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Water, Megacities and Global Change

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WATER, MEGACITIES & GLOBAL CHANGE



Portraits of 15 Emblematic Cities of the World



United Nations
Educational, Scientific and
Cultural Organization



ARCEAU
Île-de-France

WATER, MEGACITIES & GLOBAL CHANGE

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International
Hydrological
Programme



ARCEAU
Île-de-France

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Foreword

The international conference 'Water, Megacities and Global Change', organized at UNESCO Headquarters in December 2015 during COP21, shone a light on the key role that cities play in the achievement of the Sustainable Development Goals, especially Goal 6 of the 2030 Agenda, pertaining to universal access to water and sanitation.

This overview of 15 emblematic cities, co-edited by UNESCO and ARCEAU-IdF, is simultaneously the result of concrete scientific presentations and a call for general mobilization to devise the sustainable urban policies the world needs. All these urban centres share a number of common characteristics: expansive size, disparities between rich and poor districts, environmental and industrial demand that strains the natural resources of an entire region - not to mention the economic weight of the country as a whole - and a wide range of cultural, scientific and educational resources.

In 1970, the United Nations identified three megacities. This number rose to 10 in 1990 and 28 in 2014. According to projections, there will be 41 by 2030, many located in the world's least developed countries. Throughout history, these cities have often lacked both the time and the means to develop their urban services, including those relating to access to water, sanitation and rainwater drainage. This situation creates profound vulnerabilities and complex challenges. It is crucial that megacities share their experiences, so as to develop services capable of meeting the expectations of their inhabitants. Inclusive management of water resources is also the solution to a variety of social challenges, in particular, gender inequalities, as women are frequently worst hit by difficulties gaining access to water, and are on the front line when it comes to better resources management.

This book marks an important phase in the creation of an alliance of megacities focused on water-related issues in the face of climate change. UNESCO is strongly implicated in this process through its International Hydrological Programme (IHP). Cooperation for and surrounding water needs to take place at all levels - between governments, between and within societies, and at the heart of cities. Megacities embody the principal of 'creative constraint', whereby infinitely complex situations engender the mobilization of an incredible number of talents, experts and initiatives to provide solutions. In this new era of limited resources, human ingenuity and respect for each other's dignity represent our ultimate renewable resources. We need to free their potential. When all is said and done, the strength of a city comprises its capacity to assemble talents and create an environment of diversity in which men and women can work together to build a sustainable future.

Irina Bokova, Director-General of UNESCO

Preface

Each of the megacities in this publication has specific local conditions characterizing their geographic, climatic, hydrogeologic, demographic and economic situations. However, they also share similar water governance challenges with multiple actors focused on their own duties and concerns. As such, they can work together to produce solutions for climate change adaptation. Water issues in large cities encompass far too many aspects to be concentrated in a small number of hands. To produce a global vision requires cooperation among experts from multiple disciplines.

The genesis of this publication took place in the Greater Parisian region in France, which is home to both UNESCO Headquarters and ARCEAU, the association of regional water stakeholders. It was published within the framework of the international conference 'Water, Megacities and Global Change', held during COP21 in Paris.

In our opinion, the case of Paris demonstrates that cooperation among local and regional stakeholders around water challenges and issues is possible on a wide scale. It is, therefore, perhaps unsurprising that this initiative emerged from the Greater Paris megacity.

In 2015, a new French law on the organization of the French territory established the Metropolis of Greater Paris. This metropolis shares numerous characteristics with other megacities of the Western world. Its water and sanitation networks were designed and developed during the nineteenth century, and the peak of urban expansion has come and gone. The only difference perhaps lies in the fact that the River Seine, in which both treated and untreated water is discharged, has a relatively low flow.

The features of the institutional organization of Greater Paris are also common to those of other megacities. Multiple stakeholders are present, ranging from ordinary citizens to state services, passing by a number of local authorities. Paris, as a central city, is of particular importance compared to the other municipalities of the metropolitan area which form its suburbs. However, Paris employs a tripartite division - municipalities, counties and inter-counties - for the management of sanitation and water distribution, which is undertaken by three main syndicates (two of which operate in a semi-public, semi-private management capacity and one of which is run by public management).

A brief examination of the main stakeholders and their actions highlights some interesting points. The main operators habitually exchange ideas and practices with their foreign counterparts with a view to innovating and improving the management of their sanitation and drinking water supply networks. This tradition has enabled them to ensure their international reputation and good standing at international meetings. The current generation is also worthy of praise in this regard, having undertaken major projects such as the rehabilitation of the great plant of Achères, and the implementation of automated control for sanitation and drinking water networks.

The Parisian region is also home to one of the few laboratories in France working on the theme of urban water. Its researchers have - with external help - been responsible for the development of techniques for the control of stormwater at source. They are also pioneers in the development of measurement systems and modelling tools for pollution-related knowledge on wet weather discharges. Other French public and private laboratories have brought about significant progress in wastewater treatment techniques, as well as in treatment systems for the purification of water for drinking purposes. It is hoped that with time these advances will enjoy greater international exposure.

Finally, in the early 2000s, local elected officials took a renewed interest in water management, following the great tradition of their predecessors from the inter-war years, who created a sewerage treatment system for the entire Paris metropolitan area and sought to implement the shared management of water supply.

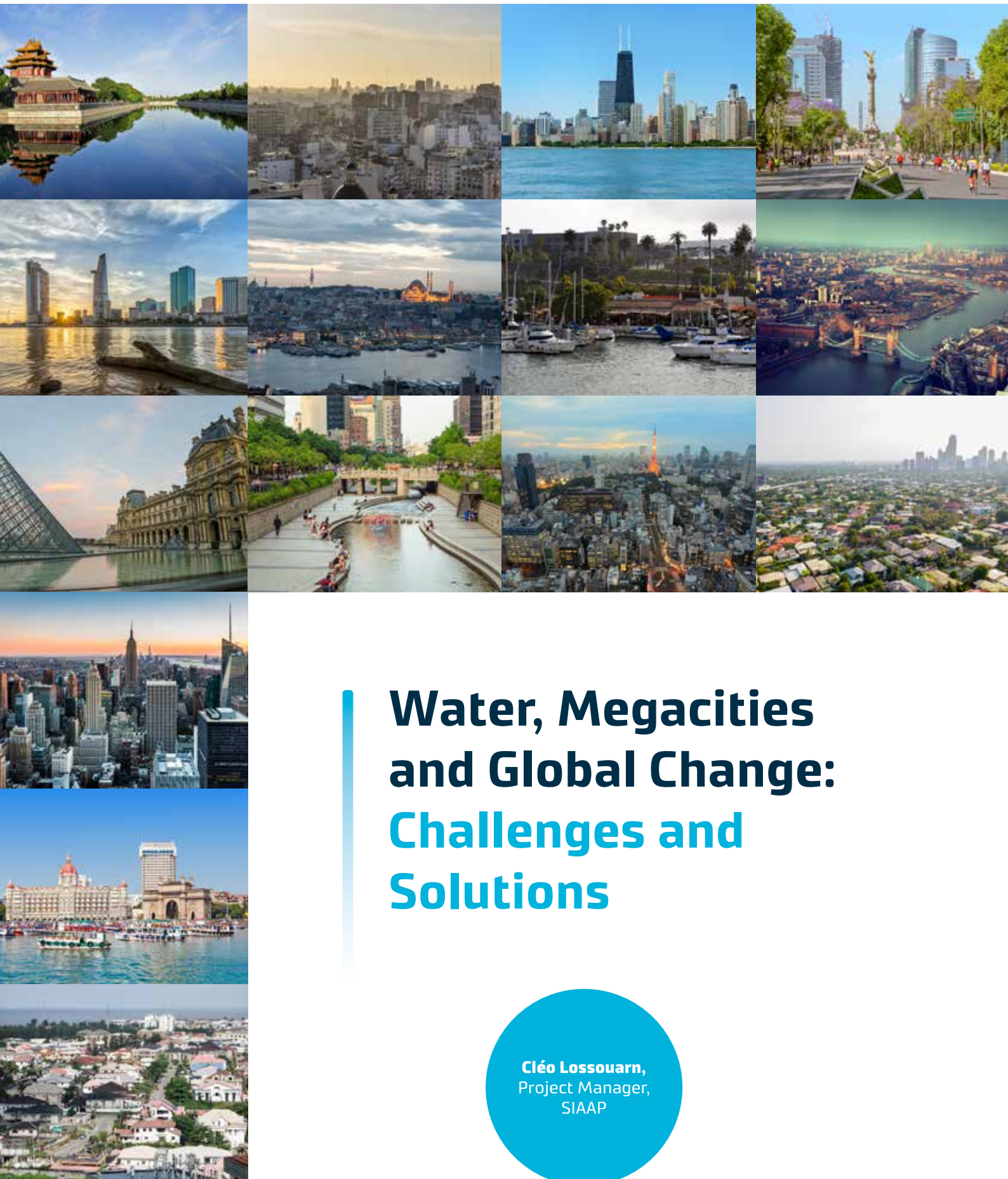
All these stakeholders are remarkable people. In 2013, a favourable conjunction brought them together around a project to promote research and local experiences, leading to the organization of the international conference, 'Water, Megacities and Global Change', held in 2015 in Paris. This configuration is, in my opinion, quite unique in the world today.

This brings us to a key question: What knowledge can stakeholders expect to gain from this publication?

The mere act of juxtaposing the monographs of the 15 megacities reveals a number of conclusions, the most important of which are elucidated in the first chapter, 'Water, Megacities and Global Change: Challenges and Solutions'. This chapter focuses both on common problems encountered in these conurbations, as well as aspects specific to each megacity. The field of study is already very wide since it concerns the management of networks and risks, relations between water and urban planning, and economic aspects and governance methods. At the same time, this study recognizes the limits of interpretation, as the definition of 'megacities' necessarily varies from one monograph to another. This lack of a single unifying definition may provoke frustration among researchers; however, this publication highlights the need for deeper analyses of the specific questions raised by urban water management in large conurbations.

These questions not only concern actions that can be taken to improve water management: a wastewater treatment plant for several million people does not function in the same manner as one serving a few thousand inhabitants. Likewise, a high urban growth rate will induce particular reflections on the quality and quantity of the water to be distributed. These questions also concern solutions that can be implemented to mitigate or adapt to climate change, thanks to the potential for research and innovation within and between universities and public associations. The extension of this approach will inevitably lead to changes at the governance level, which is where all relevant solutions are ultimately implemented.

Jean-Claude Deutsch, President of ARCEAU-IdF



Water, Megacities and Global Change: Challenges and Solutions

Cléo Lossouarn,
Project Manager,
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INTRODUCTION

Numerous studies have explored urban growth and the emergence of the megapolitan phenomenon through increasing growth in the number of cities with over 10 million inhabitants. Similarly, the processes of climate change are also the subject of study from various perspectives as part of more operational approaches or research. Rather, the objective here is to highlight the impacts of those global changes (urban growth and climate) on megacities, their resources, and their water and sanitation services. What emerges is a singular vulnerability: megacities concentrate populations, services and goods. This amplifies the consequences of water-related risks (e.g. large-scale floods, lack of resources, environmental pollution and other challenges).

This chapter summarizes a series of monographs on 13 megacities produced for the recent conference on 'Water, Megacities and Global Change'. The data that underpin this article are drawn solely from those contributions, which were mostly drafted jointly by operators often working in tandem with researchers.

Demography and territories

Identifying the territorial boundaries of a megacity raises the question of how to define a megacity. Examination of population as the determining factor risks neglecting the economic influence of the megacity, which often greatly exceeds that of the national territory. Conversely, population growth has given rise to urban growth that considerably modifies the territory and largely exceeds administrative boundaries. Urban development deeply affects the relationships that megacities develop with their area of economic influence and its hinterland. Hence, analysing water on a megapolitan scale is a complex exercise that assumes a preliminary choice between administrative boundaries, urban area or the area covered by a service operator. In this sense, the choices made by the authors of the monographs are a reflection of their institutional affiliation. Researchers and administrations tend to retain a more overall view of the territory, while operators generally present a more technical analysis confined to the area covered.

All megacities have to deal with demographic and environmental challenges. However, for some of them, urban and population growth is the leading cause of vulnerability of water resources; for others, environmental matters constitute the major challenges.

ESTIMATED POPULATION OF MEGACITIES ACCORDING TO DIFFERENT SOURCES AND REFERENCE AREAS

	Number of inhabitants in millions ¹	Rank	Number of inhabitants in millions ²	Rank	Number of inhabitants in millions ³	Rank
Tokyo	37.8	1	42.7	1	13	5
Manila	12.7	18	24.2	6	12	10
NYC	1.5	9	23.7	7	8.4	12
Lagos	12.6	19	22.8	8	23.3	1
Mumbai	20.7	6	21.9	9	12.4	9
Beijing	19.5	8	21.5	11	21.1	3
Mexico	20.8	4	20.8	12	22	2
Los Angeles	12.3	20	18.6	17	13	5
Istanbul	13.9	15	14.3	21	14.5	4
Buenos Aires	15	13	14.2	22	12.8	8
London	10.2	27	13.6	24	13	5
Paris	10.7	25	12.4	29	11.9	11
Chicago	8.7	72	9.9	40	8.3	13

Sources: 1: World Urbanization Prospects (UN, 2015); 2: population data.net; 3: Monographs.

1. VULNERABILITY TO POPULATION AND URBAN GROWTH

URBAN GROWTH AND ACCESS TO SERVICES

Two broad city types emerge with regard to inherited assets in water distribution and sanitation.

The oldest cities, such as Istanbul, London, New York and Paris, were often the first megacities, and have a long and rather slow history of immigration and settlement. They inherited a system that incorporates assets aged are over 100 years old (the age of 50% of Thames Water's mains in London), which **they have gradually been able to scale up.** Regular investments have allowed infrastructure to be renewed, especially pumping stations and electricity systems, and above all, enabled water and sanitation networks to be gradually extended. In Istanbul, the Grand Melen transmission line (with a flow rate of 35 m³/s) brings drinking water to Istanbul over a distance of 190 km, functioning as a contemporary version of the 240-km waterway that carried water from Vize to Istanbul during the Roman period. The oldest infrastructures have benefited from significant renovation and upgrading using additional systems such as ozonation and activated carbon units. For these megacities, current challenges involve constant improvement and efforts to guarantee the quality of the water distributed.

New megacities have experienced expansion that is very recent and very swift, resulting in infrastructures of historic centres that differ from those of recently urbanized areas. Generally, rapid population growth places pressure on the oldest systems of the city centre and tests the reliability of municipal services, including the water delivery system. This is the case in Buenos Aires. At the beginning of the twentieth century, it was among the cities with the best provision of services, especially in terms of water and sanitation. However, disruption occurred around 1940 and the coverage rate fell. Beijing has a 3,000-year history closely linked with water. The city has a population of over 21 million inhabitants, which has grown by 500,000 inhabitants every year since 1990. Beijing's water-supply system consists of a public distributor which, until recently, was supplemented by over 50,000 self-reliant wells and rural collective waterworks.

Meeting the demand for drinking water is yet another challenge for several of the megacities presented here. In Mumbai, the distribution system is almost non-existent in slums, which host 56% of the city's population. Where there is a network, continuity of service for all users is not guaranteed. In Lagos, the public operator, the Lagos Water Corporation (LWC), produces only 349,000 m³, insufficient to meet the daily demand of 2.9 million m³. The megacity of Lagos and its 200 shantytowns (home to two-thirds of the population) have built their own drinking-water systems, or draw supplies from private providers who operate boreholes and dug wells. This has created a completely disorganized system that fails to meet demand.

KEY FIGURES ON DRINKING WATER SERVICE

	Total available amount per day (m ³) of potable water and reclaimed water	Mains WPP	Length of distribution pipes (km)	Connections	Coverage rate (%)
Tokyo	6 859 500	11	26 613	7 164 953	100
Mexico	6 912 000	66			97
Beijing	10 090 000	68	12 000	3 710 000	
Lagos	2 541 600		2 395	178 900	8
Mumbai	4 128 000				50
New York	3 800 000				
Istanbul	5 904 000	12	18 000		
London					100
Buenos Aires	5 000 000	2	19 000	3 300 000	86
Paris	3 495 000	17	13 000	730 000	100
Manila	4 200 000				99
Chicago	3 770 000	2			100
Los Angeles		1	11 688		100

Source: monographs.

MANAGING DRINKING-WATER SERVICES

Efficiency and non-revenue water

Non-revenue water is water produced but 'lost' before delivery to the consumer. There are significant differences among megacities regarding the current situation and policies in the course of implementation to reduce non-revenue water. In Buenos Aires and Chicago, abundance of the resource means that significant losses caused by older pipes are tolerated, with measures not being taken or being taken only very recently. Conversely, performance-improvement programmes are currently in hand to reduce non-revenue water in Istanbul and Mumbai, where non-revenue water fell from 65% in 1994 to 24% in 2014, with the operator setting a target of between 15% and 17% by 2023. Efforts have been made by London companies and the Tokyo Waterworks Bureau to achieve high levels of performance that position them among world leaders in relation to leakage rates. In Paris, the output of distribution networks improved sharply from 55% to over 90% between 1960 and 2016.

Individual meters

Given the age of housing stock, a large part of which is over 100 years old, less than a quarter of domestic customers in London are currently charged on the basis of water meters. Thus, the vast majority of clients are billed on the basis of 'rateable value' (i.e. the value of the property). This is also the case in Buenos Aires, where the current policy is a historical legacy. The value invoiced is calculated based on the 'covered surface of the premises', the size of the land, the age and quality of the building, and the area where the property is located. Only 12% of users are covered by a metering system. Nonetheless, **individual meters are gradually being adopted in several megacities.** In Mumbai, nearly 75% of domestic connections have a meter, and some shantytowns draw their supply from shared standpipes that are gradually being fitted with meters. In the 1950s in New York, meters that allowed usage to be billed were also installed in response to several years of drought, in order to better regulate demand.

The water tariff

Water and sanitation services in Chicago, London, New York City and Paris are entirely (or almost entirely) funded by income from water and sanitation charges, and not (or almost not) by the municipal budget or state grants. The water tariff must finance all operating costs and asset requirements of the water and sanitation system, including capital costs related to large-scale construction projects and significant modernization works. To this end, the price of water has risen by 186% since 2007 in Chicago, from US\$5.03/m³ to US\$14.42/m³. Conversely, in Buenos Aires billing income for the water and sanitation operator, AySA (*Agua y Saneamientos Argentinos, SA* - Argentine Water and Sanitation, PLC) barely covers 41% of operating costs. AySA receives significant grants from the federal government. A substantial cross-subsidy system between the various users is applied here, as is the case in Mumbai. Overall, the principle is based on a system in which industrial and commercial users subsidize the inhabitants of slums and people living in precarious conditions. In Lagos, the water tariff is extremely unequal, with the difference between the prices charged by Lagos Water Corporation and informal private operators amounting to a ratio of 1:33. In Beijing and Istanbul, the application of a gradual tariff has become a major tool for developing a policy of optimum allocation of scarce water resources and improving effective water use by consumers, including industry.

SANITATION CHALLENGES IN MEGACITIES

Access to sanitation: public health and development requirements

Access to sanitation is usually considered only after access to drinking water, and almost always as a response to the emergence of a major public health issue. Infrastructures for managing wastewater are generally not as developed as drinking water systems. When they are, it is often a recent development, which has required addressing major challenges. Nevertheless, sanitation often plays an

important role in the growth and development of megacities. In 1889, for example, the construction of the Chicago Sanitary and Ship Canal was undertaken in part to meet sanitation needs, but also had a major effect on the future economic development of the city by linking it to the rest of US territory.

Differences have been observed between the level of access to services in historic centres, which are often connected to a sewage system, and other conurbations, which are poorly or not at all covered by networks and sometimes lack improved sanitation systems. In Manila, 99% of the population has access to drinking water, but less than 15% of the city's population is connected to a sewer system. Eight-five per cent of households still use individual systems, and part of the population must resort to open defecation. Acknowledging the existence of a public health problem has forced the authorities to initiate a strategy of full sewerage coverage by 2037. In Mumbai, only 65% of the population is connected to the sewage network, while in Lagos just 6% of households are connected to the collective system.

The need for treatment and ever-better treatment: purification systems and performance

In New York and Paris, a progressive investment policy has been in place since the late-nineteenth/early twentieth century. However, the cities had to wait until 1987 and 2000, respectively, for the establishment of wastewater treatment plants, in order to process all dry weather flows. Today, in megacities found in the richest countries, such as Tokyo, the aim is to improve the performance of purification systems. In Lagos, new legislation requires the construction of wastewater treatment systems in the megacity's new residential areas. However, individual systems will remain the principal means of treatment for the foreseeable future. For this reason, there is an active policy of raising awareness about on-site systems and septic tanks best suited to various terrains, through regular broadcasts on radio and television. In Manila, less than 50% of wastewater collected is treated. In Buenos Aires, 86% of wastewater

KEY FIGURES ON SANITATION SERVICE

	Number of main WWTPs	Total capacity in dry weather (million m ³ /day)	Proportion of wastewater treated		Length of sewage networks (km)	Coverage (%)
			Preliminary treatment and/or marine outfall (%)	Advanced treatment (%)		
Tokyo	20	5.6		100	16 000	100
Mexico	118	0.6	94	6		92
Beijing	50	3.8		86		
Lagos						6
Mumbai	8	1.5				65
New York	14	3.8		100	12 070	100
Istanbul	18	5.4	60	40	14 000	98
London	6				21 720	
Buenos Aires	6		86	14	11 000	70
Paris	33	3.0		100	15 000	100
Manila						15
Chicago				100	8 000	100
Los Angeles	4	2.2		100	10 780	100

Source: monographs.

was discharged untreated into the Río de la Plata. Today, pre-treatment is carried out and a 7.5-km extension to the outfall is planned. The remaining wastewater should soon receive primary and secondary treatment at six plants. In Beijing, most urban rivers are fed mainly by treated water discharged from treatment plants with limited processing capacity, and untreated wastewater discharged directly from sewage networks. In 2008, the Chinese capital launched an initiative to modernize treatment plants in the city centre. Over the last 20 years, levels of pollution discharged by Istanbul into the Sea of Marmara have been reduced, thanks to investment by ISKI (*İstanbul Su ve Kanalizasyon İdaresi* - Istanbul Water and Sewerage Administration) in large-scale wastewater treatment plants that apply high-performance biological treatment to nitrogen and phosphorus. When all the planned wastewater treatment plants have been brought into service, the proportion of Istanbul's wastewater undergoing pre-treatment alone will fall from 60% to less than 10%.

ENSURING THE PROTECTION OF WATER RESOURCES

Protection at source

It took a long time for the water resources of several cities to be acknowledged as fragile, and for protection measures to be applied to catchment basins to ensure sustainable resource management. In Beijing, one of the major challenges for the coming years is water conservation. An area of 3,200 km² has become a drinking water reserve where strict protection, ecological restoration and management measures have been put in place to reduce pollution. This involves adjusting the agricultural structure and ensuring better control of chemical fertilizers and pesticides. Over 100 km from Paris, an organic-farming pilot site has been set up to reduce the deterioration in quality of underground water supplies to the city centre. Furthermore, an awareness-raising programme has been adopted targeting communities and aimed at limiting the use of phytosanitary products. In the Istanbul Region, a policy initiated in the 1990s led to the reforestation of 65% of all related watersheds. Tokyo is currently implementing a

KEY FIGURES ON WATER RESOURCES

	Local resource (%)		External resource (%)		Reclaimed water (%)
	Superficial	Groundwater	Superficial	Groundwater	
Tokyo	99.8	0.2			
Mexico	7	60	21		12
Beijing	Yes	Yes	27		23
Lagos	10	90			
Mumbai	3	2	95		
New York			100		
Istanbul		2	95.5		2.5
London	70	30			
Buenos Aires	95	5			
Paris	86			8	6
Manila	98	2			
Chicago	98	2			
Los Angeles		11	82		3

Source: monographs.

similar proactive reforestation policy. For its part, New York is involved in a long-term protection strategy through the acquisition 'in fee' of large areas, and through multi-stakeholder partnerships aimed at assisting residents of the basin to protect and invest in the quality of water resources.

Preventive measures must be applied to **limit the pressures on available water resources** caused by population growth and associated demand. Resources may be renewable, but megacities may be the cause of overexploitation. Mexico is a sadly well-known case of major ground subsidence. In Beijing, the safety of the city's water-supply system has been affected by the over-exploitation of underground water over a long period, which has led to a deterioration in quality (e.g. an increase in water hardness) and a fall in water availability, the latter constituting an obstacle to economic development. In Lagos, available water resources need to be better shared and protected, otherwise the risk of underground water being polluted by fuel reservoirs and the fall in availability of high-quality water will become unavoidable. With a population of over 8 million inhabitants, London's water resources must be used carefully, even before impacts due to climate change are taken into account.

IMPROVING THE MANAGEMENT OF RUNOFF WATER

Urban growth is synonymous with growing impervious areas. Over the last few decades, this has given rise to the challenge of managing stormwater. Sewage systems that are mainly unitary (a combination of domestic wastewater and rainwater) overflow into a receiving body, which takes what cannot be absorbed by the network, thus avoiding floods in streets and buildings of megacities. Over the last few decades, those overflows have become a problem because of their damaging effect on the environment, resulting in a need for major investment. In 1987, New York stopped the construction of combined sewer systems, so that today, almost 40% of the city is covered by a system that separates domestic wastewater from rainwater. In Chicago, which has a 100% combined sewer network, frequent discharges into Lake Michigan pollute the source of drinking water for 5 million people. To address this issue, Chicago adopted the Tunnel and Reservoir Plan (TARP) at a cost of US\$3.8 billion, which will enable the capture and storage of polluted water until it can be pumped to wastewater treatment plants when capacity becomes available. Similarly, discharges from the London sewer system have reached a weekly average frequency. When the

wastewater network was built it was planned for a population of up to 4 million inhabitants, not the 8 million people who are currently covered, much less the runoff water from impervious surfaces and formerly green areas. Today, 2 mm of rain is sufficient to trigger a discharge into the natural environment. That situation will be exacerbated in a context of climate change and increasingly intense rainfall. The Lee Tunnel, the cost of which is estimated at US\$905 million, will avoid over 16 million m³ of wastewater being discharged into the River Lee each year. In the Greater Paris area, the sanitation operator, SIAAP (*Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne*), has a storage capacity of almost 1 million m³, and has been equipped with an elaborate real-time system for managing urban wastewater (wastewater and rainwater) to take advantage of the possibilities offered by its meshed network.

In cities that experience more violent episodes of rainfall, and are found in tropical areas, the challenge takes on another dimension. **Rainwater drainage systems** in these cities are designed to manage sizeable volumes and aim (not always successfully) to reduce the risk of floods. Mumbai has an annual rainfall of about 2,500 mm spread over the four months of the monsoon season. Even with rainfall of 100 mm in a single day, several of the city's quarters (the poorest located in some low-lying areas) will flood for only a few hours before the drainage system can be discharged. In Lagos, the situation is worsened by regular encroachment on those works, as well as surges caused by the ocean and the lagoon at high tide. The efficiency of drainage systems in Nigeria also constitutes a challenge of a highly political nature. In many megacities, such as Buenos Aires, lack of maintenance of drainage channels is the main cause of flooding during the rainy season. In Beijing, urban floods are becoming a major concern due to rapid urban growth and insufficient drainage capacity. These are the principal reasons behind river overflow, water and power cuts, and congestion of the road network. A system of area-based decentralized management (with seven sub-command centres) has recently been put in place to improve mesh management and to prevent watersheds from overflowing. This has

considerably improved the processes of decision-making, forecasting, giving early warnings and mobilizing the general population.

INTERACTION BETWEEN WATER AND CITIES

Reducing impervious surfaces in cities

A key challenge is establishing how to reduce runoff water upstream, in order to reduce risks of flooding, as well as potential overflows from combined sewer systems. If rainwater enters the networks it is lost as a resource, and a considerable amount of energy and chemicals is required for its treatment. In addition, the continuous increase in runoff volumes raises the question of the long-term sustainability of the water infrastructure. For this reason, rainwater should be considered a resource rather than a nuisance. When Chicago receives 254 mm of rain, this constitutes a potentially useable 17.6 million m³ of water. In New York, the Department of Environmental Protection (DEP) has started to preserve natural drainage corridors called bluebelts, which include streams, ponds and other wetlands, in order to receive transferred rainwater. The programme has resulted in the saving of tens of millions of dollars in investment compared with the cost of standard rainwater drainage systems.

Water should also be better incorporated into urban planning. Certain megacity urban-planning regulations require all buildings or parking areas of a certain surface area to have on-site rainwater retention facilities. When the first drainage works were being designed in Mumbai, the runoff coefficient was estimated at 0.5, whereas the figure used today is 1.0. This highlights the need to anticipate urban development linked to population growth. Over the last 10 years, growth observed in the frequency of floods can be attributed mainly to increased surface sealing in the Indian megacity. Ogun State, which lies north and east of Lagos, has experienced extremely rapid urban development in which land sub-divisions, factories, new towns and roads are gradually transforming forests. As all the rivers that flow through the megacity of Lagos

come from Ogun State, this development will lead to a significant increase in the risk of floods.

One generally shared finding concerns the absence of water management in urban-planning schemes. In Buenos Aires, environmental problems observed over the last few decades are the consequence of uncontrolled urbanization, both formal (with private investment that does not respect constraints relating to water preservation) and informal (the occupation of areas subject to frequent flooding). A quite different challenge relates to the availability of land for installing wastewater treatment infrastructures. This difficulty is currently a main concern in Lagos.

Urban heat islands

Buenos Aires and Manila suffer greatly from the effects of urban heat islands due to their density. In Chicago, efforts to reduce this phenomenon have resulted in a programme to plant 70,000 new trees in the city centre. In London, the temperature tends to rise in the centre of the urban area, mainly due to the effect of the urban heat island, but also on account of the city, which is set in the lowest part of an area surrounded by hills. Episodes of extreme heat in all megacities over the last ten years have had a major impact on demand for water during the hot summer months, which has often reached hitherto unheard-of levels.

Innovative green system solutions

Green infrastructures (GIs) provide a response to challenges such as reducing urban heat islands and managing rainwater where it falls, in order to significantly reduce the volumes entering sewerage systems. The numerous proposed solutions vary greatly. Examples include setting up green roofs, especially in London and Tokyo, as well as bioswales and rain gardens made of native vegetation, and installing cisterns and rain barrels to capture and store rainwater for reuse. Finally, permeable pavements allow infiltration rather than runoff. Those solutions are covered by public financing and are used in the redevelopment of old areas in Los Angeles, as well as in new urban developments, transport-infrastructure projects

(London) and schoolyards. Chicago is a leader in this area, given the multiplicity of measures adopted. In New York, the Sustainable Stormwater Management Plan (2008) concluded that 'green infrastructure' could be implemented in many parts of the city and would be more cost-effective than some large-scale infrastructure projects (e.g. storage tunnels). In Tokyo, a new energy-saving policy relies on the greening of roofs on installations and buildings. Such approaches are usually found in megacities in rich countries and often take the form of experimental pilot initiatives that are limited in scope. However, in the Paris region, many of these solutions have been widely developed since the 1990s. Meanwhile, in Manila green system solutions have not yet been added to the public policy agenda. Efforts to initiate or generalize these practices on a larger scale will have to be made over the coming decades to meet environmental needs.

Green infrastructure experiments are seen as beneficial actions to improve quality of life in response to new societal needs. They also contribute to improving air quality and favour a pedestrian-centred environment. Reclaiming urban rivers is an example of best practice. These new urban-planning projects meet technical, environmental and public needs by re-introducing biodiversity and bringing nature back to urban areas. Chicago, London and New York have all planned green and blue belt networks. There are also medium-term plans to enable swimming in the rivers of Paris alongside the development of 'green and belt' networks. Lastly, Los Angeles has set itself a planning objective of creating over 50 km of rivers by 2025, while Seoul famously reopened a river in the heart of the city.

2. VULNERABILITY TO CLIMATE CHANGE

The impact of climate change on megacities requires crucial adaptation measures and profound transformations to avoid potential crises. Planned responses and solutions depend on available funding. This is why such plans range from gigantic investment policies (Istanbul) and efforts to improve capacities for resilience (Mumbai) to awareness-raising programmes through social media and networks, which give people information on the risks incurred and rely on inhabitants to become agents of change (Lagos). Today, New York continues to invest billions of dollars in modernizing and maintaining its system to improve its reliability, particularly in the aftermath of Hurricane Sandy. However, it is acknowledged that the new challenges linked to climate change also call for a 'flexible and dynamic' response.

MITIGATION

Reducing the carbon footprint

Operators of water services and especially sanitation services undertake a variety of actions to reduce their carbon footprint. The simplest actions that have a direct impact on energy efficiency are those that involve upgrading facilities with better-performing systems, such as pumps. The Tokyo Waterworks Bureau has an ambitious energy-efficiency policy: in particular, its leakage reduction strategy led to a fall in energy consumption of

6% (i.e. 45 million kWh) between 2000 and 2013. In New York, the 'OneNYC' plan has set itself a megacity-scale overall objective of reducing greenhouse-gas (GHG) emissions by 80% between 2006 and 2050. Planned reductions in the water and sanitation system will account for 20% of that figure. In addition, the New York operator plans to attain 'net-zero energy' for wastewater treatment plants in the city centre. In Los Angeles, the water and sanitation operator will make a much smaller contribution to reducing the megacity's carbon footprint, taking into account its needs for drinking water production. Conversely, in Buenos Aires and London, there is significant albeit little used potential for reducing GHGs and improving energy efficiency. This challenge has not been addressed in certain megacities, where it is not viewed as a priority (Lagos, Manila and Mumbai).

Water reservoirs also contribute to energy production, since they are often fitted with hydroelectric dams. This is the case in Manila, Mexico and New York, where production capacity is 246 MW.

Recovering resources: energy, gas, nitrogen and phosphorus

Urban wastewater is an underused resource that is currently under close scrutiny. The different temperature of wastewater, which is higher than drinking water, is also an underused basic resource. Electricity and biomethane produced by co-generation offer new opportunities to reduce GHG emissions. From replacing fossil-origin methane to producing less-polluting biofuels, there are multiple possibilities for energy use. For example, energy from biogas produced at the largest wastewater treatment plant in the Paris area constitutes a potential resource of 410 GWh/year. London has also been able to benefit from renewable energy, heat and energy produced by sanitation, in order to reduce its energy consumption. In Istanbul, research and development at the pilot level has been carried out with organic waste from restaurants, as well as particular forms of waste to feed sludge digesters installed in large wastewater treatment plants. There are medium-term plans for at least one full-size application.

In Paris, research work on using phosphorus and nitrogen resources has been initiated. Phosphorus normally exists in limited amounts, but is present in non-negligible amounts in wastewater. The production of nitrogen fertilizers is totally dependent on fossil methane, whereas urine contains over 95% of the nitrogen ingested by a person.

ADAPTING TO THE RISK OF FLOODING

In light of the above sections, the risk of flooding cannot be attributed solely to climate change. Nonetheless, it is common knowledge that one of the most obvious effects of climate change is the significant increase in the number and frequency of devastating floods in cities, as a result of very heavy rainfall (C. Brown and M.N. Ward. 2013. *Managing Climate Risk in Water Supply Systems*. IWA Publishing).

This situation means that **authorities in megacities in vulnerable situations must take risk-management measures**. Given its topography and its extreme vulnerability to the risk of flooding, Mumbai has adopted a proactive policy in this matter, galvanized by the 2005 flood which caused €33 million worth of damage and over 180 deaths. In addition to investing in infrastructures, pumping stations and equipment for preventive measures, the city has provided training in catastrophe management to technical teams, NGOs and community organizations. Each year, a monsoon-preparation exercise is held on a systematic basis. Regardless, the capacity for resilience and returning to normal is much faster here than elsewhere, largely because the Indian population is accustomed to the situation to a certain degree. In Manila, at least 20% of the land area is considered to be subject to flooding. The city also lies along the trajectory of most typhoons that arise in the Pacific. Studies have shown that associated risks are likely to increase sharply by 2040. In England, about 15% of property in London (i.e. about half a million dwellings, as well as a number of strategic places) are subject to a significant risk of flooding. The Thames Barrier has historically enabled this risk to

be managed, however the exponential increase in its use (the barrier was closed four times in the 1980s, 35 times in the 1990s, and 75 times in the 2000s) is an indication of the increase in vulnerability. As an addition to the present innovative, high-performance management system, a coordination system, Drain London (which brings together the 33 boroughs and other institutions), has been put in place to better understand and anticipate risks. For its part, Chicago has also experienced an increase in the frequency of extreme rainfall causing damage estimated at over US\$41 million annually. To address this risk, the city has become a leader in green infrastructure, leading to a reduction in the volume of runoff of almost 1 million m³.

In Mexico, the Mexico City Metropolitan Area has established a Regional Centre for Emergency Attention to provide support to populations affected by increasingly frequent floods. This measure constitutes an addition to a plan of investment in infrastructures (dikes, dams and canals) and technological flow-management tools.

Preventive measures

The Paris floods of 1910 and 1924 led to the building of storage dams upstream from the metropolis with a storage capacity of 850 million m³. Construction was undertaken in particular to reduce the risks of flooding. While it has not yet been confirmed that climate change will significantly worsen this risk, it remains a major challenge to water management in the French megacity. In 2012, Hurricane Sandy highlighted the vulnerability of New York to episodes of extreme rainfall. The extensive damage caused led to studies being carried out that assessed risks and priority actions. In Istanbul, ISKI is preparing maps to identify all areas at risk (confirmed or potential). Proactive preventive measures have been adopted, leading in particular to the expropriation of buildings in these quarters. In Beijing, advertising campaigns and awareness-raising programmes relating to floods prevention and risks reduction have also been carried out in the media, with the aim of providing information needed to prevent catastrophes and risks in schools, workplaces, communities and families.

ADAPTING TO THE RISK OF DROUGHT

A resource that is not always renewable

In Beijing, water shortages are the main impediment to socio-economic development. Beijing has suffered from continuous drought since 1999. The amount of water available amounts to about 100 m³/inhabitant/year, which makes it one of the most water-deprived areas in the world. One way of responding to the water shortages is to restrict population growth to 23 million by 2020, by means of a regional development plan based on neighbouring Hebei Province. In the United States, the state of California forecasts an increase in the frequency of drought periods of six to eight years. Given the seriousness of the water shortages that began in 2012, Los Angeles has set itself the objective of reducing its dependence on external resources and developing the use of local resources by adopting a strategy of integrated water resource management (IWRM).

In Tokyo, periods of drought resulted in the application of restrictions once every three years. This has strengthened the determination of the Tokyo Waterworks Bureau to implement its strategic objective of 'ensuring the continuity of water resources'. New York experienced several episodes of drought during the twentieth century, and predicts that climate change may accentuate this phenomenon. A high-performance control system has been put in place to ensure the availability of the resource and to meet high demand in summer. In France, evolutionary scenarios caused by climate change vary, but retain an increased probability of the risk of drought by 2050. For this reason, further studies and research are needed to help the various sectors concerned to learn how to adapt. More generally, there is no longer any doubt that the vagaries of climate will disturb the existing balance and reduce the amount of available water. This is why Chicago, Lagos, London and Manila all highlight the gradual appearance of risk and emphasize the need for vigilance and better management of resources.

Costly infrastructures

In China, the South-North Water-Transfer Project (SNWTP) was launched in 2014 to transfer water from the Yangtze River to the north. It stretches for 1,267 km and will enable the transport of between 1 billion and 1.5 billion m³ of freshwater each year. Although this new resource will replace the production of independent wells, scarcity of water resources will remain a serious situation. Mexico City plans to add to its water resources by drawing supplies from an adjacent basin 14 km away, which will require water to be pumped along a drop of nearly 1,850 m. Over the long term, this particularly complex project will enable the transport of 30 m³/s of additional resources, if resistance from local populations and authorities to sharing the basin resources does not block the project.

Mexico is also exploring the exploitation potential of the valley's deepest aquifers, with a well recently drilled to the hitherto unheard-of depth of 2,000 m. In Istanbul, emphasis has been laid on developing water resources following the serious drought of 1994. Total production capacity was increased from 590 million to 2.1 billion m³/year between 1994 and 2014. The work done by ISKI to increase capacity to adapt to climate change includes plans for water transfers between basins, made possible by the construction of the Grand Melen Dam. Once inaugurated, this water-distribution system will be able to handle three consecutive years of drought. Similarly, New York is investing in optimizing the efficiency of its system, especially to reduce leaks from its main aqueduct in response to climate variations. This should lead to savings of 56,000 m³ to 130,000 m³/day. In Los Angeles, a seawater desalination plant is under consideration, as a local, inexhaustible solution that adapts easily to climate change.

Managing demand, progressive rates and saving water

To increase capacity for climate change adaptation, Beijing and Istanbul have ensured effective and efficient use of water by applying progressive rates and carrying out communication campaigns on saving water. ISKI users in Istanbul with a

reasonable level of consumption (<10 m³/house/month) pay less. In China, the prevailing principle differentiates between residents (5 yuan/m³) and non-residents (8.15 yuan/m³), and also encourages the use of recycled water. In Istanbul, ISKI's ordinary users are regularly made aware of and encouraged to use water-saving facilities (e.g. taps, showerheads, heaters and flushing systems). The Ministry of Science, Industry and Technologies also provides significant financial incentives for producing these domestic systems.

Awareness-raising campaigns that aim to reduce demand for water are frequent in many megacities. In Los Angeles, they have played a major role in making demand per inhabitant one of the lowest in the United States. More recently, a policy aimed at reducing lawn-covered areas and encouraging native vegetation that uses little water has been very effective. Since 1939, New York has implemented several policies aimed at lowering demand following periods of drought. Posters and brochures have today been replaced by a Demand Management Plan that set itself the objective of reducing overall demand by 5% by 2020. Data from Paris show that water use has been fallen since the start of the 1990s. Between 1999 and 2013, volume fell by 17%, while the population grew by 7%. Across the whole of the Greater Paris region, the fall in consumption per inhabitant amounts to 14%.

Reusing wastewater

The practice of reusing wastewater has been widely expanded and benefits from major investment in megacities where availability of the resource is a problem. In Beijing, the quality of wastewater treatment has been improved, as a means to address the lack of water. Thus, it has been possible to gradually extend wastewater reuse to watering gardens, industrial production, agricultural production, washing cars, flushing toilets and other areas. In 2014, 860 million m³ of treated wastewater were distributed through a 783 km-long network and reused. In Mexico, 11 m³/s of urban wastewater, most of which is untreated, is reused for services, the public parks of the metropolitan area and for irrigating agricultural land. The remaining effluent (wastewater and rainwater) from the basin is

used untreated on a large scale for agricultural and electricity production. The formerly arid basin, situated 50 km from the city, has been completely transformed by the 165 m³/s of effluent it receives as discharge.

Since 1979, Los Angeles has invested in cutting-edge treatment systems that enable the production of purified water, which can be infiltrated into underground water to help reconstitute the resource and guarantee that it will be available in coming decades. The city has committed itself to significantly increasing the reuse of treated wastewater in irrigation, industrial use and watering parks. Regardless, the economic relevance of extending non-drinking water networks in a city that is both dense and widespread is regularly assessed. Planned extensions to supply factories should lead to a 350% increase in current demand for non-drinking water by 2040. Today, recycled water accounts for 2% of total water production.

In Istanbul, studies have been carried out into the reuse of treated water from ISKI's high-performance plants, which use sand filtration and UV disinfection. The water could be used in toilet flushes and industrial procedures, and to irrigate public areas. ISKI plans to produce a minimum of 200,000 m³ to 250,000 m³/day of recycled water. In Manila, reuse of treated water is considered a potential resource to be extended in the context of growing demand, but is unused to date.

ADAPTING TO OTHER RISKS

Risk of rising sea levels, erosion and salination

The strategic position of megacities close to the sea explains in large part their economic (and thus demographic) development. However, it also makes them more vulnerable to risks associated with sea level rise. For example, the coast of Maharashtra in India is forecast to increase by 240 mm to 660 mm. Such a rise would lead to considerable damage in Mumbai, given that the city is located mostly at sea level. In Buenos Aires, the rise in the level of the Rio de la Plata increases the risk of flooding, which mainly affects the most

deprived areas. The phenomenon of the *sudestada* (south-east wind) will become more regular and will cause significant damage along riverbanks. To address this threat, the city has implemented a high-performance alarm system to forecast risks, a contingency plan, risk zoning and legal measures such as insurance. In the Lagos region, sea level increase poses a significant risk, with forecasts projecting a rise of about 40 cm by 2050. This would expose the coastline to increased erosion, damage caused by storms, floods in low-lying areas, and saltwater infiltration of water tables and estuaries. The same risks are present in Manila, which is also particularly exposed. In New York, numerous infrastructures located by the sea will suffer increasing levels of damage. A detailed study of 14 treatment plants enabled a precise assessment of potential malfunctions or closure of installations in the event of powerful storms. On the west coast of the United States, the Bay Delta dyke system is threatened by salinity, which must be mixed with water from upstream reservoirs to maintain water quality.

In Mumbai and Lagos, the side effects of water salinity include the disappearance of local species living in mangroves, coastal lagoons and marshlands. Intrusion by seawater will also destabilize economies directly linked to those resources, such as fishing and agriculture, which function as the sole means of subsistence for a significant proportion of the population.

Changes in temperatures and precipitation: imbalances and deterioration in water quality

To the west of the Black Sea, where Istanbul's main water resources lie, significant increases in temperature and, accordingly, evaporation and evapotranspiration, would lead to a decrease in the volume of surface and underground water of at least 20%. This decrease would lead to a significant increase in eutrophication and to the presence of toxic algæ in drinking water reservoirs. This in turn means that existing water treatment installations will be insufficient to guarantee water quality. The same situation regarding eutrophication and turbidity is found in the two main reservoirs that supply drinking water to New York City.

In Paris, modifications to the hydrogeological regime following climate change may cause fundamental changes to the current fragile balance regarding drinking-water distribution, as well as sanitation. Addressing this issue will require the implementation of IWRM. The main challenge concerns risks relating to the deterioration in water quality following a fall in low-water flow affecting watercourses, which would reduce capacity to dilute polluting discharges.

One-off risks

In many megacities, such as Mumbai, climate change is predicted to negatively impact sanitary conditions by increasing the number of days that encourage the spread of malaria and the risk of waterborne diseases. To address this threat, health infrastructures will have to be strengthened and more installations will need to be built in areas with no coverage.

In London, climate change is making management of the network more difficult, since extreme weather events destabilize clay soil and lead to a growing number of ground movements that damage networks.

In addition to climate change, it is important to highlight the significant risk posed by seismic activity. Los Angeles, Manila and Tokyo are particularly subject to seismic risk, and have had to develop services that take into account this vulnerability.

3. WATER GOVERNANCE

In general, water governance is highly decentralized, with overall responsibility held at the level of local government. However, there are still countries where the federal level or the state plays a key role in day-to-day operations. Large jurisdictions, such as megacities, must deal with obstacles created by the complexity of multilevel governance structures, superimposition of scale and complex participatory processes.

The most frequent situation is one in which a multitude of stakeholders are unable to coordinate matters among themselves, giving rise to a public policy that lacks effectiveness and takes a 'wait and see' approach. In Buenos Aires, the federal organization of Argentina and federated jurisdictions have their own areas of competence, especially in matters relating to water management and environmental protection. The greatest challenge is that of coordinating the various competent authorities: the national operator (AySA), the provinces and the municipalities. In Lagos, water falls under competing legislatures. In spite of ministerial desire for improved institutional cooperation, the necessary framework is not yet a reality. In Mumbai, municipal councils hold responsibility for water supply and access to sanitation. However, many other stakeholders are involved in their management, through budgets and the granting of approval for large-scale works.

Conversely, in megacities where the water sector is fairly centralized and a single authority enjoys a fair amount of leeway in making decisions, mobilizing means and implementing its policy, the sector enjoys increased efficiency. This is the case with the National River Authority, which regulates the River Thames and its tributaries, as well as water distribution and the collection and treatment of wastewater across the whole of the Thames watershed. OFWAT, the regulatory body for water and sewerage in the United Kingdom, closely supervises the four companies tasked with providing the service, and requires a very high level of performance.

In Turkey, the Istanbul Water and Sewerage Administration (*İstanbul Su ve Kanalizasyon İdaresi* - ISKI) was founded in 1981 to take charge of water supplies, wastewater and rainwater drainage, and also to protect surface and underground water resources. Since its creation, ISKI has successfully followed a wide-ranging policy of investment and upgrading. In New York, an innovative management strategy proved successful in the last century thanks to coordination and working relationships between the various water entities. Today, the DEP takes a holistic approach, playing a role in regulating air quality, hazardous waste and challenges relating to quality of life, including noise. In Manila, legacy water infrastructures are public property and belong to the Metropolitan Water and Sewerage System (MWSS). Nonetheless, water supply and sanitation services are managed by two private concessionaires that comply with contractual requirements and have produced swift improvements in the rate of access to drinking water.

On a larger scale, successful protection of watersheds in megacities cannot be achieved without the cooperation of the federal government (where one exists), the state, local authorities and non-governmental organizations. All stakeholders must coordinate among themselves to provide an efficient service in accordance with the recommendations of IWRM.

Regulatory and legal framework

The water and sanitation sector remains subject to complex regulations, given the variety of challenges. The environment, natural resources, public health, and the economic and industrial sectors are just a few examples of the sectors involved. As noted above, there is also a need for increased interaction with stakeholders and involvement with urban planning regulations in order to address the range of new challenges.

Regulations are a state responsibility, however the large majority of megacities studied here are subject to constraints specific to their territories, and are consequently subject to specific regulation. This is particularly the case for Buenos Aires, Istanbul, New York City, and so on.

In China, the Standing Committee of the National People's Congress has promulgated four laws relating to water. The State Council and Beijing Municipality have added further administrative regulations to this legal arrangement covering protection of water resources, licences to extract water, water savings, mobilizing civil society and so on.

Service operators

Service operators, whether the sole operator or one of many in metropolitan territories, ensure continuity of service and operation of water and sanitation systems. Whether public or private, these operators employ large teams of people who work on a 24/7 basis: there are 6,000 employees in New York's DEP, 11,800 in Los Angeles and 1,700 working in sanitation in Paris. Human resources therefore constitute a key element in operating services. In Tokyo, a period in which large numbers of staff entered retirement had to be carefully managed by Tokyo Waterworks, which needed their expertise at a key moment in a wide-ranging rehabilitation policy. In Manila, the delegation of drinking water distribution service to two companies and performance requirements led to the implementation of a major re-structuring policy aimed at reducing the ratio of employees per connection from 9.8 to below 1.47.

Due to considerable investment policies and equally considerable operating costs, service operators are also major economic stakeholders. ISKI's annual budget amounts to almost US\$3.5 billion, with the figure for Los Angeles being nearly US\$6 billion. In New York, total expenditure related to operating and financing the water and sanitation systems is expected to reach US\$3.85 billion in 2016. In Paris, the cumulative budgets of the three main operators came to €1.86 billion in 2014.

Civil society mobilized

Questions relating to water are also of concern to civil society stakeholders and, as such, involve them in efforts to address the issues involved. In Chicago, the RainReady programme organizes awareness-raising campaigns, training sessions and workshops, and also offers finance to encourage owners to collect rainwater at source and reduce the impact of local flooding. Civil society organizations in Manila have been very active on two levels: keeping an eye on the performance and return on investment of the two concessionaires, and promoting water-supply systems put in place by shantytown communities to provide access to a poorly served population.

In Mumbai, civil society acts as a relay to manage catastrophes through several NGOs. Beijing hosts several social organizations involved in the water sector. Each year, they are mobilized as part of large-scale campaigns to raise public awareness of water conservation through events such as World Water Day and Water Week in China.

There are many linkages between vulnerability to urban growth and vulnerability to climate change. These can also be the cause of risks that are difficult to identify. The significant variety of challenges affecting megacities adds further complexity, hindering efforts to establish a typology that could allow megacities with common features to work together. Nevertheless, these large urban centres concentrate technical and scientific potential, operational skills, economic abilities and human resources that can produce innovative solutions. By sharing experiences in technological, organizational, economic and cultural areas, these megacities can become a source of opportunity.

Gender Equality, Water and Climate Change Adaptation in Megacities

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Although it is widely assumed that cities provide better water and sanitation services than those found in rural areas, access depends upon many factors such as location of the home, the economic situation of family members, social segregation/integration within the community, whether or not the home can be connected to the pipeline, and the extent of supply coverage in the city. Geographical and social equity in distribution of services cannot be taken for granted and is dependent on a variety of complex factors. As such, pro-poor services or equality-oriented services are not generally a normal practice in megacities. Financial constraints on the part of the utilities are usually cited as a reason for unequal or inadequate distribution of services; however, a general lack of accountability among service providers towards the people is sometimes found to be the main ‘missing ingredient’¹. Accountability necessitates the meaningful involvement of users in the planning, delivery and monitoring of water services. This increases

the chances of delivering reliable, sustainable and affordable water services to more urban inhabitants². Success depends on good governance and the engagement of men and women as equal partners and agents for change³.

Strategies for public participation in policy planning and decision-making with regard to water supply services, climate adaptation and also water-related disaster response improvement are designed for the entire population of the vulnerable area, and use existing social structures for decision-making and communicating information. These existing structures do not necessarily represent the community, and do not as a rule provide space for women to participate and make their voices heard. Access to water differs for men and women, with gender-specific vulnerabilities determined by socio-economic, political and spatial contexts. An understanding of these vulnerabilities would provide a context for analysis of the different needs and capacities of men and women and

1. Yael Velleman, *Social accountability Tools and mechanisms for improved urban water services*, WaterAid, June 2010, p. 3.

2. *Ibid.*

3. www.un.org/womenwatch/feature/urban/. *WomenWatch: Gender Equality and Sustainable Urbanization - fact sheet*, United Nations.



the kinds of interventions needed to improve their water security and help them to adapt to the impacts of climate change. It would also provide guidelines for their participation in climate mitigation, enabling responses to be more effective, by focusing on the different needs, constraints and strengths of different groups of men and women in the local community.

Social constructs have made resources such as land, water, credit and capital, mobility and information more accessible to men. All over the world, women are more likely to be given the primary responsibility for family care, including the provision of food and water, and caring for children and elderly and sick family members. Where there is insufficient access to water services, food, energy and mobility, these tasks can be extremely challenging and time-consuming. The

consequence can be a loss of income, particularly for women, from inability to go to work, thus perpetuating a cycle of economic crisis. This is particularly true of female-headed households. Water scarcity also affects the schooling of children, particularly girls, when time spent in education has to be spent on collecting water. Investing in the infrastructure needed to provide adequate water and sanitation facilities can sharply reduce health costs and loss of labour as a result of illness. It can also release women for productive activities by reducing the burden of collecting water for cooking, laundry and other household uses⁴.

City farming or urban agriculture represents an important livelihood and source of income for many, especially women, who because of a lack of education and/or inability to find adequate employment are unable to

4. *Ibid.*

5. *Ibid.*



provide food security⁵ for their families. Urban and peri-urban farmers largely grow food for home consumption. For many women this is a part-time occupation and source of cash income from sale of excess production. Commodities such as fruit, vegetables, pork and poultry provide some 10-40% of the nutritional needs of urban families in developing countries, thus making a major contribution to urban food security.

The adaptive capacity of individuals and households depends upon the extent of their water, food and livelihood security. A reliable income and employment, access to financial resources, access to water, food and sanitation, quality of infrastructure, access to energy, and social support within communities are all factors that improve adaptive capacity. The most adversely affected in times of climate distress are those men and women who work in the informal sector, such as daily wage labour, and lack social and financial support systems. In this context, poor women and female-headed households have the least adaptive capacity. Women's work burden increases when there are food and water shortages due

to climate events, and their caregiving roles become more demanding when climate impacts on health and psychosocial well-being⁶. *It is also important to be aware that the role of women as family or professional carers during disasters is often invisible, while men's actions in rescue operations and emergency services tends to be more visible and recognized within the community*⁷.

Climate events and disasters not only disrupt physical infrastructure, but also the structure of the society. Lives change, as does the 'normal' ways of doing things. While social and gender disparities are magnified by the impacts of climate change⁸, natural disasters often offer women the opportunity to challenge gendered status in society⁹. Women not only take up traditionally male tasks outside their domestic spheres, but also often do so against the wishes of the men in their community, thus challenging their perceived roles in society. Women are *most effective at mobilizing the community to respond to disasters*¹⁰, and as a result of their response efforts, they develop new leadership and management skills. Only in times of extreme stress, such as droughts

6. *Guidebook on Gender and Urban Climate Policy*, June 2015.

7. *Ibid.*

8. *Ibid.*

9. PAHO (Pan-American Health Organization). 2001. *Gender and Natural Disasters. Fact Sheet of the Program on Women, Health and Development*. Washington DC, PAHO.

10. *Ibid.*



and natural disasters, are men seen to play a major role in accessing water for domestic use, which is usually the woman's responsibility.

Climate adaptation measures require building resilience, not only of infrastructure and services, but also of individuals, households and communities. The first step in this direction would be to conduct a gendered assessment of the needs, capacities and vulnerabilities of men and women in different social, cultural, ethnic and geographically located groups in the megacity. This would help in planning appropriate interventions for each group of people and increase their effectiveness.

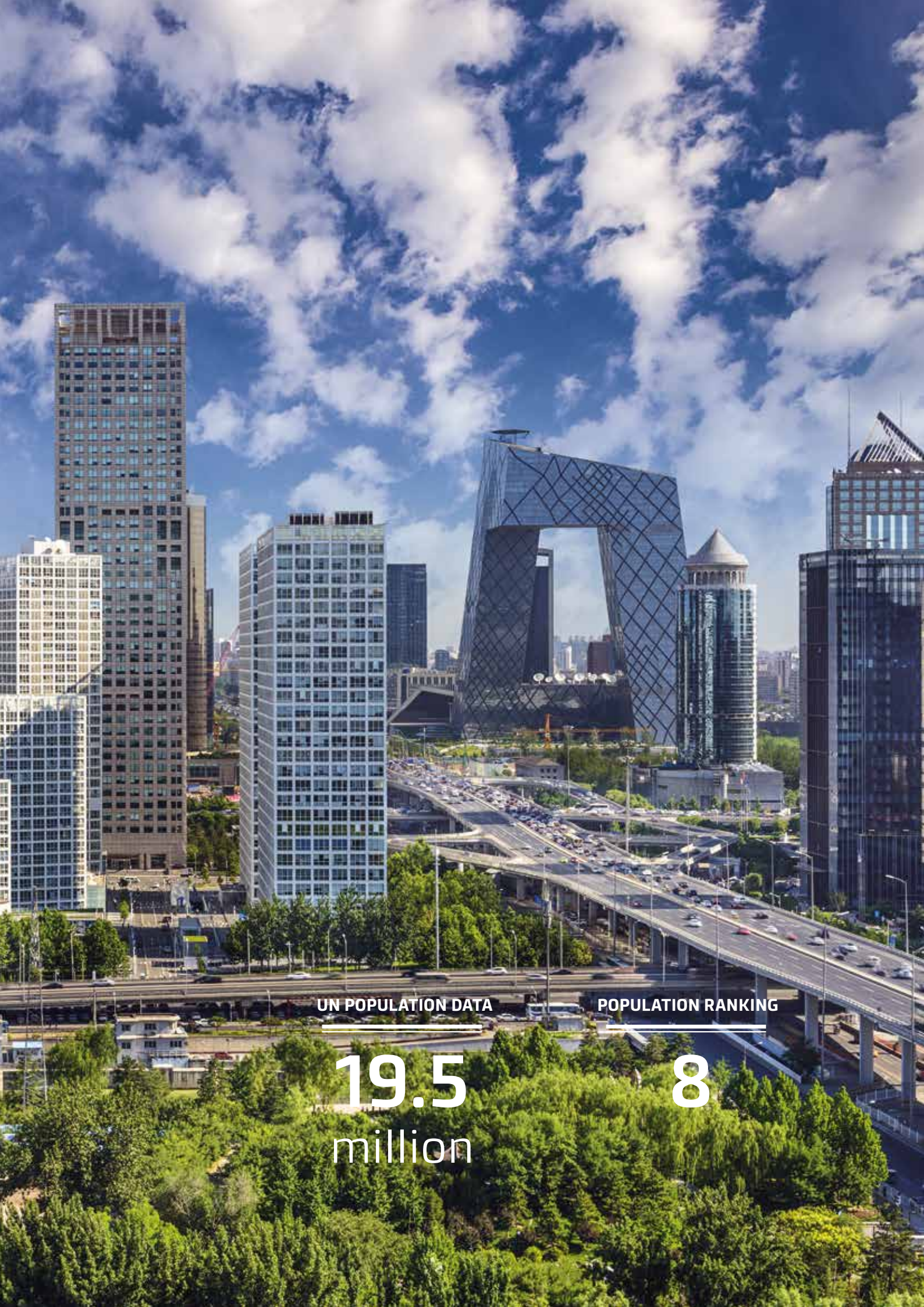
While an enabling environment can be created with a top-down policy to facilitate gender integration into climate change adaptation, a simultaneous bottom-up approach in

terms of raising awareness in local governments and mobilizing local communities will be necessary to fully address concerns. Mainstreaming gender concerns into policy, planning and implementation of climate change adaptation needs to begin with a gender analysis of sex-disaggregated information related to the needs, capacities and vulnerabilities of different social and cultural groups of men and women residing in the megacities. Mechanisms for dialogue need to be put in place, and special efforts need to be made to engage with women and facilitate their participation in policy, planning and decision-making processes.

Beijing

Sun Fenghua,
Beijing Water Authority





UN POPULATION DATA

POPULATION RANKING

19.5
million

8

Beijing

Beijing is situated on the northern tip of the North China Plain and lies adjacent to Tianjin and Hebei Province. The city is located in a very flat part of the country surrounded by mountains to the west and north-west. Its long history dates back 3,000 years and is closely interlinked with water. In Beijing municipality there are 21 million inhabitants, with an average growth of 580,000 inhabitants/year. The urban population amounts to 18.6 million inhabitants. The city covers a total area of 16,410 km² with an urban area of 1,368 km².

Beijing faces several water management problems related to: climate change impacts; poor river quality; water scarcity, which also constitutes a bottleneck for socio-economic development; and water conservation and flood control.

Precipitation occurs mainly in summer and averages about 585 mm annually. Total available water resources amount to less than 200 m³/inhabitant, making it one of most water-scarce areas in the world.

Beijing has three water resources:

- Surface water including a large-capacity storage reservoir: the Miyun Reservoir;
- Groundwater with 50,000 wells extracting about 1.4 billion m³/year, creating a huge groundwater deficit, which results in a declining groundwater table in the plains area (groundwater pollution is also an issue); and

- Diverted water from the Yangzi River pumped through the central pipeline of the South-North Water Transfer Project (SNWT), which carried 1.5 billion m³/year in 2014.

Water supply in Beijing is achieved mainly through the public utility, self-reliant wells and collective rural waterworks. The public utility operates 68 waterworks with a combined daily capacity of 5 million m³. Wastewater is collected and treated in 50 medium and large-sized wastewater treatment plants with a total capacity of 4.25 million m³/day. In 2014, 86.1% or 1.39 billion m³ of sewage water was treated (97% in central Beijing). In 2014, 860 million m³ of reclaimed water was used.

There are five major rivers within the Beijing Municipality, including the Juche, Chaobai, Beiyun, Yongding and Juma, moving from east to west. These rivers all flow into the Haihe River. Four



major drainage canals and over 30 large tributaries run through central Beijing. Most of the city's rivers are replenished mainly by reclaimed water from wastewater treatment plants. The quality of water meets Grade II for 44% of the length of the canals, while 41% is lower than grade V. There are also more than 20 lakes.

Urban inundations have become a major concern due to rapid urban expansion and insufficient drainage capacities and other facilities in urban areas. In order to mitigate the pressure of urban floods and inundations, Beijing has taken measures to develop effective flood control. The institutions and mechanisms for flood prevention have also been further improved. A Beijing Emergency Response Plan on Flooding has been set up, and emergency rescue task forces have been strengthened. Publicity and outreach

programmes on flood prevention and risk reduction have also been conducted.

Since the early 1980s, Beijing has made massive efforts to conserve water, with notable results in industry, agriculture and urban life. Water consumption per 10,000 yuan (US\$1,505) of GDP in Beijing has reduced by 8% annually over the past decade. Beijing has also conducted a comprehensive reform to adjust fees for water resources and sewage treatment, as well as prices for drinking water and water supply. The use of reclaimed water has been consistently promoted and encouraged. Since 2014, the price of reclaimed water has remained at 3.5 yuan/m³ (US\$0.53/m³), while the price of drinking water for residents is 8.15 yuan/m³ (US\$1.23/m³).

Buenos Aires



Emilio Lentini,
University of Buenos Aires

UN POPULATION DATA

15
million

POPULATION RANKING

13



Buenos Aires

The **Buenos Aires** Metropolitan Area (AMBA) is home to 12.8 million inhabitants (2010) and covers 2,500 km², stretching along the Rio de la Plata, an immense river with a flowrate of 23,000 m³/s. The city also extends across a plain endowed with a large groundwater supply. AMBA encompasses the City of Buenos Aires and 24 surrounding municipalities within the Province of Buenos Aires. A main challenge for its water and land management is the lack of a metropolitan authority.

The water and sanitation coverage of AMBA varies significantly between the central area and its outskirts. The water supply system coverage rate is 100% in the central area, but drops in the outskirts resulting in substantial deficiencies in coverage, particularly for sanitation. This results in pronounced economic, social and urban inequalities and vulnerabilities. Until 2014, 86% of collected wastewater was dumped into the Rio de la Plata without (or with very little) treatment.

Through most of its history, Buenos Aires was a city devoid of problems with regard to water resources. The idea of water as an inexhaustible resource with a 'social mission' was embodied by the state-owned utility, OSN. However, AMBA's water and sanitation networks, built at the end of the 1900s, reached capacity during the 1950s as a result of increasing

formal and informal urbanization. A number of water sector reforms took place including decentralization, international concessions and federal state management. Today, the current water and sanitation supply management of AMBA resembles a mosaic consisting of national, provincial and municipality agencies. Accordingly, responsibility for water management and environmental protection is shared among different administrative entities.

A major challenge for the development of climate change adaptation is, therefore, to implement a new governance scheme involving multi-level agencies and stakeholders to cope with this regulatory and institutional framework fragmentation. In order to develop actions to address climate change, one of the greatest challenges for AMBA is to



coordinate the three levels of government simultaneously in cooperation with civil society organizations.

Buenos Aires is highly exposed to climate risks arising from increased rainfall and temperature, as well as increasing wind intensities, hot temperature trends and heatwaves. The Buenos Aires climate change agenda includes adaptation strategies for water and sanitation issues, such as household vulnerabilities, floods, universal access to public services, solid waste collection and disposal, industrial pollution and so on. Moreover, the agenda takes into consideration changes in drinking water usage, as well as the need for better coordination among stakeholders.

Buenos Aires has entered a new phase for water and sanitation management,

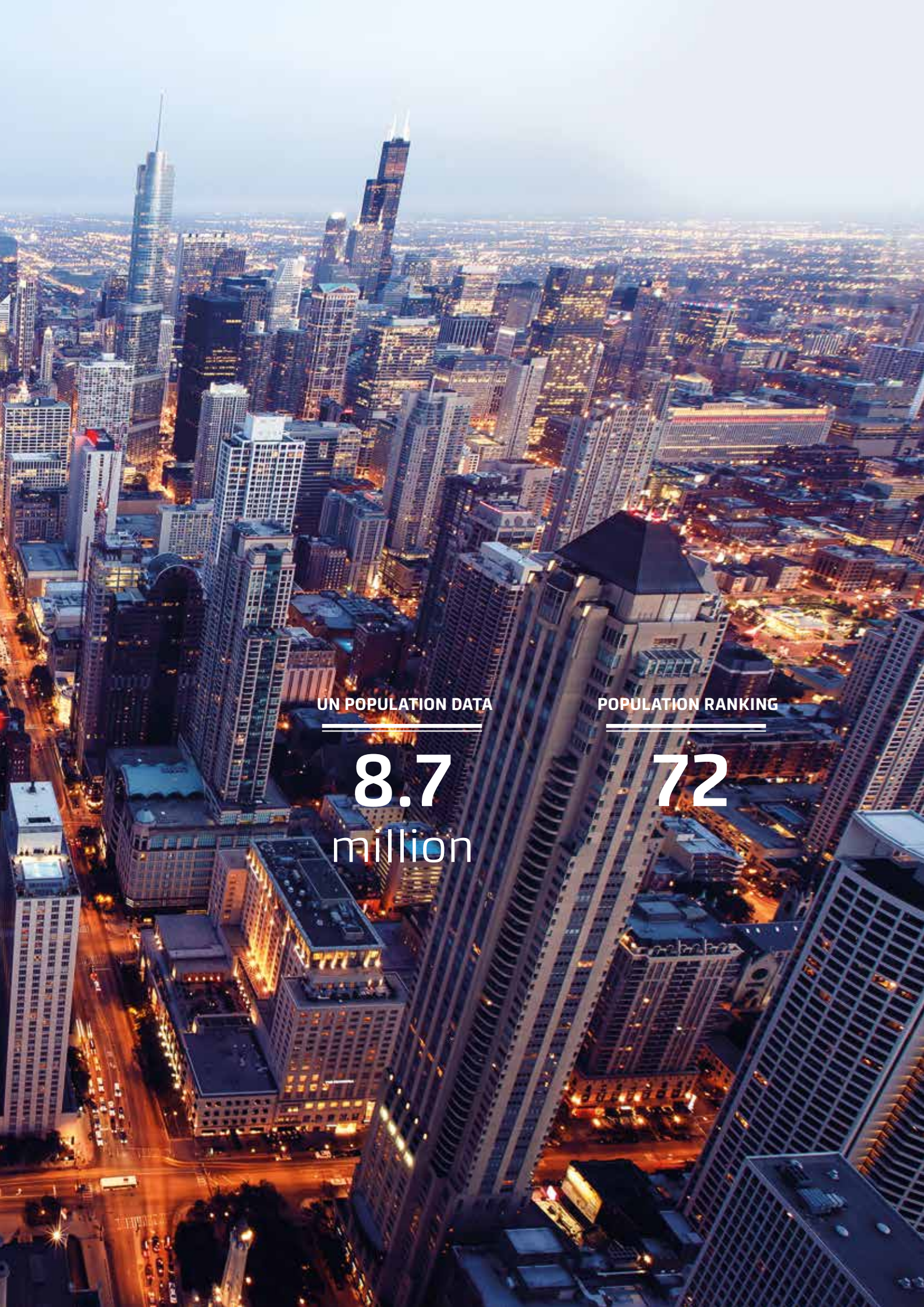
with the gradual inclusion of local actors (mostly municipalities) and civil society organizations (NGOs, *cooperativas*, grass-roots movements, users and consumer's associations, resident's movements and associations) that are usually excluded from water and sanitation management.

Chicago

An aerial photograph of the Chicago skyline at dusk. The city is illuminated with warm lights, and the sky is a deep blue. The Lake Michigan is visible in the background. The foreground shows a large, modern building with a grid-like facade.

Tim Loftus,
Texas State University

Mary Ann Dickinson,
Alliance for Water Efficiency



UN POPULATION DATA

8.7
million

POPULATION RANKING

72

Chicago

The City of **Chicago** is the third-largest city in the United States and is home to 8.3 million people. It is situated 179 m above sea level in a metropolitan region that has a continental climate with warm summers, cold winters and an average annual precipitation of 937 mm.

Throughout its history, Chicago has attracted immigrants due to the privileged natural environment associated with Lake Michigan and its economic potential for trade. The city is renowned for its architecture and the buildings situated along the Chicago River. The river itself is famous for having its flow reversed by engineers, with the aim of improving sanitation and enabling fluvial transportation of goods downstream to the Gulf of Mexico. The Chicago Area Waterway System (CAWS) is a 77-mile network of canals which has expanded in stages from its original conception.

In the Chicago Metropolitan Region, local municipal governments are responsible for 85% of community water supplies. While over 6.4 million inhabitants in 168 communities (the majority in the Chicago region) rely on Lake Michigan for their water supply, 111 other communities in the region are groundwater dependent. The City of Chicago is currently implementing a MeterSave programme to install 15,000 water meters per year. At present, more

than 80% of water sold is metered. Combined with the rehabilitation of old drinking water mains, energy efficiency gains aim to reduce carbon emissions and save more than US\$7.5 million in energy and operating costs.

Because of its relatively flat surroundings, portions of the Chicago Metropolitan Region are vulnerable to floods, with record-setting floods occurring in 1986 and 1987. Annual flood damage has been estimated to range between US\$41 million and US\$150 million in the Chicago region, affecting approximately 20,000 homes and businesses. Nearly 100% of the city's 8,000 km of sewers are combined stormwater and sanitary sewers, and heavy investments are being made to limit combined sewer overflows into Lake Michigan during heavy rain episodes.

In addition, Chicago has developed a Green Infrastructure (GI) strategy related to construction and planning to limit runoff and, thus, minimize the consequences of flooding, reduce polluted water discharge,



enhance environmental quality, and increase the city's resilience to extreme rain events and climate change. The strategy treats precipitation as a resource rather than a nuisance and generates co-benefits beyond reduction in threats or damage from flooding.

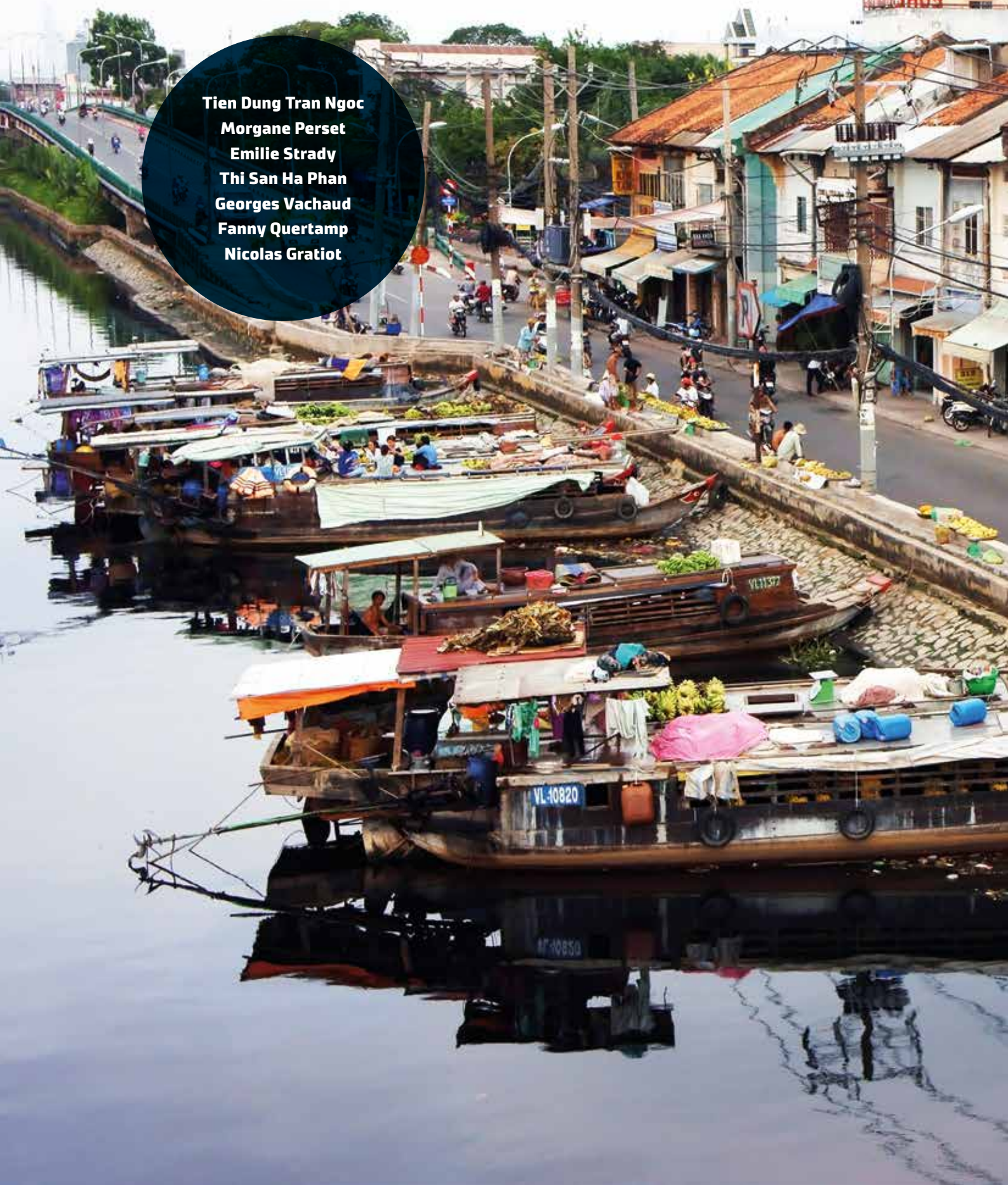
Examples of green stormwater infrastructure include: Green Roofs; Green Alleys, which replace impervious pavements with permeable walking surfaces; Green Streets, which increase the urban tree canopy; Downspout Disconnections; and Sustainable Backyards, which make beneficial use of rainwater. US\$50 million has been invested to support these initiatives with an estimated reduction in runoff of 1 million m³ each year. Enhanced coordination between city departments that manage and use public space, innovative infrastructure design, improved local regulation deployment, and increased awareness among citizens on the benefits of GI, complement policies aimed at developing a keener understanding of

the costs and benefits of using green infrastructure to manage stormwater at a large scale.

The RainReady programme provides outreach, guidance with financing, and training courses and workshops to enable homeowners and communities alike to reduce impacts from local flooding. After a local assessment of structural and environmental home conditions, homeowners and RainReady experts jointly develop a customized solution to help improve neighbourhood resistance to flooding. RainReady works to attract funding from local, state and federal sources that aim to address flooding or water quality problems associated with stormwater. Collectively, these initiatives are working to position Chicago as a US leader in the use of twenty-first century green infrastructure to improve neighbourhoods, adapt to climate change and meet other sustainable development objectives.

Ho Chi Minh City

Tien Dung Tran Ngoc
Morgane Perset
Emilie Strady
Thi San Ha Phan
Georges Vachaud
Fanny Quertamp
Nicolas Gratiot



V



UN POPULATION DATA

7.1
million

POPULATION RANKING

82

Ho Chi Minh City

Ho Chi Minh City (HCMC) covers 2,096 km² and is home to almost 10 million inhabitants (8.1 million according to the 2014 census), and one of the most important megacities in South-East Asia. The city's population grows at about 3% per year, resulting in major socio-economic and demographic changes. Since 2000, about 16 km² of this territory has been urbanized every year. The urban area has exceeded its administrative borders and HCMC has become the centre of a metropolitan area of 19 million inhabitants.

Water is ubiquitous in HCMC with a network of about 800 km of watercourses and canals. Compared to other megacities in South-East Asia and India, since the seventeenth century, the city has been developed on a delta plain favourable to environmental services such as freshwater supply, flood control, navigation and commercial shipping. These assets were altered during the twentieth century by the filling of canals and the creation of artificial wetlands. Today, rapid urbanization and the effects of climate change make HCMC one of the most vulnerable megacities in the world to flood hazard. This vulnerability is linked to sea level rise, rainfall intensification and ground subsidence, which can reach 0.02 m/year (in some geological areas), while 65% of the city is located at less than 1.5 m above sea level. In addition, the imperviousness of soils reduces infiltration potential and increases the risk

of flooding. To combat these risks, HCMC has built new infrastructures (sewers, dikes and floodgates) and its future projects are oriented towards the creation of wetlands and artificial lakes to restore lost ecological services.

Regarding access to drinking water, the megacity owns 5,460 km of water networks managed by the Saigon Water Corporation, a state-owned company. The water price is set by the local authorities, who voluntarily maintain it at a low level, so as to ensure access to drinking water for a large number of inhabitants (~US\$0.45/m³). According to recent studies, 85% of the population is connected to the water network (its present capacity is about 1.7 million m³/day).

The water supply system basically uses surface water from the Dong Nai and Sai Gon rivers (94% of daily supply, with the remaining 6% of daily supply drawn from



groundwater). Therefore, HCMC's water supply is particularly vulnerable both to the intrusion of saline water and the pollution of rivers. The situation is exacerbated by the fact that 90% of wastewater (or runoff) is dumped without treatment, because of lack of capacity in the sewer network. Between 2001 and 2011, the sewerage network was extended from 516 km to 3,095 km, however the scope of the project was not sufficient to prevent the degradation of surface waters.

Nowadays, HCMC is moving from a separate infrastructural and sectorial policy to a cross-functional and integrated one, taking into account urban sustainability goals, the preservation of environmental services and adaptation to climate change. From a political point of view, this new approach is characterized by the creation of specific entities dedicated to climate change and flood hazards. In

terms of planning, the technical services are progressively integrating the principle of hydraulic compensation in accordance with legal regulations, in order to curb the cross-effects of urbanization and flooding.

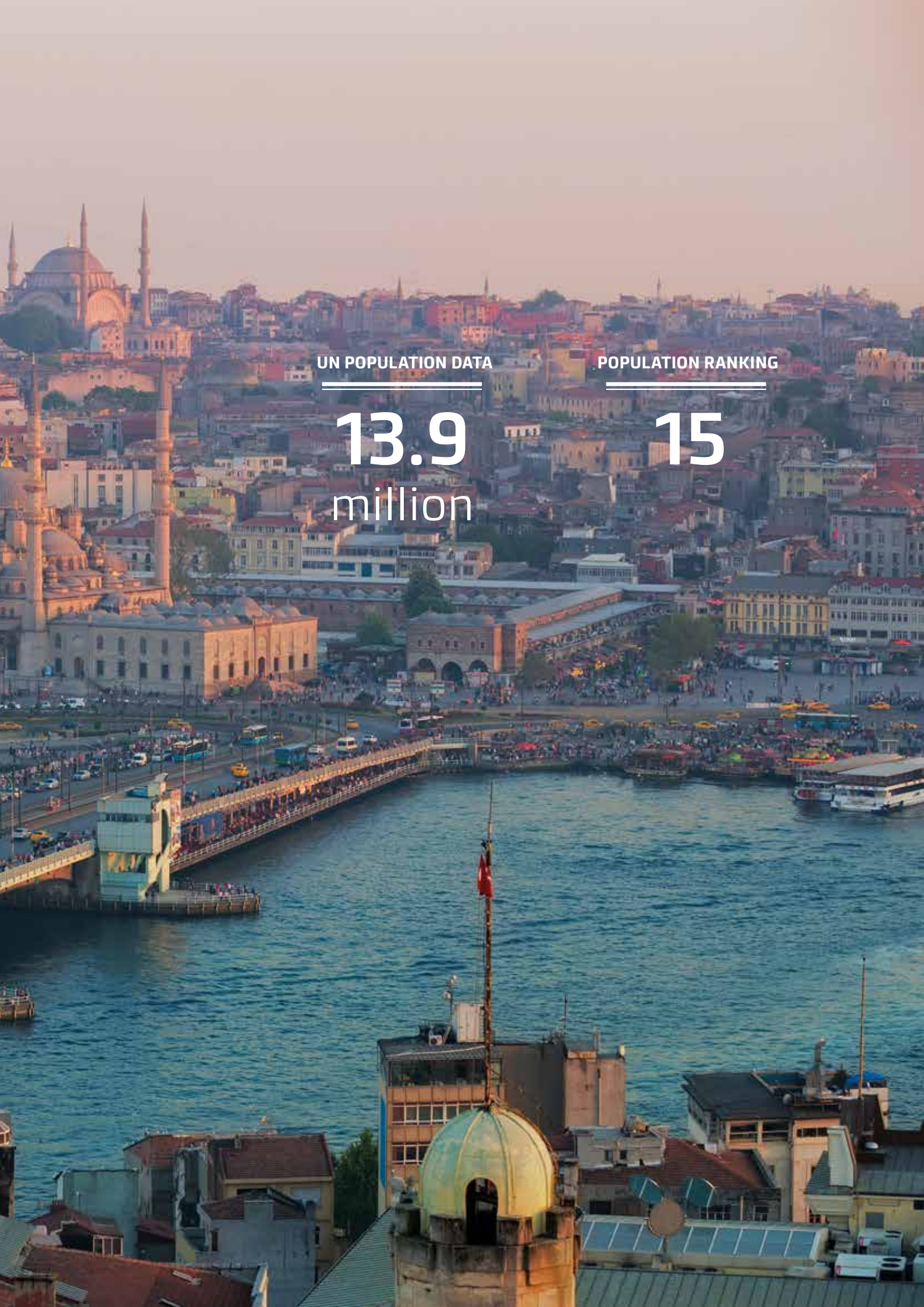
Special attention is also being given to environmental areas (wetlands and mangrove swamps), which are seen as the 'green lungs' of the megacity, providing better air quality and also an effective means of flood protection. A project to develop a network of multifunctional parks combining the creation of retention ponds and green areas is ongoing. These structural transformations should be followed by practical and efficient action, such as the strengthening of hydro-meteorological forecast capabilities.

Istanbul

Izzet Ozturk,
Istanbul Technical University

Dursun Atilla Altay,
Istanbul Water and Sewerage
Administration (ISKI)





UN POPULATION DATA

POPULATION RANKING

13.9
million

15

Istanbul

Istanbul is the only city located on the continents of both Asia and Europe, and has served for centuries as the capital of three empires. Today, it is the commercial and financial centre of the Turkish Republic, and has an urban population of around 15 million. The city was founded under the name of Constantinople around BC 659, and its first major water structures were built during the Roman Period. It then became the capital of the Byzantine Empire, which focused on the construction of cisterns throughout the city. Following the conquest of Constantinople in 1453, the Ottoman Empire developed a unique water civilization, including the rehabilitation of historic water structures, the usage of aqueducts for water flow and the construction of four dams.

The Istanbul Water and Sewerage Administration (ISKI) was founded by the Istanbul Metropolitan Municipality in 1981, and remains the responsible institution for water supply and wastewater management throughout the city. One of the ISKI's most successful projects was the Golden Horn Rehabilitation Project to clean the waters of the Golden Horn estuary, which connects to the Sea of Marmara.

The water demand of Istanbul, based on 175~250 l/person/day equivalent (losses included), was ~950 million m³/year in 2015, and will reach ~1,700 million m³/year in 2040. Ninety-eight per cent of water is supplied from surface waters mainly beyond provincial boundaries. Total water capacity increased to 2,100 m³/year in 2014, with adequate water resources

projected for 2018 - taking into account the three-year drought. The total capacity of existing water treatment plants is nearly ~4.4 million m³/day. Municipal wastewater infrastructure in Istanbul is not as developed as the water supply system. A part of the existing sewer network is a combined system and overflows during intense precipitation. Stream remediations have already been accelerated and separate systems for wastewater and stormwater collection are planned. About 60% of domestic and industrial wastewaters are connected to pre-treatment and marine outfall systems, with the remaining 40% connected to biological and advanced biological wastewater treatment plants (WWTPs).

In 2014, 98% of municipal wastewater was connected to WWTPs, designed as



activated sludge systems with nutrient removal. Industrial wastewaters from urban areas are discharged into the sewer network after pre-treatment by ISKI. The Istanbul Master Plan (1999) requires preliminary treatment for Kadikoy, Yenikapi and Baltalimani WWTPs prior to discharge into the lower layers of the Bosphorus, and secondary biological treatment for Tuzla, Kucukcekmece, Atakoy, Ambarli and Buyukcekmece WWTPs prior to discharge into the Marmara seabed. Over the long term, these facilities, including the Pasakoy WWTP, will be converted to tertiary biological treatment. More than 80% of the activities envisaged in the Master Plan have been performed by ISKI. Accordingly, the total investment requirement for water supply, wastewater management, stormwater collection and stream reclamation is estimated at approximately US\$9.7 billion (for 2000-2020).

On the basis of the IPCC Fifth Assessment Report, the Turkish State Metrological Service conducted climate modelling for the RCP4.5 and 8.5 scenarios. In addition, the study *Climate Change Projections According to New Scenario in Turkey* described the condition of the region where Istanbul's main water sources are found. The project 'Climate Change

Impacts on the Future of the Water Sources for Istanbul and Turkey', launched by the Turkish Water Foundation, highlights the importance of inter-basin water transfers, and the 'Climate Change Impacts on Water Resources of Turkey Project' examines changes in water potential in river basins. Within this framework, ISKI is implementing the following measures, as part of its current Strategic Plans (2011-2015, 2016-2020), to increase climate change adaptation capacity:

- *Mitigating the risk of drought and securing water supply:* measures include water transfers between water basins, aquifer restoration, reduction of non-revenue (unbilled) water and the use of reclaimed wastewater.
- *Ensuring the effective and efficient use of water:* ISKI applies a gradual tariff whereby consumers that consume water more efficiently (<10 m³/house/month) pay less.
- *Increasing renewable energy use:* Renewable resources such as wind power, solar energy and biogas/biomass energy are being utilized.
- *Flood control and stream rehabilitation:* Rehabilitation of high-risk creeks and expropriation of buildings in high-risk areas has been completed to a large extent.

Lagos



Akomeno Oteri,
Akute Geo-Resource Ltd.

R.A. Ayeni,
Hanorado Global Solutions
Nig Ltd.

UN POPULATION DATA

POPULATION RANKING

12.6
million

19



Lagos

Lagos State, Nigeria's largest city, is located in the south-western region of Nigeria, and encompasses an area of 3,577 km². Lagos sits on a coastal plain characterized by flat terrain at an average elevation of 15 m above sea level. Water bodies and wetlands cover over 40% of the total land area. The population of Lagos State was 17.5 million in 2006 with a growth rate of 3.2%. It is one of the fastest growing cities in the world and in 2015 the population was estimated at 23.3 million. The city has 57 local government administrative units.

Lagos is a megacity with an agglomeration of urban, peri-urban and rural communities, 32.5 of which are located in urban areas. The city has a high population living in informal housing, with two out of every three people living in slums.

The Water Sector of Lagos consists of a tripartite governance framework:

- Policy development, formulation review, monitoring and evaluation;
- Service provision, water supply and sanitation/wastewater management; and
- Regulation.

These three activities are undertaken by bodies independent of one another.

Rainfall varies across the city: in 2013, the highest annual value was 1927 mm and the lowest value was 825 mm. With its high mean annual rainfall, Lagos has abundant surface water resources. The main water provider for the city, Lagos

Water Corporation, provides water of good quality that conforms to the Nigerian Standard at the point of production. The total water demand is estimated at 2.5 million m³/day and end-user water demand is 136.4 litres/inhabitant/day. Water production by the Lagos Water Corporation amounts to nearly 1 million m³/day. There is, however, a gap between water demand and the water supplied; this gap is met by individuals through dug wells and boreholes. Industrial water supply is predominantly drawn from groundwater.

Despite the fact that drinking water production by the Lagos Water Corporation draws mainly from surface water sources, more people depend on groundwater from two aquifers in the city. The Lagos Water Corporation has a poor record of operating and maintaining groundwater schemes.



In order to meet the demand gap, the Lagos Water Corporation has developed a Lagos Water Supply Master Plan (2010-2020). The primary goal of this Master Plan is to supply water to all residents of the city by December 2020. The cost implications of the Lagos Water Supply Master Plan, which aims to produce 3.38 mm³/day, are estimated at US\$2,486 billion. The water resources of the city also face pollution challenges from saltwater intrusion and oil pollution from industry.

Lagos has no main sewerage system. Wastewater treatment and central sewage facilities are still rudimentary. Sewage disposal from domestic sources occurs predominantly through the use of septic tanks. Since 2010, the Lagos State Waste Management Office has pursued the rehabilitation of old wastewater treatment plants and the construction of new ones. As a result, the total functional wastewater infrastructure increased from 0.04% to 6%.

Most parts of Lagos are low lying with a high water table. This creates a flood risk. In 2011, Lagos was inundated with floodwaters. Effective flood management will include, among others:

- Early warning methods in the form of

regular rain pattern prediction in liaison with the Nigerian Meteorological Agency (NIMET);

- The preparation of drainage master plans; and
- Implementation of the designs followed by the operation and maintenance of flood drainage systems.

The Lagos Water Corporation charges a very low tariff, significantly lower than that charged by any state water board, and operates a public-private partnership at much lower cost than private water supplies.

Two pressing issues for the future of Lagos's water supply are:

- Climate change, especially rising sea level and/or higher rainfall, as well as higher seawaters; and
- Urban development in Ogun State, which surrounds Lagos to the north-east.

The key elements of the state's current strategy to combat climate change are:

- A public awareness and prevention campaign; and
- A climate change mitigation and adaptation programme.

London

Jo Parker,
Watershed Associates Ltd.



UN POPULATION DATA

10.2
million

POPULATION RANKING

27



London

London is the largest urban area and capital city of the United Kingdom, with a population of 8.6 million and a forecast of 11 million by 2050. Its economy is based on service industries, while the city itself is one of the world's leading financial centres. London enjoys a good transport infrastructure and the average life expectancy of residents is high. It is also a major tourist destination, often cited as the most visited city in the world.

London was first developed by the Romans as a port on the River Thames, which had a vast influence on its history and development. Much of the east and north-east of the city lies on the Thames floodplain. By the nineteenth-century, London was the largest city in the world and was facing major problems of public health and environmental deterioration.

During the second half of the nineteenth century, a substantial amount of work was carried out to develop new water supplies. During this time, major improvements were also made to the sewerage system including the design and construction of an extensive network and over 100 km of major interceptors, although provision of sewage treatment had to wait until the end of the century. Today, the majority (70%) of London's water supplies derives from the Thames and its network of tributaries, with the rest coming from boreholes. London also has one of the oldest water and wastewater infrastructures in the

world. More than half the mains are over 100 years old and a third are over 150 years old.

To address the challenges involved in maintaining this system, the government privatized the water authorities in 1989 and introduced strict financial and regulatory controls with the creation of a Director General of Water Services (Ofwat). Further regulatory provisions were made through the Water Industry Act in 1991, with the Ministry for Environment setting out the functions and powers of the Environment Agency (EA) and the Drinking Water Inspectorate (DWI).

The average Thames Water bill is £354/year and more than two-thirds of customers pay a flat rate for the water they use.

The impact of climate change on London will be wide ranging and substantial. This will include:

- Increased water demand driven by the



impact of rising temperatures and the trend towards smaller households, which are less water efficient;

- Reduction in the amount of water available for abstraction in the London basin from 2079 MI/day in 2014/15 to 2002 MI/day in 2034/35;
- Increase in the risk of flooding of critical infrastructure, already observed by the increased operation of the Thames Barrier;
- Increase in the number of discharges from sewer overflows as rainfall becomes more intense; and
- Increase in energy demand as pumping and treatment respond to rainfall and demand.

Technical modernization as well as world firsts, such as river basin approaches or the creation of the tri-partite regulatory model, have established a long-standing tradition of innovation in the United Kingdom. Today, London is working to find novel approaches to tackling the challenges posed by climate change. More proactive communication and engagement with customers and communities are used

to support initiatives in water efficiency or the management of debris discharged in sewers, and to understand customers' priorities.

Asset management tools and techniques are driving the optimization of investment across the huge asset base. Water recycling and water-efficient fittings have been tested at public scale (e.g. the Millennium Dome) and at domestic level, with the lessons learnt being implemented, among other places, at the Olympic site (with 40% lower water use than other similar venues). Partnerships such as Drain London are used to sustainably manage surface water. For tidal and fluvial flooding, the EA introduced a more cohesive and collaborative approach based on monitoring and modelling of the river, enabling impact assessment over both the short and the long term.

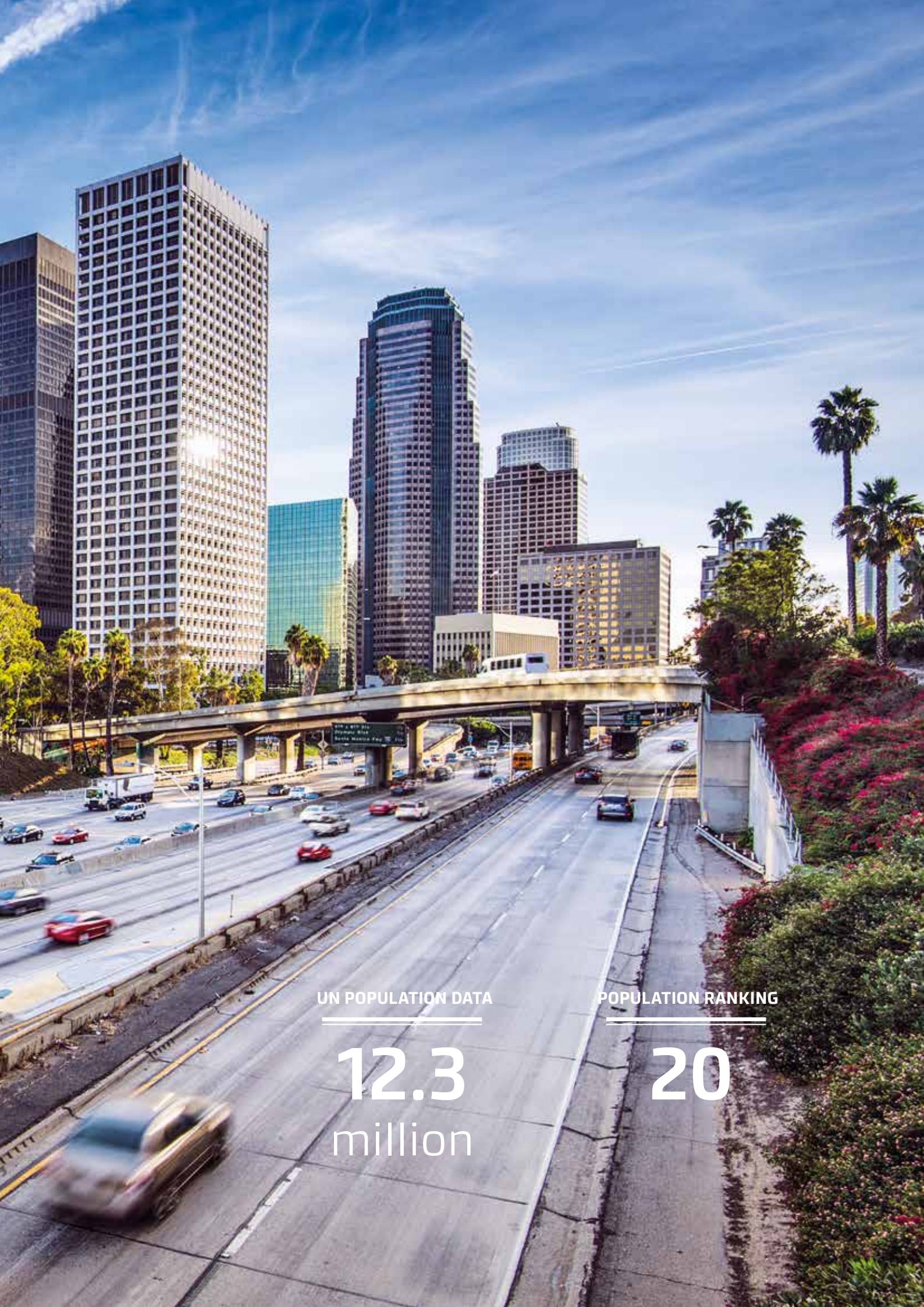
Today, Londoners enjoy continuous water and wastewater service. To address the challenges of climate change, London continues to innovate by developing partnerships and engaging proactively with customers and communities.

Los Angeles



Adel Hagekhalil,
Bureau of Sanitation of the
City of Los Angeles

Inge Wiersema,
Carollo Engineers



UN POPULATION DATA

12.3
million

POPULATION RANKING

20

Los Angeles

The City of **Los Angeles** (LA) has 4 million residents and forms the economic centre of the greater LA area, which is inhabited by 13 million people. The city is located along the Pacific Ocean in Southern California and is known for its warm climate, beautiful beaches and as the centre of the American entertainment industry.

The city's Mediterranean climate provides sunshine but only an average of 15 inches (38 cm) of rainfall/year. Rainfall from large watersheds was historically recharged into the underlying groundwater basins. However, due to rapid urbanization in the early 1900s, the city started exploring new water supply options, which resulted in three major aqueduct systems that import water from far away. Additionally, the city utilizes local groundwater, recycled water and water conservation to meet its water needs.

Many of LA's traditional water supply sources are becoming increasingly more constrained due to groundwater contamination, environmental restrictions and climate change impacts, such as reduced snowpack and prolonged droughts. Two key initiatives to achieve a more sustainable water supply are the Mayor's Executive Directive No. 5 and the city's 2015 Sustainability Plan. The former set goals for 25% water conservation by 2035 and a reduction in purchased imported water supplies to less than 50% by 2025, while the latter aims to achieve

50% locally sourced water by year 2035. To achieve these goals, the city is accelerating local supply development efforts to make recycled water and stormwater a larger part of the city's supply portfolio, while continuing proactive water conservation efforts.

Conservation

Los Angeles has a long history of implementing water conservation programmes and recently set new aggressive goals in response to the ongoing severe statewide drought. Due to these efforts, the city's water usage in 2015 was approximately the same level as 45 years ago, despite a population increase of more than 1 million.

Water recycling

The city's sewer collection system conveys wastewater to four wastewater treatment plants of which three include additional treatment facilities that produce recycled water. The city is committed to



significantly increasing the use of recycled water through a multi-pronged approach consisting of Non-Potable Reuse (NPR), Indirect Potable Reuse (IPR) and potentially Direct Potable Reuse (DPR).

Los Angeles has identified recycled water pipeline expansion segments that will collectively increase the city's current NPR amount from 12.3 million m³/year (10,000 acre-foot/year) to 55.5 million m³/year (45,000 afy) by 2040. The city is also moving forward with an IPR project that aims to produce 37 million m³/year (30,000 afy) of recycled water by 2024, along with a groundwater remediation project for the same basin by 2021. Additionally, the city is currently evaluating options for additional large-scale IPR projects and is exploring possibilities for DPR in the future.

Stormwater capture and reuse

Stormwater is an underutilized local water resource because it is difficult to capture and recharge due to the city's highly urbanized landscape and its hydrology characteristics. However, stormwater capture has become a priority as a local

water supply source and as a means to improve the water quality of LA's marine life and beaches. To increase the utilization of stormwater, the city has set aggressive goals in its Sustainability Plan to double stormwater capture and recharge to 185 million m³/year (150,000 afy) by 2035.

Planning for the future

To address its water challenges, the city is currently developing the 'One Water LA 2040 Plan', which takes an integrated approach to managing all water resources. Traditionally, municipalities have been hindered by working in a compartmentalized fashion, with separate departments focusing on only one or a few aspects of water, such as drinking water, wastewater, recycled water, stormwater and so on. The One Water LA 2040 Plan works to eliminate these compartments and proactively plan for the future with a strong focus on local supply development, collaborative policies and integrated water management solutions that will make Los Angeles a more sustainable and resilient city.

Manila

Arjun Thapan,
WaterLinks



UN POPULATION DATA

12.7
million

POPULATION RANKING

18



Manila

Manila is situated on the plain of the Pasig River that flows into Manila Bay. The city has a tropical climate with mean temperatures ranging from 20°C to 38°C. Metro Manila, comprising 17 municipalities, covers an area of about 636 km². The total urban area has a population of 24 million, while the estimated population density is 19,130 persons/km², one of the highest in the world.

The municipalities of Metro Manila function autonomously under elected mayors. This arrangement does not allow for holistic urban planning or management. Unified urban management institutions are absent, as is the unified design and execution of integrated projects.

Numerous facets of climate change will seriously affect Manila, more so than many other large cities. A temperature rise of 4°C by the end of the century is forecast, accompanied by an estimated sea level rise of up to 2 m. Saline intrusion into groundwater has already been observed, and extended wet and dry seasons will cause further uncertainties. At least 20% of the land area is considered prone to flooding. The city has had a high rainfall regime over the 30 years up to 1990, with annual precipitation ranging from 1,834 mm to 2,257 mm.

The water infrastructure assets in Manila are publicly owned by the Metropolitan Water and Sewerage System (MWSS), created in 1971. Two private

concessionaires have managed water and sewerage services since July 1997: the Manila Water Company Inc. (MWCI-east zone) and Maynilad Water Services Inc. (MWSI-west zone). The concession agreements initially lasted for 25 years. MWSS is responsible for two separate functions: to regulate and administer and manage retained assets and existing loans, thereby facilitating bulk water supplies, and to develop new water sources.

Manila's freshwater supplies come from three dams: Angat, Ipo and La Mesa. A total of 4 million m³ of raw water/day are available to the two private sector concessionaires in Manila. MWSS also draws 1 million m³ from Laguna de Bay. Although Manila has achieved almost 99% coverage in terms of access to drinking water, less than 15% of the city's population is connected to a sewerage system. Indeed, less than half of wastewater produced in the city is provided with sewage treatment. Plans are under development for full sewerage



coverage across the city by 2037. MWSS estimates that there are about 2.17 million septic tanks in Manila, with up to 75% of pollution caused by residential sewage.

The absence of effective wastewater treatment and the clogging of most water bodies with solid waste have created an appalling public health situation in Manila. The Marikina and Pasig rivers are biologically dead. In 2008, the authorities concerned were obliged to take specific actions relating to the clean up of Manila Bay, and MWCI and MWSI were required to plan city-wide sanitation and sewerage investments. As a result, both concessionaires have made progress in sanitation service delivery.

Since the award of the concessions in 1997, 24/7 water supply has become the norm, water pressure is uniformly good and water quality meets standards. Average consumption in Manila is estimated at 300 litres/inhabitant/day. However, there is continued loss of large quantities of treated water due to leaks.

In May 2015, the basic water charge was US\$0.583/m³ for areas covered by MWCI and US\$0.704 for MWSI. Civil society organizations in Manila have been active, keeping a close watch on the performance of the two concessionaires and promoting community-led water supply schemes for the population of informal settlers.

Projected water demand in 2037 is 74.3 m³/s against current demand of 35.9 m³/s. The ability of the Angat reservoir to provide more than 46.3 m³/s is uncertain. Manila has one of Asia's best water supply services, and a fast-improving and expanding wastewater management service. However, the improvement of Manila's inadequate urban water infrastructure, and efforts to improve its poor organization and management, will be important elements in any plan to accomplish the sustainable development of one of Asia's largest megacities.

Mexico

An aerial photograph of Mexico City, showing a dense urban landscape with numerous skyscrapers and buildings. A prominent dark circular overlay is positioned in the upper left quadrant, containing the name 'Rubén Chávez' and the acronym 'CONAGUA'. The city's skyline extends into the distance under a clear sky.

Rubén Chávez,
CONAGUA

UN POPULATION DATA

POPULATION RANKING

20.8
million

4



Mexico

The **Mexico** City Metropolitan Area (MCMA) occupies much of the Mexico Valley Basin. It is at once the capital of the country and its political, economic, religious and commercial hub. The basin, closed in its natural state, is bounded in the four cardinal directions by mountain ranges, so that precipitation within it generates rivers, streams and springs, whose waters flows into five large permanent lakes and several smaller ones, extending to the lower reaches of the valley.

Until the end of the nineteenth century, the basin housed a population of less than 1 million inhabitants, which is why the reduced water demand was met by the diversion of surface watercourses, from springs and numerous shallow wells. However, despite the lack of development and low population density of the time, public health issues were common due to flooding and a lack of sanitary drainage and basic sanitation infrastructure.

With the artificial drainage of the basin, which started in the seventeenth century, the great lakes slowly became desiccated, leaving large areas of the valley available for agricultural and urban use. During the twentieth century, the city and the villages scattered in the valley spread and were interconnected, engulfing agricultural areas, to become the current Mexico

City Metropolitan Area. Its population increased over 20 times in the course of the last 80 years, and now accomodates around 22 million people, accounting for one-fifth of the national population.

By far, the main water source in the basin is groundwater. Large-scale aquifer exploitation began in the late nineteenth century, when surface water sources were found to be insufficient for the growing water demands for all uses. Nowadays, the main sources are the basin aquifers, which supply two-thirds of the water demand of the MCMA. However, overexploitation of aquifers is the greatest water problem in the basin. During the last 60 years, groundwater levels have fallen across the valley. In turn, the progressive depletion of aquifer groundwater levels triggered the consolidation of clay layers



and, thus, differential land subsidence, which has caused serious damage to urban infrastructure, a severe drainage problem, and some peculiar and eye-catching manifestations (e.g. well casings converted into protruding poles several metres above the surface).

The population explosion in the basin imposed increasing pressure on groundwater reserves, so in the mid-twentieth century, the city began to import water from external basins. The great Cutzamala System became operational during the 1980s, with a main aqueduct covering a total length of 162 km, while the water it conveys must overcome a slope of about 1,366 m from origin to destination. Another major problem in the megacity is flooding: downpours caused by heavy rainfall continues to exceed the

capacity of the drainage system, triggering wastewater and rainwater floods that result in serious damage, mainly to lower economic capacity sectors of the metropolitan area.

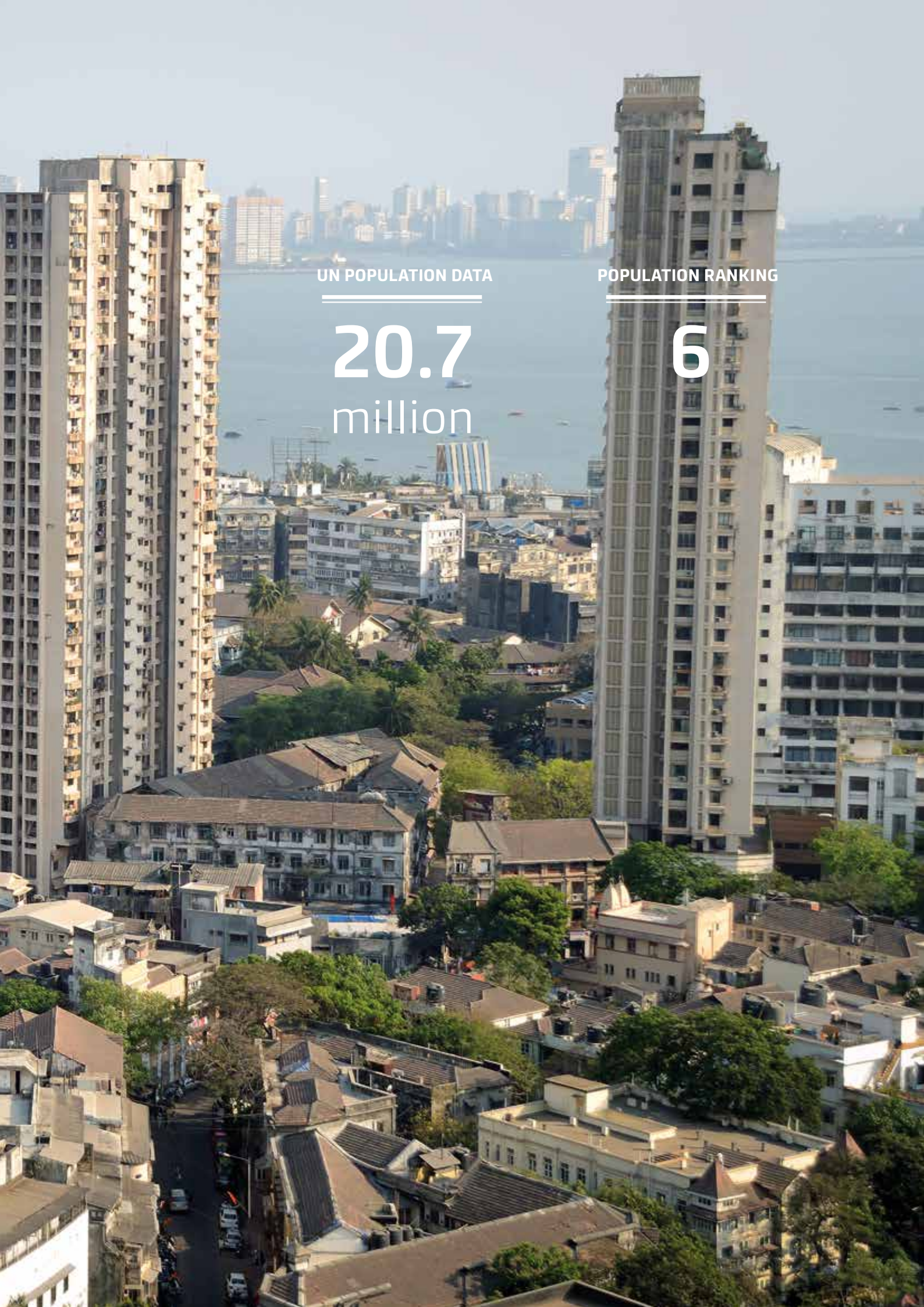
With regard to climate change, research studies conducted to estimate its potential impact on water resources in Mexico forecast that increased impacts are not expected in the Mexico Valley Basin. However, results indicate that an increase in temperature and a decrease in rainfall could be expected at the national level, the combined effect of which would produce a drastic decrease in runoff, infiltration and aquifer recharge, and the occurrence of more severe, frequent and prolonged droughts.

Mumbai

An aerial photograph of Mumbai, India, showing a dense urban landscape with numerous high-rise apartment buildings and older structures. The city is situated along a coastline, with a large body of water visible in the background. A prominent dark blue circle is overlaid on the center of the image, containing text.

Ashok Hukku,
TechVision Security
Consultants Pvt Ltd.

Jairaj Phatak,
Municipal Corporation
of Greater Mumbai



UN POPULATION DATA

20.7
million

POPULATION RANKING

6

Mumbai

Mumbai is the largest city in India. A large part of this megacity was reclaimed from the sea when the seven original islands were joined together, with the result that most of the city is at sea level. In 2011, the population of Mumbai reached 12.4 million. It had a high rate of growth, but is now showing signs of stabilization. Fifty-six percent of the citizens of Mumbai live in slums.

The City Council of Mumbai encompasses both the city and suburbs. For ease of administration the city is divided into 24 wards with local government offices in each ward. These offices handle day-to-day operations and maintenance of municipal works. The Municipal Commissioner, appointed by the state government, manages the city and is responsible for the administration of all 24 wards.

Wastewater from the city is released into the River Mithi throughout the year. This river originates from the overflow of the Vihar and Tulsi lakes during the monsoon months. The last 6 km of the river face considerable tidal action, which results in flooding. The 2005 floods in Mumbai from this river caused considerable damage, estimated at US\$37 million.

Managing water supply and sewerage is an obligatory function of the City Council. Water supply and sewerage are given a separate sub-budget and the entire process is supervised by the Municipal Commissioner. Community participation in water supply plays an important role and is largely achieved at the ward office level.

Ninety-seven per cent of Mumbai's water supply (3.7 million m³/day) comes from large lakes created by dams on rivers. These dams are located at a distance of 100 km from the city, and were built from 1955 onwards.

The Municipal Corporation sets water pricing for different categories of consumers. The price of water to the poorest domestic consumers in Mumbai is about US\$0.08/m³. Industrial and commercial users subsidize slum-dwellers and other poor people.

A Water Distribution Improvement Programme is underway to accomplish the following:

- Upgrade the water distribution network to provide continuous supply;
- Reduce UFW (unaccounted for water)/NRW (non-revenue water);
- Roll-out universal metering to improve information and water billing;
- Introduce a telescopic tariff structure for water consumption to aid in water conservation; and
- Reinforce system resilience to ensure 24/7 supply for all customers.



Although there are stray cases of contamination of water in slums, the tap water in Mumbai is largely safe to drink.

Average consumption in Mumbai is 190 litres/inhabitant/day; as such, the distributed quantity of water is quite adequate for the population. Even though there are only 75% metered connections, the main challenge is to improve distribution and to provide a constant supply to all.

There has been improvement in water supply in Mumbai, but issues stemming from endemic poverty and informal housing structures have placed end users at risk.

Sewerage networks only cover about 65% of the population of Greater Mumbai. Sewerage taxes are recovered through water bills and normally account for 60% of the average water bill.

The Mumbai Sewage Disposal Project I (MSDP-I) was completed in 2009. Upgrading of sewage treatment plants and networks has resulted in improvements to coastal water quality, health and aesthetic benefits, and increased fish yields. Although substantial progress has been made overall, expectations of a world-class city sewerage system are yet not fulfilled in Mumbai.

Mumbai is frequently subjected to extreme storm events. Maintenance of stormwater infrastructure is therefore a high priority for the city. All drains are cleaned prior to monsoons in a major exercise to mitigate the destructive effects of heavy rains and floods.

Rainfall intensity during monsoons sometimes exceeds 100 mm/hr, and occurs a number of times per day. During the rainstorm of 26 July 2005, more than 900 mm of rainfall were recorded in 24 hours, underlining the need for effective disaster management (DM) procedures. To augment DM capability, Doppler radar was installed.

With regard to the impact of climate change on Mumbai, a 3°C rise in average temperature is expected during the current century. It is also anticipated that average daily rainfall will increase by 0.34 mm annually.

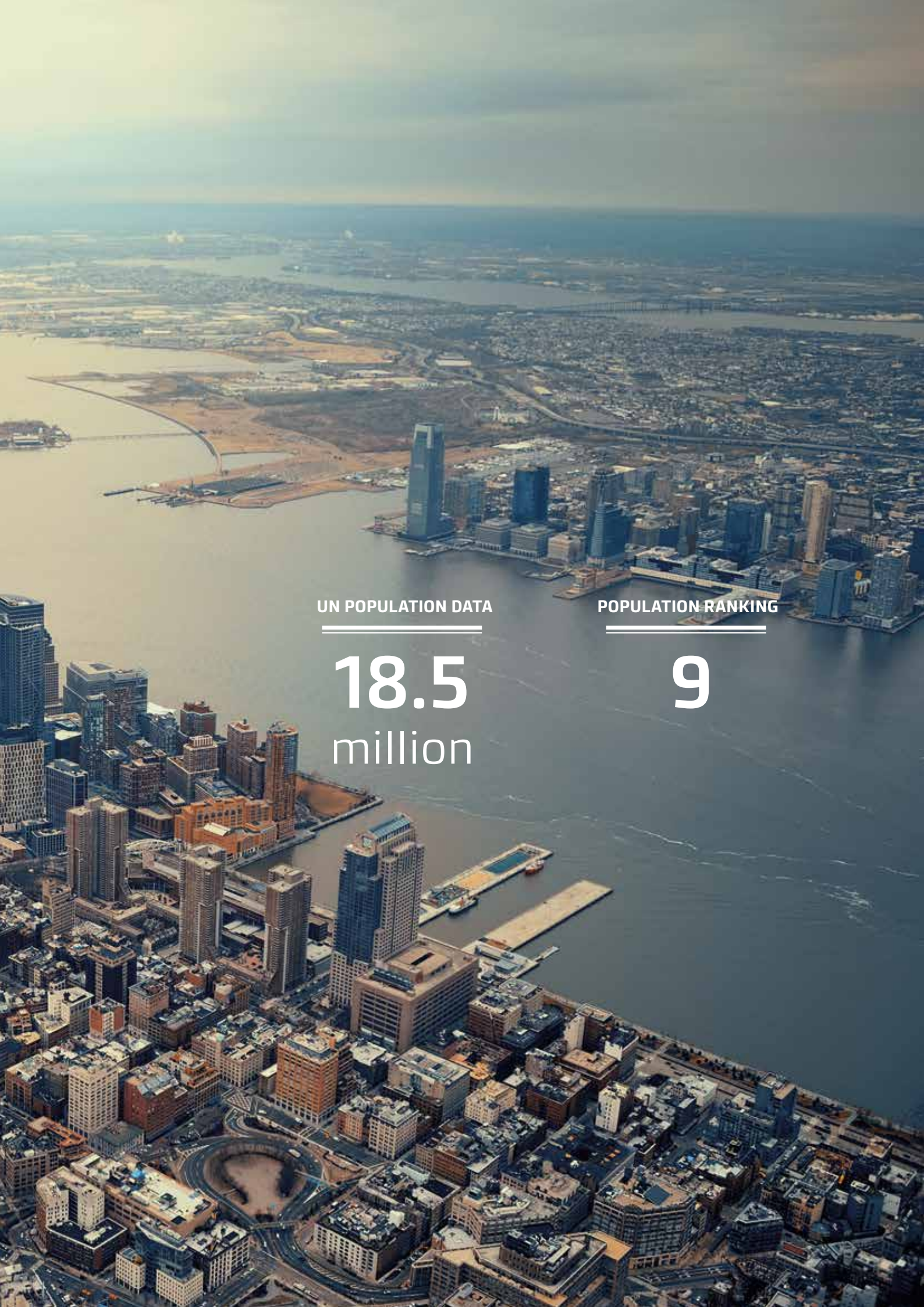
In addition, sea level rise in Mumbai has increased from 1.3 mm/year to 3.1 mm/year.

Mumbai faces many water-related risks. Very heavy rains during the monsoon weather and tidal actions experienced by the city continue to put it at significant risk of flooding.

New York

An aerial photograph of New York City, showing a dense cluster of skyscrapers in the foreground and middle ground. The Freedom Tower is prominent on the right side. The city extends to the water's edge, with a large body of water and distant landmasses visible in the background under a hazy sky.

Angela Licata,
New York City Department of
Environmental Protection



UN POPULATION DATA

POPULATION RANKING

18.5
million

9

New York

New York City (NYC) has the largest unfiltered water supply in the United States. More than 9 million customers and visitors rely on three extensive reservoir systems, including 19 reservoirs and three controlled lakes, which hold a storage capacity of nearly 2.2 trillion litres. This system was meticulously designed as an interconnected network that has ensured a flexible, reliable and resilient supply of drinking water for more than a century. Rain water and wastewater is conveyed via a 12,070-km network of sanitary storm and combined storm sewers, and treated by 14 large municipal wastewater treatment plants. Currently, long-range planning and adaptive management efforts are being undertaken by the city to address the challenging impacts of a growing population, aging infrastructure and climate change.

With nearly 8.4 million people, the city's population is at an all-time high, and is expected to reach 9 million by 2040. This increased population will strain the city's older infrastructure and test the reliability of municipal services. In response, the city is investing heavily in improving the redundancy, resiliency and inter-connections of its water delivery systems. For example, NYC is nearing completion of its third water tunnel and a new raw water supply inter-connection project.

As a coastal city, NYC faces growing risks from the impacts of global climate change, including rising sea levels, and increases in the intensity and frequency of hurricanes and coastal flood events that can affect both water and wastewater assets. For

instance, in 2011 Tropical Storms Irene and Lee resulted in high levels of sediment and bacteria in reservoirs and prompted unprecedented control measures. In 2012, Superstorm Sandy resulted in a storm surge that significantly affected NYC's wastewater assets, causing more than US\$95 million in damages to wastewater infrastructure, while knocking out power and critical equipment at key facilities on the waterfront. The city must also contend with climate change risks to the wastewater collection system as a result of high intensity rain events, or 'cloudbursts'.

In response, the city is accelerating efforts to mitigate climate risks, with a holistic green and grey strategy that



includes significant investment in green infrastructure to manage increasing volumes and intensities of stormwater. NYC is also investing in a Wastewater Resiliency Plan to protect waterfront treatment facilities from the impacts of coastal storms and sea level rise, while pursuing ambitious greenhouse gas reduction targets that include a goal to reach net-zero energy consumption at in-city wastewater treatment plants by 2050.

The Department of Environmental Protection (DEP) is integrating new tactics to manage both extreme and chronic climate events, through system optimization, green infrastructure, demand management and flood protection of critical facilities. These techniques can be adapted and expanded as monitoring highlights their efficacy, and as new information about climate change emerges. However, investments in resiliency and water quality improvements can compete with parallel needs to maintain a state of good repair, build new infrastructure, and invest in energy improvements to meet the city's ambitious greenhouse gas reduction goals, all while

ensuring affordability for the city's most vulnerable residents.

Climate change also presents challenges in the form of competing funding needs and moving targets for meeting regulatory requirements. Meeting water quality criteria may become a greater challenge as rainfall increases and as the physical and chemical characteristics of waterbodies shift. Furthermore, as the risks from heavy rainfall, sea level rise and storm surge increase, DEP will need to advance new methods and technologies for managing stormwater runoff to meet water quality, drainage and coastal protection objectives.

Moving forward, DEP continues to pursue long-term solutions that optimize capital, maintenance and operating costs, while minimizing environmental impacts. These solutions will leverage public and private partnerships, re-envision urban land use, improve existing infrastructure, and allow the city to develop tools to optimize and enhance the existing water and wastewater systems to adapt to a changing climate.

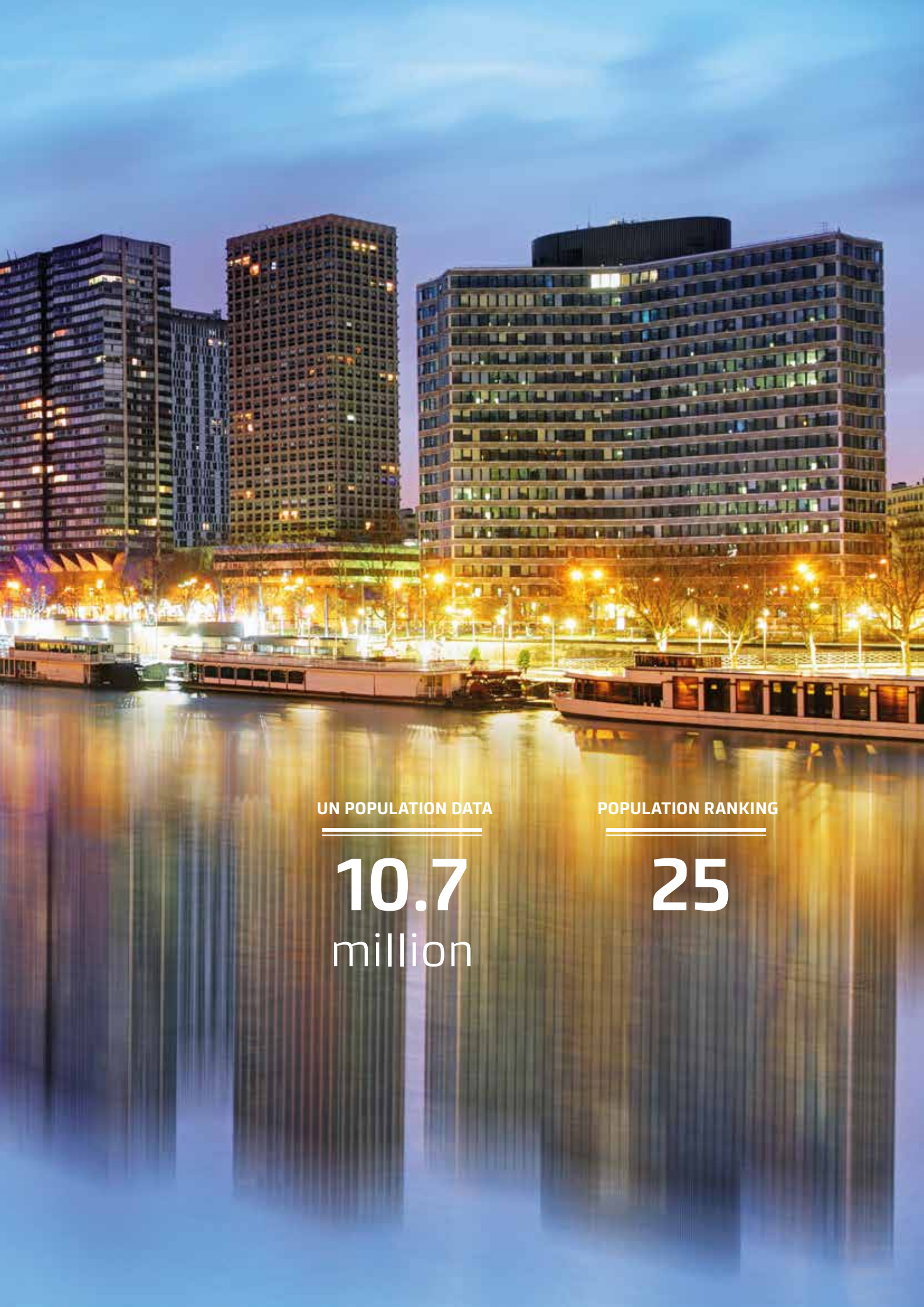
Paris

A nighttime photograph of the Paris skyline. The Eiffel Tower is on the left, illuminated and reflected in the water. To the right, several modern skyscrapers are lit up, with their lights reflecting in the water. The sky is a deep blue, and the overall scene is a vibrant cityscape at night.

Jean-Pierre Tabuchi,
SIAAP

Bruno Tassin,
Ecole des PontsParisTech

Cécile Blatrix,
AgroParisTech



UN POPULATION DATA

10.7
million

POPULATION RANKING

25

Paris

Greater **Paris**, considered as the continuous built-up area around the city, has 10.5 million inhabitants. It can be considered an old megacity that grew denser at its centre in the nineteenth century and at the periphery following the Second World War. It is located in a temperate climate that is relatively dry, with 650 mm of rainfall/year well distributed all year round.

Management of water in the central part of the urban area is largely dependent on water supply and sanitation infrastructure built between 1850 and 1890. A variety of drinking water networks developed progressively, while wastewater from the megacity is connected to a unique sewage system.

Half of the city's drinking water is transferred underground from places up to 100 km from the city centre, while the remaining half is produced from the Seine and Marne rivers. Drinking water for the suburbs originates mainly from waterways, especially the above rivers. Between 1949 and 1990, four reservoirs were built with a total capacity of 810 million m³, in order to ensure a minimal flow in summer in the Seine and Marne. The reservoirs also dilute treated wastewater, cool the city's power plants and reduce flood hazards on either side of the river.

Concerning wastewater, the city of Paris and the nearest suburban cities are served by a combined sewer system consisting of 2,100 km of main sewers, while the remaining parts of the suburbs are served by a separate system consisting of 650 km of rainwater main sewers and 450 km of wastewater main sewers. Six wastewater treatment plants clean the wastewater of the Paris megacity for a total capacity of 10 million population equivalent (dry weather) and 15 million population equivalent (wet weather). The purification capacity of Greater Paris has only recently caught up with requirements, resulting in an improvement in the water quality of the Seine, which is better now than 200 years ago.

As of January 2016, a new administrative structure, the 'Métropole du Grand Paris', has been set up. This major political change is predicted to lead to major institutional and governance changes in



the field of water, although it is too early to predict what form these will take.

Two major challenges lie ahead for water management in the Parisian megacity:

- The rate of population growth is estimated at 9% for 2012-2030 with possible modifications in population density distribution at the scale of the megacity. Accordingly, the key issues relate mainly to the development of sustainable rainwater management, based on the principle of restoration of the water balance. This will include a reduction in runoff and an increase in infiltration and evapotranspiration across the megacity, to be achieved through well-designed urban development. This will also help to reduce flood hazards. To a lesser extent, this population growth will also impact the purifying capacity of wastewater treatment plants in the megacity.
- The city must develop an adaptation strategy to climate change. Even if the consequences are not as severe as in other places and megacities elsewhere on the planet, they will not be negligible. The main consequences will include risks of long drought episodes, which will make it more difficult to preserve the water quality of rivers, especially the Seine, and to maintain drinking water supply for the Paris megacity. In addition, decrease in summer flows will reduce the dilution capacity of the river. Achieving the objectives of the EU water framework directive will, thus, become increasingly difficult and new wastewater management strategies, including urine-source separation, will have to be tested in the coming years.

Seoul



Yonghyo Park,
K-water

Kwansik Cho,
K-water

UN POPULATION DATA

POPULATION RANKING

9.8
million

29



Seoul

The development and rapid industrialization of the Republic of Korea in the 1960s and 1970s saw people move to the **Seoul Metropolitan Area** (Seoul and satellite cities) seeking decent jobs and better opportunities for their future. Today, the total population amounts to approximately 20 million, accounting for almost half of the country.

Annual precipitation reaches around 1,300 mm but is concentrated during the monsoon season from June to August. As a result, large dams have been built to control the continuous drought and floods. Local governments have final responsibility for drinking water supply, which is controlled and subsidized by the Ministry of Environment, while 50% (by capacity) of the country depends on bulk water supplied by K-water (Korea Water Resources Corporation), a state-owned enterprise (SOE) affiliated to the Ministry of Land, Infrastructure and Transportation. The quantity and quality of bulk water are decided at the planning stage, depending on the needs of local governments. The tariff is the same throughout the country, but varies depending on water quality (treated or raw), and is partly subsidized by the central government.

The Metropolitan Area required huge infrastructure investments, including water supply, to meet the needs of industrialization and population influxes. Han River, which delivers all of Seoul's potable water, passes through the centre of Seoul, and has proved a remarkable water resource with acceptable quality, but does not serve satellite cities in the metropolitan area. Therefore, the government decided to supply bulk water to cities where water was not

quantitatively and economically available, including a small portion to Seoul City. Total capacity is 8,535,000 m³/day with five intakes, nine water treatment plants (WTP) and large-scale pipelines stretching 1,079 km that supply water to 13 million citizens.

Climate change

Climate change has already impacted precipitation trends in the Republic of Korea, with heavier rains during the monsoon season and severe drought during the rest period. In addition to the existing large dams, the government initiated a huge project for four major rivers, including Han River, involving sand dredging and the construction of additional weirs between dams to prevent flooding from heavier rains, and to secure more water during severe drought.

Over the last two years (2014-2015), precipitation has fallen by 60%, however water was supplied without the need for shutdowns. Conversely, WTP operators had to operate in spite of algae issues caused by decreased water quantity and increased water temperature.

Advanced water treatment

All WTPs depended on conventional treatment, that is, sedimentation to rapid



filtration and disinfection. Despite the high level of treatment, public complaints regarding taste and odour persisted. The cause of these issues turned out to be two organic compounds found frequently in drinking water: Geosmin and 2-MIB. The first project to address this issue started in 2006. As of now, most WTPs supplying drinking water are equipped with advanced treatment processes, which deal perfectly with the taste and odour caused by Geosmin and 2-MIB.

In 2007, K-water completed construction of its integrated operation centre, which now monitors and controls the whole system using a small number of operators at each facility. As an SOE, this approach was taken to ensure public satisfaction more than to decrease cost. Databases at all facilities use geographic information systems (GIS), with real-time data collection and automatic detection for leakages linked to an alarm system. This enables immediate detection and appropriate actions in response to any possible issues with water supply.

FUTURE PLANS

Dual pipelines

Water network inter-connection has been a good solution for system reliability, but still carries some latent risk properties. Therefore, in some areas of Seoul, dual pipeline systems are inevitable to avoid

shutdowns. A dual pipeline has been planned, along with additional network inter-connections, to minimize the risk of water supply shutdown.

Healthy water supply

K-water monitors water quality for 250 parameters, while national criteria cover only 85. However, the percentage of people drinking tap water directly is small at around 5%, while the percentage in other OECD countries, such as Canada, Japan and the United States, is around 50%. As a bulk water supplier, cooperation with local governments is necessary to boost this figure. Increasing K-water's ability to continue to supply high-quality water with healthy substances, such as minerals, and control the chlorine concentration in the network, will enhance the proportion of direct water supply users in Seoul and its surrounding communities.

Smart water supply

K-water monitors the water supply from an operation centre integrated with a state-of-the-art ICT-based smart water system. However, efficient operation and maintenance can be compromised at the point of supply or by the operator of the facilities. K-water is trying to encourage transparency by providing water supply information to the public through electronic displays on the street and/or smartphone applications.

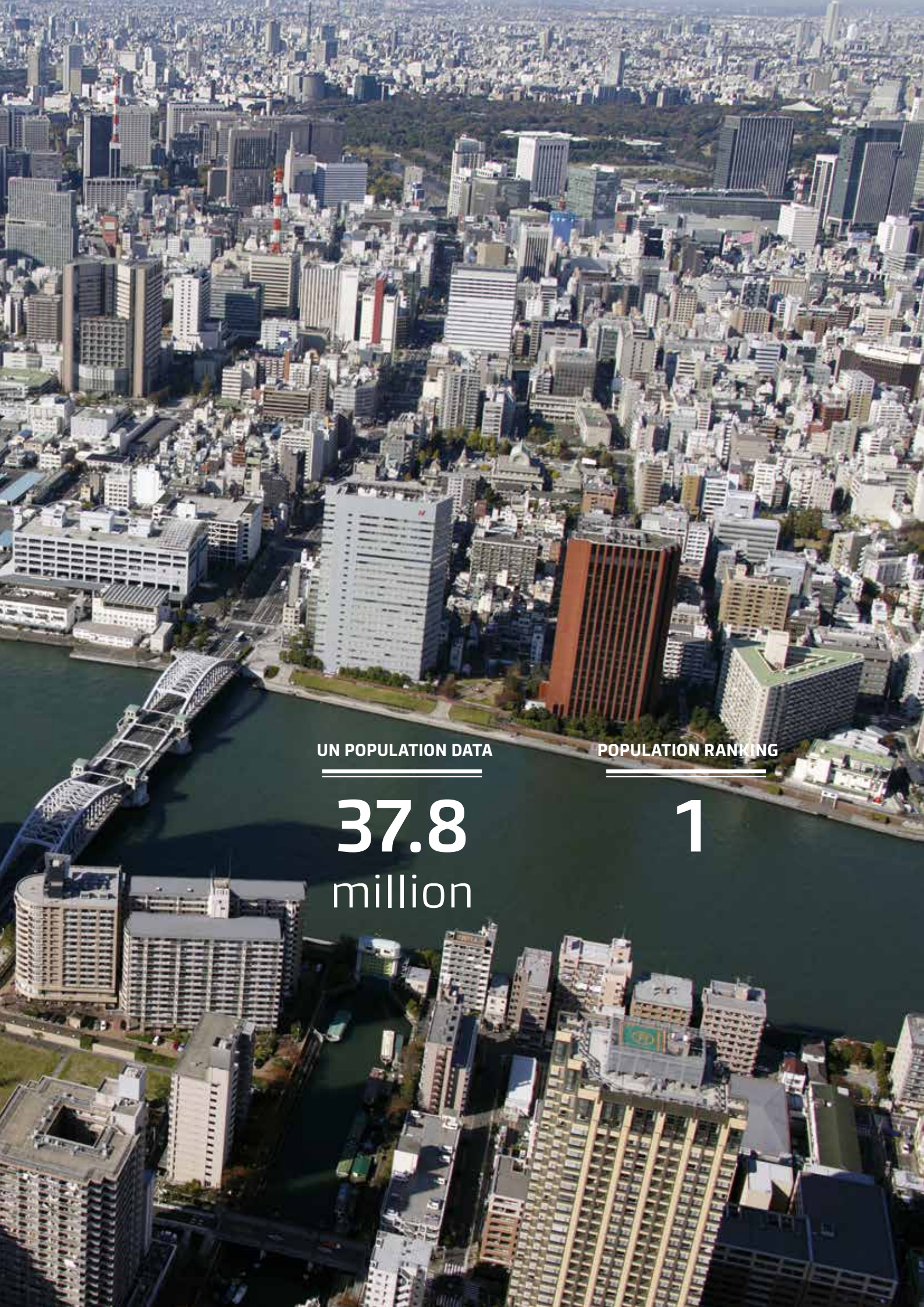
Tokyo

An aerial photograph of a dense urban area in Tokyo, Japan. The image shows a mix of modern skyscrapers and older, more compact buildings. A large, curved stadium or arena is visible in the middle ground, situated near a body of water. The sky is clear, and the overall scene is brightly lit, suggesting a sunny day. A dark circular callout is overlaid on the left side of the image, containing white text.

Ei Yoshida,
Tokyo Metropolitan
Waterworks Bureau

Kiyotsugu Ishihara,
Tokyo Metropolitan
Sewerage Bureau

Yugi Daigo,
Tokyo Metropolitan
Waterworks Bureau



UN POPULATION DATA

POPULATION RANKING

37.8
million

1

Tokyo

Water and wastewater service in **Tokyo** dates back to the 1890s, approximately 130 years ago. Facilities have been expanded continuously to keep up with the population's desire for improved services. The city's water-related offices have struggled to provide the best possible service, while confronting new challenges from climate change and natural disasters. Currently, water-related services cover a population of approximately 13 million and an area of 1,239 km². Service coverage is 100% from 11 water purification plants and 20 wastewater treatment plants.

Climate change

In light of recent droughts that led to water restrictions on the Tone River system - the main water source for Tokyo - and growing concerns about the impact of climate change on water resources, the Tokyo Waterworks Bureau is now working to ensure stable water resources that can respond to droughts. In addition, a back-up system covering all water facilities has been implemented, made possible by the development of alternative facilities, duplexing and the networking of transmission pipes. This system enables continuous water supply even when

waterworks facilities are forced to cease operation, such as in the event of disasters or accidents.

The wastewater system is presently working to cope with frequent, localized heavy rains, which exceed 50 mm/hr. Services in the urban area are being secured by the use of an advanced flood control measurement system.

Advanced water treatment

The Tokyo Waterworks Bureau also introduced advanced treatment systems in all purification plants in the Tone River system, with the aim of efficiently

WATER AND WASTEWATER SUPPLY IN TOKYO

	Population	Area (km ²)	Plants (capacity) (m ³ /day)	Pipelines (km)	Service coverage
Water*	13 million	1 239	11 (6.86 million)	26 774	100%
Wastewater			20 (5.56 million)	16 000	

Notes: Data are for 2015, with the exception of pipelines, which represents the total length of distribution pipes in 2014. * The majority (more than 97%) of water resources depend on surface water.



removing and reducing substances that cause musty or chlorine odours. As of 2013, the advanced systems treat 100% of the city's water supply. In the upper basin of the Tama River, powdered activated carbon treatment has been adopted for the treatment of musty odour substances, while the introduction of more efficient water treatment systems is being considering for facility renewal.

Advanced treatment is also to be introduced to reduce the frequency of red tides in Tokyo Bay, which occur around 80 days/year as consequence of effluent from wastewater. The introduction of advanced treatment is also required to further improve effluent quality to improve the water environment of Tokyo Bay, and to save energy.

Natural disasters (earthquakes) and energy efficiency

Based on lessons learned from the Great East Japan Earthquake and the Tokyo Metropolitan Government's new earthquake damage projections, the Tokyo Waterworks Bureau will implement a project to improve the resistance of its facilities and pipelines to seismic activity. The '10-Year Project for the Use of Earthquake-Resistant Joints in Pipelines' will also effectively reduce fire damage

caused by water outages during and after earthquakes.

In the case of large-scale earthquakes, substantial damage is expected, for example, the fracturing of joints between sewers and manholes, and the displacement of manholes themselves. In order to protect sewerage systems and secure traffic flow (e.g emergency transport roads), Tokyo is developing countermeasures against major earthquakes and tsunamis.

Tokyo will also undertake the duplexing of conveyance facilities and transmission pipes and the networking of transmission pipes, in order to strengthen back-up functions. In addition, the city plans to promote energy self-sufficiency by building and enhancing non-utility power generation facilities.

Monitoring and control systems

The Tokyo Waterworks Bureau has promoted efficiency of water supply operations by making facilities unmanned at normal hours. This was made possible by the integration of operation control services (which used to be undertaken by municipal staff) into four centralized control rooms for remote monitoring and control.

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The international conference 'Water, Megacities and Global Change', organized at UNESCO Headquarters in December 2015 during COP21, shone a light on the key role that cities play in the achievement of the Sustainable Development Goals, especially Goal 6 of the 2030 Agenda, pertaining to universal access to water and sanitation.

Irina Bokova, Director-General of UNESCO

This book is the outcome of the International Conference 'Water, Megacities and Global Change', and represents the collective work of 33 authors and co-authors. It contains summaries of monographs on 15 emblematic megacities: Beijing, Buenos Aires, Chicago, Ho Chi Minh City, Istanbul, Lagos, London, Los Angeles, Manila, Mexico, Mumbai, New York, Paris, Seoul and Tokyo. This edition provides unique information about water management in these megacities. A USB stick is attached to this printed edition containing three digital versions in English, French and Spanish, as well as the full-length versions of the original monographs (English and French versions). The digital content is available in open access at the publishers' websites: www.unesco.org, www.arceau-idf.fr and/or www.eaumeqa.org.



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