued after the end of the project. Another example of the relevance of governance is all the work and reports that have been provided by the OECD Water Governance program. The activities of the OECD are summarized in this Brochure. The OECD principles for water governance are available in a comprehensive report that can be downloaded here.

The WssTP has provided a lot of input too. The WssTP Vision for a Water-Smart Society and SIRA (Strategic Innovation and Research Agenda) documents aim to set out the pathways towards better use, valorization and stewardship of our water sources by society and businesses while developing resilient and sustainable solutions for our key global water challenges. It describes how these challenges can be turned into opportunities for Europe to develop new technologies, solutions, business and governance models for the water-smart society of the future. This vision is of a future where water scarcity and pollution of ground- and surface water in Europe are avoided; water, energy and resource loops are largely closed to foster a circular economy; the water system is resilient against climate change events; and European business dependent on water thrives as a result of forward-looking research and innovation. As such, it frames the context for developing a renewed Strategic Innovation and Research Agenda (SIRA) that defines the most important research, development and innovation actions to be promoted by WssTP and its collaboration partners for the upcoming decades. The WssTP Vision focuses on European water challenges, trends and required developments, but it also indicates how these are connected to Europe's role in solving global water challenges, including the United Nations Sustainable Development Goals, while confirming and strengthening Europe's position in the global water-related economy valued at €62.9 trillion. In order to help the water-smart society to materialize, WssTP proposes that research, development and innovation investments in Europe focus on four key impact parameters:

1. Reducing the impact of European society on our natural water resources by 50%;
2. Delivering the true value of water for our society, the economy and the environment;
3. Boosting the European water market as well as the global competitiveness of European water industries.
4. Securing society's long-term resilience, stability, sustainability and security about water.

To achieve these objectives, Europe will need to develop innovative water technologies, digital solutions and economic, business and governance models that contribute to solving water challenges in Europe and for the world at large.

WssTP also promotes a future-proof European model for a water-smart society that entails a paradigm shift in the way our future society will be organized and managed with regard to water. It requires bold and courageous decisions, investments, changes and new types of collaboration for stakeholders at all levels of society, involving citizens, public authorities at all levels, industries and farmers, as well as representatives of our natural environment. Its advantage comes from dramatically higher levels of manageability enabled by the emerging cyber-physical society, "digital water" technologies and increased availability of "multiple waters" to complement freshwater sources, as well as much deeper levels of awareness, integration and collaboration between organizations and citizens. These important changes will offer a boost for European industry, which requires significant investment in redesigned and adapted infrastructure as well as innovative technologies. It also provides complex challenges that require a longer-term program to foster stable migration towards the new water-smart society.

4 Extreme weather events

As explained in the introduction (Section 1) three important types of flooding are identified: river floods, coastal floods, urban drainage flooding (due to extreme rainfall) and groundwater flooding. All three types of flooding are expected to increase both in frequency and severity due to climate change. Especially urban regions are often situated in flood prone areas. Moreover, the soil sealing by impermeable concrete, asphalt and rooftops leads to high rainfall runoff making cities vulnerable for urban drainage flooding.

4.1 Best practices in Leicester

4.1.1 Mapping and assessment – Understanding risks of extreme weather events

Leicester City Council (LCC) has complied with reporting requirements of the Flood Risk Regulations (2009) introduced to bring the EC Floods Directive into domestic law in England and Wales. Due to the significant level of risk identified at the first stage of reporting, this has involved further stages, including extensive mapping and assessment exercises. The reporting comprises:

- **Preliminary flood risk assessment (LCC, 2011)** to identify areas where potential significant flood risk exists. This study identified that more than 30,000 people could be at risk of flooding from a severe rainfall event. As a result, Leicester has been identified as one of the top ten cities in the UK at risk from flooding and designated a ‘nationally significant’ flood risk area.
- **Surface Water Management Plan (LCC, 2012)** which includes flood risk and hazard maps.
- **Strategic Flood Risk Assessment**
  including information on historic flooding and modelling of rainfall scenarios (LCC 2017a).
- **Local Flood risk management Strategy**
  This document explains the Council’s duties and responsibilities, together with those of other risk management authorities such as the Environment Agency and Water Company, and sets out objectives and an action plan covering the short term (1-2 years), the medium term (2-5 years) and long term (5 or more years). Actions include prevention, protection and preparedness (LCC 2017b.

The extensive mapping of flood incidents and outcome of the detailed flood risk modelling provided the required evidence for cost-benefit analysis and justification for national investment (Figure 2).

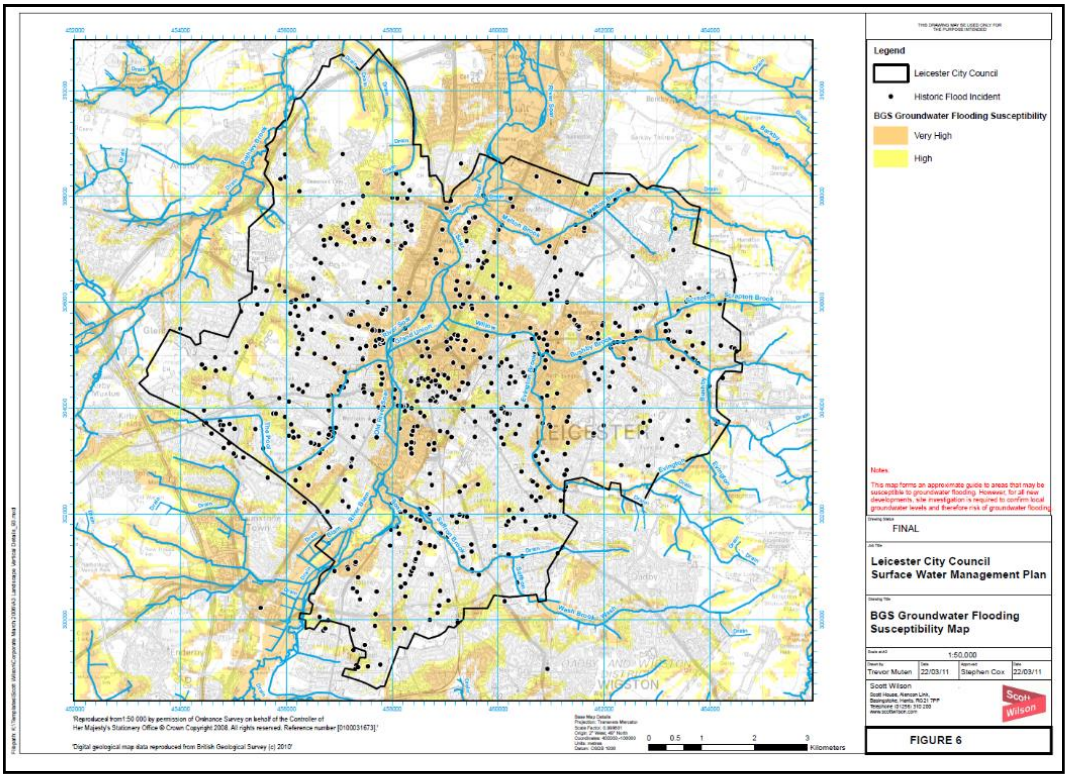


Figure 2 Flood risk map of Leicester.

4.1.2 **Flood alleviation measures**

In collaboration with the Environment Agency, LCC has secured national funding of £7.83 million (Department for Environment, Food and Rural Affairs, Defra) for the River Soar conveyance project to deliver a series of flow improvements along the River Soar through the city of Leicester. The project aims to reduce flood risk to approximately 4,700 properties in Leicester through modifying green infrastructure.

Phase 1 work increased capacity for river flow through the existing flood arches beneath the Great Central Way Biam Bridge (Figure 3 and Figure 4), with the aim of reducing flooding to approximately 250 properties in Braunstone Town and Aylestone.

Figure 3 Increasing river flow capacity at the Great Central Way Biam Bridge.

Figure 4 After increasing river flow capacity at the Great Central Way Biam Bridge.

Phase 2 has involved lowering public open spaces to increase the storage capacity of flood plain areas (Figure 5, Figure 6 and Figure 7).

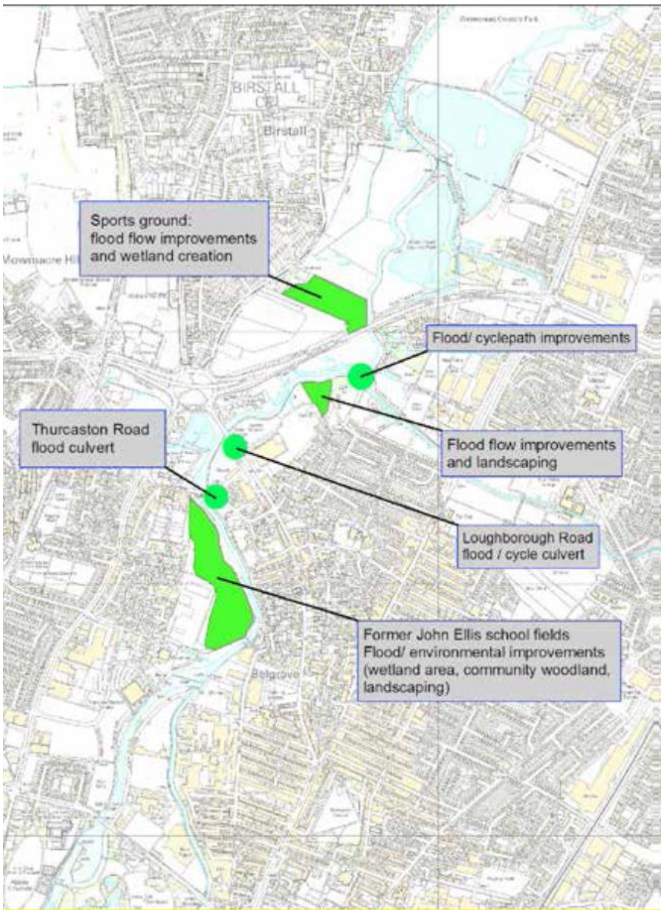


Figure 5 Adaptation measures in Leicester.

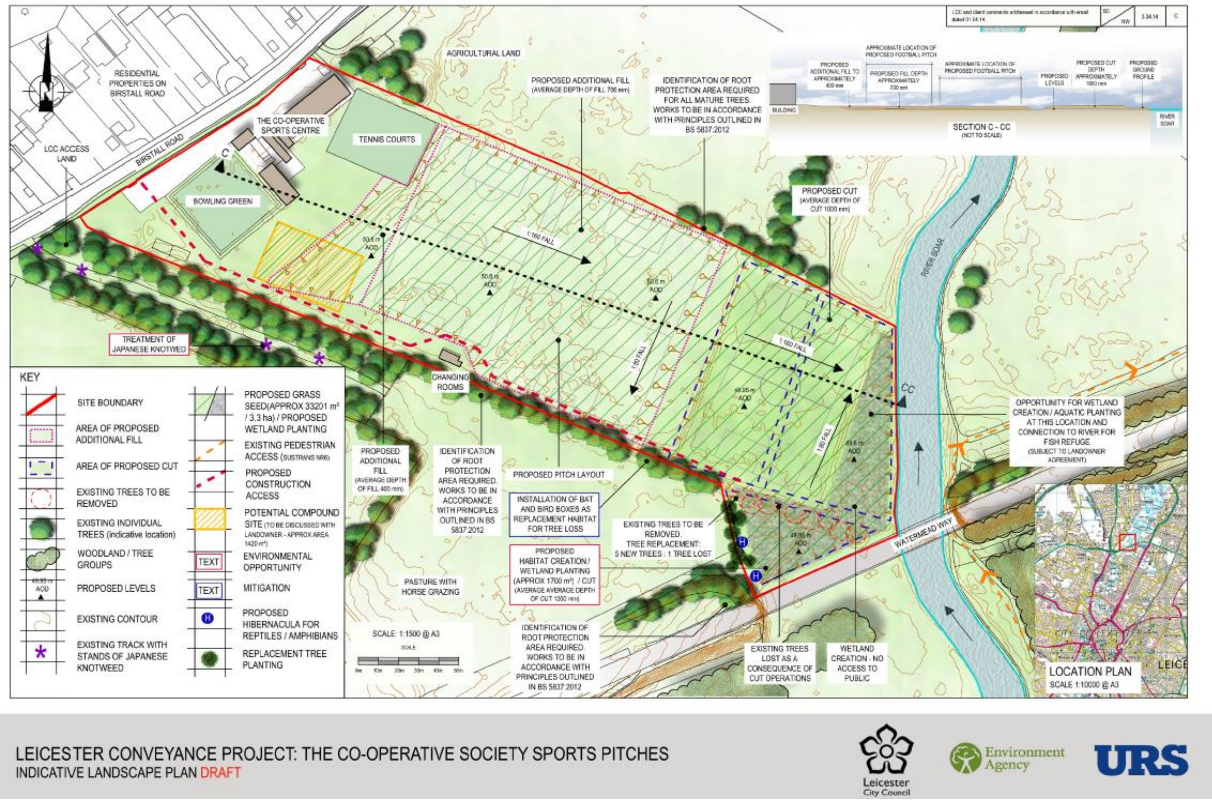


Figure 6 Draft landscape plan of Leicester.

Figure 7 Leicester Conveyance project: Abbey Meadows and Beaumanor Open Space.

Phase 3 consists of building culverts at the Loughborough Road Bridge (Figure 8) and Thurcaston Road Bridge reduce the throttling effect to flood flows in the River Soar created by the existing bridge structures.

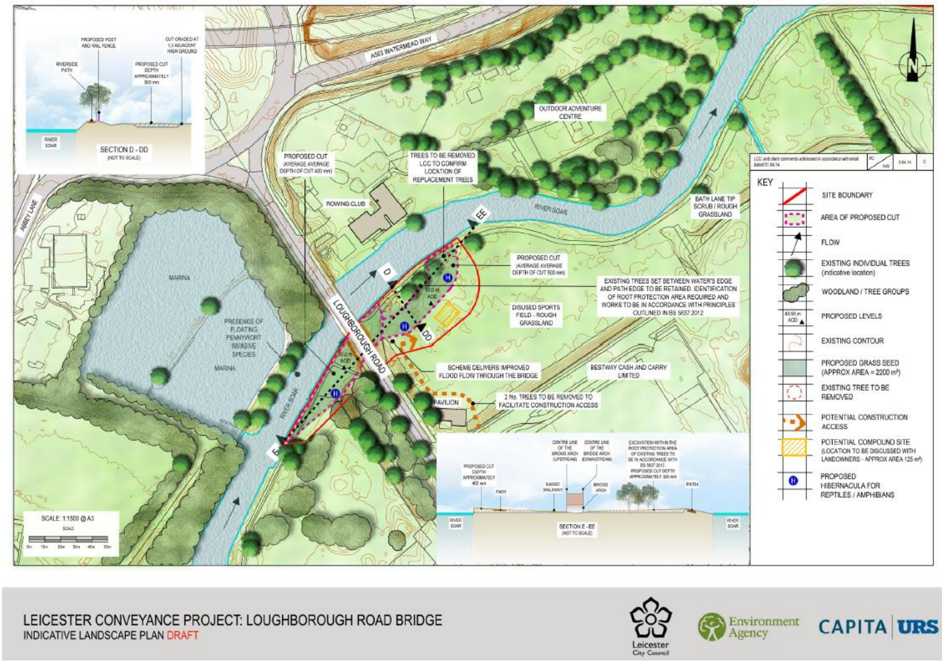


Figure 8 Leicester Conveyance Project: Loughborough Road Bridge (indicative landscape plan).

4.1.3 Planning – Sustainable water management to minimise flood risk

Minimising flood risk is at the heart of LCC's approach to the planning process. National guidance requires the implementation of sustainable drainage systems (SuDS) for developments comprising upwards of 10 houses. However, in recognition that every property makes a contribution to the overall surface water flooding risk, LCC has a policy of requiring consideration of SuDS and flood risk for any number of properties (one upwards).

Within the planning regime, LCC's Planning Service has been proactive in promoting SuDS as a means of attenuating rainfall and runoff before reaching rivers or groundwater. An attractive and informative SuDs guidance document has been published, explaining and illustrating different SuDS schemes (Sustainable Drainage Guide, LCC, 2015). Within the next two years the Council plans to issue formal guidance for developers on SuDS schemes.

A sample page from Sustainable Drainage Guide (LCC 2015)

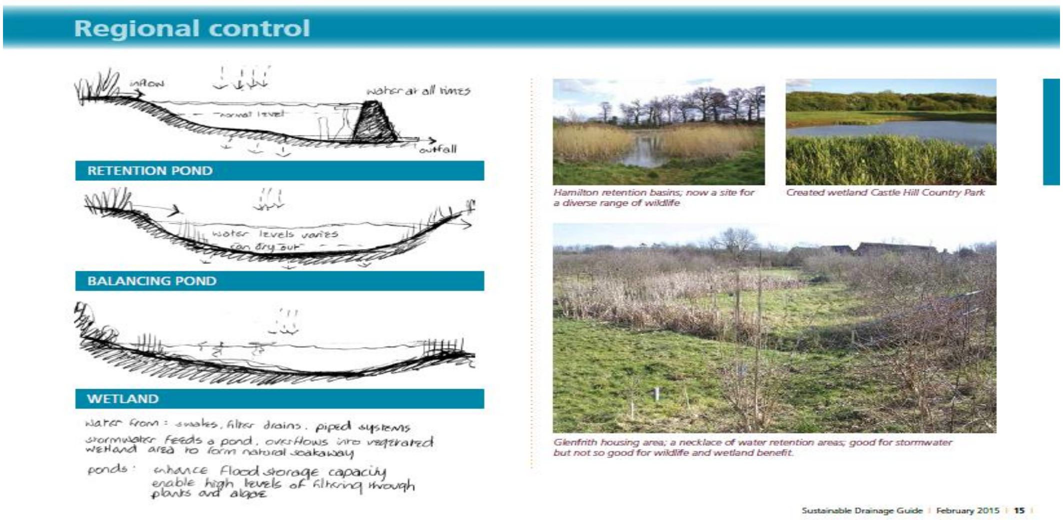


Figure 9 Sustainable drainage examples.

LCC has been active in applying SuDS schemes to its own land; the following case studies are a selection of projects undertaken.

4.1.4 **Case Study: Humberstone Gate, Applegate**

Work has recently been completed on the revamp of Leicester's main pedestrianised shopping streets and the area around Leicester's old town, creating attractive pedestrian-friendly areas.

The improvements include wider pavements, tree planting and permeable surfaces to reduce surface water runoff (Figure 10).

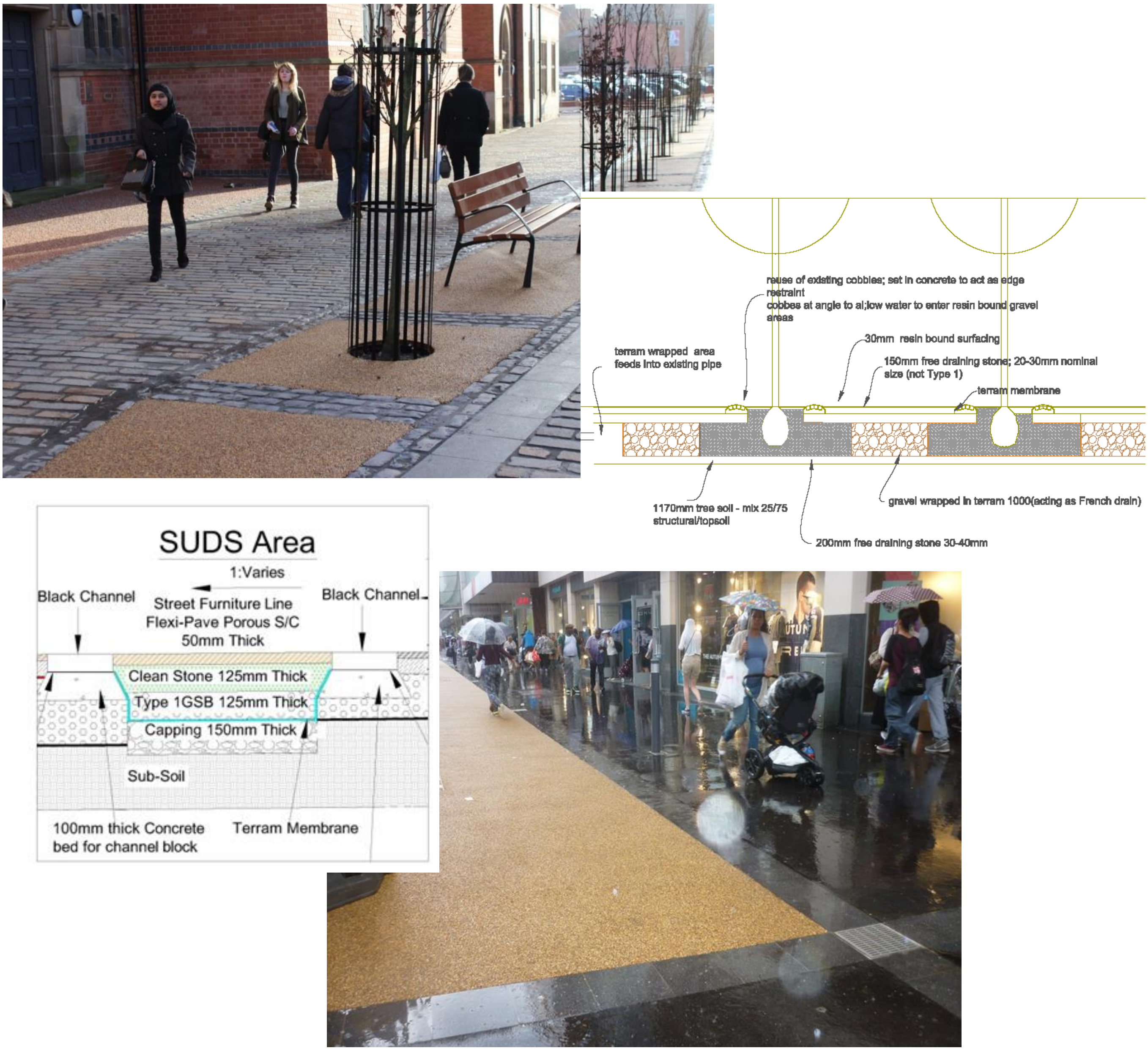


Figure 10 Improving permeable surfaces in Leicester.

4.1.5 Case Study: Spinney Hills Park

In an effort to combat flooding of the 1950's and 60's, in the 1970's many of the city's minor water courses were heavily channelled and culverted. LCC has undertaken work to return water courses, including the brook in Spinney Hills Park, to a more naturalised state. The vegetation and sinuous course slow the passage of water to reduce the potential of flash flooding downstream, and additionally offer added amenity value, and improved biodiversity (Before and after shown by photograph (Figure 11) and planning drawing (Figure 12).

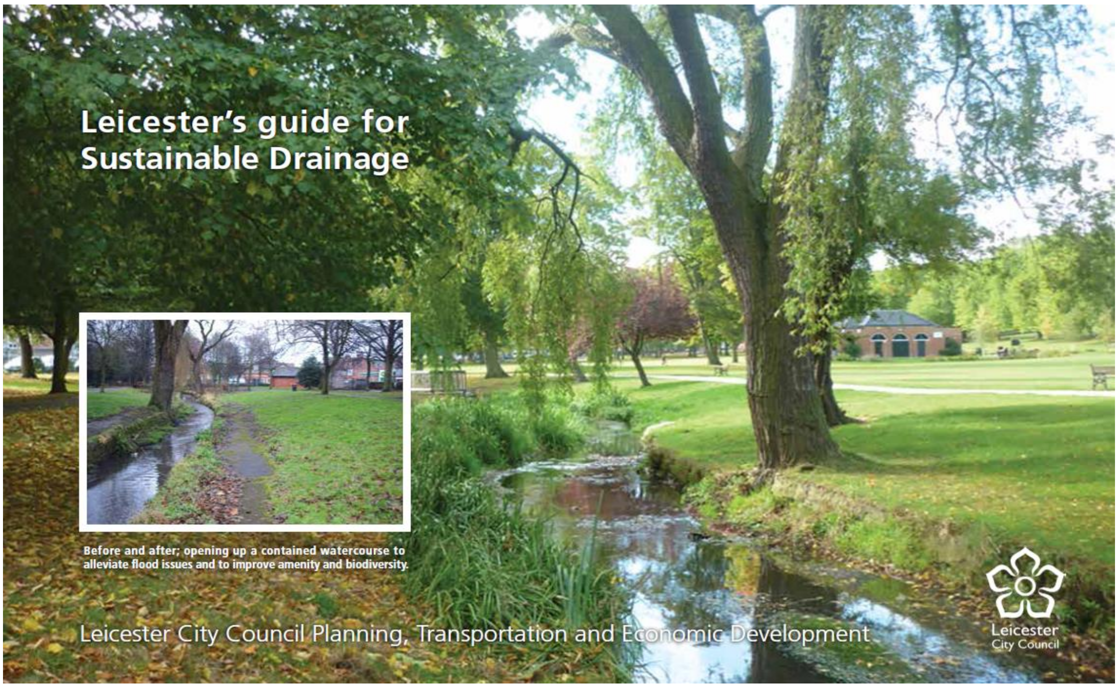


Figure 11 Opening up a watercourse in Leicester to improve amenity and biodiversity. Rear cover of LCC's Sustainable Drainage Guide (LCC 2015)

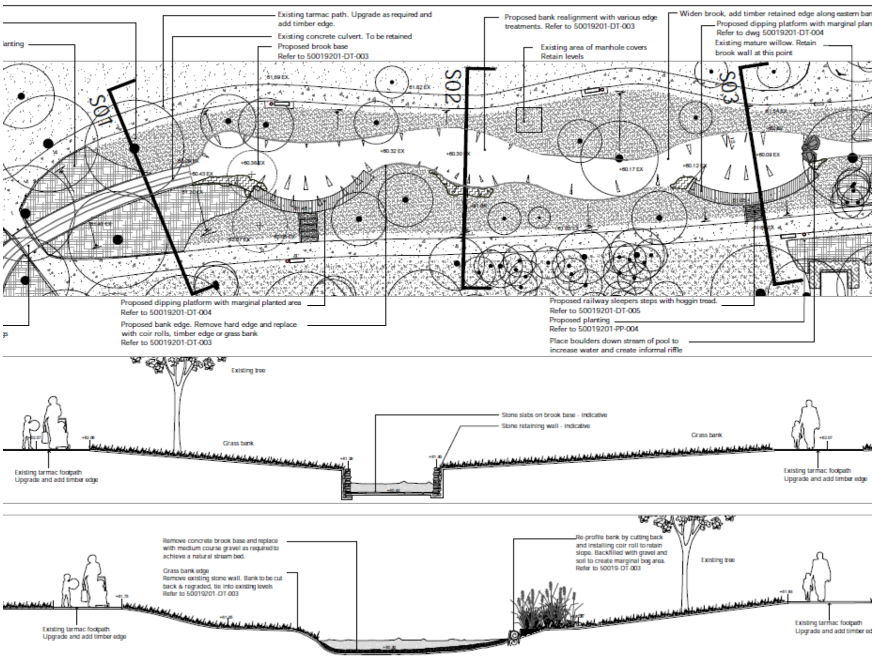


Figure 12 Sustainable drainage in Spinney Hills Park (Leicester).

4.1.6 Case Study: Abbey Meadows Wetland project (completed 2011)

Abbey Meadows is an area of open land between the River Soar and the Grand Union Canal. A ditch running through the area was susceptible to flooding, often rendering sports pitches unusable. Flooding of the ditch also impacted on surface water quality: flooded water drained onto the busy A6 road, carrying pollution into the storm drains which discharge into the River Soar.

LCC widened the ditch to create 1,000m^3 of flood storage capacity, protecting playing fields, preventing traffic disruption and improving the quality of storm drain water (Figure 13).

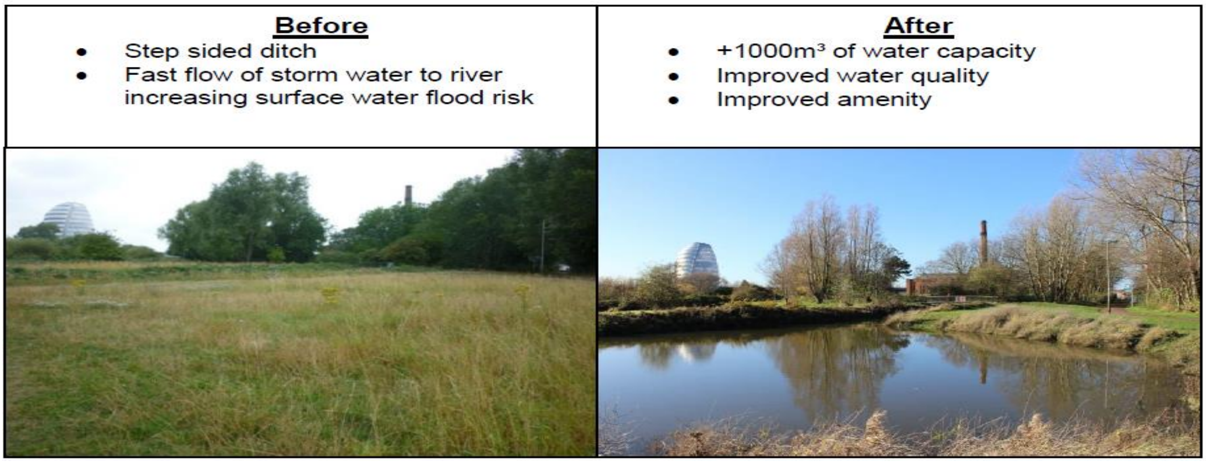


Figure 13 Abbey Meadows Wetland project (Defra 2014).

Experience of implementing such schemes has allowed LCC to establish good practice and contribute to national debate and guidance on the practice of sustainable water management.

4.1.7 Knowledge base

LCC has retained a wide knowledge base despite changing roles in the management of drainage (e.g transfer of responsibility for sewers in 1989 from the Council the water company (Severn Trent Water) and the loss of the sewerage agency in 2000. The Council is actively involved in training of a new generation of specialists: LCC has provided sponsorship for staff to attend a flood risk course and participated in a training scheme offered to graduates who have been unemployed for more than 12 months.

Through sharing of know-how and contribution to professional publications, LCC has contributed to establishing good practice and developing national guidance and standards on SuDS. Chryse Tinsley has been a member of the project steering group for 'The SuDS Manual' (CIRIA, 2015) CIRIA (a not-for-profit organisation within the construction industry, 2015) and part of government advisory panel formulating National Standards for sustainable drainage systems issued by Defra (2015).

4.2 Best practices in front-running cities to improve the management of extreme weather events

Figure 14 and Figure 15 show the relevant TPF and CBF indicators with respect to extreme weather events. Figure 14 shows the cities that have issues of great concern (marked red) with respect to urban drainage flooding (i.e. % of impermeable surface coverage) and river peak discharge (% that would flood with a metre river level increase and failing flood defences). Cities with best practices are cities that score high on these two indicators while at the same time have high performances for indicators of green space (% coverage by green permeable areas), stormwater separation (% stormwater that is collected is separate drainage system than sewer), climate adaptation (plans), climate robust buildings and management and action plans (Figure 15).

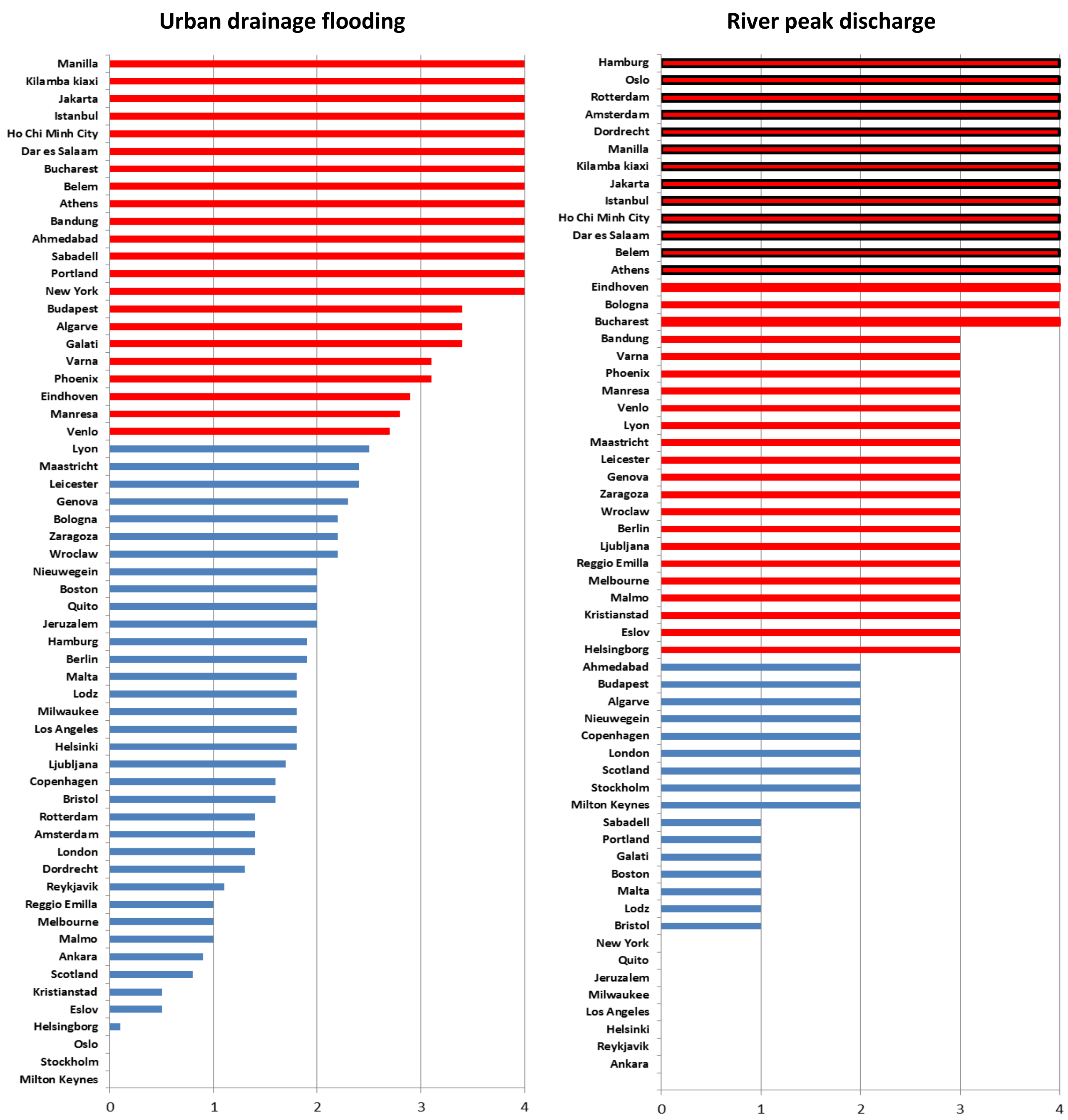


Figure 14 Left: cities facing a concern or great concern regarding urban drainage flooding or sensitivity to river peak discharges are marked with red bars. Right: cities that are also vulnerable to sea level rise are marked in red.

Figure 15 Overview of the City Blueprint indicators relevant for extreme weather events. For each indicator the top fifteen cities are shown.

Cities that turn out to have to a certain extent endured pressures regarding extreme weather events and at the same time perform high on the performance indicators are: Amsterdam (the Netherlands), Berlin (Germany), Bristol, (UK), Copenhagen (Denmark), Dordrecht (the Netherlands), Hamburg (Germany), Jerusalem (Israel), Melbourne (Australia), Milton Keynes (UK), New York (USA), Portland (USA), and Seoul (South Korea). However, it should be noted that also cities that put in considerable efforts to improve their resilience regarding extreme weather events are very suitable cases of best practices. An important example is the city of Leicester. Furthermore, it should be noted that there are many more cities with best practices regarding extreme weather events that are not assessed by the City Blueprint® which may apply specific best practices that are not identified because of the integrated nature of the indicators.

Figure 14 shows many cities with considerable pressures regarding extreme rainfall (i.e. urban drainage flooding) and vulnerability to river peak discharge. Also note that the cities that are the most vulnerable to river peak discharges often are also vulnerable to sea level rise. These cities might be follower cities that are interested in the DSP regarding extreme weather events based on the challenges these cities face. Within Europe, we identify a few cities that might have a particular interest in the DSP based their high vulnerability to extreme weather events and river peak discharge. Examples of these are the city of Athens (Greece), Bucharest (Romania) and Varna (Romania). However, it is important to state that many more cities in Europe and beyond are vulnerable to weather events. Extreme rainfall events will increase both in frequency and magnitude because of climate change and can affect most cities (EEA 2012). Because cities have large surfaces that are impermeable - covered roofs, concrete or asphalt - cities are vulnerable to rainfall runoff. A well-known example is the city of Copenhagen that has been affected by an extreme rainfall event (Section Copenhagen4.2.1). However note that this city is by far not the most vulnerable to urban drainage flooding (Figure 14). This implies that many cities are vulnerable to extreme rainfall and that is merely a matter of awareness – sometimes due to recent events – that makes cities interested in addressing these challenges through the use of the POWER DSP.

We provide two short introductions of two front-running cities. First the city of Copenhagen (Denmark) and second the city of New York (USA). What is to be noted is that both cities have experienced extreme weather events in recent years and this has boosted their awareness.

4.2.1 Copenhagen

In many cases, a combined sewer system drains the urban wastewater from households and industry together with rainwater runoff. The urban soil is often largely sealed with impervious pavements such as roofs, roads and parking lots. This leads to an urban drainage system that generates much runoff during rain events. Existing drainage systems cannot process these large amounts of water and the frequency as well as the intensity of rainfall events is projected to increase under climate change (EEA 2007; Stern 2007;Koop and Van Leeuwen 2017). The consequences of intensive rainfall event can be serious. For example, the city of Copenhagen experienced nearly one billion euros damage from a 2 hour rain event in which 150 millimetres of rain affected the city (Leonardsen 2012). Sewers were unable to handle this amount of water and large parts of the city were flooded. Many roads were closed and people had to be rescued because they were trapped inside their cars. Moreover, the city's two main hospitals were almost evacuated. Such extreme weather events may happen in many other unprepared cities and regions. Blue/green solutions (Figure 17; Table 5

Table 5 Error! Not a valid bookmark self-reference.provides a comprehensive overview from Voskamp (2015) of 31 blue-green adaptation measures that can provide options that can support the concepts of storage, retention and slow runoff. The blue-green solution website of Atelier Groen-Blauw (2017) provides 128 different examples on how to deal with the challenges of climate change. In conclusion, green-blue urban grids make cities sustainable, resilient and climate-proof. This website and the design tool will help to find fitting measures and inspires with attractive examples.

) are able to substantially decrease the peak surface runoff by means of direct infiltration or water storage, provided that these solutions are adequately incorporated in urban planning. During short meetings with Leonardsen in Brussels and Malmo, it appeared that the city council of Copenhagen has decided to strongly invest in climate adaptation measures. The cost of these measures is considerable (Figure 16). Copenhagen has been included in our City Blueprint activities (Koop and Van Leeuwen, 2015b) and the Urban Water Atlas for Europe (Gawlik et al. 2017).

Figure 16 The cost of adaptation in Copenhagen (Leonardsen 2012).

4.2.2 **New York City**

Parts of the North-American continent suffer from droughts, whereas in 2012, New York suffered from hurricane Sandy. Sandy's impacts included the flooding of the New York City subway system, many suburban communities and many road tunnels entering Manhattan. Sandy damaged 200,000 homes and was blamed for 117 US deaths. The total damage in New York was estimated at more than $19 billion (Toro 2013). The USA emits double the average amount of GHGs, while their BCI is about average (World Bank 2015; Koop and Van Leeuwen 2017). New York is vulnerable to extreme weather because the urban soil is largely sealed with impermeable concrete, asphalt and stone (NYC 2010). Rainwater can hardly infiltrate and forms large amounts of runoff which may result in urban drainage flooding and amplifies the impact of extreme weather which happened in 2012. Furthermore, New York produces a lot of solid waste and can improve on solid waste recycling, sewage sludge recycling, sewer maintenance and green space (Koop and Van Leeuwen 2017). UNESCO (2015a,b) concludes that increasing resource use efficiency, reducing waste and pollution, influencing consumption patterns and choosing appropriate technologies are the main challenges facing both Europe and North America.

Based on discussions with the Climate Programme Director NYC Department of Environmental Protection, a decision was taken to perform a complete City Blueprint Approach to analyse the City of New York. First, an extensive literature study was carried out to determine the preliminary scores for all forty-three TPF and CBF indicators and sub-indicators. These preliminary scores were presented to the authorities in the cities. Key persons within these organizations were asked to provide feedback. The data for the GCF for New York City were gathered by conducting fifteen qualitative semi-structured interviews. Eight interviews were held with respondents that work for the state or city government. Seven interviews were held with respondents that work for non-governmental organizations (NGOs) that are influential in New York City water governance (Feingold et al. 2017). The relevant stakeholders were identified and a number of stakeholders were interviewed based on availability and willingness to participate. Subsequently, the snowball method was employed in order to facilitate efficient navigation of the New York City water governance network and identify other available relevant stakeholders in the network. NGOs were included in order to obtain multiple viewpoints from stakeholders as it was determined that solutions to complex environmental problems need to include stakeholder participation in decision making (Backstrand 2003; Bingham et al. 2005). The organizations involved in this study were the NYC Department of Environmental Protection, the Mayor's Office of Resiliency and Recovery, the NYC Department of Sanitation, the Waterfront Alliance, the Science and Resiliency Institute at Jamaica Bay, the Natural Resources Defense Council, GrowNYC, Riverkeeper, NYC Department of Parks and Recreation, West Harlem Environmental Action (WE ACT), NYC H2O, and the New York Soil and Water Conservation District.

Recently, the City has taken a big step in a positive direction. The Mayor's Office unveiled One New York: The Plan for a Strong and Just City (OneNYC), which addresses the city's challenges through a long-term, integrated approach (OneNYC 2017). The plan was created with extensive community engagement and the goal of increasing civic engagement is central to many of its initiatives. The inclusion of a diverse group of stakeholders in the formulation of OneNYC is important in rebuilding trust with the community. In the future, this newfound trust can serve to open a dialogue between various stakeholders and city agencies and result in new fit-for-purpose partnerships to successfully address unconventional challenges and build a more resilient city. They are strongly focussing on incorporating blue-green infrastructure (Figure 17**;**
Table 5 Error! Not a valid bookmark self-reference.provides a comprehensive overview from Voskamp (2015) of 31 blue-green adaptation measures that can provide options that can support the concepts of storage, retention and slow runoff. The blue-green solution website of Atelier Groen-Blauw (2017) provides 128 different examples on how to deal with the challenges of climate change. In conclusion, green-blue urban grids make cities sustainable, resilient and climate-proof. This website and the design tool will help to find fitting measures and inspires with attractive examples.
) solutions in a very dense city. Water quality is also an important goal. For example, the city has made it a critical goal to that green infrastructure is at least processing 10 per cent of runoff from permeable surface. In this way the number and severity of combined sewer overflows is reduced. The city made a green infrastructure plan in which funding for the coming 20 years are granted (Copenhagen Climate adaptation plan 2011). One of the main objectives is to provide besides flood alleviation many other benefits such as cooling the city, reducing energy use, increasing property values and improving air quality.

4.3 Promising concepts to address extreme weather events

4.3.1 Storage, retention and slow runoff

The increasing of extreme precipitation events, caused by climate change, result in combined sewer overflows because many existing sewer systems are not capable of handling excess runoff. In recent times this development, together with the realisation that clean rainwater is a valuable resource which can be used above-ground to benefit urban areas, has caused policies and practices to be reconsidered. The new policy for the urban water system is to slow the runoff of rainwater by capturing it for as long as possible or allowing it to infiltrate immediately (Atelier Groen-Blauw 2017). The reason is that the pumps and ditches do not have sufficient capacity to process large volumes of rainwater if it is led off at an accelerated pace. The purpose is to approximate the natural water balance as closely as possible. Even better than buffering it or delaying the runoff of rainwater is capturing and using it, which also saves on drinking water. In Belgium this policy has already been officially adopted. The heavier rainfall caused by climate change will lead to more overflows in districts without sufficient buffering facilities. Rainwater buffering facilities can be realised by reducing the proportion of hard surface areas and introducing green roofs, rainwater ponds, underground reservoirs and decentralised infiltration systems. The form of infiltration or buffering that is selected depends on the permeability of the ground, the groundwater level, the quality of the runoff and the space available for infiltration or buffering facilities. (Atelier Groen-Blauw 2017). A general overview is presented in Figure 17).

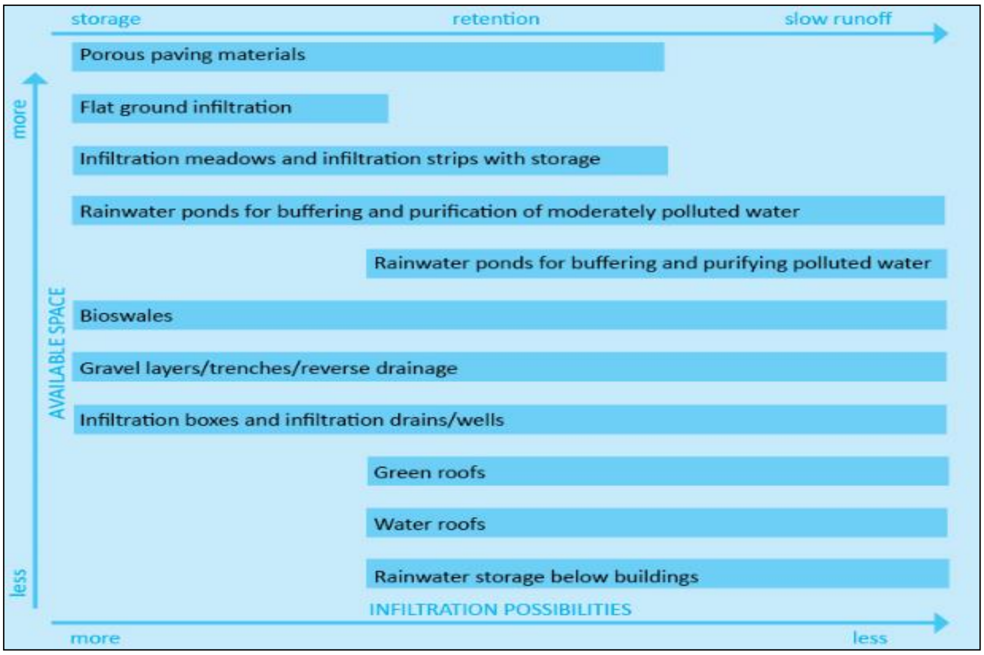


Figure 17 Overview of measures to deal with extreme rain events (Atelier Groen-Blauw 2017).

Table 5 Error! Not a valid bookmark self-reference.provides a comprehensive overview from Voskamp (2015) of 31 blue-green adaptation measures that can provide options that can support the concepts of storage, retention and slow runoff. The blue-green solution website of Atelier Groen-Blauw (2017) provides 128 different examples on how to deal with the challenges of climate change. In conclusion, green-blue urban grids make cities sustainable, resilient and climate-proof. This website and the design tool will help to find fitting measures and inspires with attractive examples.

Table 5 A comprehensive overview from Voskamp (2015) of 31 blue-green adaptation measures that can provide options that can support the concepts of storage, retention and slow runoff.

Blue-green measure	Description of the measure	Storage & harvesting	Attenuation	Infiltration	Cooling
Adding grass/herbs in streetscape	Replacing paved surfaces by grass or herbs, e.g. as tree pit.	0	+	+	+
Adding shrubbery in streetscape	Replacing paved surfaces by planting shrubs, like hedges on parking lots.	0	+	+	+
Adding trees in streetscape	Planting trees e.g. in streets or at squares.	0	+	0	+
Artificial urban wetland	Urban area used as wetland.	+	0	0	+
Bioswales	Vegetated ditch for stormwater storage, drainage and infiltration. Storage is provided above grounds, while an infiltration/drainpipe is situated subsurface to provide drainage and infiltration.	+	+	+	+
Cooling with water elements	Use of fountains as cooling elements; uchimizu practices.	0	0	0	+
Deep groundwater infiltration	Infiltration of water in aquifers.	0	0	+	0
Ditch or infiltration-strip	Dry small-scale channel with aboveground storage, used for infiltration.	0	+	+	+
Extensive green roof	Roof covered with soil and plants.	0	+	0	+
Green facades	Facades of buildings covered with plants.	0	0	0	+
Green shores and riverbanks	Vegetated banks for canals, rivers and coastal areas.	0	+	+	+
Helophyte filter	Zone of reeds for natural water purification.	+	0	0	+
Increase area of surface water	Increasing the area of surface water increases its overall storage capacity. In canals and rivers, it also increases the discharge capacity, such that locally, more rainfall runoff can be discharged.	+	0	0	+
Infiltration and Transport-sewer	Porous stormwater sewer pipes from which stormwater can both infiltrate into the soil and be discharged and groundwater can be drained.	0	0	+	0
Infiltration boxes	Crates that are installed subsurface, for instance under sport fields and playgrounds. These boxes can store stormwater for a short period of time, subsequently water leaves the crates by the sides and infiltrates.	0	0	+	+
Infiltration field	Area of sufficient size and porosity used to infiltrate stormwater (from roofs and paved surfaces) directly on meadows and green areas.	0	0	+	+
Infiltration trench	A lowered area filled with gravel or similar material, often applied next to an impervious surface (e.g. road, building) to allow stormwater infiltration.	+	+	+	+
Intensive green roof	Roof covered with thick layer of soil with plants and possibly small trees.	+	+	0	+
Lowering embankments	Realizing seasonal storage by creating extra storage height for surface water.	+	0	0	+
Park or urban forest	Area of open green space or collection of trees in a city, used for recreation.	0	+	+	+
Porous pavement	Pavements that allow rainfall runoff to (quickly) infiltrate into the soil. Two types exist: pavement systems where water passes around the pavement elements (e.g. bricks) and pavements where water passes through it.	0	0	+	0
Private green garden	Greening the garden or street side.	0	+	+	+
Rainwater retention pond	A pond that buffers and infiltrates rainwater. If it has a more natural design, including vegetation, also purification can take place.	+	+	0	+
Rainwater storage below buildings	An underground reservoir that is used to store water below a building, e.g. incorporated in a parking garage.	+	0	0	0
Rainwater tank	A storage tank that is used to store water in. Most often these are used to store rainfall runoff from especially roofs and are located on private property and the water is stored for reuse.	+	0	0	0
Specific seasonal storage facility	Storage reservoirs with a multifunctional character used to compensate summer shortages.	+	0	0	0
Swale	A moist, low-lying area or strip of land. When such a depression is planted, it is often designated 'rain garden'.	0	+	+	+
Systems for rainwater harvesting	System to harvest and reuse rain water within a building, including a rainfall collection point, a storage reservoir, pumps.	+	0	0	0
Urban agriculture	Growing fruit and/or vegetables within a city.	0	+	+	+
Water roof	Roofs to store water on and slowly discharge, or evaporate (two types: permanently wet and temporarily wet).	0	+	0	+
Water squares	Square having an area depression to store water in, during rainfall events. After the event the water is slowly discharged to the groundwater, surface water and/or the sewer system.	0	+	0	0

4.3.2 Water squares in Rotterdam

The city of Rotterdam is situated in the deltas of the River Rhine and River Meuse. Historically the city has experienced flooding from the sea and rivers. Furthermore, the groundwater level is high which implies that rainwater infiltration is highly limited. Rotterdam is a dense city that has limited space for climate adaptive structures. Hence, the challenges for Rotterdam to adapt to extreme drought, heat stress and excessive rainfall require extra innovative multi-objective solutions. As part of the comprehensive plan named 'Rotterdam Climate Proof' various water squares are being developed or at the planning stage (Rotterdam Climate Proof 2017). These water squares increase the storage capacity of excessive rainwater in the city. The water squares are composed of multiple areas with varying elevations that are flooded during extreme rainfall events. The water that is temporarily stored in these squares can slowly exit the square by flowing into the surface water, sewer system or groundwater. However, the squares are dry most of the time. During these periods part of the square serves as playground for children, outdoor theatre, and is used for all kinds of sport activity and even for ice skating during winter times etc.

Figure 18 Water square Benthemplein, Rotterdam (Rotterdam Climate Proof 2017).

Importantly, general support and the finance for these water squares are achieved by combining multiple goals. At first, the location for these squares are chosen to be low lying areas which experience regularly rainfall flooding and, preferably, where some maintenance and replacement work for sewer or road was planned anyway. Moreover, locations are selected where the water squares could provide an extra value in terms of attractiveness. Especially locations were selected where people were unhappy about the current physical appearance. The local inhabitants and users of the water square, were actively incorporated in design of the water square during public meetings and the developments were carefully communicated to the general public by means of websites, folders and meetings. The biggest water square is Benthemplein (Figure 18) with a total storage capacity of 1.700 m^3. The water square consists of two smaller basins with a depth of 1 metre that together can store 550 m^3 and a bigger basin with a depth of 2.5 metres that can store 1150 m^3. This bigger basin is also a sport field. Rainwater from the surrounding roofs and parking lot flow via shallow gutters towards the two smaller basins. The first rainwater that enters these small basins is polluted by uncollected solid waste, oil and grease from traffic and faecal origin (birds, dogs etc.). Hence, the water that is flowing towards these basins during the first hour is pumped into the sewer system. After one hour the pumping is stopped and the cleaner rainwater is stored in the water two smaller basins. The rainwater enters the bigger square via an underground connection that is designed in a mailbox shape in which the first most polluted water flows into a underground chamber. After this chamber is filled the cleaner water overflows into the bigger square (Rotterdamclimateinitiative.nl). The Benthemplein is first large water square in the world. The city of Rotterdam developed a smaller water square named Bellamyplein with a storage capacity of 250m^3. Furthermore, Kleinpolderplein is a storage area that is used as a museum square and can be flooded up to a depth of 40 centimetres in order to store excess rainwater during storm events. Rotterdam is a nice example as the mayor of Rotterdam, explained to us that Rotterdam is actually vulnerable to flooding from four different directions: from upstream (rivers), downstream (North Sea), from below (high groundwater levels) and above (cloud bursts). Climate mitigation is therefore a top priority for Rotterdam and many other Dutch Cities (Ministry of Infrastructure and Environment 2017). Rotterdam has been included in the City Blueprint activities (Koop and Van Leeuwen, 2015b) and the Urban Water Atlas for Europe (Gawlik et al., 2017). Further information can also be found in Rotterdam (2015a,b). As part of the POWER project, a governance capacity analysis is currently being carried out following the recently developed methodology (Koop et al., 2017).

4.3.3 Punggol waterways ridges, Singapore

The Punggol waterways ridges is a four hectare housing project under construction in which stormwater runoff is collected, treated and transported towards the stream. About 70% of the rainwater is channelled through multiple rain gardens and vegetated infiltration ditches that meander between the buildings (Figure 19).

Figure 19 Design and construction of Punggol waterways ridges in Singapore. These ridges are rainwater detentions that form a train of water gardens and swales in which stormwater runoff infiltrates.

These gardens and swales are only filled during rain events acting as detention basins. Subsequently, the rainwater infiltrates through a 400 millimetre sand column, 100 millimetre transitional layer and a 400-850 millimetre gravel layer. When the gravel layer is saturated, the water will flow to the manhole. The water level in the gardens and swales is allowed to rise to 200 millimetres in order to avoid drainage flooding. Above the 200 millimetre level, the runoff will flow directly into the overflow manhole. When both the infiltrated water flowing into the manhole via the gravel layer and the excess water flowing directly into the manhole exceed a certain level, water will be discharged into the surface water (Figure 20).

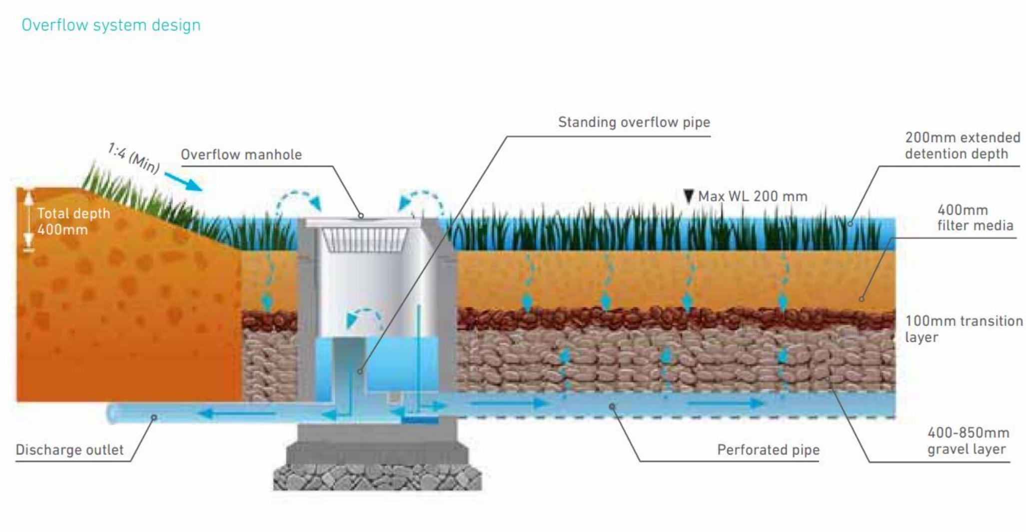


Figure 20 Construction Punggol water gardens and swales.

The stormwater runoff is infiltrated and its quality is improved by removing at least 80% of the total suspended solids to less than 10 parts per million. Remove 45% of total phosphorus to less than 0.08 parts per million and removing 45% of the total nitrogen to less than 1.2 parts per million. Specific vegetation is selected that improve the biodiversity, filtering capacity and aesthetic value. Finally, the area serves as public recreational area during dry weather.

5 Reduction of water consumption

The drinking water consumption in cities differs substantially between cities across the globe. This indicates that there is a lot of potential gain in reducing the consumption of drinking water (Figure 21).

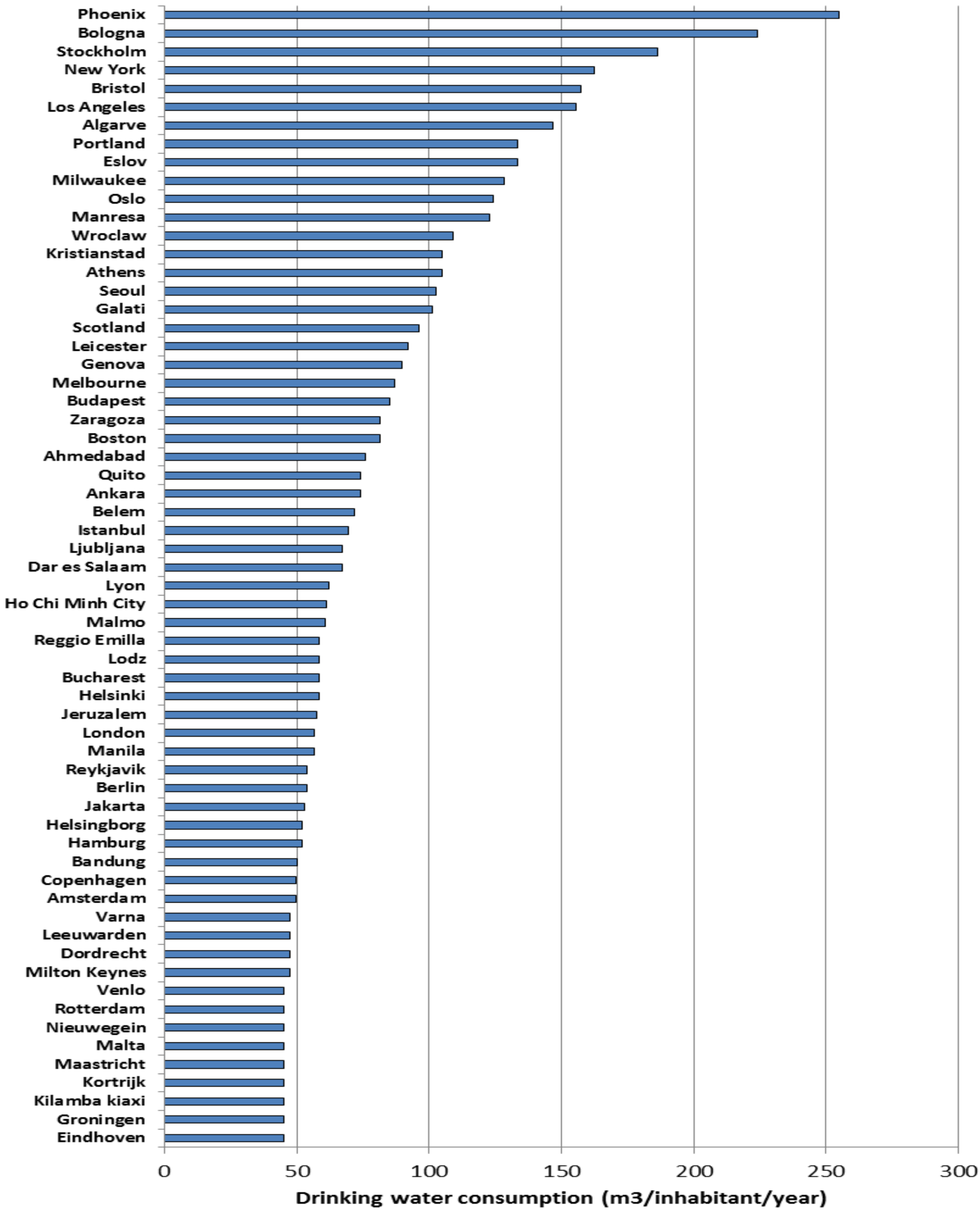


Figure 21 Drinking water consumption (m^3/inhabitant/year) in the 60 cities in 30 countries assessed by the City Blueprint.

Water scarcity is only one of the challenges in cities (Figure 22). Actually, drinking water consumption in cities makes up only a small fraction of the total water footprint. For example, people in the Netherlands use about 2300 m^3 of water per person per year of which 67 % is for agriculture, 31 % is used in industry, while only 2 % makes up household water (Van Oel et al. 2009). This means that water challenges in cities need to be solved predominantly by actors outside the traditional water sector. In fact, half of all cities with populations greater than 100,000 are located in water-scarce basins. In these basins, agricultural water consumption accounts for more than 90 % of all freshwater depletions (Hunger and Doull 2008; Richter et al. 2013).

Figure 22 Megatrends pose urgent challenges in cities (Van Leeuwen 2013).

In a critical analysis, Richter et al. (2013) point out that nearly all water used for domestic and industrial purposes is eventually returned to a water body. For instance, toilets are flushed and purified wastewater as well as cooling water in power plants is often returned to rivers. Because much of this water is not consumed, efforts to reduce urban water use or to recycle water with the aim to alleviate water scarcity per se, hardly makes any difference. In total, the domestic, industrial and energy sectors account for less than 10 % of global water consumption (Richter et al. 2013; Hoekstra et al. 2012). Of course, proper urban use and reuse of water, as well as adequate sanitation, contribute significantly to pollution reduction, local water availability, as well as to energy efficiency, energy and nutrient recovery. Hoekstra et al. (2012) estimate that agriculture accounts for 92 % of the global blue water footprint. Land, energy and climate studies have shown that the livestock sector plays a substantial role in deforestation, biodiversity loss and climate change. Livestock also significantly contributes to humanity's water footprint, water pollution and water scarcity (Jalava et al. 2014; Hoekstra 2014). Furthermore, the Food and Agriculture Organization of the United Nations (FAO) estimates that 32 % of all food produced in the world was lost or wasted in 2009 (Lipinski et al. 2013; FAO 2011a,b). Therefore, consumers, i.e. citizens, can play a major role in the reduction in the global water footprint by both reducing the fraction of animal products in their diets and by curbing their food waste, as many productive agricultural areas are irrigated by ever scarcer groundwater and other freshwater resources (Hoekstra et al. 2014; Figure 23).

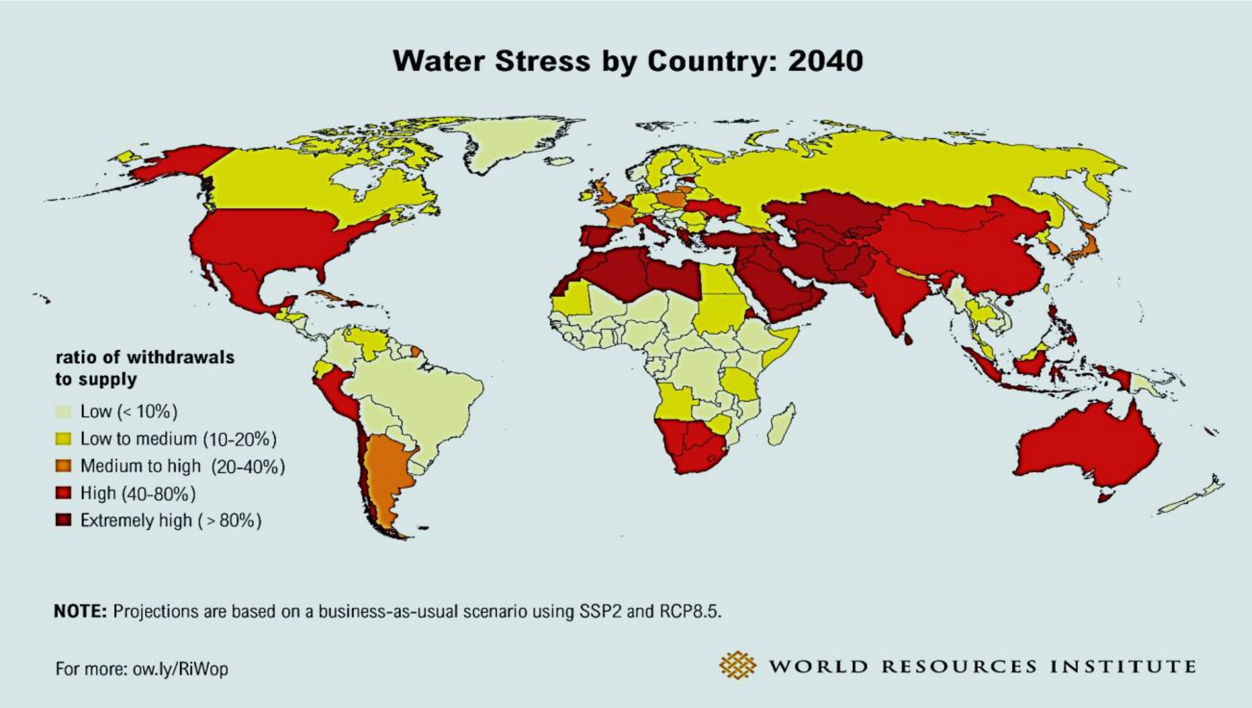


Figure 23 Water stress by country according to the WRI.

5.1 Best practices in Milton Keynes

5.1.1 Background

Unlike in some countries, as a municipality, Milton Keynes Council does not have any direct statutory responsibility for the management of the water supply. Anglian Water is the organisation responsible for infrastructure and supply of mains water in the Borough of Milton Keynes and the East of England. Milton Keynes Council has an account manager at Anglian Water Authority and a good working relationship is maintained to ensure best practice is followed and where appropriate, pioneered.

Anglian Water does not publish data solely for Milton Keynes planning and analysis is generally presented for Anglian Water's individual administrative Resource Zones (RZs). Milton Keynes is located in Ruthamford South RZ, which also includes the towns of Huntingdon, Bedford and Buckingham. Some information, such as leakage rate, is only available as a company average.

Most European Cities have the responsibility for their water supply but this is not the case in the United Kingdom. Establishing a good working relationship with key personnel in Anglian Water has many benefits and leads to saving water particularly in properties owned and managed by Milton Keynes Council. The City Council works closely together with Anglian Water utility to improve citizen engagement, water monitoring, data collection and project collaboration.

Milton Keynes is one of the fastest growing places in the United Kingdom. If we can reduce water consumption per capita, it means the increasing population has less impact on water resources. Whilst we have no data for the cumulative savings from the collaborative working with Anglian Water, there will be a significant increase in water efficiency. These water saving measures will lead to keeping down the cost of water compared with a scenario of business as usual.

5.1.2 Case study: Anglian Water Leakage Reduction

Anglian Water has achieved the lowest mains leakage rates in the UK water industry. In 2012-13 leakage was reduced to a rate of 4.97 cubic metres per kilometre of main per day (m3/km/d), i.e. a total of 189 Ml/d over Anglian Water's network. This was 10% below the sustainable economic level of leakage (SELL) target of 211 Ml/d set by the water industry regulator Ofwat, and nearly half the industry average leakage rate of 8.87 m3/km/d.

Anglian Water's mains leakage is now 30% less than it was 20 years ago. This has been achieved through significant investment, notably in an innovative new Integrated Leakage and Pressure Management System which allows quicker detection of leaks and improved response times. During 2012-13 Anglian Water invested £17 million on proactive leakage control and £18 million on reactive repair work, and deployed on average 128 leakage technicians throughout the year.

The company has set itself the target of reducing leakage to 172 Ml/d during the current asset management period, AMP6, (i.e. by 2020). More details of how this will be achieved are included in the Water Resource Management Plan (2015). An expected capital expenditure of £118.48 million will be required to achieve the 39Ml/d saving against the SELL.

Anglian Water are sharing their expertise by providing a specialist advice service on leakage control to commercial and industrial customers where requested.

The POWER project will contribute to the Anglian Water Leakage Reduction campaign by raising awareness of the importance of meter reading to look for anomalies in consumption. This will apply to citizens, schools and businesses through the DSP and attendance at local events. There will be opportunities to be present at planned events through working with other departments within MKC such as transport and arts and culture. Scheduled community events, conferences and schools events can be attended through networking with local organisations as well as Anglian Water. Water awareness can also be promoted through events and web page links with other MKC projects managed by the Sustainability Team at MKC. Establishing interdepartmental collaboration requires many hours of officer time but the benefits will be long lasting and - given the water scarcity and future prospects of water availability in the region – water conservation is estimated to be a good investment for the future with considerable returns for the city of Milton Keynes.

5.1.3 Case study: Anglian Water Customer Awareness Campaigns

Anglian Water's strapline 'Love every drop' (Anglianwater 2017f) conveys the message of the value of water which is promoted through a number of customer awareness aimed at encouraging reduction in water consumption:

- **'Bits and bobs'**: free water-saving equipment (such as dual flush converters, shower heads, shower timers, hosepipe gun, tap/shower inserts) installed on a home visit, accompanied by an energy and water consumption assessment and water-saving advice.
- **Drop 20**: challenging everyone to reduce their water use by 20 litres of water each day (see Waterwise leaflet);
- **Potting Shed club**: tips for using water wisely when gardening, including a free kit.

Public awareness campaigns continue to be part of Anglian Water's strategy for managing water resources. Cost-benefit analysis of the 'Bits and bobs' scheme for AMP6 suggests that a saving of 8.6 Ml/d could be achieved at a cost of £16.26 million (based on 180,000 water efficiency audits with free fitting of water saving devices and an estimated saving of 48 l/p/d per audit; Anglian Water, 2015) (Figure 26). A saving of 1.53 Ml/d is targeted specifically in Ruthamford South RZ.

Customer awareness campaigns include a bus tour and school visits (Figure 24). MKC aims to take part in the school visits and provide support with understanding how to read meters and interpret the data. In February 2017, the MKC partners established contact with the Community Education Centre Manager at Leighton Linslade Water Recycling Centre. Leighton Linslade is the nearest education centre to Milton Keynes. Two significant meetings with Heads of Service and the Open University have been arranged since establishing contact and we are continuing to work on ways to reinvigorate the schools lesson plans and data management in the schools who had meters installed in the MK:Smart project (MK:Smart 2017; Figure 25).

Figure 24 The Customer awareness campaign includes a bus tour and school visits (Anglianwater 2017a).

Figure 25 Example of community education through school visits (Anglianwater 2017b).

Figure 26 Cutting water use in Milton Keynes. Left: the bits & bobs campaign (Anglianwater 2017c); right: The Drop 20 leaflet 'Waterwise' (Anglianwater 2017d).

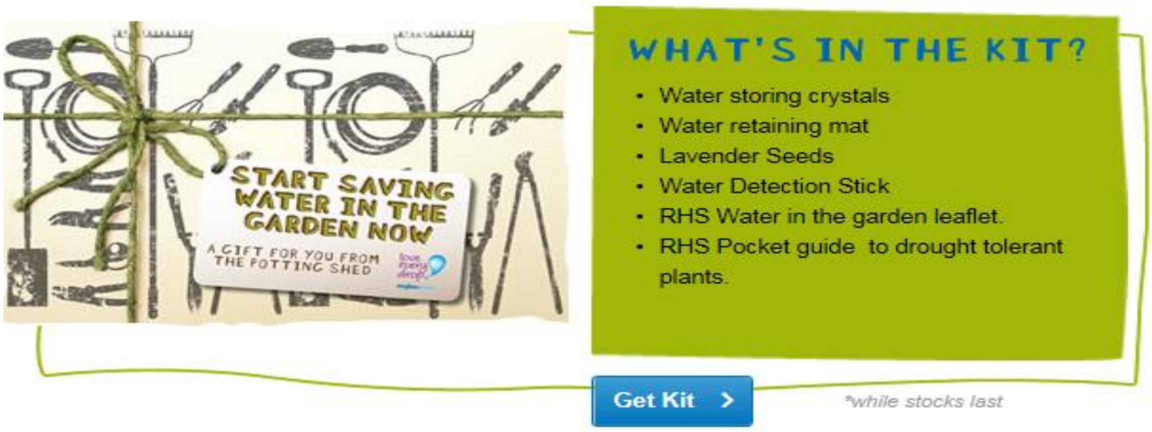


Figure 27 Water saving kit of Milton Keynes (Anglianwater 2017e).

Links to the Anglian Water campaigns have the benefit of providing good quality information at low cost to Milton Keynes Council. The low cost is because there is no need to create web pages for citizens. Whilst it has taken several months to reach the Anglian Water personnel who have permission to grant approval for the links, the benefits to the POWER project are manifold. There are several pages designed to engage with younger students such as an animation game of spotting how frogs waste water at bedtime with leaving the tap running while they clean their teeth. Good fun and certainly gets a message across in a fun way, a positive benefit for keeping the interest of younger audiences. There are also many pages that provide hints and tips for reducing water and the opportunity to source free devices to help households save water.

5.1.4 Case study: Anglian Water – Water Resources East Anglia (WREA) project

Anglian Water is using an innovative regional scale, multi-company, multi-sector approach to evaluate water resource needs in the long term (25+ years) through the Water Resources East Anglia (WREA) project (Anglian water 2014). The project, costing £4.2 million, aims to develop a robust long-term water resources strategy to increase the resilience of the supply-system and combat the anticipated reduction in supply-demand balance (forecast to reduce by 249 Ml/d by 2040 for a dry year scenario). Collaborative working is essential for making substantial changes in water consumption and this initiative is an investment in the future of securing water resources and raising awareness.

Over the next five years the project will undertake activities such as:

- **Groundwater and surface water investigations** to determine the longer term impacts of climate change and the feasibility of water resource development and management schemes;
- **Engineering appraisals** to develop schemes for maintaining the supply-demand balance;
- **Model development** to test and evaluation of future supply-demand strategies.

The WREA project will be based on the ‘Robust Decision Making (RDM)’ approach to planning, which focuses on plans which perform well in many different plausible future scenarios, rather than optimally in a few. RDM has recently been completed water resource study in the Colorado Basin, US.

5.1.5 Water consumption in Milton Keynes

The main influence Milton Keynes Council has on water consumption is through the planning system. Milton Keynes is still in a period of growth and all planning and projects are required to take sustainability into consideration. Planners have been aware for many years that the supply of water is a potential limiting factor for growth in the borough.

Guidelines for development are outlined in bullet point 1 below. The other seven headings outline the examples of good practice that MK Council are working on to help reduce water consumption.

1. MKC planning

Milton Keynes Council planning is governed by compliance with the Building Regulations, Part G: Sanitation, hot water safety and water efficiency. Section G2 covers water efficiency requirements. Requirements are prevention of undue consumption of water: this is 125 litres/day or an optional 110 litres/day if planning permission requires compliance to the lower consumption figure.

Milton Keynes Council seeks all new development and redevelopment that requires planning permission to use SuDS to reduce flood risk, improve water quality and present options for biodiversity and public amenity. This is consistent with existing national guidance and local planning policy. Furthermore, SuDS can have a considerable contribution to the recharge of groundwater which is an important source for the production of drinking water.

The Local Plan has the requirement to conserve water supplies and natural water levels and the Sustainability Team attends the MK Strategy for 2050 workshops and takes these opportunities to keep the focus on water efficiency and the POWER project. The Sustainability Team produced a 2050 Strategy in 2014 which highlighted water as a key indicator for a sustainable city in 2050 (Milton Keynes Council 2014). The most recent workshop was July 4th 2017 which was attended by a member of the Sustainability Team and the manager of the team. The team continues to attend workshops and seminars to keep water as a major consideration for future of MK and the region. The benefits of attending these planning meetings include the opportunity to remind policy writers of the importance of saving water and incorporating water efficiency into future sustainability objectives.

2. Work with local water provider to reduce consumption in Council offices and depot

During the summer of 2014, The Sustainability Team liaised with Anglian Water and formed an agreement to work on reducing water consumption of Council operations. Three MKC administrative premises were surveyed by water engineers contracted to Anglian Water. During the survey the engineers identified a major leak at the transport depot which was immediately rectified. The engineers also reduced tap flows to 7 litres/second and replaced washers where required. The benefits of this has saved water and money and raised awareness of staff to watch for signs of leaks.

3. Monitor water consumption data at Council properties

Milton Keynes Council uses Team Sigma software to monitor energy and water. Costs and consumption data are recorded and regularly checked for any unusual or unexpected figures. This process identified a major mains leak at the premises of an industrial area of Milton Keynes in 2015. This was reported to Anglian Water and repair work commenced within 24 hours. The team continue to monitor consumption of the buildings in the MKC portfolio to check for anomalies in consumption. The team continue to monitor consumption of the buildings in the MKC portfolio to check for anomalies in consumption. Whilst this takes tiem, it ensures water wastage is kept to a minimum and MKC can demonstrate we lead by example.

4. Liaise with local water provider to negotiate smart meters to increase quality of consumption data and consolidation of bills

Milton Keynes Council has been in discussions with Anglian Water to identify costs and benefits of installing smart meters. Upgraded meters would provide half hourly and real time consumption data. With this data it is possible to detect times of high usage and facilitate monitoring of behaviour change projects. Data collection of smart meters requires substantial IT infrastructure investments at MKC. Negotiations on pilot schemes are ongoing.

5. Learning and prospecting on new ways of working with the local water authority: the Anglian Water Innovation Shop Window

The restriction on smart meter installations is the cost of the investment and the speed of technology progress. It was proposed at a recent Waterwise event that meters are fast becoming smarter and cheaper so installing meters on a large scale might lead to a lock-in quickly outdating technologies. A more holistic approach has been taken by Anglian Water with their Innovation Shop Window project in Newmarket (Anglianwater 2017g). This is a large scale pilot project that brings together innovative approaches to the entire man-made water cycle with aims to reduce supply system leaks to zero, improve river quality, flood risks and water awareness. This project has about 100 partner organisations over dozens of projects. Innovation Shop Window is in the early stages but the strong links with between MKC and Anglian Water means we are in a position to learn from what works and how to encourage citizens and businesses to be wise about their water consumption and waste water. A benefit of Milton Keynes being a second area for Anglian Water to roll out their Innovation Shops Window project is that we will be able to learn from the pilot study in Newmarket. This will show us what works and where there is room for improvement.

6. Work with local project MK:Smart on water reduction initiatives in pilot area of the city

Milton Keynes Council is a partner in the MK:Smart (2017) project and the Sustainability Team at MKC have attended the MK:Smart initiative plenary meetings and conferences. MK:Smart has seven work packages under the administration of the Open University in Milton Keynes. These work packages cover water, transport, education, energy, enterprise, data and citizens. Water scarcity has been identified as a major consideration in the MK area and a pilot scheme to engage householders to reduce water was launched in April 2016. This has not been well supported by the community and further action is under consideration. The local Community Action charity has assisted with inviting residents but there has been no interest in joining the pilot scheme. The Sustainability Team continues to maintain contact with the water project manager at MK:Smart and the project leader of MK:Smart who is keen for POWER to continue their pioneering work. The benefits of this initiative is twofold, the pioneering work of MK:Smart progresses to actions and MKC can demonstrate how to lead on best practices. This also paves the way for further collaboration between the Open University, Anglian Water and MKC.

7. Work with local water provider on potential of water reduction in schools through behaviour change

The Sustainability Team has been in negotiations with Anglian Water since 2015 regarding behaviour change initiatives. The MKC measures would be in addition to the water authority‘s own schools project which includes web support and lesson plans for students. MKC will be working closely on the sustainability issues of the environment and raising awareness of water through the Anglian Water Schools programme and establishing water awareness days in Milton Keynes communities. These will link with other MKC projects and initiatives. A programme for the 2017/2018 is currently being discussed with plans for collaborative working top of the agenda. The benefit of this is that Anglian Water gain more opportunities to work with the schools because Milton Keynes already has established working relationships with several key schools. This collaboration should lead to more water saving opportunities being presented to Milton Keynes students.

5.2 Best practices in front-running cities to enhance the reduction of water consumption

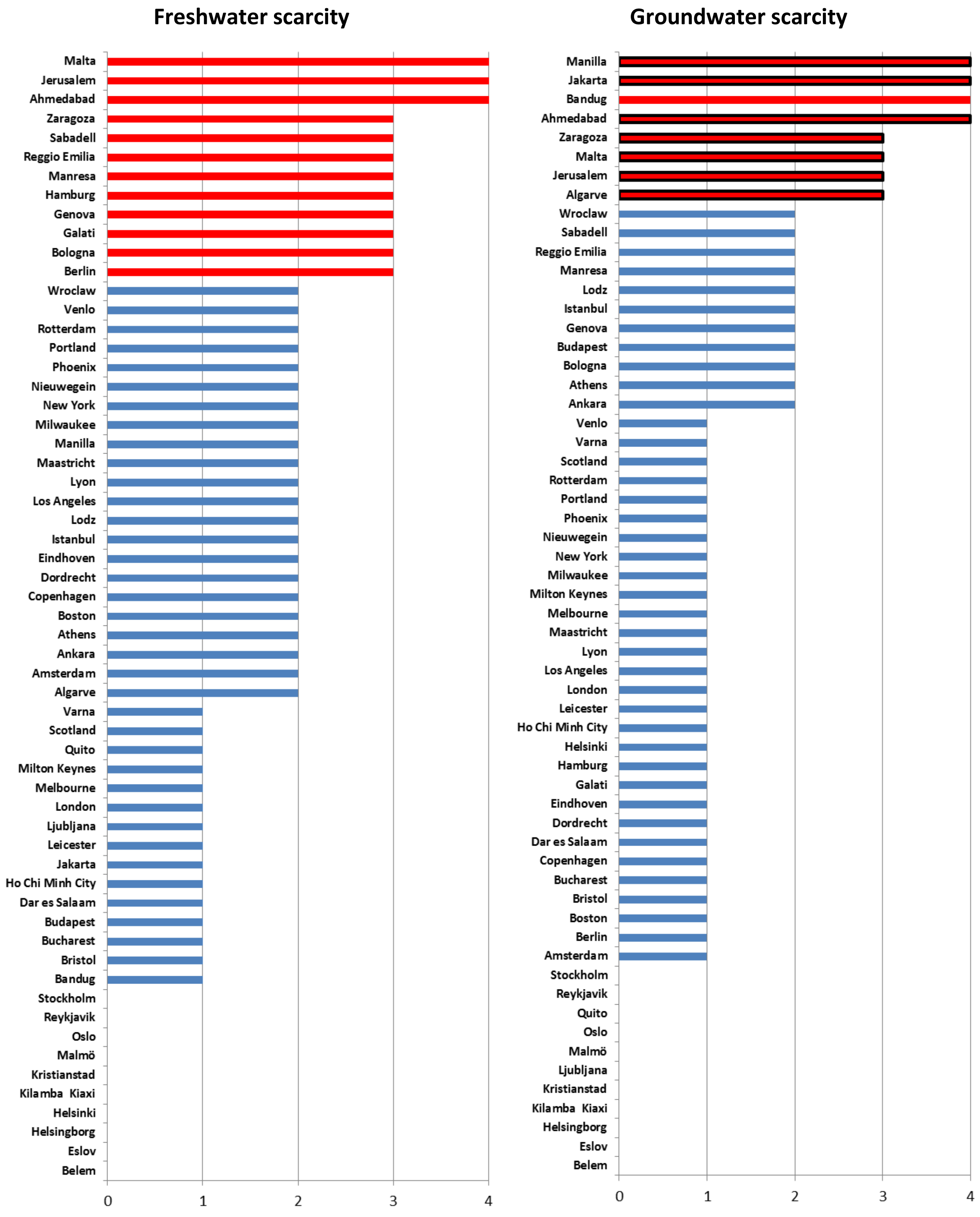


Figure 28 Overview of City Blueprint indicators fresh water scarcity (left) and groundwater scarcity (right). Red bars show cities that experience a concern or serious concern according to the TPF. On the top right, cities with red bars are also vulnerable to salinization and seawater intrusion.

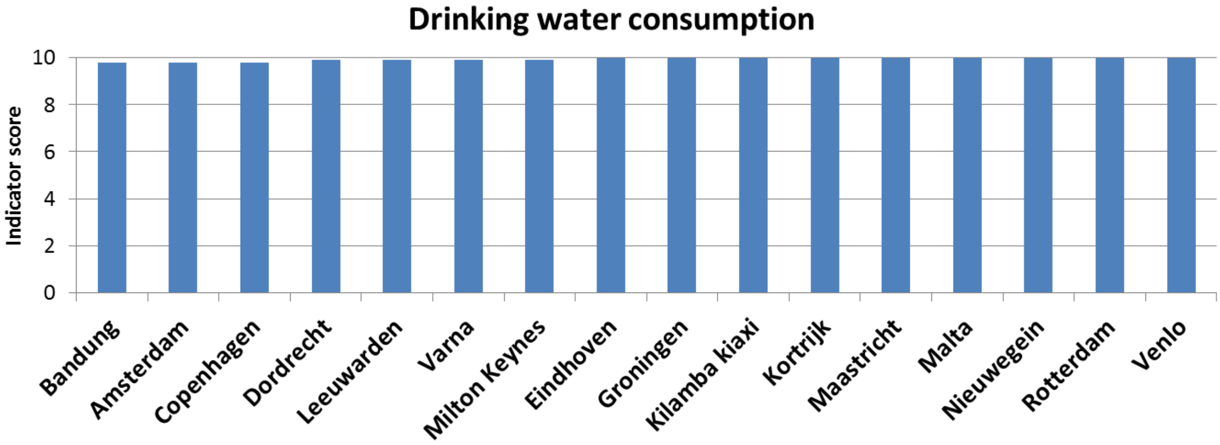


Figure 29 Overview of the City Blueprint indicators relevant for reduction of water consumption and variables related to water conservation. For each indicator the top fifteen cities are shown.

Malta is an example of a country that has considerably endured pressures regarding water scarcity and at the same time have a low drinking water consumption (i.e. high performance regarding this indicator; Figure 28 and 27). Moreover, many cities have less serious pressures but perform high on drinking water consumption as well. Examples are Kortrijk (Belgium), Milton Keynes (UK), Copenhagen (Denmark) and most Dutch cities.

However, it should be noted that also cities that put in considerable efforts to improve their resilience regarding extreme weather events are very suitable cases of best practices. For example, some cities in the Mediterranean have in general a relatively low consumption but have an overall drinking water consumption because of the large number of summer tourists that consume large quantities of drinking water.

Many cities such as Zaragoza (Spain), Reggio di Emilia (Italy), Manresa (Italy), the Algarve (Portugal) but also cities in the north of Europe (e.g. Germany) have limited freshwater availability and therefore might be interested in exchanging best practices via the POWER DSP. Another city that is frontrunner in reducing water consumption is the city of Melbourne (Australia).

5.2.1 Melbourne

Melbourne is the capital and most populous city in the state of Victoria, and the second most populous city in Australia. Melbourne is a city with a moderate rainfall pattern and receives on average approximately 600 mm of rainfall per year. According to the Food and Agriculture Organization of the United Nations (FAO, 2013) water withdrawal in Australia is predominantly for agriculture (7,359 km^3), municipal purposes (3,520 km^3) and industry (2,400 km^3). The total withdrawal per capita per year in Australia is 1152 m^3, leading to a total fresh water withdrawal in Australia of 4.58% of the total renewable water resources. In the decade known as the 'Millennium Drought' between 1998 to 2007, Victoria experienced rainfall 14 per cent below average and recorded temperatures 0.4 °C warmer than the 30 year average (City of Melbourne, 2015). The challenges of integrated water resources management (IWRM) under a changing and uncertain climate became starkly apparent during this *'Millennium Drought'* (Chong, 2014). The first author of this deliverable was engaged by the Office of Living Victoria (OLV 2014a) to undertake a sustainability assessment of IWRM for the city of Melbourne which was chosen as a case study because it represents a city with a moderate rainfall pattern, affected by climate change (Van der Steen, 2011). Furthermore, the recent 'Millennium Drought' served as a wake-up call (Government of South Australia 2017), turning Melbourne from a reactive into a proactive city concerning water and climate adaption, with concomitant changes in water governance in a relatively short period of time. During a short period a lot of people in Melbourne were interviewed and documents were reviewed (Van Leeuwen 2017).

The 'best practice' from Melbourne is the process that was organized by the authorities to deal with the Millennium Drought and to turn Melbourne into a water sensitive city (Brown et al. 2009; Ferguson et al. 2012). The reforms of the Office of Living Victoria were intended to change the way that Melbourne uses rainwater, stormwater and recycled water and provide for Victoria's next major augmentation. Looking at the challenges for Melbourne and at the changes that have taken place over the last years to meet the political goals for Melbourne related to IWRM (City of Melbourne 2015), it can be concluded that the performance of Melbourne as a reaction to the 'Millennium Drought' is impressive. This transition process is unique although a very recent political decision abolished the Office of Living Victoria. The development of the City Blueprint approach started in 2011 and at that time no use was made of the OECD multi-level governance framework (OECD 2011). Nevertheless, a comparison with the seven key co-ordination gaps of the OECD as presented in Table 6 is very interesting. In fact, it shows that water governance in Melbourne is very well organized on all these seven aspects and these aspects are discussed shortly. The administrative gap (gap 1) seems to be absent. Much has been done to bridge the information gap as adequate information on IWRM issues is available on high quality websites accessible to all stakeholders (e.g. Melbourne Water, 2015; Victorian Government, 2013). Policy gaps were bridged as a well-coordinated transparent multi-stakeholder process has been used to develop strategic plans for IWRM that included consultation with customers and stakeholders on many aspects of IWRM (OLV 2014b). Capacity gaps were prevented as a relatively small group of internal and external experts with complementary skills were pooled or worked together allowing for sufficient scientific, technical and policy expertise. Furthermore significant investments have been made by the Australian government to set up cooperative research centres for water sensitive cities (CRC 2015).

Table 6 The OECD multi-level governance framework: key co-ordination gaps in water policy (OECD 2011).

1. Administrative gap	Geographical 'mismatch' between hydrological and administrative boundaries. This can be at the origin of resource and supply gaps.
2. Information gap	Asymmetries of information (quantity, quality, type) between different stakeholders involved in water policy, either voluntary or not.
3. Policy gap	Sectorial fragmentation of water-related tasks across ministries and agencies.
4. Capacity gap	Insufficient scientific, technical, infrastructural capacity of local actors to design and implement water policies (size and quality of infrastructure, etc.) as well as relevant strategies.
5. Funding gap	Unstable or insufficient revenues undermining effective implementation of water responsibilities at subnational level, cross-sectorial policies, and investments requested.
6. Objective gap	Different rationales creating obstacles for adopting convergent targets, especially in case of motivational gap (referring to the problems reducing the political will to engage substantially in organizing the water sector).
7. Accountability gap	Difficulty in ensuring the transparency of practices across the different constituencies, mainly due to insufficient users' commitment, lack of concern, awareness and participation.

Adequate funding has also been provided for the development and implementation of these plans. As the decision was made to adopt network governance, i.e. a range of organisations and agencies working together to develop and implement the new whole-of-water-cycle management planning approach, the participants were also working towards a clear common objective. Transparency is key as the reasoning that is behind policy processes needs to be accessible. Network governance also facilitates clear accountability as it also acknowledges that each institution has its own area of responsibility and authority through which actions in the whole-of-water-cycle management plans will be implemented. This is also supported by the view of UN Secretary-General Ban Ki-moon on World Water Day 2015: *'The onset of climate change, growing demand on finite water resources from agriculture, industry and cities, and increasing pollution in many areas are hastening a water crisis that can only be addressed by cross-sectoral, holistic planning and policies – internationally, regionally and globally.'*

5.2.2 Athens

For cities, there are many options to reduce water consumption (Koop and Van Leeuwen 2017). Probably the most important ones are reducing food waste (Lipinski et al. 2013; FAO 2011a,b) and reducing meat consumption (Hoekstra 2014; Gawlik et al. 2017; Figure 30):

- Water demand management, including the diversification of water resources: rainwater harvesting, groundwater use and recharge
- Water reuse and recycling
- Leakage and water loss reduction

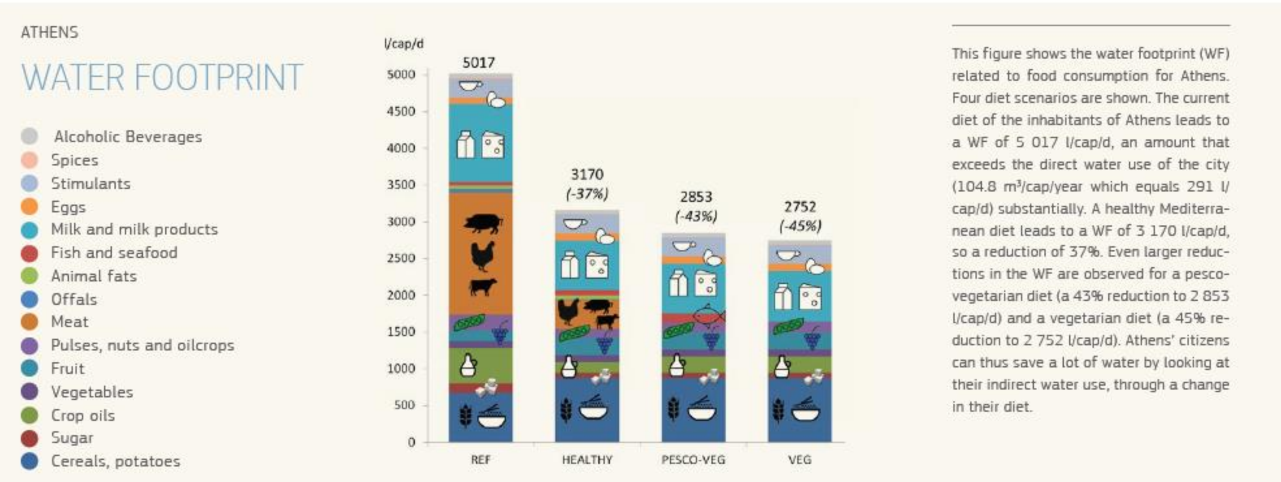


Figure 30 Water footprint for inhabitants of Athens based on their diet (Gawlik et al. 2017).

5.3 Promising concepts to reduce water consumption

There are many approaches to reduce water consumption. The approaches comprise technical, social and educational solutions. A number of cases will be discussed shortly, but it should be noted that many other approaches exist.

5.3.1 Public awareness in Jordan

In Jordan, the water demand exceeds the available renewable water resources which have been overexploited to bridge the gap. The adoption of a new strategy for water planning is crucial because this situation cannot be maintained without endangering sustainable development. For this reason, a National Water Master Plan has been developed for Jordan in 2004 while a National Water Strategy was developed and approved in 1997 and updated every few years (Ministry of Water & Irrigation 2016). The focus was on improving the knowledge, attitudes, and behaviour of Jordanians regarding water issues and included: NGO capacity building, community grants, water audits and building retrofits, media campaigns, and training workshops. Thanks to this programme and to the collaboration with the Ministry of Education, interactive water education programmes are today widely available and accessible to teachers, students in public and private schools, religious leaders, and NGOs. As part of the educational strategy (Hussein, 2010):

- a water conservation curriculum has been integrated into school textbooks grades 1–11 in five subject areas since December 2002.
- an interactive CD for Children on Water Demand Management concepts, to support school curriculum concepts has been developed.
- steps have been taken to establish a master's degree programme in Water Demand Management at Jordan University for Science and Technology in Irbid. This master programme is a pioneering programme that includes a series of highly specialized courses in Water Demand Management such as Best Management Practices, Demand Forecasting and Analysis, Strategic Planning for Water Demand Management; Planning Urban Demand Management Programmes, Alternative Water Supply; and Water Demand Management in Agriculture. This programme is designed to create a pool of specialized professionals to institutionalise domestic demand management. As part of the programme, more than 50% of religious leaders received training and materials on water issues and conservation techniques.

Finally a widespread media campaign was used to disseminate its message through television, radio, newspaper and magazines, to explain the water situation and how to participate in efforts in conserving water or using water more efficiently. Within each theme, issues such as scarce water resources, sector consumption of water, misuse of groundwater, water-saving devices, water cost, and importance of water to industry were included.

5.3.2 Water budget rate structure & progressive water tariff structure

Motivated by the previous, water utilities in Southern California have pioneered since 1991 the *Water Budget Rate Structure* (WBRS). WBRS implements the following four basic targets of a successful pricing scheme according to Whittington (2003), as detailed below.

Revenue sufficiency

From the water supplier's point of view, the main purpose of the tariff is often cost recovery. The revenue from water users should be sufficient to pay the operation and maintenance costs of the water utility's operations, repay loans undertaken to replace and expand the capital stock, provide a return on capital at risk and maintain a cash reserve for unforeseen events. The revenue stream must thus be adequate to attract both equity capital and debt financing.

Economic efficiency

Economic efficiency requires that prices be set to signal to consumers the financial and other costs that their decisions to use water impose on the rest of the society. From an economic efficiency perspective, a tariff should create incentives that ensure, for a given water supply cost, that users obtain the largest possible aggregate benefits. This means that volumetric water charges should be set equal to the marginal cost of supplying water. When capacity is constrained and water is scarce, it is commonly assumed that the marginal cost of supplying water can be approximated by the average incremental cost (AIC), i.e. the average cost of water from the next water capacity expansion project. Alternatively, the AIC of additional water may be the unit cost of reducing unaccounted-for-water.

Equity

Equity means that the water tariff treats similar customers equally, and that customers in different situations are not treated the same. This would usually be interpreted as requiring users to pay monthly water bills that are proportionate to the costs they impose on the utility by their water use.

Poverty alleviation

Many people feel that water services are a "basic right" and should be provided to people regardless of whether or not they can pay. This objective leads many people to recommend that water services be provided free, at least to the poor. Providing water free, through private connections, conflicts with the objectives of cost recovery and efficient water use.

WBRS is a tiered pricing scheme, but it differs from the traditional increased tier pricing schemes in that it is designed to provide revenue security to the water utility and at the same time guarantee fairness to the customers. Fixed costs of service are handled, mainly by political compromise. Of the amount calculated as fixed cost of service, utilities distribute certain percentage as fixed (irrespective of water use by the customer) and the remaining percentage as variable, assigned to the amount of water used. Utilities are aware of the trade-off between risk of low cost recovery of the fixed share and customer dissatisfaction from higher rates. Common practise among water utilities is to set the ratio off fixed cost distribution between the fixed and the variable portion of the bill to 20-30 and 80-70% respectively.

The WBRS is comprised of fixed costs and variable cost components. The fixed cost part is kept at a both a reasonable level for the customers and the water utility. The variable costs are comprised of several increasing tiers (between 4-6), depending on the water utility. The first and second tiers represent reasonable use of water by about 75% of the customers. The first tier in each WBRS refers to indoor water use and the second tier refers to outdoor water use (Dinar 2011).

Customers that exceed the first two tiers are considered not-efficient and face a significantly higher prices per unit of water consumed, compared to the second tier. Many water utilities compute the prices of the tiers following the second tier, by using the next alternative for water (the opportunity cost approach), such as imported water or water that are associated with much higher cost of provision. The WBRS is applied to the service area of the utility, using normative parameters. Customers are then given then the option of requesting to adjust the tiers (Variance) to their own parameters. Customers can request variance in tier 1 and/or 2 only (Dinar 2011).

The agencies that adopted WBRS succeeded in stabilizing revenues, reducing risk of revenue loss when customers use less water, increasing water efficiency, improving customer services and even reducing urban runoff.

The Public Utilities Board of Singapore (PUBS) is using a *progressive water tariff structure* that penalizes inefficient water usage. Effective from July 2000, domestic consumption of up to 40 m^3/month and non-domestic uses are charged at a uniform rate of €0.77/m^3 (S$ to € conversion at 18/8/2017). For domestic consumption of more than 40 m^3/month, the tariff becomes €0.85/m^3, which is higher than non-domestic consumption. In addition, the water conservation tax (WCT) that is levied by the Government to reinforce the water conservation message is 30% of the tariff for the first 40 m^3/month for domestic consumers and all consumption for non-domestic consumers. However, domestic consumers pay 45% WCT, when their water consumption exceeds 40 m^3/month. In other words, there is a financial disincentive for higher water consumption by the households. Similarly, water-borne fee (WBF), a statutory charge prescribed to offset the cost of treating used water and for maintenance and extension of public sewerage system, is €0.18/m^3 for all domestic consumption (Tortajada 2006). The impact of this pricing policy was that the consumption in 2004 was 11% less than in 1995. During the same period, the average monthly bill has more than doubled. These figures indicate that the new tariffs had a notable impact on the behaviour of the consumers, and have turned out to be an effective instrument for demand management. This is a positive development since the annual water demands in Singapore increased steadily, from 0,403 km^3 in 1995 to 0,454 km^3 in 2000. The demand management policies introduced have resulted in lowering of this demand, which declined to 440 million hm^3 in 2004. This tariff has several distinct advantages, among which are the following (Tortajada 2006):

- There is no “lifeline” tariff which is used in many countries with the rational that water for the poor should be subsidized since they cannot afford to pay high tariffs for an essential requirement for human survival. The main disadvantage of such a lifeline tariff is that it also subsidizes water consumers who can afford to pay for the quantity of water they actually consume. The poor who cannot afford to pay for the current water tariffs receive a targeted subsidy. This was considered a more efficient policy in socio-economic terms, instead of providing subsidized water to all for the first 20-30 m^3 of water consumed by all households, irrespective of their economic conditions.
- The current domestic tariff of water consumption up to 40 m^3/month/household is identical to the non-domestic tariff. Both are set at €0.77/m^3. In other words, commercial and industrial users do

not subsidise domestic users, which is often the case for numerous countries. The tariff structure penalizes all those households who use more than 40 m^3 of water per month. They pay the highest rates, €0.86 m^3, for consumption above this level. This rate is higher than the commercial and the industrial rates, and is a somewhat unusual feature compared to the existing norm.

- Water conservation tax (WCT) is 30% of the tariff for all consumers, except for domestic households who use more than 40 m^3/month. The WCT on consumption of each unit higher than 40 m^3/month goes up by 50%, from 30% to 45%, which must be having perceptible impacts on household behaviour in terms of water conservation and overall demand management. Water-borne fee (WBF) is used to offset the cost for treating wastewater and for the maintenance and extension of the public sewerage system. It is set at €0.18 m3 for all domestic consumption. For non-domestic consumption, this fee is doubled, €0.37/m^3, presumably because it is more difficult and expensive to treat non-domestic wastewater. A Sanitary Appliance Fee (SAF) is also levied per sanitary fitting per month. It is currently set at €1.8 per fitting.
- There are two components to water tariff. A major component of the overall revenue collected through water tariffs accrue to the PUBS recovering all operation and for considering maintenance costs and new investments. However, revenue from WCT accrues to the government and not to PUBS. This pricing scheme is combined with a proactive management of the company installations. PUBS, through a programme of leakages and losses minimization and elimination of illegal connections, has achieved a remarkably low unaccounted for water (UFW), which is 5%. This is a level which no other country has matched at present. In comparison, in England and Wales the best any private sector companies have managed to achieve is almost twice the level of Singapore. Similarly, UFW in most Asian urban centres now range between 40 and 60%.

5.3.3 Metering in Ontario and Sofia

Although installed meters do not conserve water directly, they do help in determining the effectiveness of conservation measures. Metering also serves to implement conservation measures such as pricing and mandatory rationing of water and these cannot be implemented without meters. In addition, meters are also necessary to determine system losses. Excessively leaky portions of a distribution system and leaks inside buildings are more easily identified if the system is completely metered. Many water supply companies print a message on the water bill to alert the customer to high consumption. The water supply companies advises the customer to check whether there are leakages in the plumbing system and to take appropriate follow-up actions if the consumption of this period is significantly higher than the consumptions of previous periods. Moreover, it is argued that metering, and hence cost is a direct incentive to reduce household consumption. Thus, metering perhaps is more than an indirect conservation measure.

There are examples of the effectiveness of water metering for water conservation from several countries. According to an Environmental Canada's study (Gan, 2000) on average an unmetered household used about 50% more water than a metered households in Calgary and in Edmonton. Also, the metering improvement programmes implemented in the latter part of last decade in four cities in Ontario reduced the water consumption by 15–27% on a long-term basis. A meter installation policy was also implemented in Sofia, Bulgaria when the water supply situation became critical (Dimitrov and Alitchkov, 1992). By the end of 1995, all consumers had to install individual water meters for measuring their consumption. The cost of meter repair is included in the price of water. Studies of water consumption in Sofia showed that users who installed individual meters consumed about 10% less water than those with common meters.

5.3.4 Residential water conservation in Miami-Dade, USA

In response to increasing water demand, Miami-Dade County, FL, USA implemented water conservation incentives for the residential customers. These incentives include rebates and unit exchange programmes for showerheads, toilets and washing machines. Water conservation practices assist end-users to implement efficiency measures to reduce water demand. Water conservation practices promoted by MDWASD include projects such as a full retrofit programme for the elderly and for low income families, high efficiency showerhead (SH) exchange programme, high efficiency toilet (HET) rebate programme, and high efficiency clothes washer (HEW) rebate programme. For the rebate programmes (HET and HEW), consumers have purchased the high efficiency appliances approved by either the EPA Water Sense programme (for SH and HET) or the Energy Star programme (for HEW). The certified Water Sense or Energy Star products must be at least 20 per cent more efficient than the other conventional products. For the HET rebate programme, the qualified toilets have flow rates less than 6 litres per flush (GPF), which is lower than that for a conventional toilet (13 litres). For the SH exchange programme, MDWASD offers low flow showerheads (5.7 litres per min) and equipped with on/off valve and swivel head for user comfort and convenience. A retrofit kit with two high efficiency aerators is included in the SH exchange package. With respect to HEW rebate programme, the certified HEW products are usually front-loader designs which can reduce the total water volume during washing. These programmes were promoted in different years, starting in 2005 for SH, 2006 for HET and 2007 for HEW.

Water savings and water use trend shifts of the customers were evaluated during the first four years after the implementation of water conservation practices. About 6–14% reduction in water demand has been observed during the first and second years. The water savings continued during the third and fourth years at a lower percentage. Water savings for water use efficiency measures were about 10.9%, 13.3% and 14.5% for the showerhead, toilet, and washing machine programmes; respectively. Adoption of more than one type of water efficiency appliance contributed to additional saving in residential water use. Table 7 demonstrates the reduction of the potable water demand achieved (as %) with the implementation of each one of the programmes (Lee et al. 2011).

Table 7 Reduction of potable water demand achieved by the implementation of three programmes (HET: High Efficiency Toilet; HEW: High Efficiency Washing machine; SH: high efficiency Shower Head) for Mean, High user and Low user water demand (Lee et al. 2011).

	HET	**HEW**	**SH**
Mean	19	18	14.7
High user	23.6	17	14.3
Low user	22.1	20.6	0.1

5.3.5 Integrated management in Melbourne

The City of Melbourne has practised total water-cycle management since 2002, supported by its adoption of the Total Watermark policy in 2004 and the Water Sensitive Urban Design (WSUD) Guidelines in 2005. Total water-cycle management is the integrated management of all components of the hydrological cycle within urban areas and landscapes – including water consumption, stormwater, wastewater and groundwater to secure a range of benefits for the wider catchment. The city has recently revised Total Watermark to place it within a ‘city as a catchment’ context. Within this context Melbourne implemented the following interventions across the public and private sectors (City of Melbourne 2009;

Table 8).

Table 8 Implemented interventions in terms of actions and reduction percentages in the 'city as a catchment' approach within the Total Watermark policy of the City of Melbourne (City of Melbourne 2009).

Location	Actions
Council Parks	Reduce potable water use in parks through: • irrigation efficiencies (subsurface, soil moisture sensitive, technological improvements, limited time) • understanding of soil types and subsequent soil moisture levels • mulching to prevent evaporation • planting climate responsive, drought-tolerant species • recirculating and recycled water in fountains • staff training programmes and contract provisions.
Council Buildings	Reduce water use in Council-owned buildings through: • efficient fittings – flow restrictors on taps, showerheads • efficient toilets – dual flush, reduced header tank flow • fire sprinkler testing (reduced from weekly to monthly, or recirculating) • cooling tower efficiencies
Residential	Residential: reduce water use in households through: • efficient fittings – flow restrictors on taps, showerheads • appliances – efficient washing machines and dishwashers • gardens – efficient species, layout and irrigation (to be maintained when water restrictions are not in place) • swimming pools – pool covers, reuse of backwash • householder behaviour change through education • high-rise residential – balance ring mains, fire sprinkler and cooling tower efficiencies.
Commercial including industrial	Commercial: reduce water use in commercial/industrial settings through: • fire sprinkler testing (reduced from weekly to monthly, or recirculating) • cooling tower efficiencies • appliances – efficient washing machines and dishwashers • efficient fittings – flow restrictors on taps, showerheads • gardens – efficient species, layout and irrigation (to be maintained when water restrictions are not in place) • property management and tenant behaviour change programmes.

5.3.6 Water efficiency in Sydney

Sydney Water's water efficiency initiatives in 2010-11 included residential, business and school programmes. These programmes are supported by community education and research and development activities (Sydney Water, 2011).

Residential water efficiency

During 2010-11, indoor water efficiency programmes provided an opportunity for households to replace inefficient fittings such as showerheads, tap flow regulators and toilets. Specifically:

- WaterFix provided households with an opportunity to have a qualified plumber: to install a new water efficient showerhead; to install tap flow regulators; to install toilet cistern flush arrestor for single-flush toilets; to repair minor leaks. Each WaterFix service was estimated to save 20.9 m^3 a year. Since the programme started in 1999, a total of 485211 properties, including Department of Housing properties, have taken up a WaterFix service.

- The DIY Water Saving Kits were developed as an alternative to the full WaterFix service. The kits provided simple devices customers could install to make existing showerheads and taps more water efficient. Each DIY kit was estimated to save about 6.7 m^3 a year. Since the programme began in 2004, 211,623 DIY kits have been distributed.
- Replacing a single-flush toilet with a 4 star dual-flush toilet can save about 23 m^3 a year. Since it started in July 2008, 28,224 toilets have been replaced as part of this programme.
- Sydney Water offered customers a $150 rebate for purchasing a water efficient washing machine. Since 2006, 186,634 rebate applications have been paid, saving each household on average 18 m^3 a year.
- As part of the New South Wales (NSW) Government's Climate Change Fund, a $150 rebate was offered for installing a hot water circulator with instantaneous gas hot water systems. A hot water circulator sends the cold water back into the hot water system to be reheated or used later. The NSW Government estimated that each hot water circulator would save up to 17 m^3 a year.
- Sydney Water offered customers a rebate for installing and connecting a new rainwater tank to existing homes. It is estimated that each rainwater tank installed saves between 35 to 60 m^3 a year on average depending on how it is installed.
- A programme that helped customers identify and repair concealed leaks in their homes. Meter reading data was used to identify long and short term leaks. Once notified of this consumption anomaly, if a targeted customer could not find their leak an expert contractor was provided to detect the leak using specialist leak detection equipment. Since 2008, over 230 leaks have been detected and repaired. It is estimated that this service saved each participating household 50 m^3 a year. In total, these programmes saved 17.5 million m^3 of water in 2010-11.

Non-residential water efficiency

Sydney Water helped businesses and government save water by identifying opportunities and management improvements to reduce water use through a series of programmes. These programmes are:

BizFix helped business customers by offering 50:50 co-funding for retrofitting water efficient fittings in bathrooms and kitchenettes. The programme helped 327 business sites to identify potential water saving opportunities. From its commencement in 2009, at the end of 2010-11 a total of 203 businesses had implemented water savings identified by the programme, with each saving on average 1.8 m^3/year.

Smart Rinse offered a free replacement of inefficient pre-rinse spray valves with efficient ones in commercial kitchens and retail food shops. The programme provided 4,707 spray valves to business customers, each saving on average 253 m^3 /year.

Top 100 online monitoring offered online monitoring of water use to customers using more than 100 thousand l/day to better manage their water use and identify leaks. The programme monitored 162 sites each saving just over 300 m^3/year on average.

HiRise pilot targeted 30 commercial/retail high-rise buildings over three years to learn about these buildings and identify water efficiency opportunities and develop key performance indicators for the sector.

School water efficiency

High water using schools or schools that have identified water efficiency as a priority, have participated in the Every Drop Counts (EDC) in Schools Programme or the School Amenities Programme. EDC in Schools focused on helping schools track water use and identify potential leaks through education materials, teacher training courses, dedicated education officers and online water use monitoring. The Amenities programme fitted 26 high schools with water efficient amenities. These two programmes and the Rainwater tanks in Schools Programme have saved around 502 million litres of water a year.

5.3.7 Use of seawater for toilet flushing in Hong Kong

The growth in population and of the economy of Hong Kong has caused a significant increase in the demand for fresh water. To secure sufficient water supply and to reduce reliance on imported water from Dongjiang (East River) in Mainland China, the Hong Kong Special Administration Region (HKSAR) government has implemented a wide range of water conservation measures which include the use of seawater for toilet flushing.

For areas outside the seawater supply zone, fresh water is used for toilet flushing. It is usually billed at 4-monthly intervals according to meter readings. Only one meter is installed in each building to record the total consumption of fresh water used for toilet flushing by all flats in the same building. The charges payable are calculated on a two-tier tariff structure. The first tier of 30 m^3/flat is free of charge; and the second tier of any consumption above the level of 30 m^3/flat is charged at HK$4.58 (€ 0.50) per cubic meter. In 2006, about 82 million cubic meters of the fresh water was supplied for toilet flushing, which was equal to about 9% of the total fresh water consumption.

6 Variables related to water conservation

As provide before, the management of water supply can be split into five components, each of which is influenced by a wide range of factors in addition to the amount of rainfall a city receives (Philip 2011). These are:

6. Resource – The source of a city's water supply, for example rivers, aquifers and lakes.
7. Abstraction – The removal of water from the source through channels, pumps and boreholes.
8. Treatment – The application of treatment processes to produce water of potable quality.
9. Distribution – Pumping of the treated water to the points of use.
10. Demand – The use of water by people, industry, services, nature, etc.

This process is schematically given in Figure 31. It shows that water supply management is complex and covers natural, socio-economic, legislative, technical, political, financial and behavioural aspects.

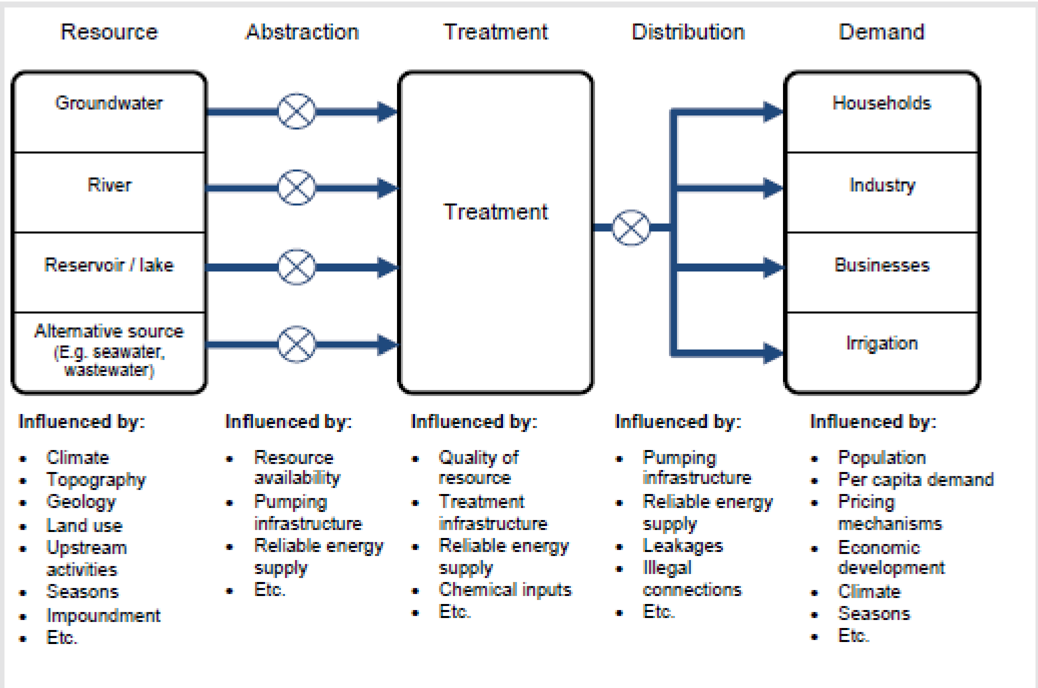


Figure 31 Management components of water supply services (Philip 2011).

The challenges for resilient, future-proof water management is also provided by Philip (2011) and shown in Figure 31. Another nice scheme from the SWITCH training modules is provided in

Table **9**, where conventional and more integrated approaches are provided. Water supply plays a central role in cities and many experiences have been reported (Koop and Van Leeuwen 2017).

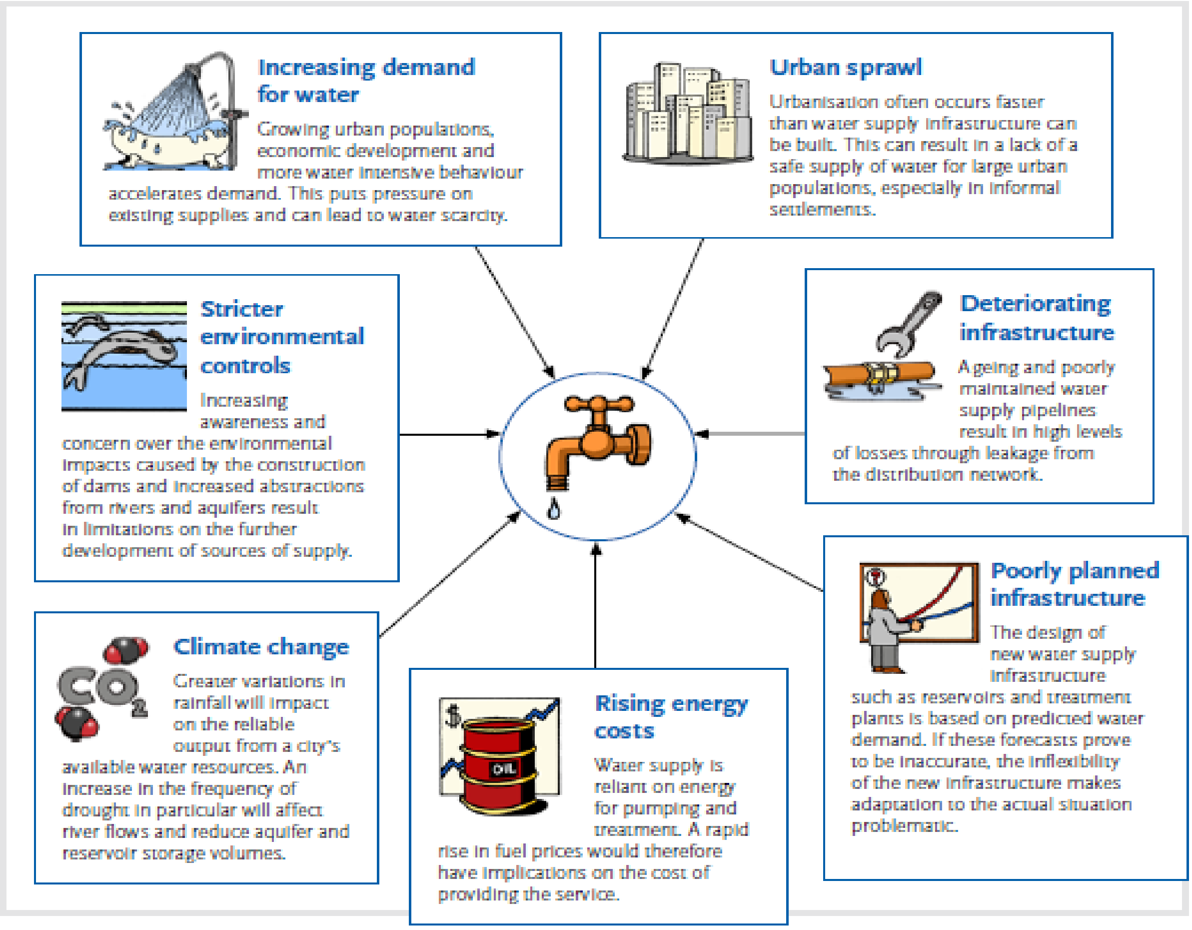


Figure 32 Examples of future pressures on urban water supply services (Philip 2011).

Table 9 Differences between conventional and an integrated approaches to water supply services (Philip 2011).

Aspect of water supply	Conventional approach (supply driven)	More integrated approach (demand driven)
Supply-demand balance	Increased demand is met through investments in resources and infrastructure to increase supply	Options to reduce demand, harvest rainwater and reuse
Treatment	Treatment technologies are improved in line with the type of pollutant that needs to be removed	Pollution control at the source and natural pre-treatment techniques are sought before new technologies are invested in
Leakage reduction	Leakage detection and repair is driven by economic factors	Leakage detection and repair is driven by economic, social and environmental factors
Pricing	Users are charged for water based on a fixed cost or, if available, the recorded volume they use	Users can be charged based on tariff systems that account for different volumes of use, purpose of use, season, etc.
Resource planning	Predicted resource availability is based on past hydrological records	Predicted resource availability includes adjustments for different climate change scenarios
Demand forecasting	Future water demand is forecast using historical trends, demographic estimates and projected economic growth	Future water demand is forecast by analysing future end uses in different sectors and is acknowledged as being uncertain.
End use requirements	Water of potable quality is supplied for all uses	Water of potable quality is provided only for uses that require it. Alternative sources are sought for non-potable demand

6.1 Best practices in Jerusalem (Hagihon)

Hagihon is the Regional Water Utility of Jerusalem and Hagihon's main goals through the POWER project are to promote water conservation behaviours, achieve quantifiable water savings and improved awareness regarding water quality by sharing data with other water utilities. The best practices regard water quality monitoring and water conservation in distribution networks.

6.1.1 Water quality monitoring

Monitoring – Faucet water in Israel is required by the Israel Ministry of Health to be of drinking water quality, with 24/7 supply. Water quality is achieved by proper water treatment (including disinfection by chlorine), carried out in our case by the National Water Supplier – MeKorot. Hagihon's responsibility, as municipal water utility, is to maintain the quality of water supplied by Mekorot through the use of mortar lined steel pipe, clean reservoirs, proper planning to ensure flow and circulation in the system, pro-active flushing of known problem pipes and of blow valves on major lines, extensive water sampling and testing carried out in Hagihon's accredited laboratory, including on-line water quality monitoring.

The laboratory tests are carried out in accordance with the requirements of the public health regulations, drinking water's sanitary quality, 1973-4 (combined version – 2000). The Israel Laboratory Accreditation Authority and the Ministry of Health oversee, with continuous supervision, the functioning of the Hagihon laboratory, in order to ascertain that it maintains a high level of functioning.

Hagihon's Water Quality Lab (Israel Laboratory Accreditation Authority ISO 17025 – 2005), has adopted a strict regime to prevent water contamination, taking more samples and more types of tests than required by regulation. Moreover, on-line sensors and monitoring systems are operational which are also not required by regulation:

- Manual Sampling – Hagihon takes approx. 4,500 samples/year equivalent to approx. 20 samplings per day whereas the national regulation requires 10 samples daily (Figure 33).
- Lab Tests – Hagihon performs types of tests that are above the types required by regulation. These include; Turbidity which in the past was not required by regulation and has been performed for years in Hagihon to improve prevention of contamination; Hardness which is not required but provided to customers as a service; and HPC (Heterotrophic plate count) is performed to improve prevention of contamination. Finally, it should be noted that Hagihon monitors micro-organisms in the water distribution network, using both the Membrane Filter Method for E. Coli and the HPC for Total Bacteria.

Figure 33 Manual sampling at Hagihon.

Hagihon has 28 fixed monitoring stations situated throughout the drinking water network (e.g. Figure 34). These stations provide on-line real-time monitoring of Chlorine, turbidity, pH, conductivity, Total Organic Carbon (TOC) or /UV detection, particle count and Oxygen Reduction Potential (ORP). The location of these monitoring stations is optimized for both cost-effectiveness (number of stations) and maximizing protection (minimum injury to residents, minimum dissemination of contaminant, minimum damage to water network etc.).

Hagihon is active in developing and implementing innovative technologies to improve the monitoring of Jerusalem's water quality. These activities include initiatives with local companies, cooperation with non-Israeli water utilities and collaboration with EU entities (such as Hagihon's participation in the FP7 Safewater project).

Figure 34 Water metering of Hagihon.

Empowering customers to maintain water quality in rooftop tanks – Hagihon provides residents with information and instructions on how to maintain water quality in rooftop water tanks. Some residents have installed water storage tanks on their roofs. This practise is widespread in neighbouring countries where, in contrast to, Jerusalem, water supply can be irregular. The issue is that use of rooftop tanks for storing water, may be a source of contamination when it is not cleaned and maintained sufficiently. It is Hagihon's intention to improve our engagement with this population of customers, in the framework of POWER, and to empower these customers with the knowledge and information in order to maintain proper quality of drinking water.

Results of water quality monitoring are published through the utility's internet site on a monthly, quarterly, semi-annual, annual basis (e.g. Figure 35).

The monthly water quality includes the following parameters:

- Chemical: chlorine, turbidity, fluoride, Trihalomethanes, pH, chlorides and hardness.
- Microbiological: total coliform, faecal coliform and heterotrophic plate count.

Customer complaints regarding water quality are answered by professional teams that arrive at site/home 24 hours a day.

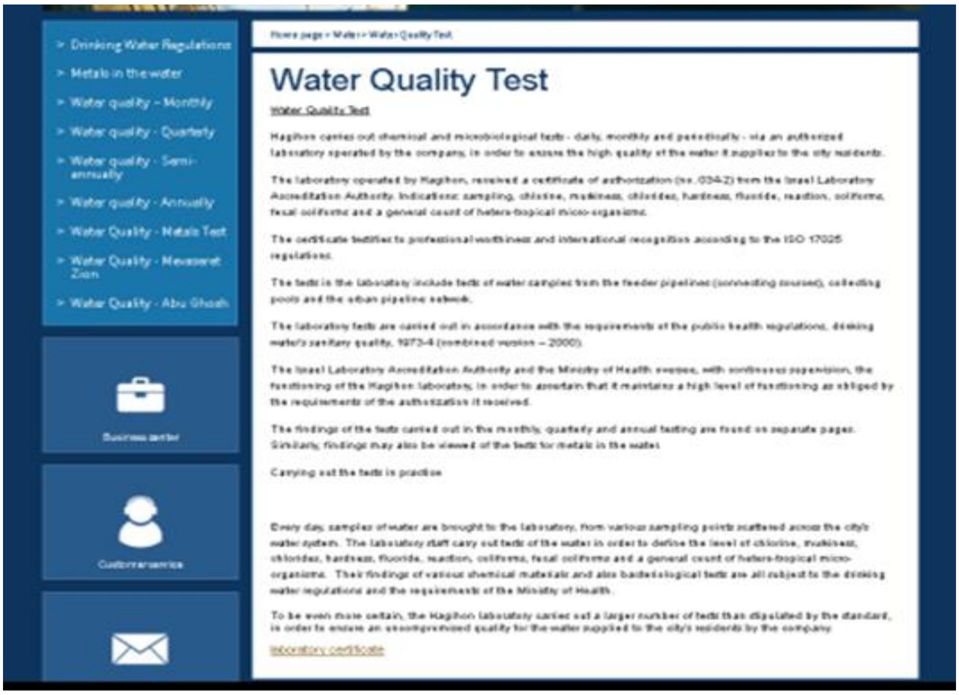


Figure 35 Water quality testing at Hagihon.

6.1.2 Water conservation

Water Conservation in distribution networks

In the past, water utilities served mostly as caretakers of systems/infrastructure (Baietti et al. 2006). The present trend in municipal water utilities is active management of the system, including managing water pressure, managing water quality, managing water flow – this by the implementation of a growing number of sensors and very advanced analysis systems.

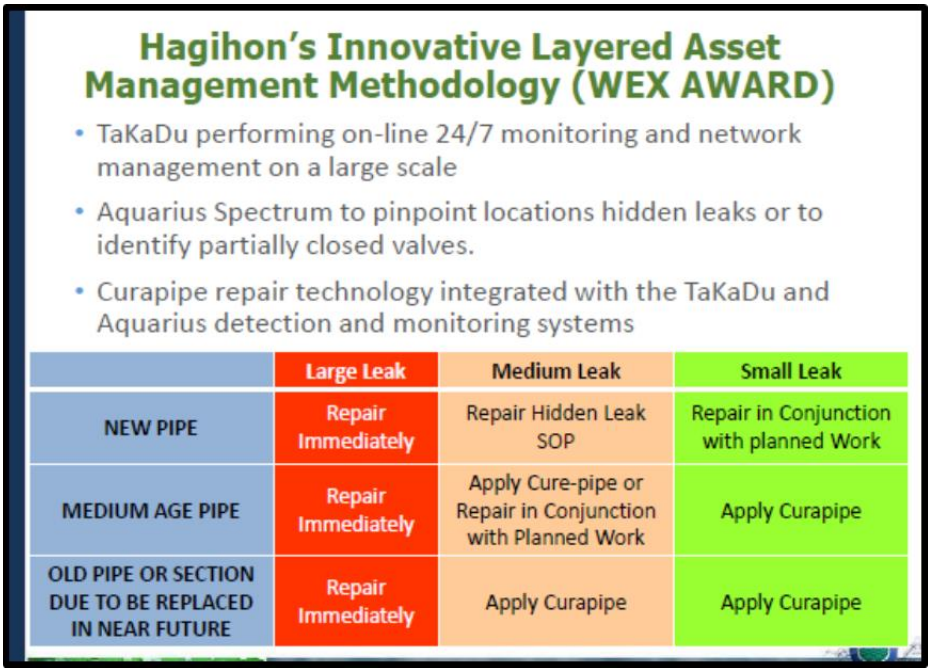
Located in a semi-arid climate, the issue of conservation is of major importance to Hagihon. With this understanding, Hagihon has achieved global recognition as an early adopter of innovative technologies, especially in the area of decreasing Non-Revenue Water (NRW) or "water loss in the network system").

It should be noted that the issue of NRW, is of substantial relevance to water utilities worldwide.

Hagihon has developed a multi- layered approach for lowering NRW including the following main factors:

- Customer Interaction:
    - Every household / customer is metered independently.
    - Meters are read at intervals of not more than 65 days.
    - Water loss is tested in every building every 60 days.
    - Response to letters from customers within 5 days.
    - Incoming customer phone calls are answered within 40 seconds.
    - Customers meet with Utility representative in Utility Customer Relations Centers within 10 minutes of arrival.
    - Customers with extremely high water bills are notified directly (phone, sms, letter) about potential leak in house network.
    - A customer who shows evidence of fixed household leak is billed at Low Rate.
    - Water meters replaced every 5 years.
    - Customer has 18 days to pay the bill.
    - In multi-cultural urban areas, all customer interaction (publications, phone calls, frontal reception, internet site, online chats service) is to be provided in relevant languages.
    - Facilities, customer centers and Utility internet site are accessible for disabled.
    - Telephone Hotline (abbreviated number) for all complaints including reports of leaks/burst pipes
    - Repair crews must arrive at scene of reported leak within two hours.
    - Unannounced water outages to be limited to 8 hours.

- Methodology & Technology:
    - Monthly NRW round-table meetings chaired by CEO and attended by senior professionals from engineering, IT, finance/accounting and customer service. The forum reviews NRW data from each District Metering Area (DMA), discussing measures that need to be taken.
    - Improving the water infrastructure by:
        - Forming and maintaining DMA's (Hagihon has 108 DMAs and increasing), installing flow meters and pressure meters (sensors) throughout the water system.
        - Proactive dynamic pressure management in service area, including construction of different pressure zones and implementation of mechanical, hydraulic and/or digital pressure modulators.
    - Implementing a smart network management solution:
        - 24/7 monitoring of water flow events and water pressure issues within DMAs. Using smart systems that employ statistical based technology identifying network anomalies and indicating location, size, priority and time. This is done by comparing real-time readings to the expected network behaviour, considering historical patterns as well as correlations between different parts of the network, indicating development of hidden leaks, other network issues and enabling to set the right priorities for the repair teams.
        - Implementation of advanced fixed acoustic leak detection system that monitors water network each night identifying the existence and exact location of hidden leaks. The cloud based system provides daily management of suspected leaks.
        - Implementation of Trenchless Automated Leakage Repair (TALR) solution, which is a new low cost trenchless repair category for bulk reduction of leakage in drinking water pipes, addressing leaks in the range of 40 l/hr to 3,000 l/hr. Bulk reduction of leakage is aimed at impacting water resources, energy savings, asset management and public relations for the utility.
        - The result is Hagihon's Award Winning (WEX Global Award – 2014) for Efficient Asset Management, enabling Hagihon to fix leaks in a planned fashion – before disturbing traffic and municipal life - and thus lowering overtime Human Resources and inventory costs (Figure 36).



	Large Leak	Medium Leak	Small Leak
NEW PIPE	Repair Immediately	Repair Hidden Leak SOP	Repair in Conjunction with planned Work
MEDIUM AGE PIPE	Repair Immediately	Apply Cure-pipe or Repair in Conjunction with Planned Work	Apply Curapipe
OLD PIPE OR SECTION DUE TO BE REPLACED IN NEAR FUTURE	Repair Immediately	Apply Curapipe	Apply Curapipe

Figure 36 Hagihon's Efficient Asset Management award.

While the Israeli inhabitants are conscious of the importance of water conservation, Hagihon reinforces this awareness and has for years provided a hotline number for residents to report burst pipes and water leaks. Hagihon intends to leverage POWER to encourage residents to report water leaks and to inform our customers and additional stakeholders of the innovative smart water utility NRW reducing technologies and methodologies implemented.

Water Conservation – Community Gardens

Hagihon has begun working with community gardens in Jerusalem, facilitating and assisting them in achieving efficient and sustainable gardens. This initiative is also supported by the municipality of Jerusalem. It is our intention that the POWER DSP will serve as a forum between different community gardens in Jerusalem and community gardens throughout the world. The POWER DSP may hence the exchange of ideas, techniques and methodologies for water-saving irrigation methods.
It should be noted that each community garden is responsible for their own activity. Hagihon facilitates the activity, interacts with community gardens and municipal authorities and provides access to an Irrigation Calculator. So far, Hagihon has initiated communication with two community gardens. Municipal officials have indicated to us that they are interested in our collaborating with about 70 community gardens in Jerusalem.

Water Conservation – School Children

Hagihon considers the educating of school children about the importance of water conservation and water quality as an important part of its social mission. For this purpose, Hagihon has developed curricula adapted to the various cultural and ethnic communities in Jerusalem. In addition to curriculum in Hebrew and Arabic, Hagihon has also developed curriculum for students from Jewish ultra-orthodox schools.

Hagihon's related activities include:

- Hosting educational visits of a wide variety of school children – from different cultural & ethnic backgrounds for 3 – 4 hour sessions regarding importance of water conservation. During 2016 over 6,000 children have been involved and since early 2017 students from 57 schools are engaged as well.

- Providing professional advice to schools regarding installation of rainwater storage tanks for irrigation purposes in the summer or for flushing the toilets throughout the year**.**

Hagihon has also identified several environmentally-oriented classes to interact with the POWER DSP and to develop and upload to POWER DSP "children friendly and oriented" content.

6.1.3 Costs and benefits of water conservation activities & water quality monitoring

The cost and benefits of each activity can be estimated in the following manner:

1. Water Conservation – the savings from the various POWER Hagihon activities is different in relationship to the specific activity, with:
    a. Education of school children and the general public to notify Hagihon regarding water leaks / pipes in the municipal distribution network translates first and foremost into lower spills of Non-Revenue Water (NRW) for Hagihon (each 1% NRW above the regulatory recognized level of 8% is estimated at about Euro 1 million in company revenue) and diminished damage to municipal infrastructure (roads, walls, buildings etc). In addition, water conservation lowers the amount of water produced (most of Jerusalem's water is sourced from desalination plants) and pumped to Jerusalem (from sea level to 1,000 meters altitude). Previous studies have estimated the energy cost per cubic meter to Jerusalem at 7.3 kwh/m^3 – energy which costs money and also incurs carbon emissions.
    b. Community gardens – here there is no loss to Hagihon as the gardens are metered and pay for the consumption. Nonetheless, lowering consumption in the community gardens, as well by any consumer (in home or business) incurs the other savings described above relating to the cost of producing and pumping to Jerusalem each additional cubic meter of water = 7.3 kwh (the monetary price of each kwh varies as it dependent on the time of day and season of year).
    c. The potential amount of water that can be conserved and monetary and emissions savings varies greatly based upon the consumption of each end-user and this is very difficult to estimate. Hagihon has been decreasing NRW steadily over the last five years and the NRW (beginning 2017) is 9.2%. We are working very hard to achieve the regulators goal of 8%.
2. Regarding Water Quality in Rooftop tanks, this issue relates completely to the private/home sector and really does not affect Hagihon on a business level. The savings here – for a homeowner to have a non-contaminated water tank on his roof, translates into non-motorized benefits of health for his family.

6.2 Best practices in front-running cities to deal with variables related to water conservation

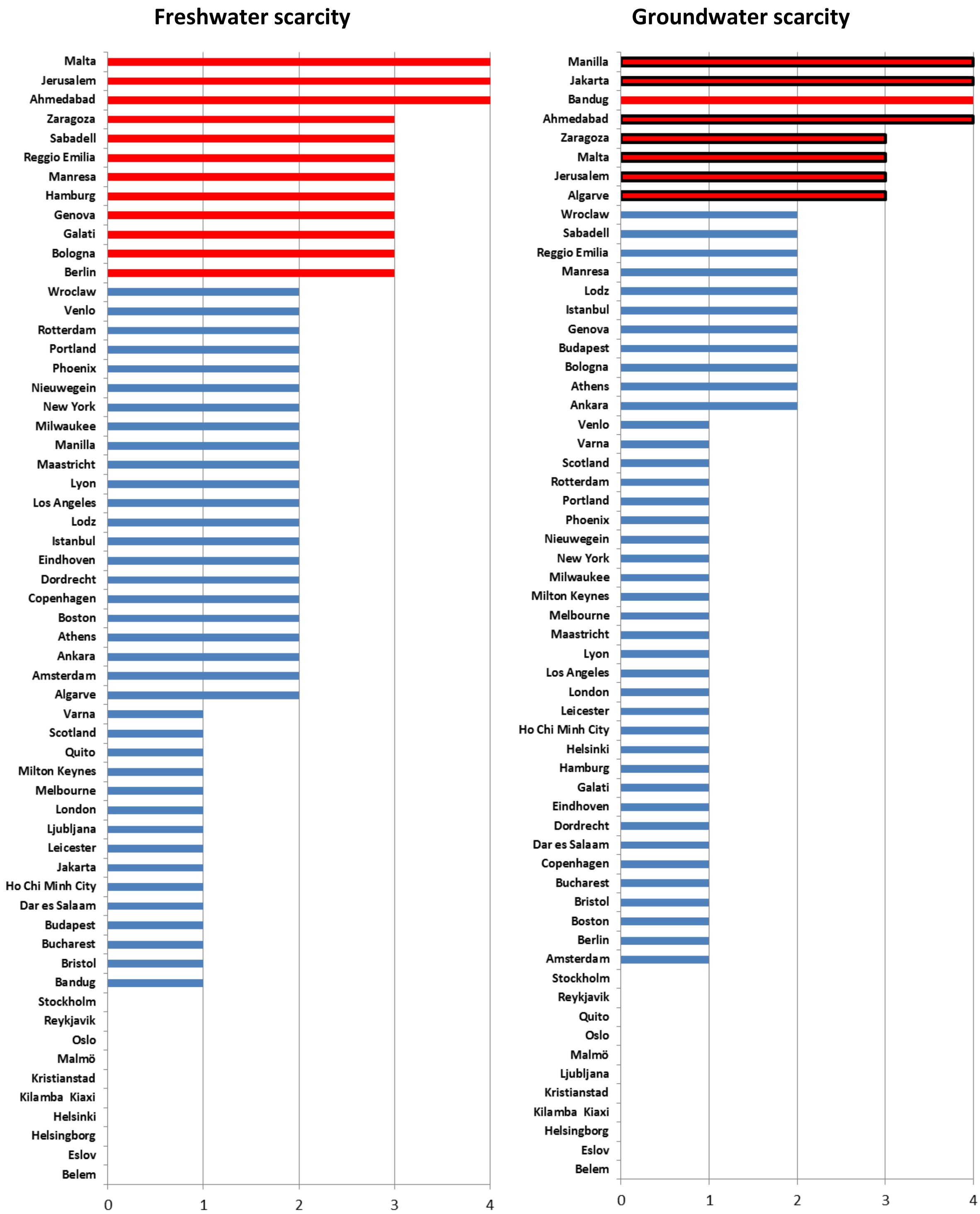
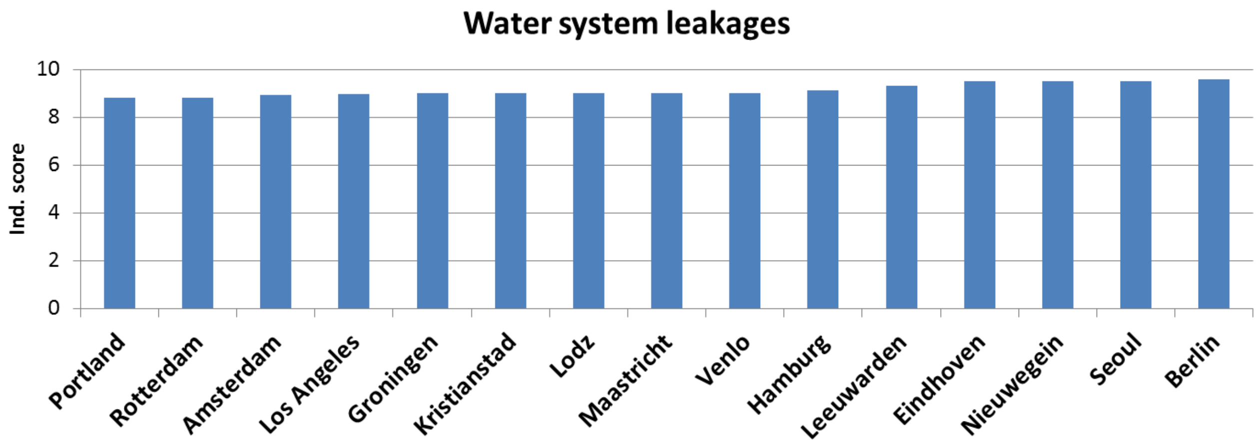


Figure 37 Overview City Blueprint indicators fresh water scarcity (left) and groundwater scarcity (right). In red are cities that experience a concern or serious concern according to the TPF. On the top right, cities that are also vulnerable to salinization and seawater intrusion are marked in red.



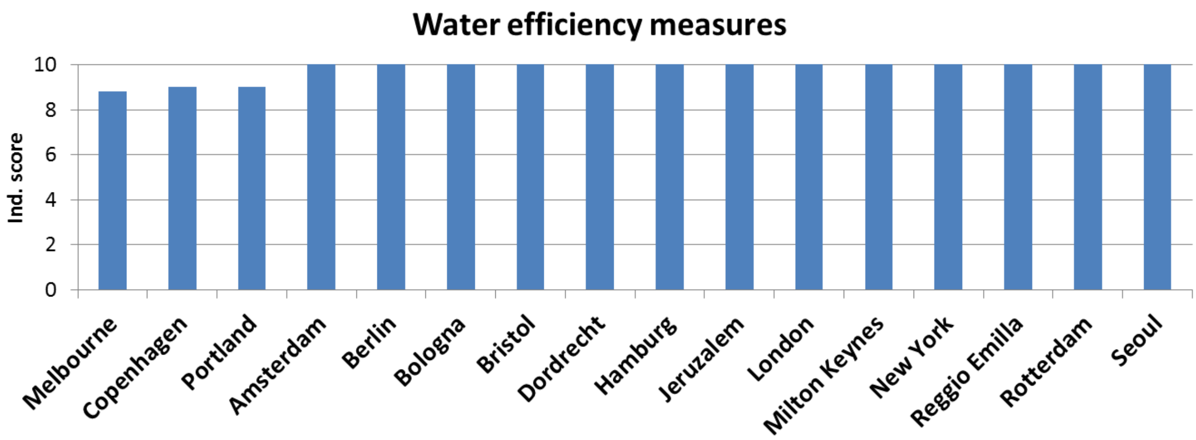


Figure 38 Overview of the City Blueprint indicators relevant for reduction of water consumption and variables related to water conservation. For each indicator the top fifteen cities are shown.

As for the theme of drinking water consumption, Malta is an example of a country is facing pressures regarding water scarcity (Figure 37). However, with respect to variables related to water conservation, Malta can still reduce its freshwater demand. Cities that face less serious pressures but perform high on water efficiency measures and reduction of infrastructure leakages are cities such as Berlin (Germany) Jerusalem (Israel), Seoul (South Korea), Hamburg (Germany) and Rotterdam (the Netherlands) (Figure 31). However, it should be noted that also cities that put in considerable efforts to improve water conservation have important best practices to share. Many cities such as Zaragoza (Spain), Reggio di Emilia (Italy), Manresa (Italy), the Algarve (Portugal), but also cities in the north of Europe (e.g. Germany) have limited freshwater availability and therefore might be particularly interested in exchanging best practices via the POWER DSP.

6.2.1 Berlin

The city of Berlin has much experience in social, economic and technical aspects of water consumption. Here a short summary of the city's best practices regarding variables related to water conservation is provided based on Heinzmann (2003). Various techniques are applied to systematically detect leakages in the network:

- Preventive search for leakage losses
  A systematic and approach has been developed to proactively detect leakages. Specific vulnerable areas have been identified based on a database of the pipe network of the city. A sound level meter is used accurately detect leakages. The sound level meters are installed into hydrants, section gate

valves or house connections in order to determine exact positions of the pipes and then monitor distinctly-selected sections of the pipe system for leakages. The sound level meters are equipped with antennas and wireless transmissions. During low consumption periods (from about 1 a.m. to 4 a.m.), the sound level meters are recording. Data recordings are then evaluated by a correlation measuring technique.

- Correlation measuring techniques
  The correlation measuring technique is a technique to locate leakages in the underground pressure pipe systems. The noise caused by a leakage spreads out within the pipe system in both directions with a distinct velocity. This is transformed by converters into electric signals, magnified and transmitted by wireless transmitters to the main correlation unit. The exact position of the leakage may be calculated by means of the difference of the running time of the leakage noises.
- Database
  A database was developed consisting of 1) damage statistics (natural events, road construction, increasing traffic, increasing truck use, construction measures as well as information about the pipe materials), 2) age of the pipes, 3) pipe conditions, and 4) hints and statements about leakage losses. All information has been structured according to five classes:
  1. Damages caused by the manufacturing
  2. Damage caused by pipe-laying and mounting
  3. Technical and biological ageing
  4. Natural earth movements
  5. Damage due to the management and to the pipe system.

  The database useful to recognise patterns, identify vulnerable areas that need increased monitoring, and understand fundamental causes of leakages based on extensive empirical data.

Over a period of 10 years, the Berlin Water Works succeeded in achieving a considerable reduction of the water losses caused by breakages in the pipe network, from about 25 per cent to around 4.5 per cent (Heinzmann 2003).

6.3 Promising concepts to deal with variables related to water conservation

6.3.1 Pressure control in Sao Paulo, Brazil

Pressure management has been around for many years in its basic form as a means of hydraulic system control and more recently has been very successfully introduced in many countries to combat leakage. Pressure management, as a means of combating leakage, can be used in most systems whether they are pumped or gravity fed, although the design of the scheme will change dramatically due to different hydraulic patterns. Often the reduction of pressure from one level to another can be a controversial subject, and one which sometimes utility managers prefer not to prioritise as there is a potential for customer dissatisfaction. Sao Paulo, Brazil, utilised demand-based dynamic, time-based and fixed traditional methods to control the pressure in the distribution network. Various types of control were deployed and tested, including (Burn et al. 1999):

Flow-based dynamic modulation of a hydraulic valve: This is the best type of control for areas with changing conditions, head loss, fire flow requirements and the need for advanced control. This type of control is affected by controlling outlet pressure in relation to demand by connecting the controller to a metered signal output.

Time-based modulation of a hydraulic valve: This can be affected by using a controller with an internal timer. Control is affected in time-bands in accordance with demand profiles. This methodology is very effective for areas with stable demand profiles and head losses and is usually used where cost is an issue, but advanced pressure management is desired. Time-based modulation controllers can be supplied with or without data loggers and/or remote links. Some manufacturers connect the controller to the pilot valve and alter the set point of the pilot valve by introducing a force against the existing force of the pilot spring.

Fixed outlet hydraulic control: This is the traditional method of control and uses a basic hydraulically operated control valve. This method is effective for areas with low head losses, demands which do not vary greatly due to seasonal changes, and areas with uniform supply characteristics.

6.3.2 Centralized rainwater harvesting in Germany and the UK

Rainwater utilisation in Germany is widespread since the 1980s (Nolde, 2007). Typically, the water is collected from the roof and is filtered, stored and primarily used for toilet flushing, garden watering and household laundry. Nolde presents a novel approach: instead of using only the water from the roofs, he suggests that that rainwater draining from the streets and courtyard surfaces could also be reused. This could be a viable option for densely populated urban areas and reduces drinking water consumption and wastewater production. It also minimizes the entry of pollutants into the surface waters, without the need for a sewer connection. He found that 70% of the toilet-flush demand can be replaced by treated stormwater without any comfort loss. In one pilot application about 11,770 m^2 of sealed surface area are connected to a rainwater reservoir situated in the cellar of the pilot building. 63% of the collected surfaces originate from the roof, 35% from courtyards and sidewalks and 12% from traffic surfaces. Rainwater is first discharged into the existing rainwater sewer of the Berlin water company, and from there it drains into the rainwater reservoir until the reservoir reaches its full capacity. The 190 m^3 rainwater reservoir is filled with rainwater until the water level in the reservoir reaches the sewer level. Excess water is discharged into surface water. Biological treatment of the rainwater takes place in a “planted” substrate filter which has been installed in the building. Rainwater plant site in Berlin- Lankwitz (Nolde 2007). About 10 m^3 of rainwater are treated daily followed by disinfection with UV (28 Watt). The service water reservoir (6 m^3) serves as a storage tank for the treated rainwater and acts as a system buffer during consumption peaks. The rainwater harvesting plant supplies 80 apartments and 6 small trade units (a total of 200 persons) with high-quality service water for toilet flushing and garden watering. The selected substrate filter consists of two layers each is 2.2 m long, 1.1 m wide and 0.7 m deep. The above layer consists of expanded clay particles (8–16 mm grain size) while the lower layer is filled with gravel (4–8 mm). The two layers are placed 1 m apart. Rainwater percolates from above continuously and uniformly over the whole substrate bed. The rainwater plant has been operating since 2000 without clogging or other technical problems.

Similar approaches have been applied in Southampton (Figure 39). The system comprises of a 15 m^3 underground tank, 3 vortex filters, a single pump and a 450 litre header tank. The rainwater harvesting area is 1000 m^2. The building occupancy is 150 people. Average annual rainfall is 800 mm and the scheme is expected to provide 1690 l/d. The capital cost was €4.74 (currency rate 18-08-2017) and the payback time is estimated at 5.3 years.

Figure 39 Administration and Student Services Building, University of Southampton (Rainharvesting systems 2012).

6.3.3 Low water gardening in Cyprus

Smart gardening techniques can be used to reduce significantly the water demand for garden irrigation. The following figure demonstrates the development of a garden in Cyprus (Figure 40). The garden was planted with xeriscape shrubs. A spaghetti tube water system was installed and the ground was covered with a landscaping fabric (prevent the growth of most weeds). Afterwards the area was mulched with white gravel. Mulching trees and shrubs is a good method to reduce landscape maintenance and keep plants healthy. Mulch helps conserve moisture by achieving a 10 to 25 per cent reduction in soil moisture loss from evaporation (Evans 2000). Mulches help keep the soil well aerated by reducing soil compaction that results when raindrops hit the soil. They also reduce water runoff and soil erosion (Evans 2000).

Figure 40 Low water gardening in Cyprus (Rural Cyprus 2012).

7 Water quality

Drinking water can be produced from a variety of sources, i.e., surface water, groundwater, by rainwater harvesting, desalination, and by reuse. The Sabadell case (Section 2.4) is actually about drinking water itself. Globally approximately 50% of all drinking water comes from groundwater, whereas the other 50% comes from surface water.

Groundwater

Groundwater overexploitation as a result of agricultural, industrial and domestic activities is taking place globally (Wada et al. 2010; 2012; OECD 2015b; Van der Gun 2012). Groundwater abstraction is very unevenly distributed across the globe (Figure 41). It differs not only from country to country, but also shows pronounced spatial variation within countries. The world's aggregated groundwater abstraction as per 2010 is estimated to be approximately 1,000 km3 per year, of which about 67% is used for irrigation, 22% for domestic purposes and 11% for industry. Two-thirds of this is abstracted in Asia, with India, China, Pakistan, Iran and Bangladesh as the major consumers (Van der Gun 2012). Furthermore, the global groundwater abstraction rate has at least tripled over the last 50 years and still is increasing at an annual rate of between 1% and 2% (Van der Gun 2012).

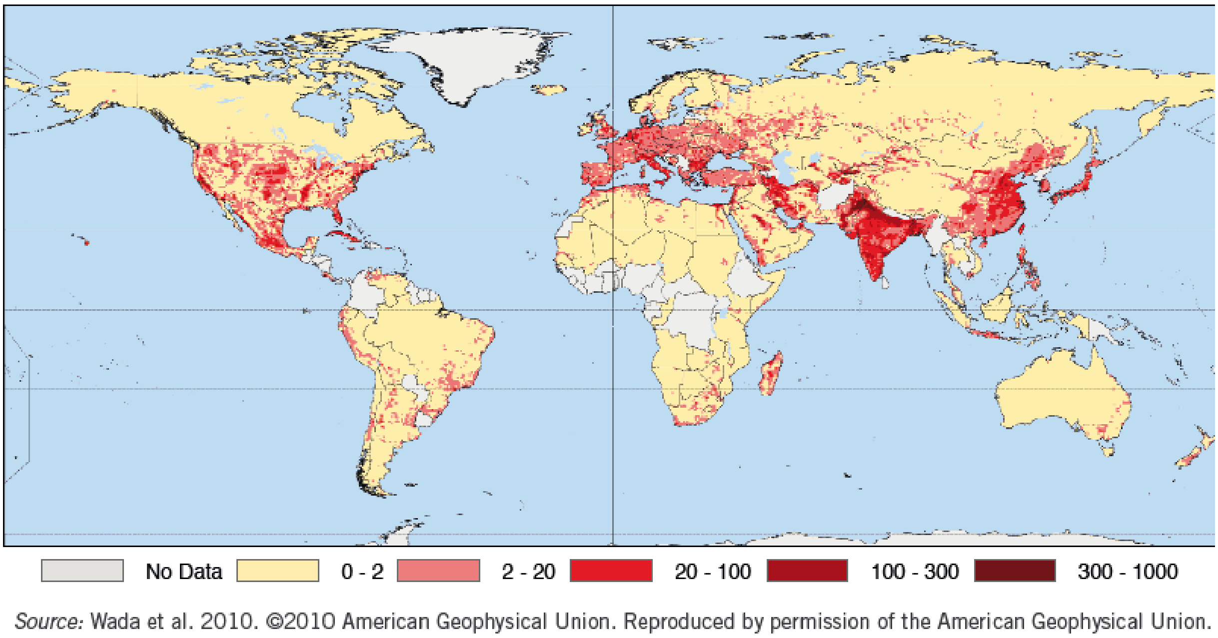


Figure 41 Intensity of groundwater abstraction by the year 2000, as allocated to 0.5° x 0.5° grid cells by the PCR-GLOBWB model, in mm/year (From Van der Gun 2012).

Groundwater pollution is a major issue as well. Information collected by the European Environmental Agency and by KWR Watercycle Research Institute shows that a significant number of samples show the pollution of groundwater by pesticides, degradation products, and nutrients. It has therefore been argued that a more holistic approach is needed, not only for water quantity (Sarni 2011; Figure 42), but also for water quality.

Figure 42 Sustainable drinking water management requires a holistic approach (Sarni 2011).

An effective water stewardship strategy (Figure 41) has three key phases and programmes to support the actions of each phase. It is essential to keep stakeholders, local communities, and employees engaged in the stewardship activities on across all phases.

Surface water

Surface water is another major source of drinking water and the quality of both surface water and groundwater is clearly affected by cities. Cities in general are concentrated centres of production, consumption and waste (Grimm et al. 2008; Bai 2007). Ecological studies of cities have shown that they sometimes exceed their environmental footprint by a factor 10–150 (Doughty and Hammond 2004).This creates enormous pressure not only on water supply, solid waste recycling and wastewater treatment

(Grant et al. 2012), but also on nature and the built environment too, including soil, air and water pollution (UN 2013a; Hoekstra and Wiedman 2014). Water pollution reduces the availability of healthy water (Schwarzenbach et al. 2006; WHO 2008; Van Leeuwen and Vermeire 2007). Cities are therefore becoming increasingly dependent on rural areas for the supply of energy, water, building materials and food, as well as for the removal of waste and waste substances (OECD 2015a; UN 2014). As stated before, in most cases surface water and groundwater are the main sources of drinking water today.

Drinking water

Water leaving drinking water treatment plants is tested for compliance with the EU and national standards. There are 50 parameters that are monitored to determine the microbiological, chemical and aesthetic qualities of drinking water (Water Supply (Water Quality) Regulations 2000). The water quality is also tested at customers taps, by taking the samples from addresses selected at random within each particular water supply zone. In the UK all the test results are recorded on the Drinking Water Register. Examples of microbiological and chemical parameters which are monitored are coliform bacteria and *E. coli*, and pesticides concentration and turbidity respectively. Aesthetic qualities are measured by so called 'quantitative taste and odour parameters.

A more sustainable approach makes use of proactive measures to maintain operational efficiency and influence user demands. Rather than accepting deteriorating quality at the source and increasing water usage, the approach looks to prevent these from occurring in the first place. One of the main benefits of managing demand, using alternative sources and controlling resource pollution is the added resilience to future uncertainty that this approach offers. Most supply infrastructure is designed to operate under anticipated future conditions. Problems arise if these forecasts turn out to be wrong as the infrastructure is typically inflexible and cannot easily be adapted to operate outside of its design range of variability. Moving towards a demand driven approach such as that outlined in Figure 31increases flexibility and reduces reliance on assumed future conditions (Philip, 2011). The SWITCH training modules provide valuable information on all aspects discussed so far. On drinking water the clear focus on flexibility provides additional benefits that have been summarized by Philip (2011):

- More efficient treatment: Source control of resource pollutants and the use of natural systems such as riverbanks to pre-treat abstractions reduce the treatment required to produce water of drinking standard.
- Economic savings: Reducing water demand results in less water to abstract, treat and distribute. This saves in chemical and energy costs.
- Environmental protection and enhancement: Reduced demand results in less water to be abstracted from the environment. This helps to maintain and restore ecosystems that rely on a healthy aquatic environment.
- Improved service: Reduced demand and the use of alternative supplies relieve pressure on resources such as reservoirs and aquifers that may be scarce during dry periods. This lessens the risk of water use restrictions and supply interruptions for households, businesses and industry.
- Reduced carbon emissions: Managing demand and source pollution results in less energy consumed for the abstraction, treatment and distribution process. This reduces carbon emissions in cities where non-renewable energy is used for this purpose.
- Flood control: The collection of rainwater from roof surfaces for non-potable water supply reduces the volume of runoff that has to be managed by a city's drainage system. This reduces the risk of downstream flooding and erosion.
- Reduced volumes of wastewater: Low-flush toilets and greywater reuse for non-potable purposes reduces the volume of wastewater to be collected and treated. This improves the performance and economic efficiency of the wastewater treatment process.
- Greater resilience: Uncertainty surrounding future demand and availability of supplies complicates decision-making for water supply investments. Solutions that target demand reductions and the

use of alternative sources rather than resource development and infrastructure expansion make it easier to cope with inaccurate forecasts and predictions.

Include more information of what is happening at the European level

See http://ec.europa.eu/environment/water/reuse.htm

and all the links from this page

7.1 Best practices in Sabadell (CASSA)

With a population of 207,649 inhabitants and an area of almost 37 km^2, Sabadell is one of the main cities of Catalonia and co-capital of Vallès Occidental. Companyia d'Aigües de Sabadell (CASSA) is the organisation responsible for infrastructure and supply of potable and non-potable water in Sabadell (more than 100,000 clients). CASSA have the commitment to guarantee a high level of quality in the water sector, not only to assure the analytical quality but also in its infrastructures and service. That is why CASSA has made the commitment to continuous improve and innovate. This is done by continuous interaction with CASSA's clients, watching over the protection of environment and society in order to increase the value of the territory.

The combination of a highest quality water service cover, respect for the environment and sustainability, excellence in our service, innovation, customer orientation, ethics and transparency, social implication, communication and proximity to customers and administrations in the core task of CASSA. Many solutions and activities are carried out every year, which are being detailed below.

CASSA also manages more than 25km of non-potable water network and two Waste Water Treatment Plants (WWTP) in Sabadell: WWTP Riu Sec and WWTP Riu Ripoll. CASSA also manages in the control and disinfection of irrigation systems for the prevention and control of Legionella risk.

7.1.1 Analytical quality

The quality of water is one of the main points of the management of water in Sabadell. Water that reaches Sabadell is already potable drinking water delivered by Aigües Ter Llobregat (ATLL; the Catalan drinking water company) and by Aguas de Barcelona (AGBAR; the drinkingwater provider in Barcelone). CASSA, in turn, distributes this water to the clients in Sabadell. CASSA Water Company (Operations department and quality department) monitors chlorine levels and water safety in different parts of the network supply24 hours a day, 365 days a year.

Figure 43 Chlorine analysis equipment.

As a Company manager of potable water, CASSA has the responsibility to:

- Provide water that is suitable for human consumption.
- Maintain sanitation facilities.
- Use natural water for the production of water of human consumption (captured by the manager) or bought to third parties) with guarantees and of the best possible quality.
- Prepare and keep updated the protocol for self-control and management.
- Carry out the self-checks.
- Authorization to manage the public water network, operation of infrastructures, etc.
- Contract suppliers and services (substances, materials, laboratories, cisterns, etc.) that meet the requirements set in the current regulations.
- Inform the Department of Health and the population about the quality of the water.
- Guarantee that the personnel in direct contact with the water of consumption have the training and / or instruction and supervision appropriate to the tasks that they carry out.
- Participate in the National Information System for Consumer Water (SINAC) as a manager.

There are two types of controls: by smart systems and in-situ tests.

1. The smart system and remote control analyses both monitor the state of the water infrastructures and send data to CASSA Control Department. CASSA Control Department (SITT) has configured alarms and limits, in order to act swiftly in case any parameter is not correct or any problem has been detected.

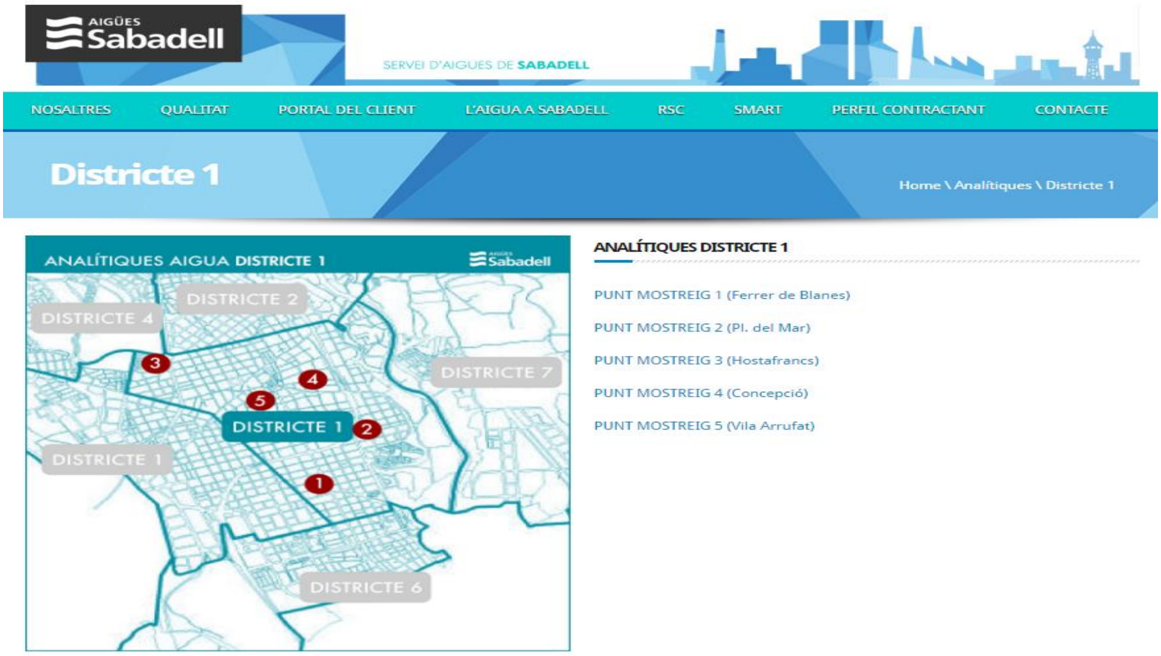
2. In situ controls are done by authorized workers of CASSA. The results of these in-situ controls are recorded in the municipal water quality book which is retained for the sanitary authorities. The in-situ controls performed by authorised laboratories are carried out periodically in many places around the city which validate results and coordinated with CASSA (Operational department and Quality Department).

In 2014, 12,185 analysis and examinations were performed, much more than the 6,942 that the Royal Decree 140/2003 requires for a city of the size and population of Sabadell (Figure 44; Figure 45). This Royal Decree establishes the health criteria for the quality of water for human consumption, such as the minimum control analyses that must be carried out in each town.

In order to intensify the policy of transparency and meet the needs of our customers, the results of analysis of the water - done by the official and authorised laboratories - at different sampling points of Sabadell are regularly published through the CASSA website (http://www.aiguessabadell.cat/analitiques/).

The user can choose between different districts of the city and select the sampling point on a map of the area.

Figure 44 Results of analyses of water at different sampling points of Sabadell are regularly published.



The water analysis results are also provided to the Spanish Ministry of Health through the platform SINAC (National Information System of Water Quality), to the city council and to the health department of Generaliltat de Catalunya.
http://sinac.msssi.es/CiudadanoWeb/ciudadano/informacionAbastecimientoActionEntrada.do

Figure 45 Sampling points in Sabadell.

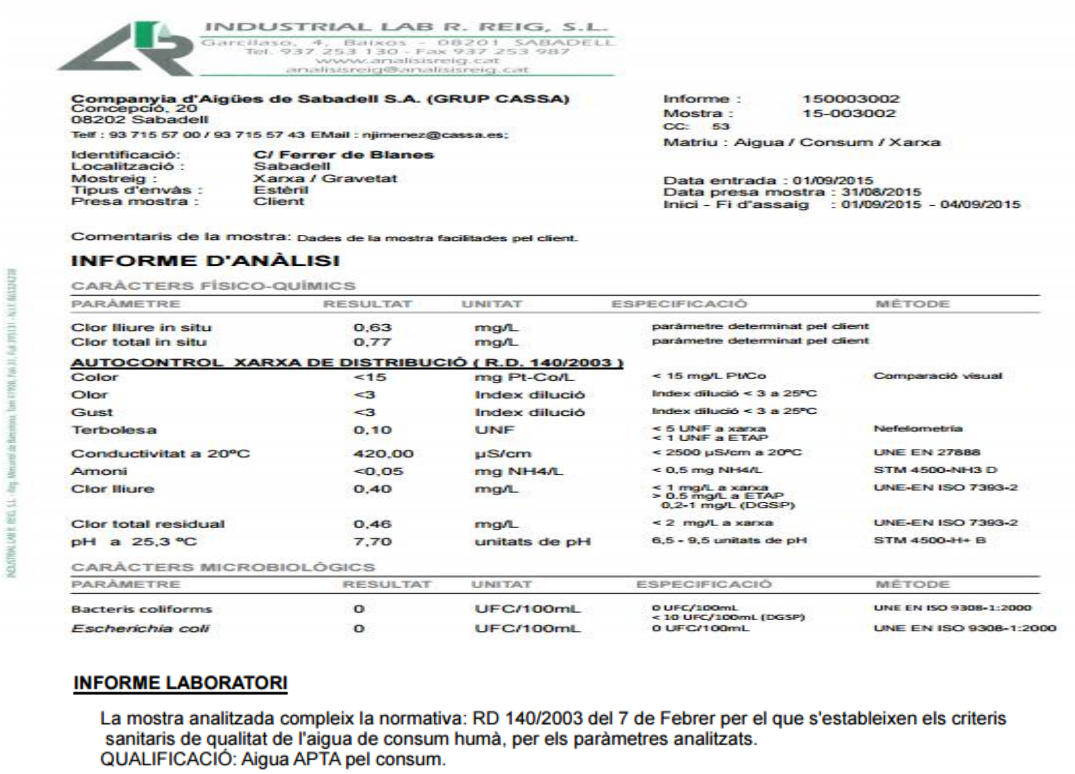
The limits and process are completely defined by regional and state regulations (Sabadell 2017). The Control analytic published analysis the following parameters and it is performed several times each month at 36 points of the city of Sabadell (

Table 10).

Table 10 Water quality parameters.

Free Residual Chlorine	**Limit**
Combined Residual Chlorine	0.2-1 mg/l
Colour	2.0 mg/l
Smell	15 mg/l Pt/Co
Taste	3 a 25 ºC Dilution Rate
Turbidity	3 a 25 ºC Dilution Rate
Conductivity at 20º	5 UNF
Ammonium	2.500 µS/cm-1 a 20 ºC
PH at 25,3º	6,5-9,5 UpH
Coliform Bacteria	0 UFC en 100 ml
Escherichia coli	0 UFC en 100 ml

In addition, daily analysis of the levels of free chlorine and total chlorine are carried out in various parts of the city and organoleptic tests are performed several times a week. The complete monthly analysis carried out (
Figure 46) shows levels of many more parameters (biological and chemical indicators).



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Telf : 93 715 57 00 / 93 715 57 43 EMail : njimenez@cassa.es;

Informe : 150003002
Mostra : 15-003002
CC: 53
Matriu : Aigua / Consum / Xarxa

Identificació: **C/ Ferrer de Blanes**
Localització : Sabadell
Mostreig : Xarxa / Gravetat
Tipus d'envàs : Estèril
Presa mostra : Client

Data entrada : 01/09/2015
Data presa mostra : 31/08/2015
Inici - Fi d'assaig : 01/09/2015 - 04/09/2015

Comentaris de la mostra: Dades de la mostra facilitades pel client.

INFORME D'ANÀLISI

CARÀCTERS FÍSICO-QUÍMICS

PARÀMETRE	RESULTAT	UNITAT	ESPECIFICACIÓ	MÈTODE
Clor lliure in situ	0,63	mg/L	paràmetre determinat pel client	
Clor total in situ	0,77	mg/L	paràmetre determinat pel client	
AUTOCONTROL XARXA DE DISTRIBUCIÓ (R.D. 140/2003)				
Color	<15	mg Pt-Co/L	< 15 mg/L Pt/Co	Comparació visual
Olor	<3	Index dilució	Index dilució < 3 a 25ºC	
Gust	<3	Index dilució	Index dilució < 3 a 25ºC	
Terbolesa	0,10	UNF	< 5 UNF a xarxa < 1 UNF a ETAP	Nefelometria
Conductivitat a 20ºC	420,00	µS/cm	< 2500 µS/cm a 20ºC	UNE EN 27888
Amoni	<0,05	mg NH4/L	< 0,5 mg NH4/L	STM 4500-NH3 D
Clor lliure	0,40	mg/L	< 1 mg/L a xarxa > 0.5 mg/L a ETAP 0,2-1 mg/L (DGSP)	UNE-EN ISO 7393-2
Clor total residual	0,46	mg/L	< 2 mg/L a xarxa	UNE-EN ISO 7393-2
pH a 25,3 ºC	7,70	unitats de pH	6,5 - 9,5 unitats de pH	STM 4500-H+ B

CARÀCTERS MICROBIOLÒGICS

PARÀMETRE	RESULTAT	UNITAT	ESPECIFICACIÓ	MÈTODE
Bacteris coliforms	0	UFC/100mL	0 UFC/100mL < 10 UFC/100mL (DGSP)	UNE EN ISO 9308-1:2000
Escherichia coli	0	UFC/100mL	0 UFC/100mL	UNE EN ISO 9308-1:2000

INFORME LABORATORI

La mostra analitzada compleix la normativa: RD 140/2003 del 7 de Febrer per el que s'estableixen els criteris sanitaris de qualitat de l'aigua de consum humà, per els paràmetres analitzats.
QUALIFICACIÓ: Aigua APTA pel consum.

Figure 46 Example of water quality measurement.

In order to have a more precise control (not only in tanks and big pipes), there is a water monitoring equipment which detects chlorine and pressure, working 24 hours a day, 7 days a week with an alarm system. This equipment has been installed in several points of the city (Figure 46). These systems send data in real time to the CASSA Control Department (SITT) where they are analysed and allow swift action if necessary or if any alarm is activated.

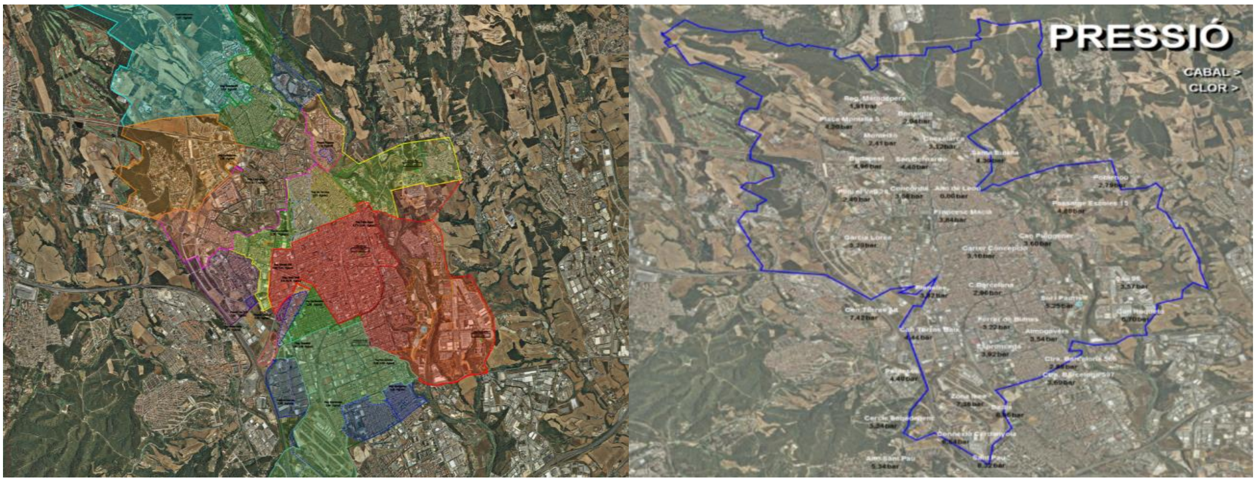

Figure 47 Left**:** Real-time data collection in different of the city. Right: Water pressure in different parts in the city.

A remote control system has access to the operation of any of the facilities in real time from the CASSA control room. Facilities are equipped with many sensors monitoring many parameters such as the level of the water tanks, water flow of the main pipes, chlorine sensors, water pressure, operation of pumps and other equipment. This information enables quick action against any incident at any time while ensuring water supply to the city and its quality.

In addition, the efficiency of the network is constantly evaluated and monitored as many data and alarms are available (Figure 48). Cost and consumption data are recorded and checked for any unusual figure. In order to reduce costs, systematic programme is running that controls the water levels and the pumps the depots when electrical tariffs are cheapest (e.g. during night time).

If any of the sensor detects any malfunction of the system, SITT manager of CASSA defines and coordinates the technical solution. If the malfunction affects the water consumers, the communication department and client department inform the citizens.

Figure 48 Control room in Sabadell.

7.1.2 **Supply and service**

Water is supplied from the river Llobregat (through the water treatment plant in Abrera) and Ter (through the pipe of Cerdanyola) to more than 101,000 customers.

Sabadell drinking water network, which has a length of about 630 km is monitored and managed from the headquarters of the company in Sabadell.

The net of non-drinking water of Sabadell has a length of 25 km and supplies water to clean streets, watering parks, flushing toilettes, and other non-drinking uses. Currently the water has two different origins; reclaimed water from WWTP Riusec, and groundwater from different installations, the quality of which is not within the limits for drinking water.

The Operations department of CASSA (SITT) is responsible for the management of the water infrastructure.

7.1.3 Water supply plan

Sabadell has a Master Plan of non-potable water and is in the final phase of approval of the Master Plan of Drinking Water.

This Plan studies the needs, availability, and assessment of the current water flow balance and defines the facilities and the strategies to follow in order to ensure the proper use and maintenance of the network in the next 15 years. The Plan presents and analyses the adequacy of the whole installation, not only taking into account the total current demand, but also predicted demand. Thus, the monitoring ensures the supply of drinking water to the population, always in sufficient quantity, quality and the appropriate pressure at each point of the water network. The Plan of non-potable water also takes into account the extension of the existing network to cover several points with reclaimed water currently supplied with drinking water in order to reduce the consumption of drinking water. Investments of 1.000.000 € to improve the efficiency, quality, and safety in the water network are carried out annually (Figure 49). The plan is implemented by the operations department of CASSA (SITT), in coordination with the city council of Sabadell.

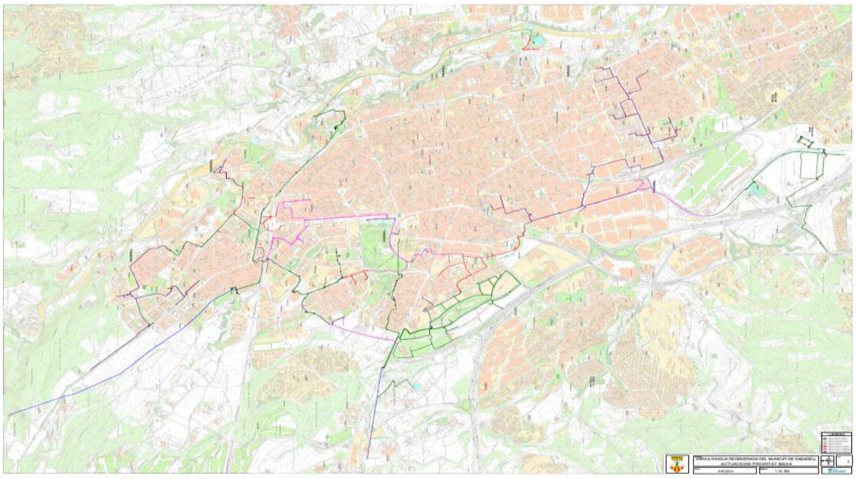

Figure 49 Master Plan of the Non-Potable Water. Different colours show if the network is existing, and future pipes depending on its priority to be constructed.

7.1.4 Failure SMS service

CASSA client department and sustainable development department have been developing automated custom alert which communicates via SMS to the clients in case of breakdowns or incidents that affect their supply. Free of charge, customers can register on the website (http://www.aiguessabadell.cat/es/sms/). If there is any problem with the water service that will affects clients or is already affecting clients, a SMS text message is sent to the clients' mobile phones in order to inform the date of the outage, time and duration (Figure 50).

The software that is used for this combines a Geographic Information System (GIS) and clients' information to allow the location of the customer's service point and determine if it is affected by the water service interruption. More than 20,000 clients of CASSA are incorporated to this service.

Figure 50 Service interruption reporting.

7.1.5 **Water Works information**

CASSA Engineering department and sustainable development department report the planned improvement works to be carried out in the municipality through its web platform (http://www.aiguessabadell.cat/es/avaries/). This planned works can be for maintenance or to expand the water network and could affect traffic, pedestrians and neighbourhoods. It specifies the start date, duration and the affected area (Figure 51).

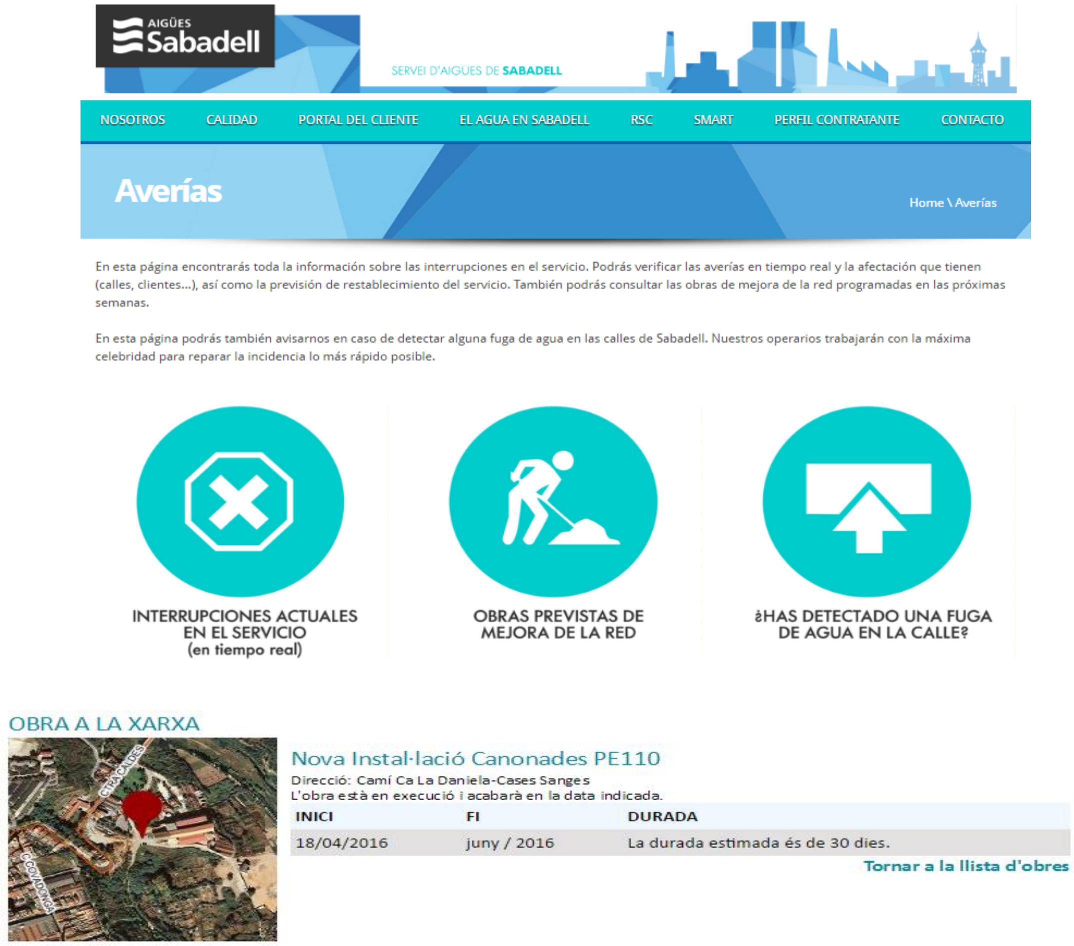

Figure 51 Communication of service interruptions in Sabadell.

7.1.6 Mobile App

CASSA's sustainable development department operates a mobile application that facilitates the booking of appointments and notice leaks detected. The app, available for iOS and Android, also includes a game about the water cycle in the city, a map with the location of all ornamental fountains and news about water in Sabadell, among other features including the opportunity for the citizen to report to the local water company any water leaks detected in the street.

The aim is to prevent the loss of resources and act as quickly as possible in case of failure. The operating mechanism is very simple: if a water leak is detected in the street, the user just enter the mobile app, take a picture and enable location. The notice will automatically inform the Operations team, who will check the damage and proceed to repair.

Through the new application (**Figure 52**), users can also access to all company communication channels (phone, address and hours, website, e-mail and Twitter profile) and to the latest news related to the service.

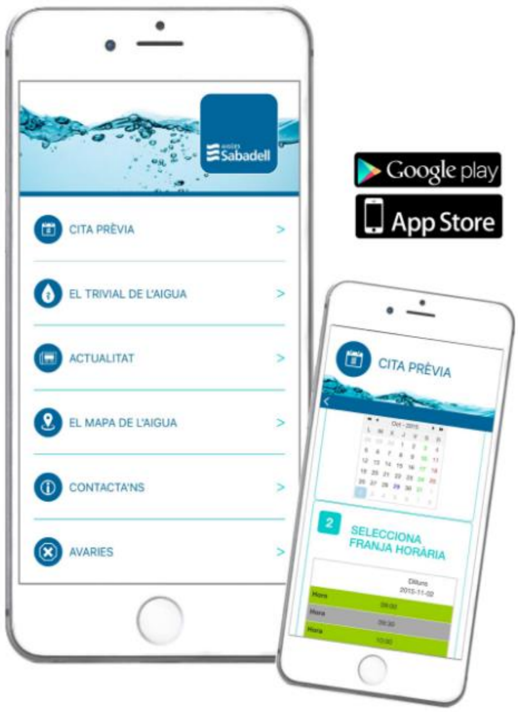

Figure 52 Water app of Sabadell. http://www.aiguessabadell.cat/es/appmobil/

7.1.7 Solidarity Fund

One of the priorities of CASSA is that no family is left without water because they cannot cope with the service invoice. CASSA and Sabadell City Council have formed a Solidarity Fund endowed with 79,000 €, from which 1,350 households have benefited, equivalent to 3,500 people at risk of exclusion. This measurement is carried out in coordination with the city Council of Sabadell. Social services evaluate the right to a discount upon presentation of the relevant documentation. As a result any user previously identified by the Social Services of the City as having "economic difficulties" will not suffer any cut in the water supply. In the first 6 months of the programme 2014, more than 650 families (more than 2,500 people) have benefitted from this programme. In order to help families that risk social exclusion, NGOs specialised in eradicating poverty, have also been incorporated and supported (e.g. Red Cross, Caritas, Cipo, Actua Valles, Emmaus).

7.1.8 Education

With the participation of more than 7,000 students and after 30 editions, the cities of Sabadell, Santa Perpètua de Mogoda, Parets del Valles, Palau-Solita i Plegamans and Sant Quirze del Vallès have adopted CASSA's education programme named EDUCASSA. EDUCASSA is an educational programme managed by CASSA (sustainable development department) which educates and raises awareness of the importance of water (quality, consumption, etc.). EDUCASSA targets three age segments, covering the whole of compulsory basic education.

For 3 to 5 year olds the water cycle is explained through stories and games. Between the ages of 6 and 9 years they will know how the municipal water is managed. At between 10 to 14 years old the children visit a waste water treatment plant, to understand the process used to purify the water.

CASSA (sustainable development department) also manages the water classroom (Figure 53), to facilitate educative activities, workshops, etc., in order to reach out to families, the elderly and citizens. It is in Concepcio street, 14 Sabadell and freely accessible facility that includes:

- Stories of the past: history of water supply in Sabadell, from the 11th century to the constitution of CASSA.
- Torre del Agua: monographic dedicated to the history and architecture of the icon of the city.
- The integral water cycle: main phases, responsible water consumption advice and a diagram of how water reaches homes.
- Experimentation: simple experiments that relate the water with the five senses to 'touch' the water without getting wet. The Trivia of Water also allows visitors to test their knowledge about water, the environment and Sabadell.

Figure 53 Water classroom.

7.1.9 Dissatisfied customer management

In order to improve the attention given to customers and enhancing the attitude of active listening, CASSA organizes several focus groups with clients who have been dissatisfied with their customer experience. The clients explain their experience to CASSA; the causes and how it could have been avoided are discussed. The aim is to create a truly empathetic situation towards the episode experienced by the customer. CASSA publishes the survey results of customer satisfaction (Figure 54).

Enquesta satisfacció clients
Resultat any 2014

Aigües Sabadell

ATENCIÓ PRESENCIAL	2014	2013
Temps d'espera		
> 10 minuts	11%	10%
< 10 minuts	10%	11%
Tracte		
Mot deficient	1%	-
Deficient	1%	1%
Bé	88%	24%
Molt bé	10%	75%

ATENCIÓ TELEFÒNICA	2014	2013
Atenció amb amabilitat	97%	100%
Resolució problema	94%	79%
Resposta clara	94%	98%
Interès per atendre	91%	100%
Li han agafat el telèfon sense dificultat	62%	88%
Valoració	8	8

FACTURES	2014	2013
Comprensió factura	89%	77%
Recepció a temps	75%	91%

Figure 54 Customer satisfaction service.

7.1.10 Information to clients

Meetings are scheduled with Sabadell District Councils and Residents Associations to present the activity of CASSA in different neighbourhoods and communities, coordinated by clients department and sustainable development department of CASSA.

CASSA has a corporate profile on the social network Twitter (@ AigüesSabadell).

Periodically, the company broadcasts messages to facilitate commercial transactions and information about a responsible water consumption and curiosities about the water service. It also provides real time information if there is a noticeable breakdown in the water service.

Through Twitter, CASSA also answers any questions from users, integrating Twitter profile (Figure 55) in the communication approach and customer service of the company.

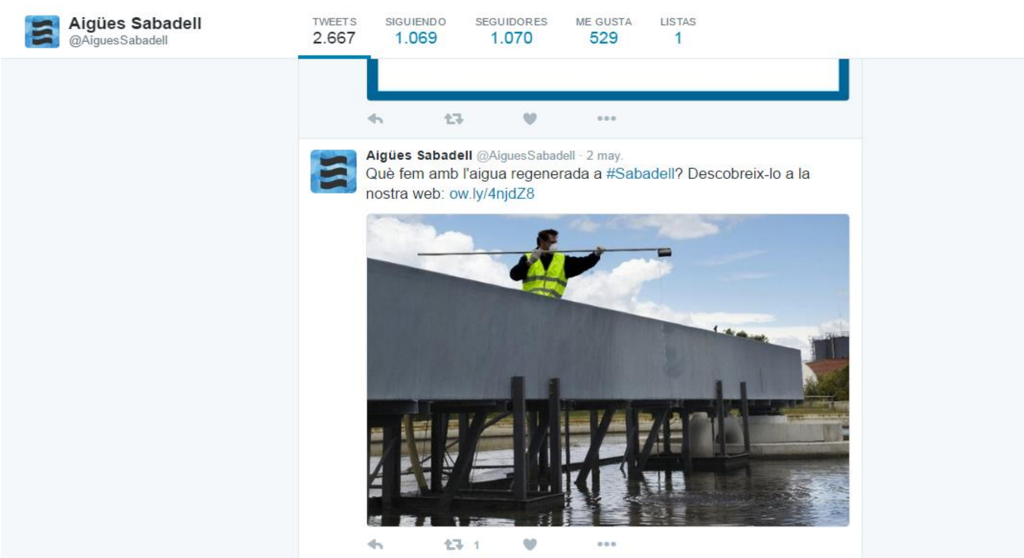

Figure 55 City-level communication on water in Sabadell.

Furthermore, in order to facilitate the understanding of the different sections of the bill, on the reverse there is an explanation of the concepts. In addition, the website has an informative brochure about the bill, which is also available in person at the office customer services point.

CASSA promotes the use of paperless invoice among its clients. Based on a web platform on-line, more sustainable, rapid and convenient for the customer, the new system includes much more useful information for the subscriber, such as their historical consumption, among other data (Figure 56).

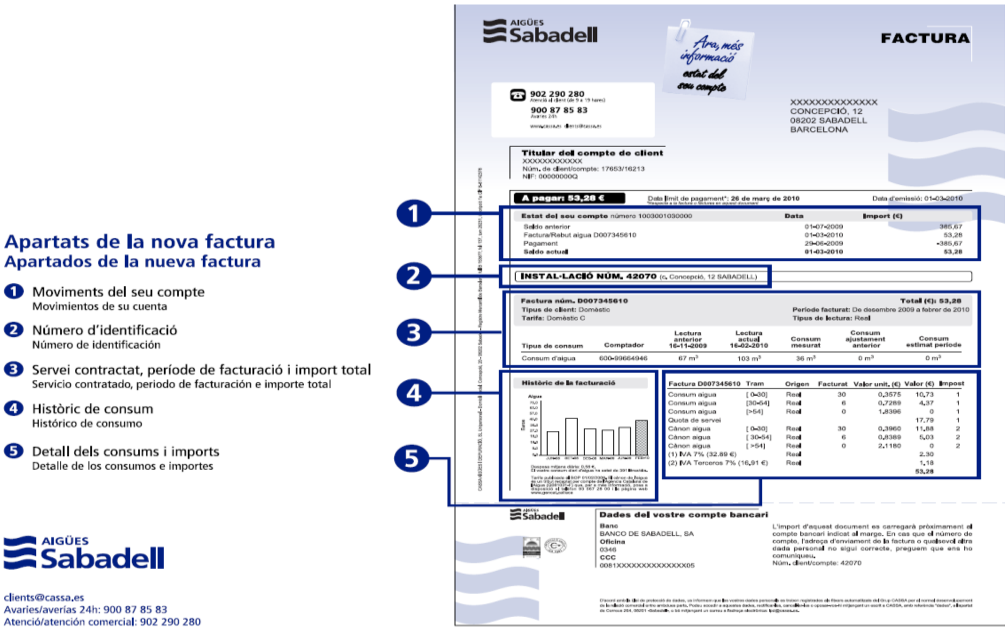

Figure 56 Online billing in Sabadell.

7.1.11 Renovation of the Ripoll, Sabadell

The historical concentration of the textile industry throughout the River Ripoll, which extracted water from the aquifer and discharged waste water into the course of the river after its use, caused a deterioration of both the river and the aquifer. Although the industries started to be equipped with purification systems, the quality of the water of the river was not good enough. With the construction of the WWTP River Ripoll, a lot of small water discharges from industries where transferred to the WWTP. This caused also the decrease of flow of the River Ripoll. In order to solve this problem, the town council of Sabadell commenced a construction of a new pipeline.

The new water pipeline returned purified water from the Waste Water Treatment Plant river up to three points, in Sant Oleguer (end), Torrella Mill (middle point of the river course in the municipality) and the torrent of Colobrers (beginning of the municipal area) with a dual purpose: to maintain the ecological flow and to favour the recharge of the aquifer. A pipe collects treated water in the Ripoll River WWTP and drives by gravity to the Torrella Mill. From this point, water is pumped to the torrent of Colobrers. Sant Oleguer discharge point is opened when the flow of the WWTP exceeds the discharge that can be emitted to the other two points.

CASSA maintains and manages the Ripoll River WWTP and the pipeline and pumps, to guarantee the performance of the infrastructures. The city council of Sabadell determinates the operating criteria of the system, based in the minimum water flow of the river, season of the year, quality of the water, etc.

7.1.12 Benefits of the best practices

The application of the best practices in water supply constitutes an assurance of quality that result in the benefit of the consumer, manager and authorities.

The designs and application of the best practices explained does not only assures the water quality but also improves customer services.

- The controls and analyses done in the network guaranties that the water parameters are within the limits that the regulation requires. Involved personnel receive the required training, laboratories are certificated and infrastructures are maintained by the water manager. The resulting benefits from these practices are:

 - An increase in consumers' confidence that the authorities adequately ensure their daily provision of high quality drinking water
 - Statutory compliance (to the law and existing regulations)
 - Assure the water quality

- The control in the water network, master plans and investment in maintaining, improving or creating new infrastructures. The resulting benefits from these practices are:
  - Reduction of costs; (time, materials, etc.)
  - Reduction of environmental impact (water loss by leakages, reduce the use of vehicles by better coordination and digital communication)
  - An emphasize on innovation and the benefits of sustainable processes
  - Guarantied quality in the service (pressure, amount of water available) and provision of save drinking water
  - Reduction of the frequency and duration of service delivery failure which in turn reduces the overall costs and increases the return of investments because:
    - the manager can act effectively and fast if there is any problem in the water network
    - the implementation of alternatives ensures adequate water supply during any type of problematic situation
    - strategy plans and quality control tasks are in place to prevent problems as much as possible
- The transparency in the communication with the client result in several benefits including:
  - Reduction of clients' inconveniences
  - Increased customer confidence in the work done by the managers
  - It enables the manager to improve and detect problems and to implement new ideas
  - Reduction of overall costs (less phone calls, less visits to offices, etc.)
  - Promotion of dialog and involvement in order to fulfil clients expectations by showing the managerial efforts to the customers
- Educational program and solidary funds result in several benefits including:
  - Reduction of the impact of poverty for vulnerable and/or socially marginalized costumer groups
  - Improved access to clean water to ensure good health and well-being
  - Reduction of social inequality
  - Raised awareness about environmental challenges such as climate change
  - Increased educational quality

7.2 Best practices in front-running cities to improve water quality

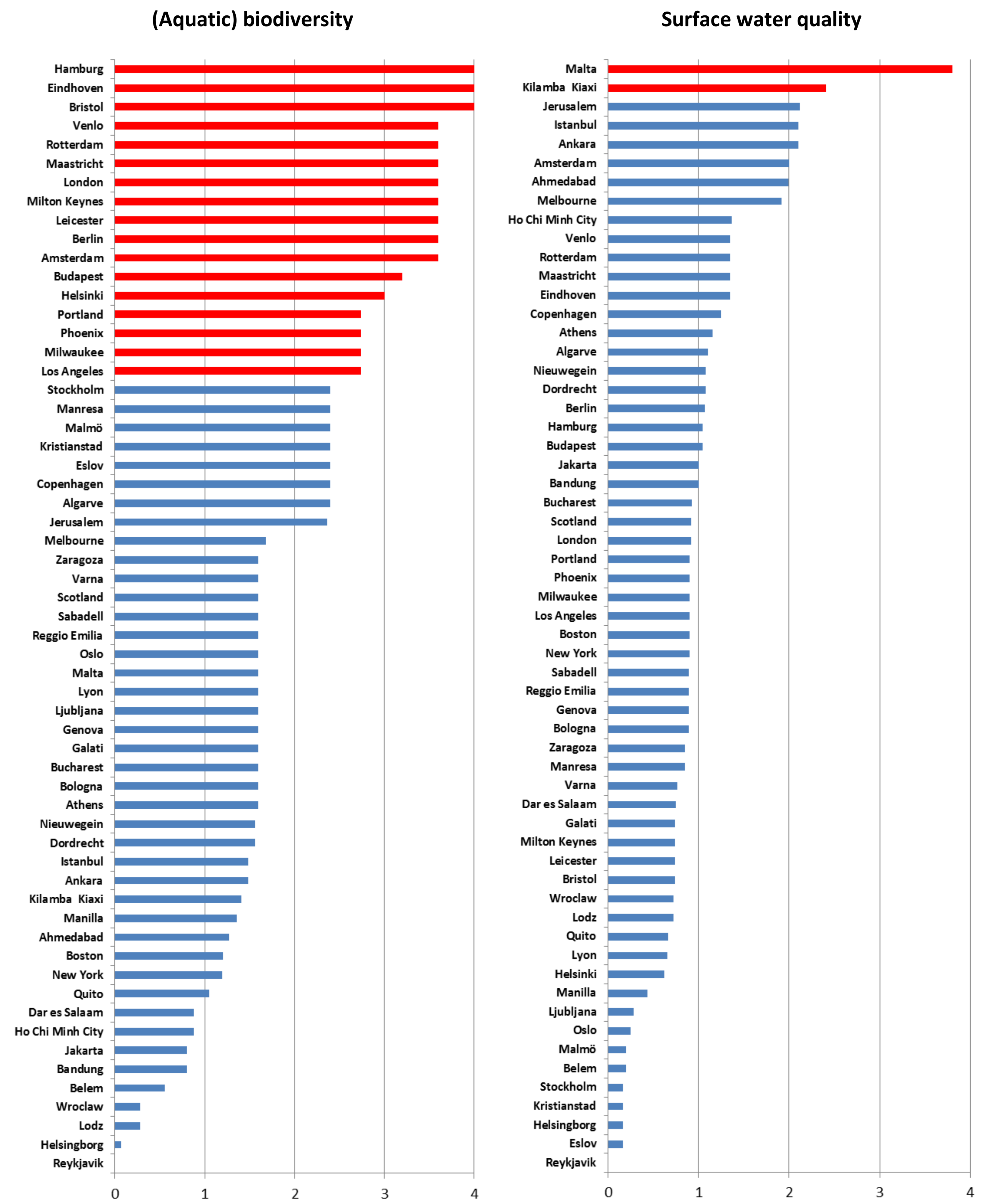

Figure 57 Overview City Blueprint indicators (aquatic) biodiversity (left) and surface water quality (right).

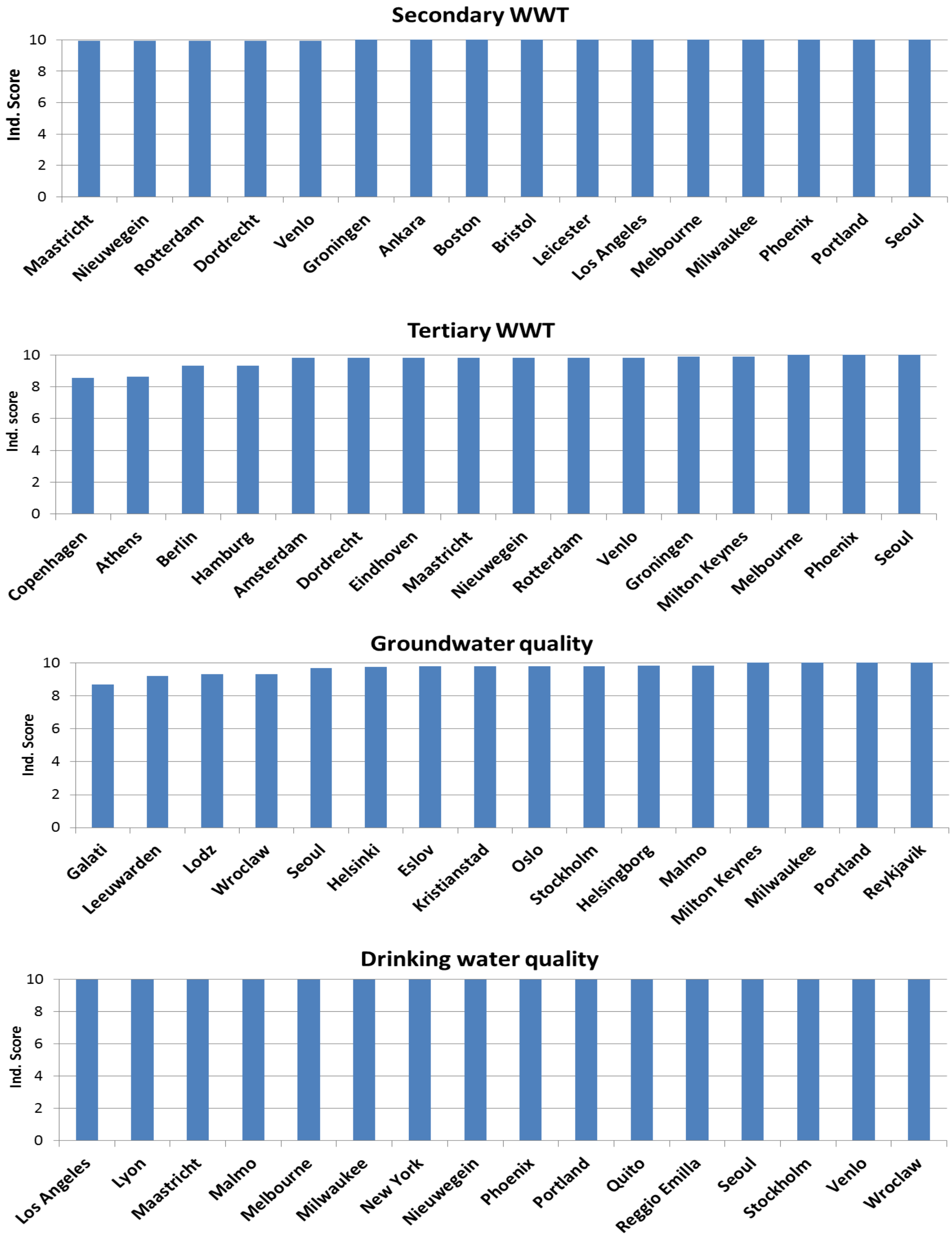

Figure 58 Overview of the City Blueprint indicators relevant for water quality. For each indicator the top fifteen cities are shown. Secondary treatment is a treatment process for wastewater by physical removal of deposited solids and a biological process to remove dissolved and suspended organic compounds. Tertiary wastewater treatment is a final treatment step to remove additional solids and/or carbonaceous Biological Oxygen Demand (BOD) and sometimes further nitrification.

Globally, water quality is one of the most difficult components to catch into indicators. The City Blueprint® performance Indicator (Figure 57) are not detailed enough to show clear differences between high perform (western) cities. The trends and Pressure indicators (Figure 57) do show that cities in cities in for example the Netherlands and the UK have trouble meeting the EU Framework Directives regarding water quality and (aquatic) biodiversity in groundwater and surface water. Cities are often large sources of pollution and can have a large contribution to improving the water quality. The quality of drinking water is another component of the theme water quality and within the urban water system water quality is also important as different quality standards can be applied for different services. In general this is applied in industrial processes but is increasingly applied on a municipal scale to combat problems of water availability. In these systems same water can be reused two or even three times with minimal treatment.

Florida (USA) reuses over half of its treated wastewater. The city of Hong Kong uses for example sea water to flush toilets. In Flanders (Belgium) water is reused to recharge groundwater as has happened in the city of Torreele. Moreover, the use of rainwater for domestic applications such as the toilet, showering or the washing machine are well established in Flanders as well. In particular, Australia has municipalities and regions with different water quality networks including rainwater harvesting in order to mitigate droughts. Furthermore, various sites are being summarised in the DEMOWARE project in which treated wastewater is reused for various purposes such as for greenhouses in Torre Marimón (Spain), industrial purposes in Tarragona (Spain), for irrigation purposes in Shafdan (Israel) and urban and recreational purposes such as in Sabadell and El Port de la Seva (Spain) (DEMOWARE 2017).

7.2.1 Melbourne

Desalination is an expensive option and is normally used in cases of serious freshwater scarcity, as in the case of Melbourne during the millennium drought. Water reuse has been applied in Melbourne too by treating waste water. These greywater treatment systems or on-site wastewater treatment systems may provide viable options for uses such as toilet flushing and watering of small green spaces (Van Leeuwen, 2016). Melbourne is also an example of rainwater harvesting as it became clear that actually enough rain falls on Melbourne and that these resources have not been sufficiently used in the past. Almost all water used in Melbourne today comes from rivers and reservoirs. This is about 10 times the amount of groundwater or recycled water, and over 70 times the amount of rainwater and stormwater currently used in Melbourne. Only limited rainfall that falls within a city is collected. Instead it runs off roofs and hard surfaces becoming stormwater. There are many opportunities to increase the use of these alternative sources of water since around 80% of Melbourne's drinking water comes from remote closed water catchments in native forests, i.e. the Yarra Ranges and around 20% of the drinking water comes from lowland water sources. Melbourne actually needed a "Millennium Drought" to become a water-wise city.

7.3 Promising concepts to improve water quality

7.3.1 Managed aquifer recharge

Subsurface Water Solutions (SWS) provide innovative, practical concepts for advanced freshwater management, with the common objective of protecting, enlarging and sustainably utilizing fresh groundwater resources. SWS build on experiences with Managed Aquifer Recharge and Aquifer Storage and Recovery (ASR), but their applicability is much wider due to innovations in water well designs and groundwater modelling and management. Examples include Freshkeeper to stop and reverse salinization of aquifers and water wells by intercepting intruding brackish groundwater and ASR Coastal to store freshwater, such as harvested rainwater or reuse water in brackish aquifers and reclaim it unmixed for irrigation purposes. SWS introduce a new thinking of water management and provide practical answers for freshwater challenges faced by farmers, utilities, industry and cities: https://www.watershare.eu/communities/Subsurface-Water-Solutions/

The project in Salisbury South Australia was conducted by the Australian National Water Commission. The main objective was to scientifically understand the main processes affecting water quality in the practice of injecting of stormwater into the aquifer for storage and reuse as potable water. This process is referred to as Aquifer Storage, Transfer and Recovery (ASTR). ASTR is similar to traditional Aquifer Storage and Recovery (ASR), however for ASR the same well is used for injection and recovery from the aquifer. FOR ASTR different wells are installed for injection and recovery of the water. The ASTR technique ensures a longer residence time of the injected water in to the aquifer than other ASR systems.

The Salisbury ASTR project is located on the Parafield Airport and Parafield Gardens Oval, on the Northern Adelaide Plains, South Australia. In fact this aquifer was initially brackish and needed to be flushed with fresh stormwater. The stormwater originated from the Parafield and Ayfield catchments which contain residential, business and industrial areas. The Parafield catchment yields on average 1,100m^3 of urban stormwater annually. The stormwater harvesting at Parafield consists of a weir which diverts water from the Parafield Drain into the 47,000m^3 in-stream basin which serves as an initial settling basin for the stormwater. Excess stormwater flow overtops the diversion weir and continues to flow down the Parafield Drain during a storm event. Water flows into the in-stream basin and is pumped at 3 000 m^3/hour to the 48,000m^3 holding storage until capacity of the holding storage is reached or the in-stream basin is drained. Water in the holding storage then flows by gravity into the cleansing reedbed which is vegetated with seven different species of reeds, planted in parallel rows that are perpendicular to water flow direction. The capacity of the reedbed is approximately 25,000m^3 per week and it has a surface area of 2 hectares. The cleansing reedbed and holding storage are designed to achieve a minimum residence time of 7 days. Water is pumped from the reedbed outlet to two storage tanks, and from there it is pumped to the ASTR well field (Figure 59).

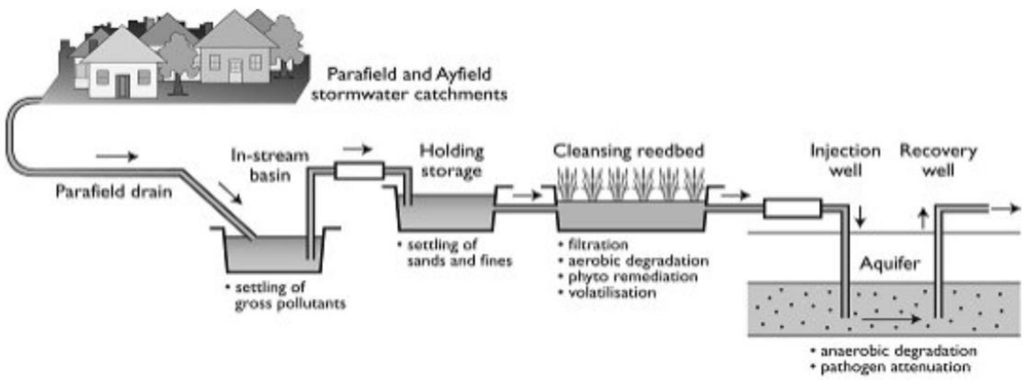

Figure 59 The concept of Aquifer Storage, Transfer and Recovery (ASTR) as applied in the city of Salisbury, Australia (City of Salisbury 2017).

The ASTR system comprises four injection wells surrounding two recovery wells and a series of three piezometers. The system has been designed to produce a mean residence time in the aquifer of 6 months. The ASTR system operates in conjunction with a two-well ASR system at Parafield Airport for the storage of excess stormwater. When operating at capacity, the ASR system processes water at a maximum rate of 3,600m^3/day. This capacity is more or less what is needed for the Michell Australia wool processing plant and is also the maximum injection rate into the aquifer from the current wells (CSIRO 2010). Other examples are provided in Watershare (2017a)

7.3.2 ICT application in managing water (quality) in distribution systems

There should be an urgency to improve the efficiency of Water Distribution Systems (WDSs) especially reducing water losses and reducing water and energy consumption (Koop and Van Leeuwen, 2017). ICT technology is one of the important enablers in achieving this objective. At the level of a water company there are four categories of activities: planning, design and construction; maintenance; operational control and customer services, as shown in Figure 60:

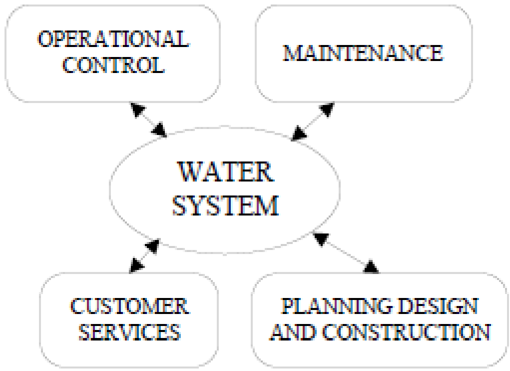

Figure 60 Groups of activities in a water company.

In order to effectively manage a WDS it is necessary to gather all available information about physical system components (assets). GIS systems can be used to visualise the asset information and display them against geographical maps. This approach is indispensable for carrying out maintenance tasks and the management of incidences. Typically, databases keep static information about components. However, they should evolve to keep time stamped records of maintenance and failures.

Engineers in water companies spend a significant proportion of their working time retrieving and processing information from many incompatible databases. Information integration facilitated by a common data model of the WDS data can be applied to overcome this problem. An open source initiative involving a significant part of the water community including researchers and industrial engineers could succeed in such a job.

Simulation models of the WDSs calculate flows, pressures and concentrations of substances in a WDS over an extended period of time. The input information required to execute such a model includes components data, initial conditions in reservoirs, water demands and control schedules for pumps and valves. The simulation models support effectively what-if scenarios and have become a ‘language’ the water engineers can communicate with. The simulation models have been accepted by regulators (i.e. mainly Ofwat) in the UK to demonstrate some performance measures.

In the area of operational control, advances have been made in the development sensors, real-time collection of measurements and remote actuation of control elements. Initially the analysis of collected information and decisions were taken by an operator. Gradually, more stages of the control loop have been automated. For instance, (real-time) simulation models are used to test control schedules before applying them to a physical system and they also serve as soft sensors where simulated variables are used as surrogates for physical sensors. Traditionally, sensors were placed at plants and inlets to DMAs. In order to increase WDS observability sensors can now be installed at some internal DMA points and along important trunk mains. Cheap sensors, wireless communication and potential to harvest energy from water in pipes to power the sensors facilitate such arrangements.

The role of ICT technology on the water production side is important but there is great potential to support water consumers in reducing demands and in the rationalisation of water usage. Smart metering, for instance, enables the monitoring of current water usage and also helps to identify failure events inside and outside property. ICT can facilitate closer collaboration between water producers and water consumers.

Furthermore, there is an untapped potential regarding water reuse in properties, including the recycling of rain water, recycling grey water from a shower and a sink and the use of advanced toilet technology. This can only be achieved through consumer education and a close dialogue with producers. Such processes can be very efficiently facilitated by interactive media such as wikis, blogs and twitter.

7.3.3 Handling discolouration events and pipe flushing

The most frequent customer complaint connected to water quality is caused by discolouration events. On rare occasions, tap water may become discoloured and cloudy due to very small suspended particles (Figure 61). In most cases discoloured water is not harmful.

Figure 61 Discolouration in potable water distribution systems (Vreeburg and Boxall 2007).

However on rare occasions, it may contain pathogenic bacteria or micro-organisms. Recent research (Boxall and Saul, 2005), (Douterelo et al. 2014) and (Vreeburg and Boxall 2007) has provided an explanation for the phenomena and has allowed for developing more effective discolouration management procedures. Some chemical and biological substances originating from treatment works or contamination enter broken pipes and evolve further during a long journey to a consumer’s tap. Through the interaction between the bulk water and the pipes a thin layer of material is developed on the pipe walls bounded by strong adhesive forces. This layer is a complex matrix of biofilm and very fine particles of inorganic matter as shown in Figure 62 and 54.

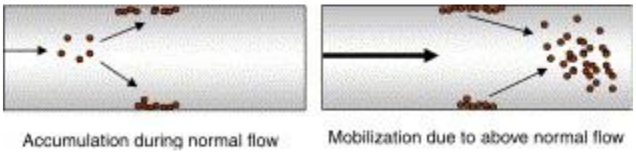

Figure 62 Accumulation and detachment of adhesive layer in pipes (Vreeburg and Boxall 2007).

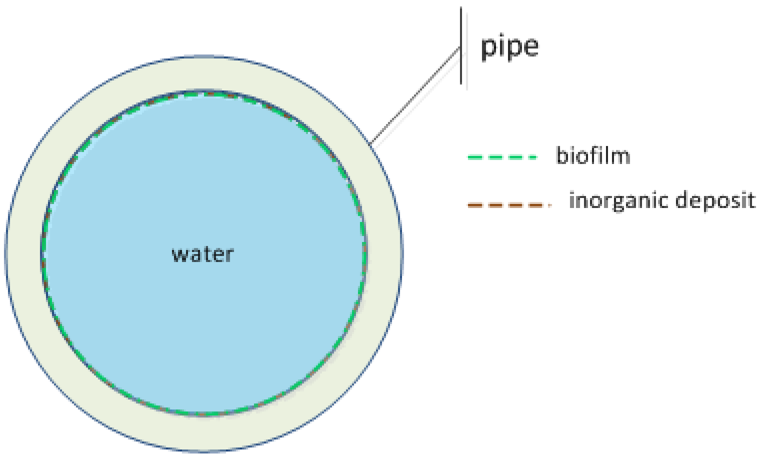

Figure 63 Adhesive layer on the pipe well made of inorganic deposit and biofilm.

In steady state hydraulic conditions there is some balance between accumulation and detachment of the material. The inorganic matter in the UK is typically dominated by very fine iron and manganese particles with the average size of 10 µm coming from upstream pipes and fittings (Boxall and Saul 2005). Biofilms are structurally complex and consist of micro-organisms attached to a surface and to each other and embedded in an extracellular polymeric matrix (EPS) made of polysaccharides and proteins. Discolouration events are caused by erosion of the adhesive layers due to changes in the system hydraulics and resulting changes in shear stress at the pipe wall, for example due to change in demand or a burst. Once the particles are suspended they remain as a permanent wash load or dissolve. The new models proposed in (Boxall and Saul 2005), (Douterelo et al., 2014) and (Vreeburg and Boxall 2007) facilitate the prediction of the adhesive layer growth and the planning of preventive actions.

Figure 64 Pipe flushing operation.

The remedy to prevent discolouration of water at a customer's tap is a properly managed programme of pipe flushing (Figure 64). In the unidirectional flushing procedure a path of pipes for cleaning is identified and isolated from the water network by closing some valves so the water can only flow in one direction. At the downstream end of the path a hydrant with an additional valve to control the flow is opened and the water is released on the road surface. High velocity flow in the pipes creates shear stress strong enough to remove the adhesive layer from the pipe walls. The time interval between flushing is optimised to maintain asset conditions but at the same time to minimise network interventions in order to save time and money. One of the planning tools which is relatively accurate in predicting accumulation is the PODDS model described in (Boxall and Saul 2005).

7.3.4 Managing water drinking quality aspects related to leakages

A water distribution system, especially in big cities, can comprise thousands of kilometres of pipes between a treatment plant and the consumer. The water from the drinking water treatment plant is transported by big diameter transmission mains which then branch into distribution mains going along individual streets. Houses are connected to a distribution main via connection pipes up to a point of metering/consumption. All mains consist of short individual sections linked by joints every few meters depending on the pipe material. Such piping systems are prone to leaks which may happen at joints between pipe sections, connections between distribution mains and the individual houses or by pipe breaks due to corrosion. Water infrastructure is ageing and deteriorating rapidly and leakage management is one of the biggest challenges for the utilities (Koop and Van Leeuwen, 2017; EU Reference document, 2015; Lambert, et al., 1998).

District Metering Areas (DMAs)
The practice of decomposing water distribution systems (WDS) into district metering areas (DMAs) has been introduced by the UK water utilities. A part of a WDS with no more than a few thousand properties is isolated from the rest of the system by closing isolation valves present on distribution mains apart from one inlet. In order to control flow and pressure the inlet is typically equipped with a pressure reducing valve (PRV) and associated instrumentation including pressure and flow meters. Generally, decomposing a complex system into smaller parts facilitates the understanding of the system and its management. There are a number of very specific benefits of such an approach including 1) efficient pressure management 2) efficient asset management 3) identification and repair of unreported bursts. The burst events are identified by observing the night flow between midnight and 05:00 when the consumption is low and burst anomalies are more visible (Wright et al. 2014).

Pressure control
The consumer demands vary in time with high consumption during the day and low consumption during the night. In the periods of high consumption the high flow causes head losses in pipes reducing the pressure supplied to consumers. At night the head losses in the pipes are low due to low flow and the supply pressure increases. The aim of the pressure control is to maintain constant and possibly low pressure over entire time. Decomposition of a WDS into DMAs facilitates effective pressure control. The inlet pressure to a DMA needs to be sufficient but not higher to deliver minimum service pressure to critical point (CP), typically the highest elevation point in the WDS. The simplest control strategy is to maintain the PRV set point constant over 24 hours. Although, the minimum pressure is maintained during the day this strategy leads to excessive pressure during the night. The more advanced approach is the time modulation strategy, the PRV set-point varies in time, is higher during the day and lower during the night. However, such control will not react to failures inside the DMA because the time schedule is calculated in advance and does not use any feedback information. The flow modulation strategy (Aquavent UK Ltd 2015) introduces elements of feedback control. The PRV set point is controlled by head/flow curve, if the flow increases the set point increases, when the flow decreases the set point decreases. The control system reacts to the flow changes regardless of the causes of these changes making the control system more robust. There are also explicit feedback control schemes where pressure at the CP is continuously monitored and communicated wirelessly to the PRV controller which adjusts the set-point accordingly. The benefits of pressure control are very significant: all customers receive stable uninterrupted pressure, the background leakage is reduced as are the frequency of bursts. The available statistics (WLRandA Ltd:ILMSS Ltd 2015) show an example that reduction of the maximum pressure from 62 mH2O to 47.6 mH2O reduced the frequency of breaks in distribution mains by 72%.

Burst detection
The management of a DMA follows the subsequent steps 1) identify and repair the existing unreported (hidden) bursts, 2) introduce pressure control, 3) introduce on-line monitoring of the DMA to identify newly developing bursts and other abnormal events. In step 3 the major indicators are unusual patterns in the night flow when consumption is low and leakage represents a significant part of the flow. The flow patterns can be analysed by a human operator or more reliably by a computer algorithm (Romano et al., 2014). The basic principle is to compare the current DMA inflow measurements with a demand prediction. A significant difference between the two may indicate a burst event inside the DMA and requires further investigation. Monitoring the boundary flow and the critical pressure is not sufficient to pin-point the location of the event and this is done by an off-line investigation. The most accurate but at the same time most resource demanding are acoustic methods such as listening sticks and portabl**e** noise correlators used by leakage practitioners. In order to narrow the area in the DMA to be searched, an off-line active identification experiment can be undertaken such as that described in (Skworcow and Ulanicki 2011). It requires placement of a number of pressure loggers e.g. 20 for a typical DMA and performing a pressure stepping experiment (eFAVOR test) at night. Analysis of the measurements narrows the search for a burst to a relatively small area, in one case 1 meter from the predicted location as reported by the Affinity Water company in the UK (Affinity water 2017; Figure 65).

Figure 65 The detected leak within 1m of model prediction

8 Conclusions

8.1 Integrated approaches

The benefits as described in the SWITCH training modules (e.g. Philip 2011) and our own research (Koop and van Leeuwen 2017) demonstrate that water supply has many links to other areas of the water cycle (stormwater and wastewater management) and urban development as a whole (energy, environment, economic development, etc.). A more sustainable approach to water supply is therefore not only concerned about efficiency and improved performance within the sectorial boundaries, but also with how management decisions impact upon other sectors in the urban environment. Furthermore, proponents of the new technologies often mistakenly attribute the capacity to produce efficiency and productivityof the technologies and operational features itself . However, technologies only operates within an existing network of institutions, discourses and practices (OECD 2015c).

8.2 Best practices

The previous chapters and the SWITCH training modules (http://www.switchtraining.eu/modules/) present best practices on climate adaptation (floods and water scarcity), water quality and variables related to water conservation in four cities. For each of these themes, technologies and approaches are available that can really increase the performance of current urban water services and the resilience of cities. The best practices in this document provide insight in applied knowledge that has been shown by research and experience to produce optimal results and that can be proposed as a standard suitable for widespread adoption in the following cities and beyond. Based on this summary of best practices five important lessons for the next stages in the POWER project are formulated:

1. **Multi-sector approach:** Almost all best practices are integrated measures consisting on successful collaboration between different sectors and different levels of government that traditionally have separate tasks and scopes. It is therefore key to identify key water and climate adaptation issues and link them to other challenges and objectives in the city. The best practices identified in the four KDCs are without exception win-win solutions meaning that the measures result in multiple benefits and meeting multiple objectives within the city. Hence, the DSP should not only focus on citizen engagement but also be a tool that connects and facilitates the social learning and planning process between different sectors, stakeholders, institutions and citizens acting on the municipal level.
2. **Long-term scope:** Best practices often demand substantial investments in long-term facilities such as water infrastructure, increasing water storage capacity or flood defences. It is therefore essential that best practices are not only adapting to current conditions but also to long-term trends such as demographic changes and climate change. The cost of not adapting to changing future conditions such as climate change, '*The cost of inaction*' can be high. This cost of inaction may be a powerful tool to convince cities, stakeholders and citizens of their financial benefit to adopt best practices.
3. **Cohesiveness:** Best practices may be very effective when viewed in isolation. However, it should fit into a cohesive strategy where measures and best practices do not conflict, overlap or pursue contradictory goals. Developing a DSP poses a significant opportunity to provide insight in the joint effects of different combinations of best practices and strategies. This can provide valuable new insight and optimise bundles of best practices serving multiple objectives.
4. **DSP for city-to-city learning:** The essence of the communication of best practices is that it is not necessary to reinvent the wheel time after time. Most technologies do already exist and have been tested and implemented somewhere. More importantly, experiences with regards to social, institutional and implementing processes can be highly valuable. By selecting best practices from cities with similar water-related problems, significant opportunities for exchanging knowledge and experiences can be seized. Each municipality has its own social, environmental and financial contexts and therefore best practices are no '*one size fits all*' solution, specific aspects of best practices need to be taken into account in order to explore different alternatives and find optimal

solutions within each city. Therefore, the POWER DSP should be developed in such a way that different local circumstances can be included and stakeholders can choose from a variety of best practice options. In this way, an extensive database can be developed that assists stakeholders within their local decision-making process.

5. **Covering the most important water-related issues**? From a problem-oriented perspective, the best practices in the four KDCs address water-related issues of water scarcity, flood risk (urban drainage flooding and river flooding) and water quality. However, best practices addressing coastal flooding are not present in the KDCs. Nevertheless, coastal flooding needs to be considered as important aspect in the POWER DSP since (1) the world most densely populated areas are in delta's and along the coast, (2) sea level rise is expected to increase substantially, and (3) flooding of saline water leads to more severe damage. The POWER DSP will invite user contribution to include best practices which extend the water-related issues beyond the four water priorities tackled by the key demonstration cities .

8.3 Best practices: Strengths, weaknesses, opportunities and threats

Finally, we provide an summary of the overall potential strengths, weaknesses, opportunities and threats of the sharing of best practices - that have been described in this deliverable – through the POWER DSP.

Strengths	**Weaknesses**
• **Improves management efficiency** • **Provides content to promote meaningful interaction between citizens, professionals and managers** • **Consolidates sustainable behaviour** • **Enhances effective decision-making and implementation**	• **Time consuming process before tangible results are achieved** • **Daily post-project support from a technical team is required** • **Definition of best practices can be interpret differently**
Opportunities	**Threats**
• **Engaging other sectors and initiatives such as circular economy lead to additional benefits** • **Build-up of a large database of best practices may provide guidance for the European Union, national governments and municipalities to better support them**	• **Simple 'copy paste' of best practices may lead to suboptimal solutions** • **Potential weak stakeholder involvement** • **The experimental nature may compromise the achievement of short-term targets**

8.4 Political implications: walking the talk

The political entities responsible for creating broad international strategies, have, during the last decade, clearly stated that, in their opinion, municipalities have a vital role to play with regards to the improved management of water. In 2014, the former UN Secretary General, Ban Ki-moon, emphasised the role of municipalities as both the cause of and solution to, many such challenges when he said that, '*Urbanization brings opportunities for more efficient water management and improved access to drinking water and sanitation. At the same time, problems are often magnified in cities, and are currently outpacing our ability to devise solutions"* (http://www.un.org/waterforlifedecade/water_cities.shtml)

This view has been further reinforced by the description of the UN Sustainable Development Goals, (SDGs) and the conclusions of such UN initiatives as HABITAT III, held in Quito, Ecuador in October 2016. The OECD (2015) has voiced its conviction that there is, in the global issue of water, '*a need for in particular for the contribution of metropolitan governance, rural-urban partnerships and stakeholder engagement',* whilst the Union for the Mediterranean, in both the UFM Water Agreement signed in Malta, in April, 2017 and the subsequent 7th Water Experts Group, held in Barcelona in July, 2017 agreed to support an enhanced municipality-based strategy whilst seeking to further regional cooperation on water.

The European Commission (Gawlik et al. 2017), in the recently published 'Urban Water Atlas for Europe', pointed out that '*National and international institutions are effective at identifying the broad global trends to be addressed. But it is municipalities who must lead the implementation of policies and practical actions whilst engaging the citizen*.'

In order to demonstrate their determination to support such a view with action, the European Commission, has broadened the highly successful Covenant of Mayors, (which was launched originally as a policy to reduce CO2 and increase both energy efficiency and renewable energy production), so that now its objectives for 2030 encompass all aspects of climate change, including water and waste. Within the initiative known as the European Innovation Partnership (EIP) Water, led by DG ENVIRONMENT, certain Action Groups (AGs) such as City Blueprints, have emphasised the importance of the role of local and regional stakeholders, whilst, within the calls for proposals, both for HORIZON 2020 funds and other such programmes, including LIFE and ENI-CBC-MED, there is a broad consensus that municipal partners will be key in order to create awareness, encourage citizen engagement, promote international cooperation and more importantly at a practical level, improve the efficiency and sustainability of water management.

The results of this approach have been diverse. Researchers work more than ever in tandem with their municipal counterparts. Nevertheless, whilst funding has been forthcoming, many calls for proposals have proved to be repetitive, with consortia partners being asked to propose initiatives which have, in a number of cases, already been completed by previous funded projects. Therefore, a consistent and logically developed construction of improved management processes, building on the experience and lessons learnt by former efforts, has often been lacking. Water, is compared to the established smart-city trident of energy, transport and ICT still the weaker political element. The Water sector is still influenced principally by the private sector and associations such as the WssTP, limiting municipal participation in high-level, decision-making procedures. Despite statements to the contrary, a number of European Commission DGs, including CONNECT, refuse to embrace the subject of water within their own EIPs such as that dedicated to Smart Cities and Communities.

As a result, funding to address issues of municipal water management although often cited as vital (e.g. the Financial Strategy to support the implementation of the UFM Water Agenda, promoting the progressive deployment of financial resources and facilitating access to existing funds) is often comparatively low compared to that devoted to other more politically-visual environmental issues. Financial support when forthcoming is destined for regional and more often national agencies, who in many European and non-European countries maintain a firm grip on their centralised governance processes.

The fact that water is the *missing link* within the concept of a resilient city which must efficiently manage its available resources, be resilient to extreme weather events, and maintain a clean, healthy and attractive environment has not yet been fully embraced by elected representatives at any political level. This is reflected by the slow municipal, urban (as opposed to rural), undertaking of measures which would lead to integrated policies whereby the Water-Energy-Food-Eco-System nexus (WEFE) is acted upon rather than simply expounded in countless European conferences.

References

Affinity water (2017) If a pipe bursts. https://www.affinitywater.co.uk/if-a-pipe-bursts.aspx [Accessed 18 August 2017]

Anglian Water (2014) Drought Plan. http://www.anglianwater.co.uk/environment/our-commitment/our-plans/drought-plan.aspx [Accessed 18 August 2017]

Anglian Water (2015) Water Resources Management Plan. http://www.anglianwater.co.uk/environment/our-commitment/our-plans/water-resource-management.aspx [Accessed 18 August 2017]

Anglianwater (2017a) Anglian Water launches its Big Conversation. http://www.anglianwater.co.uk/news/anglian-water-launches-its-big-conversation.aspx [Accessed 18 August 2017]

Anglianwater (2017b) Education centres http://www.anglianwater.co.uk/community/education/education-centres/ [Accessed 18 August 2017].

Anglianwater (2017c) Save bucket loads with a FREE water saving home visit http://www.anglianwater.co.uk/environment/how-you-can-help/using-water-wisely/we-products/ [Accessed 18 August 2017]

Anglianwater (2017d) Dropping 20 and beyond http://www.anglianwater.co.uk/_assets/media/LED279_Waterwise_8pp_A5_leaflet_ART.pdf [Accessed 18 August 2017]

Anglianwater (2017e) Welcome to the Potting Shed Club http://www.anglianwater.co.uk/environment/how-you-can-help/using-water-wisely/save-water-in-the-garden.aspx [Accessed 18 August 2017]

Anglianwater (2017f) Love Every Drop. http://www.anglianwater.co.uk/about-us/love-every-drop.aspx [Accessed 18 August 2017]

Anglianwater (2017g) Our Innovation Shop Window. http://www.anglianwater.co.uk/about-us/shop-window.aspx [Accessed 18 August 2017]

Atelier Groen-Blauw (2017) http://www.urbangreenbluegrids.com/water/buffering-and-infiltration/ [Accessed 11 July 2017]

Aquacraft Inc, “Residential End Uses of Water,” prepared for American Water Works Research Foundation, 1999

Aquavent UK Ltd, http://www.aquavent.net/ [Accessed 20-11-2015]

Bäckstrand K (2003) Civic science for sustainability: reframing the role of experts, policy-makers and citizens in environmental governance. Global Environ Polit, 3:24-41

Bai X (2007) Industrial ecology and the global impacts of cities. Journal of Industrial Ecology, 11, 1–6

Baietti A, Kingdom W and van Ginneken M (2006) Characteristics of well-performing public water utilities Water Supply & Sanitation Working Notes published by the Water Supply and Sanitation S3ector Board of the Infrastructure network of the World Bank Group.

Bingham LB, Nabatchi T, O'Leary R (2005) The new governance: practices and processes for stakeholder and citizen participation in the work of government. Public Admin Rev, 65:547-558

Boxall, JB and Saul, AJ (2005) Modelling Discolouration in Potable Water Distribution Systems. Journal of Environmental Engineering ASCE 131(5): 716-725.

Brown RR, Keath N, and Wong THF (2009) Urban Water Management in Cities: Historical, Current and Future Regimes. Water Science and Technology, 59:847–855

Burn S, DeSilva D, Eiswirth M, Hunaidi O, Speers A, Thornton J (1999) PIPE LEAKAGE – FUTURE CHALLENGES AND SOLUTIONS, Pipes Wagga Wagga, Australia 1999

Chong J (2014) Climate-readiness, competition and sustainability: an analysis of the legal and regulatory frameworks for providing water services in Sydney. Water Policy, 16:1–18

CIRIA (2015) The SuDS Manual.
http://www.ciria.org/Resources/Free_publications/SuDS_manual_C753.aspx

City of Melbourne (2009) Total watermark: City as catchment. City of Melbourne (2015) Drought and reduced rainfall. Retrieved from
https://www.melbourne.vic.gov.au/Sustainability/AdaptingClimateChange/Pages/Drought.aspx [Accessed 26 May 2015]

City of Salisbury (2017) Aquifer Storage and Recovery.
http://www.salisbury.sa.gov.au/Live/Environment_and_Sustainability/Wetlands_and_Water/Water_Recycling/Aquifer_Storage_Recovery Accessed 17-07-2017CRC (2015) CRC for Water Sensitive Cities. Retrieved from http://watersensitivecities.org.au/ [Accessed 12 January 2015]

CSIRO (2010) Managed aquifer recharge case study risk assessments. http://CsiroMAR.notlong.com (Accessed 15 March 2015) DEMOWARE (2017) Innovation Demonstration for a Competitive and Innovative European Water Reuse Sector. http://demoware.eu/en [Accessed 11 July 2017]

Copenhagen Climate Adaptation Plan (2011) Copenhagen Climate Neutral by 2025.
http://international.kk.dk/artikel/climate-adaptation [Accessed 8 August 2017]

Defra (2014), Sustainable Drainage Newsletter (3rd Defra Newsletter), January 2014.

http://www.susdrain.org/files/News/suds_newsletter_jan_2014_v2.pdf

Defra (2015) Sustainable Drainage Systems. Non-statutory technical standards for sustainable drainage systemshttps://www.gov.uk/government/uploads/system/uploads/attachment_data/file/415773/sustainable-drainage-technical-standards.pdf

Dimitrov G, Alitchkov D (1992) Measurements of the Water Usage in Municipal Water Supply Systems in Bulgaria. IWSA Workshop on Water Metering in Municipal Supply Systems, Warsaw during September 1992

Dinar A (2011) Water Budget Rate Structure: Experiences from Urban Utilities in California, Evaluating

Economic Policy Instruments for Sustainable Water management in Europe

Dobbs R, Smit S, Remes J, Manyika J, Roxburgh C and Restrepo A (2011) Urban world: Mapping the economic power of cities. Washington, DC: McKinsey Global Institute

Doughty M and Hammond G (2004) Sustainability and the built environment at and beyond the city scale. Building and Environment, 39:1223–1233

Douterelo I, Sharpe R and Boxall J, Bacterial community dynamics during the early stages of biofilm formation in a chlorinated experimental drinking water distribution system: implications for drinking water discolouration, J Appl Microbiol. 2014 Jul; 117(1), pp 286–301, doi: 10.1111/jam.12516.

EEA (2007) Climate change: the costs of inaction and the costs of adaptation. Technical report No13/2007. Copenhagen: European Environment Agency

EEA (2012) Urban adaptation to climate change in Europe: Challenges and opportunities for cities together with supportive national and European Policies. (EEA Report 2/2012). Copenhagen: European Environment Agency

EIP Water (2017a) European innovation partnership on water. Indicators of the trends and pressures framework. http://www.eip-water.eu/City_Blueprints [Accessed 11 April 2017]

EIP Water (2017b) European innovation partnership on water. Indicators of the city blueprint framework. http://www.eip-water.eu/City_Blueprints [Accessed 11 April 2017]

EIP Water (2017c) European innovation partnership on water. Indicators of the governance capacity framework. http://www.eip-water.eu/City_Blueprints [Accessed 11 April 2017]

EIP Water (2017d) The City Blueprint® Approach. Improving implementation capacities of cities and regions by sharing best practice on urban water cycle services. https://www.eip-water.eu/sites/default/files/E-Brochure%20City%20Blueprint%20Approach%20%28v7%29.pdf [Accessed 12 July 2017]

EU Reference document Good Practices on Leakage Management WFD CIS WG PoM,(2015) © European Union, ISBN 978-92-79-45069-3, doi: 10.2779/102151.

Evans E (2000) Mulching Trees and Shrubs. http://mulch.notlong.com/ (Accessed 25 April 2015)

FAO (2011a) Global food losses and food waste—Extent, causes and prevention. Rome: The Food and Agriculture Organization of the Unities Nations

FAO (2011b) The state of the world's land and water resources for food and agriculture: Managing systems at risk. Rome: The Food and Agriculture Organization of the Unities Nations

FAO (2013) Aquastat: Global information system on water and agriculture. Rome: Food and Agricultural Organization of the United Nations

Feingold D, Koop SHA, van LeeuwenCJ (2017) The City Blueprint Approach: Urban Water Management and Governance in six Cities in the U.S. Environmental Management (under review)

Ferguson B, Frantzeskaki N, Skinner Rand Brown R (2012) Melbourne'stransition to a water sensitive city. Melbourne: Monash University

Folke C, Hahn T, Olsson P Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev Environ Resour, doi:10.1146/annurev.energy.30.050504.144511

Gan TY (2000) Reducing Vulnerability of Water Resources of Canadian Prairies to Potential Droughts and Possible Climate Warming. Water Resour Manage14:111–135

Gawlik BM, Easton P, Koop S, Van Leeuwen K, Elelman R (eds) (2017) Urban Water Atlas for Europe. European Commission, Publication Office of the European Union, Luxembourg, 160 pp. ISBN: 978-92-79-63050-7 ; DOI: 10.2788/003176. Available at: https://publications.europa.eu/en/publication-detail/-/publication/c296a413-24cc-11e7-b611-01aa75ed71a1/language-en/format-PDF/source-32266847

Government of South Australia (2017) Millennium drought. https://www.environment.sa.gov.au/managing-natural-resources/river-murray/about-the-river/millennium-drought [Accessed 18 August 2017]

Grant SB, Saphores JD, Feldman DL, Hamilton AJ, Fletcher TD, Cook PLM (2012) Taking the ‘‘waste’’ out of ‘‘wastewater’’ for human water security and ecosystem sustainability. Science, 337:681–686

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X and Briggs JM (2008) Global change and the ecology of cities. Science, 319:756–760

Heinzmann B (2003) Measures to minimize water consumption and water losses – case study of Berlin. Berliner Wasserbetriebe, Germany

Hunger M and Döll P (2008). Value of river discharge data for global-scale hydrological modeling. Hydrology and Earth Systems Science, 12(3), 841–861.

Hoekstra AY (2014) Water for animal products: A blind spot in water policy. Environmental Research Letters, 9, 091003

Hoekstra AY and Wiedman TO (2014) Humanity’s unsustainable environmental footprint. Science, 344:1114–1117

Hoekstra AY, Mekonnen MM, Chapagain AK, Mathews RE and Richter BD (2012) Global monthly water scarcity: Blue water footprints versus blue water availability. PLoS ONE, 7(2), e32688. doi:10.1371/journal.pone.0032688.

Hunger M and Doull P (2008) Value of river discharge data for global-scale hydrological modeling. Hydrology and Earth Systems Science, 12:841–861

Hussein H (2010) No water in Jordan? Let’s reduce its demand! http://development.thinkaboutit.eu/think3/post/water_demand_management__jordan/ (Accessed 4 March 2015)

IPCC 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K.

OECD (2015). Water Governance in Cities: GOV/RDPC (2015)17. Paris: Organisation for Economic Cooperation and Development.

Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

Jalava M, Kummu M, Pokka M, Siebert S and Varis O (2014) Diet change—A solution to reduce water use? Environmental Research Letters, 9, 074016

Koop SHA and Leeuwen CJ (2017) The challenges of water, waste and climate change in cities. Environment, Development and Sustainability. 19:385–418. DOI :10.1007/s10668-016-9760-4. http://link.springer.com/article/10.1007%2Fs10668-016-9760-4

Koop SHA and Van Leeuwen CJ (2015a) Assessment of the Sustainability of Water Resources Management: A Critical Review of the City Blueprint Approach. *Water Resources Management*. 29:5649–5670. DOI: 10.1007/s11269-015-1139-z

Koop SHA and Van Leeuwen CJ (2015b) Application of the Improved City Blueprint Framework in 45 municipalities and regions. *Water Resources Management*, 29: 4629-4647. DOI: 10.1007/s11269-015-1079-7

Koop SHA, Koetsier L, Doornhof A, Reinstra O, Van Leeuwen CJ, Brouwer S, Dieperink C, Driessen PPJ (2017) Assessing the Governance Capacity of Cities to Address Challenges of Water, Waste, and Climate Change. Water Resources Management. doi:10.1007/s11269-017-1677-7

Lambert, A., Myers S and Trow, S (1998) Managing Water Leakage. Economic and technical issues. Financial Times Energy, London, ISBN 1 84083 011 5.

LCC (2017a) Leicester City Council: Flood risk studies. http://www.leicester.gov.uk/your-environment/flooding-and-severe-weather/flood-risk-studies/ [Accessed 8 August 2017]

LCC (2017b) Leicester City Council: Local flood risk management strategies. http://www.leicester.gov.uk/your-environment/flooding-and-severe-weather/local-flood-risk-management-strategy/ [Accessed 8 August 2017]

Lee M Tansel B, Balbin M (2011) Influence of residential water use efficiency measures on household water demand: A four year longitudinal study, Resources, Conservation and Recycling 56:1–6

Leonardsen L (2012) Financing adaptation in Copenhagen. http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Webinar_Series/Webinar_Presentations/Leonardsen__financing_adaptation_in_Copenhagen_ICLEI_sept_2012.pdf [Accessed 12 May 2015]

Ligtvoet W, Hilderink H, Bouwman A, Puijenbroek P, Lucas P and Witmer M (2014) Towards a world of cities in 2050. An outlook on water-related challenges. Background report to the UN-Habitat Global Report. Bilthoven: Netherlands Environmental Assessment Agency

Lipinski B, Hanson C, Lomax J, Kitinoja L, Waite R and Searchinger T (2013) Reducing Food Loss and Waste. Working Paper, Installment 2 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute. http://www.worldresourcesreport.org

Melbourne Water (2015) Enhancing life and liveability; Website of Melbourne Water. Retrieved from http://www.melbournewater.com.au/ [Accessed 7 January 2015]

Milton Keynes (2015). The Building Regulations. Sanitation, hot water safety, and water efficiency. http://webarchive.nationalarchives.gov.uk/20151113141044/http://www.planningportal.gov.uk/uploads/br/br_pdf_ad_g_2015.pdf [Accessed 20 August 2017]

Milton Keynes Council (2014) Imagine 2050 strategy. A roadmap for a sustainable Milton Keynes. https://www.milton-keynes.gov.uk/environmental-health-and-trading-standards/mk-low-carbon-living/imagine-mk-2050-project [Accessed 18 August 2017]

Ministry of Infrastructure and Environment (2017) Delta Programme. https://www.government.nl/topics/delta-programme [Accessed 8 August 2017]

Ministry of Water & Irrigation (2016) National Water Strategy 2016-2025. http://www.mwi.gov.jo/sites/en-us/Hot%20Issues/Strategic%20Documents%20of%20%20The%20Water%20Sector/National%20Water%20Strategy(%202016-2025)-25.2.2016.pdf [Accessed 8 August 2017]

MK:Smart (2017) Smart Cities UK 2017 awards. http://www.mksmart.org/water/ [Accessed 18 August 2017]

Nolde E (2007) Possibilities of rainwater utilisation in densely populated areas including precipitation runoffs from traffic surfaces, Desalination 215:1–11

NYC (2010) City of New York: NYC green infrastructure plan. A sustainable strategy for clean waterways. http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_plan.shtml [Accessed 25 March 2015]

OECD (2011) Water Governance in OECD Countries: A multi-level approach. Paris: Organisation for Economic Cooperation and Development.

OECD (2015a) Water and cities: Ensuring sustainable futures. Paris: Organisation for Economic Cooperation and Development

OECD (2015b) Drying Wells, Rising Stakes: Towards Sustainable Agricultural Groundwater Use, OECD

OECD (2015c) OECD Principles on Water Governance. OECD, Paris

OneNYC (2017) One New York: The Plan for a Strong and Just City, New York. https://onenyc.cityofnewyork.us/ [Accessed 20 April 2017]

Pahl-Wostl C (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Glob Environ Chang 19:354-365

Philip A (2011) SWITCH training kit. Integrated urban water management in the city of the future. Module 3. Water supply. Exploring the options. ICLEI, Freiburg. http://www.switchtraining.eu/ [Accessed July 6, 2017]

Rainharvesting systems (2012) Case studies; Southampton University. http://www.rainharvesting.co.uk/ (Accessed 4 January 2015)

Richter, B. D., Abell, D., Bacha, E., Brauman, K., Calos, S., Cohn, A., et al. (2013). Tapped out: How can cities secure their water future? Water Policy, 15, 335–363.

Ridder D, Mostert E, and Wolters HA (2005) Learning together to manage together. HarmoniCOP, University of Osnabrück, Osnabrück

Rural Cyprus (2012) Family life in rural Cyprus. littlewhitedonkey.blogspot.com/2010_08_01_archive.html (Accessed 30 August 2012)

Rotterdam (2015a) http://www.rotterdamclimateinitiative.nl/nl/dossiers/klimaatadaptatie/projecten-klimaatadaptatie/kleinpolderwaterplein,-de-waterbuffer-van-overschie?project_id=197&p=1 [Accessed 10 July 2017]

Rotterdam (2015b) Rotterdamclimateinitiative.nl. perskit opening Benthemplein. http://www.rotterdamclimateinitiative.nl/benthemplein [Access 2 July 2017]

Rotterdam Climate Proof (2017) Rotterdam Climate Proof http://www.rotterdamclimateinitiative.nl/nl/dossiers/klimaatadaptatie/rotterdam-climate-proof [Accessed 8 August 2017]

Sabadell (2017) [Pla de vigilància i control sanitari de les aigües de consum humà de Catalunya and by REAL DECRETO 140/2003, de 7 de febrero, por el que se establecen los criterios sanitarios de la calidad del agua de consumo humano].
http://salutweb.gencat.cat/ca/ambits_tematics/per_perfils/empreses_i_establiments/empreses_gestores_de_subministrament_daigua/programa_de_vigilancia_i_control_sanitari_de_les_aigues_de_consum_cat/ and https://www.boe.es/buscar/act.php?id=BOE-A-2003-3596

Sarni W (2011) Corporate Water Strategies.i Earthscan, London, 2011, 262 pp., ISBN 9781849711852

Schreurs E, Koop SHA, Van Leeuwen CJ (2017) The water management and governance challenges of Quito (Ecuador). Environment, Development and Sustainability DOI 10.1007/s10668-017-9916-x

Schwarzenbach RP, Escher BI, Fenner K, Hofstetter TB, Johnson CA, Von Gunten U and Wehrli B (2006) The challenge of micropollutants in aquatic systems. Science, 313:1072–1077

Skworcow P and Ulanicki B (2011) Burst Detection in Water Distribution Systems via Active Identification Procedure. In proceedings of the international CCWI2011 conference, 5-7 September 2011, Exeter, UK.

Stern NH (2007) The economics of climate change: the Stern review. Cambridge, UK: Cambridge University Press

Studies on Water, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264238701-en [Accessed 11 June 2017]

Styles M, Keating T (2000) Water Efficient Schools Chesswood Middle School Project, Final Project Report, October 2000

Sydney Water (2011) Water Efficiency Report. http://www.sydneywater.com.au/water4life/WhatSydneyWaterIsDoing/Initiativ es.cfm (Accessed 4 December 2014)

THELMA (1997) “THELMA Impact Analysis,” EPRI Retail Market Tools and Services, prepared by SBW Consulting, Hagler Bailly Consulting, Dethman & Associates, and the National Center for Appropriate Technology

Toro R (2013) Hurricane Sandy's impact. http://www.livescience.com/40774-hurricane-sandy-s-impactinfographic.html [Accessed 24 March 2017]

Tortajada C (2006) Human Development Report 2006: Beyond scarcity: Power, poverty and the global water crisis, UNDP

UN (2014) The United Nations world water development report. Water and energy Vol. 1. New York: United Nations Development Programme

UNESCO (2015a) The United Nations world water development report Water for a sustainable world. Paris: United Nations Educational, Scientific and Cultural Organization

UNESCO (2015b) Facing the Challenges. Paris: United Nations World Water Assessment Programme, United Nations Educational, Scientific and Cultural Organization

URBAS (2017) Risikomanagement extremer Hochwasserereignisse. Vorhersage und Management von Sturzfluten in urbanen Gebieten. http://www.urbanesturzfluten.de/project/recommendations [Accessed 10 July 2017].

Van der Gun (2012) Groundwater and Global Change: Trends, Opportunities and ChallengesUnited Nations World Water Assessment Programme. Programme Office for Global Water Assessment. Division of Water Sciences, UNESCO 06134 Colombella, Perugia, Italy

Van der Steen P (2011) Application of sustainability indicators within the framework of strategic planning for integrated urban water management. Sustainable Water Management in the City of the Future.

UNESCO-IHE Institute for Water Education. Retrieved from: http:// www.switchurbanwater.eu/outputs/pdfs/W1-1_CALE_MAN_D1.1.7_Indicators_Manual.pdf [Accessed 10 July 2017]

Van Leeuwen CJ and Vermeire TG (Eds.) (2007) Risk assessment of chemicals. An introduction (2nd ed.). Dordrecht: Springer Publishers

Van Leeuwen CJ, Chandy PC (2013) The city blueprint: experiences with the implementation of 24 indicators to assess the sustainability of the urban water cycle Water Science and Technology: Water Supply 13.3 769-781

Van Leeuwen CJ and NP Bertram (2013) Baseline assessment and best practices in urban water cycle services in the city of Hamburg. Bluefacts 2013: 10-16. http://wvgw.de/blaettern/bluefacts/2013/Van [Accessed 10 July 2017]

Van Leeuwen CJ (2013) City Blueprints: Baseline assessment of sustainable water management in 11 cities of the future. Water Resources Management 27:5191–5206

Van Leeuwen CJ (2017) Water governance and the quality of water services in the city of Melbourne. Urban Water Journal 14:247 -254. DOI 10.1080/1573062X.2015

Van Leeuwen CJ, Dan NP and Dieperink C (2016) The challenges of water governance in Ho Chi Minh City. Integrated Environmental Assessment and Management 12(2):345-52. DOI: 10.1002/ieam.1664

Van Oel PR, Mekonnen MM and Hoekstra AY (2009) The external water footprint of the Netherlands: geographically-explicit quantification and impact assessment. Ecological Economics, 69:82–92

Van Vuuren DP, Bijl DL, Bogaart PW, Stehfest E, Biemans H, Dekker SC, Doelman JC, Gernaat D, Harmsen M, and De Vries BJM (2016) The global food – water – energy nexus. Development in a resource-constrained world. Copernicus Institute of Sustainable Development, Utrecht University, 40 pp.

Victorian Government (2013) Sustainable management of Victoria's groundwater resources. Retrieved from http://www.vic.gov.au/ [Accessed 7 May 2013]

VMM (2011) How to deal with flooding. Vlaamse Milieu Maatschappij. https://en.vmm.be/publications/how-to-deal-with-flooding [Accessed 15 July 2017).

Voskamp IM and Van de Ven FHM (2015) Planning support system for climate adaptation: Composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events. Building and Environment 83 (2015) 159-167

Vreeburg JHG and Boxall JB (2007) Discolouration in potable water distribution systems: A review, Water Research, 41: 519–529, doi:10.1016/j.watres.2006.09.028

Wada Y, van Beek L andBierkens M (2011) Modelling global water stress of the recent past: on the relative importance of trends in water demand and climate variability. Hydrol Earth Syst Sci 15:3785–3808

Wada Y, van Beek L and Bierkens M (2012) Nonsustainable groundwater sustaining irrigation: a global assessment. Water Resour Res 48

Watershare (2017a) https://www.watershare.eu/communities/subsurface-water-solutions/ [Accessed 16-07-2017],

Water Supply (Water Quality) Regulations 2000, http://www.legislation.gov.uk/uksi/2000/3184/regulation/13/made [accessed 10-02-2016]

Whittington D (2003) Municipal water pricing and tariff design: a reform agenda for South Asia Water Policy 5:61–76

WHO (2008) Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health. Geneva: World Health Organization

WLRandA Ltd:ILMSS Ltd, http://www.leakssuite.com/concepts/pressure-and-bursts/ [Accessed 20-11-2015]

Wong THF and Brown RR (2009) The water sensitive city: principles for practice. Water Science & Technology

World Bank (2015) CO_2 emissions (metric tons per capita). http://data.worldbank.org/indicator/EN.ATM. CO2E.PC. [Accessed 4 January 2016]

Wright R, Stoianov I, Parpas P, Henderson K and King J (2014) Adaptive water distribution networks with dynamically reconfigurable topology, Journal of Hydroinformatics 16:1280-1301

Annex 1 Questionnaire

Dear colleague,

You are being invited to participate in this research of the EU project POWER http://www.power-h2020.eu/ *because of your expertise and experience with resilience, water issues, water governance, water systems engineering, water resource management and other water-related research or management. We try to cover views from OECD (water governance), IWA, WssTP, Watershare, EIP Water, one City (Amsterdam), NetwercH2O and a WHO collaborative center.Completing this questionnaire will take approximately 20 minutes. References to key websites and documents of your organization are appreciated.*

GOAL of the SURVEY

The goal of our survey is to compile and synthesize knowledge and practices for building resilience in the context of water planning and water governance on the following specific issues:

- Flood risk
- Water scarcity
- Variables related to water conservation
- Drinking water quality (potable and non-potable water)

Your views and experiences will help fill gaps in understanding how to build resilience in the water sector.

1. General aspects

How do you define best practices?

2. Strategies that build resilience to floods

In the context of dealing with floods, several strategies have been identified as potentially useful for building resilience. Please indicate how important (or not) you think the following factors would be for achieving resilience to floods. 1 = not important at all, 5 = very important

Strategies that build resilience to floods	score
Increasing infrastructure redundancy	
Prioritizing learning to live with floods, rather than trying to prevent them	
Diversifying response options	
Livelihood diversification	
Using "soft" or non-structural approaches, such as "green" infrastructure, flexible options, etc.	
Fully utilizing the water cycle at the local scale (i.e. stormwater capture and reuse; use of treated wastewater, etc)	
Adopting an integrated approach to manage water across different scales	
Prioritizing flood mitigation through infrastructure and planning	
Other options	

Please provide comments and specific examples

If cities want to improve on these aspects, what do you recommend them to explore further.
What sources of information?
Participating in specific networks?
Baseline assessments and proper planning?
Other options?

Please provide links to these sources, networks, websites, etc.

3. Strategies that build resilience to drought

In the context of dealing with droughts, several strategies have been identified as potentially useful for building resilience. Please indicate how important (or not) you think the following factors would be for achieving resilience to droughts. 1 = not important at all, 5 = very important

Strategies that build resilience to drought	score
Diversifying sources of water supply	
Using small-scale water storage systems	
Increasing ability to quickly mobilize alternative sources of water	
Decentralizing drought management approach with authority to act at smaller scales	
Prioritizing demand management and water conservation	
Adapting by switching to less water intensive livelihoods	
Water recycling	
Expanding water supply schemes (dams, tap into groundwater)	
Imposing strict regulations on water withdrawals	
Utilizing natural or “green” infrastructure” (such as wetlands, streams, rivers)	
Implementing water resources management at the catchment scale	
Adopting integrated land and water use planning	
Other	

Please provide comments and specific examples

If cities want to improve on these aspects, what do you recommend them to explore further.
What sources of information?
Participating in specific networks?
Baseline assessments and proper planning?
Other options?

Please provide links to these sources, networks, websites, etc.

4. Strategies that build resilience to water conservation

In the context of dealing with droughts, several strategies have been identified as potentially useful for building resilience. Please indicate how important (or not) you think the following factors would be for achieving resilience to droughts. 1 = not important at all, 5 = very important

Strategies that build resilience to water conservation	score
Strict water metering practices	
Using small-scale water storage systems in homes	
Prioritizing demand management and water conservation	
Water reuse	
Public campaigns to demonstrate water conservation practices	
Subsidies to reduce water use in house by providing cheap option for improved toilet flushing, water saving showers, etc.	
Wastewater use for garden irrigation	
Progressive water tariffs	
Other	

Please provide comments or specific examples and best practices

If cities want to improve on these aspects, what do you recommend them (sources of information, participating in specific networks, baseline assessments and proper planning, etc.)

Can you provide links to these sources, networks, websites, etc.

5. Strategies that build resilience to water quality (water reuse schemes)

Drinking water can be produced from a variety of sources, i.e., surface water, groundwater, by rainwater harvesting, desalination, and by reuse. The Sabadell example (Spain) is about drinking water itself. In order to reduce drinking water consumption, water –reuse is proposed. The proposal is to supply piped water with two different qualities: (1) piped water that can be used as drinking water and (2) piped water used for other non-drinking water purposes. Please indicate how important (or not) you think the following factors would be for achieving resilience to water scarcity by applying reuse approaches. 1 = not important at all, 5 = very important

Strategies that build resilience to water quality	score
Diversifying sources of water supply	
Public campaigns to stimulate the using of non-potable water resources	
Campaigns to explain health risks of non-potable water	
Low prices for non-potable water	
Subsidies to install third pipe systems in houses	
Subsidies to collect non-potable water (rainwater harvesting tanks)	
Other	

Please provide comments or specific examples and best practices

If cities want to improve on these aspects, what do you recommend them (sources of information, participating in specific networks, baseline assessments and proper planning, etc.)

Can you provide links to these sources, networks, websites, etc.

6. Strategies that build resilience to water in general

In the context of water planning and governance in general, several strategies have been identified as potentially useful for building resilience. Please indicate how important (or not) you think the following factors would be for achieving resilience. 1 = not important at all 5 = very important

Strategies that build general resilience in the water sector	score
Polycentric governance (i.e., management or governance systems that have multiple centers of authority at different scales)	
Redistributing functions, power and authority from national to provincial and municipal levels of government	
Ability to quickly respond to changes, reorganize and adapt	
Openness to institutional change	
Rescaling governance from the local scale to the watershed or catchment scale	
Strong integration of different water sectors (e.g., wastewater, bulk water, sanitation)	
Inclusive, fair and equitable governance	
Building redundancy in infrastructure systems	
Having diverse water resource options	
Restoring and maintaining healthy ecosystems	
Acknowledging and dealing with uncertainty in the variability of the water cycle	
Other	

Please provide comments and specific examples

If cities want to improve on these aspects, what do you recommend them to explore further.
What sources of information?
Participating in specific networks?
Baseline assessments and proper planning?
Other options?

Please provide links to these sources, networks, websites, etc.

Any other comments or views are welcome