MAY 2020

# The W12 Framework

## Supporting Collaboration Among Cities for Water Security


Authors:

Jesse Knapp (Lead Author)
Philip Clayton
Jeremy Fackenthal
Anna Hixson
Ellie Leaning
Azra Tanovic


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# Acknowledgements

We acknowledge the generous contribution of time, knowledge, and insights from people around the world. It is not possible to cite here all the authors of the water studies on which this water protocol is based. But the individuals listed below have offered expert advice in ways that have contributed significantly to this project, and we gratefully acknowledge their role.

The W12 project was born from the inspiration of the City of Cape Town, South Africa, where, faced with a "Day Zero" water scenario, the citizens and city leadership launched an unprecedented program of water conservation. Through their combined efforts, water usage was reduced almost by half. Cape Town's success led to the W12 vision: that leaders from water-stressed cities might gather, share solutions and innovations, and together find ways to meet the water needs of their residents.

In January 2020, with the support of the City of Cape Town, 150 specialists from 15 countries assembled at the University of the Western Cape in South Africa as part of an international collaboration to find and share water solutions for cities. Participants included scientists, scholars, government officials, industry leaders from the water and finance sectors, and heads of nonprofit organizations. Excerpts from the conference reports are included in this framework document, covering the diverse fields of politics, economics, technical sciences, natural sciences, social sciences and humanities, and civil society. Full refereed versions of the position papers will appear in a special issue of a major journal. Although only the names of the lead authors appear on the conference reports below, we gratefully acknowledge all the experts whose work contributed to what we hope will be the first in a series of South African and international conferences on this topic.

Thomas Boynton
Kelly Bridges
Gregg Brill
Charon Büchner-Marais
Kirsty Carden
Khanyisile Chaba
Ernst Conradie
Liz Crosson
Jenny Day
Mark Dent
Joanna Fatch
Jessica Fell
Burtram Fielding
Pablo Garcia
Mafaniso Hara
Greg Holliday
David Johnstone
Richard Kaufman
Emil Svaneborg Mathiasen
Shannon McCarthy
Tanvi Nagpal
Abishek Narayan
Bongani Ncube
Josh Newton
John Oldfield
Stephanie Pincetl
Michael Rouse
Chris Serjak
Andy Shrader
Darlington Sibanda
Seth Siegel
Larry Swatuk
Adrian Sym
Nick Tandi
Neal Turner
Stefan Uhlenbrook
Jonas Villadsen
Michael Webster

# Abbreviations

## General Abbreviations

| | |
|---|---|
| **CWS** | Continuous Water Supply |
| **DMA** | District Metering Area |
| **IWS** | Intermittent Water Supply |
| **IWRM** | Integrated Water Resource Management |
| **LPCD** | Liters per capita per day |
| **MLD** | Million liters a day |
| **NGO** | Non-Governmental Organization |
| **NPO** | Non-Profit Organization |
| **NRW** | Non-Revenue Water |
| **PCB** | Polychlorinated Biphenyl |
| **POD** | Point of Distribution |
| **PRV** | Pressure Reducing Valve |
| **PPP** | Public-Private Partnership |
| **RWH** | Rainwater Harvesting |
| **WFD** | Water Framework Directive |

## Abbreviations of Organizations

| | |
|---|---|
| **EU** | European Union |
| **FAO** | Food and Agriculture Organization |
| **IFC** | International Finance Corporation |
| **UN** | United Nations |
| **WHO** | World Health Organization |

## Case Study Specific Abbreviations

### Amman, Jordan

| | |
|---|---|
| **DZ** | District Zone |

### Cape Town, South Africa

| | |
|---|---|
| **CoCT** | City of Cape Town |
| **DWS** | National Department of Water and Sanitation |
| **WASH-FIN** | Water, Sanitation and Hygiene Finance Program, led by USAID |
| **WCWSS** | Western Cape Water Supply System |

## Chennai, India

| | |
|---|---|
| **CPCL** | Chennai Petroleum Company Limited |
| **CMWSSB** | Chennai Metropolitan Water Supply and Sewerage Board |
| **IT** | Information Technology |

## Istanbul, Turkey

| | |
|---|---|
| **GAP** | Southeastern Anatolia Project |
| **IIWF** | Istanbul International Water Forum |
| **ISKI** | Istanbul Water Supply and Sanitation Administration |
| **IWC** | Istanbul Water Consensus |
| **SCADA** | Supervisory Control and Data Acquisition |
| **WWC** | World Water Council |

## Kigali, Rwanda

| | |
|---|---|
| **REMA** | Rwanda Environment Management Authority |
| **RNRA** | Rwanda Natural Resources Authority |
| **WASAC** | Water and Sanitation Corporation |

## Los Angeles, California

| | |
|---|---|
| **LA** | Los Angeles |
| **LADWP** | Los Angeles Department of Water and Power |
| **MWD** | Metropolitan Water District |
| **UCLA** | University of California Los Angeles |

## Mexico City, Mexico

| | |
|---|---|
| **CDMX** | Mexico City ("Ciudad de México") |
| **CONAGUA** | Mexico's National Water Commission ("Comisión Nacional del Agua") |
| **SEDEMA** | The Environmental Secretariat of Mexico City ("Secretaría del Medio Ambiente de la Ciudad de México") |
| **SEMARNAT** | National Ministry of the Environment and Natural Resources ("Secretaría de Medio Ambiente y Recursos Naturales") |
| **NWP** | National Water Program |
| **WSP** | Water Sustainability Program (in Mexico City) |
| **ZMCM** | Mexico City Metropolitan Area ("Zona Metropolitana de la Ciudad de México") |

## Mostar, Bosnia-Herzegovina

| | |
|---|---|
| **BiH** | Bosnia and Herzegovina |

## Pune, India

| | |
|---|---|
| **JS2** | Jalswarajya II, World Bank Project |
| **MIDC** | Maharashtra Industrial Development Corporation |
| **WASH** | Water, Sanitation and Hygiene |

## Quang Tri Town, Viet Nam

| | |
|---|---|
| **ASSIST** | Asia Society for Social Improvement and Sustainable Transformation |
| **IFU** | Danish Investment Fund for Developing Countries |
| **P4G** | Partnering for Green Growth and the Global Goals 2030 |
| **VWSA** | Viet Nam Water Supply and Sewerages Association |

## São Paulo, Brazil

| | |
|---|---|
| **Sabesp** | State of São Paulo's water utility ("Companhia de Saneamento Básico do Estado de São Paulo S.A.) |
| **SEHAB** | São Paulo's Municipal Secretariat for Housing and Urban Development ("Secretaria da Habitação e Desenvolvimento Urbano") |
| **SP** | São Paulo |
| **SPMR** | São Paulo Metropolitan Region |

# Introduction

By 2050, nearly 7 billion people will be living in cities. They will need safe, convenient, and reliable water supplies. Yet the challenge of water scarcity, already acute in many cities around the world, will only increase with rapid urbanization and reduced precipitation due to climate change.

Urban water provision today depends on complex systems of infrastructure, governance, and business. In many cities, these systems produce a high degree of water security for most inhabitants. In others, they have enabled significant progress. Yet for many more, water security remains a distant goal, and a growing number of cities face the threat of catastrophic water shortages.

Change in the way cities think about and use water is needed. How can existing methods evolve to address future challenges? How can solutions that worked in one city be adopted in another? Solutions are known. It is the complexity of interrelated challenges on the ground in water-scarce cities that stands as the ultimate barrier to progress.

The W12 project proposes a way forward—an approach to collaboration among cities facing water scarcity. Its goal is to support city leaders and decision makers and to involve stakeholders from all parts of society. The W12 materials and programs include:

- The W12 Congress, an annual gathering of city leaders, the first of which will take place in Cape Town, South Africa
- The W12 Protocol, an electronic resource designed to connect city utilities managers with solutions drawn from case studies on cities around the world
- A mechanism for peer-to-peer communication among city utilities managers
- Knowledge resources that include not only written documents but also contact persons within technical organizations who consult on all aspects of water delivery and problem solving
- Support in the search for funding, especially through public-private partnerships (PPPs)

## Central Assumptions

1. Climate disruption will continue to reduce precipitation for many of the most vulnerable urban centers. At the same time, global warming combined with population growth will increase the demand for water. According to a recent report, a quarter of humanity faces looming water shortages.[1]
2. The proportion of humans living in urban centers will continue to increase over the

1 "A Quarter of Humanity Faces Looming Water Crises," New York Times, August 6, 2019; https://www.nytimes.com/interactive/2019/08/06/climate/world-water-stress.html

coming decades such that, according to the UN Department of Economic and Social Affairs, roughly 68% of the world's population will be located in cities by 2050.[2] Rapid urbanization has raised problems of incredible complexity, but it also offers the space for solutions that can affect millions of people.

3. Finding water solutions for cities requires models that extend 30 years into the future and beyond. Strategies and projects that do not take the longer-term horizon into account may lead to financial loss and, in some cases, may actually exacerbate a city's water scarcity issues.

4. The escalating crisis of cities and water cannot be solved by reforms within a single sector, whether it be the political sphere (say, a single global water governance structure[3]), the private sphere (say, privatization of city water delivery), or technological innovation. The water challenge cuts across many sectors and academic specializations. Adequate responses to the challenges will therefore also have to be multi-sectoral.

5. Many of the best practices in water management are already known and widely available in existing documents, just as the major challenges are well understood. The Istanbul Water Guide of 2009, for example, contains 140 recommendations, many of which would still count as best water practices.[4] The International Water Association has also compiled and published best practices for city water management.[5]

6. The problem therefore is not lack of information. Brilliant work is being done by the world's top specialists on water. We need to learn from it, not duplicate it.

7. Instead, the task is to organize existing knowledge of challenges and best practices in ways that are most helpful for city leaders.

8. The escalating water crisis is a long-term problem. Real solutions thus require long-term thinking. Yet the case studies show that initiating wise long-term programs brings co-benefits for citizens in the short term as well.

## Core Values

**Water is indispensable not only to human survival, but also to human dignity.**

**Water is not merely a commodity.** By its very nature, it flows across all sectors of society and touches them all. The benefits of access to sufficient amounts of clean, affordable water affect health, education, and

2 In 2018, 55% of the global population lived in cities. See https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html.

3 See the PhD thesis on the topic by Joshua T. Newton, "An Exploration of the Lack of a Formal Global Water Governance Regime," The Fletcher School of Law and Diplomacy, Tufts University (2014).

4 5th_world_water_forum_-_Istanbul_-_Turkey_-_global_water_framework_Istanbul_2009_part_1_final. Published online at https://www.worldwatercouncil.org/en/istanbul-2009.

5 See for example IWA (2016), "The IWA Brochure on Water Wise Cities," https://iwa-network.org/wp-content/uploads/2016/08/IWA_Brochure_Water_Wise_Cities.pdf, and IWA (2018), "Action Agenda for Basin-Connected Cities," https://iwa-network.org/wp-content/uploads/2018/09/Basin-Action-Agenda_SCREEN.pdf.

poverty alleviation for individuals, groups, cities, and entire nations. Together with air and food, water forms the foundational level in any hierarchy of human flourishing.[6]

**Water stewardship is crucial to human survival.** The Alliance for Water Stewardship (AWS) has taken a leading role in setting standards for water stewardship around the world. The AWS report from 2019 defines water stewardship as "the use of water that is socially and culturally equitable, environmentally sustainable and economically beneficial, achieved through a stakeholder-inclusive process that involves site-and catchment-based actions."[7]

**Good water governance requires the participation of local communities**.[8] Water policy cannot be set only at the national level. Obtaining water with low carbon costs means that humans need to rely on water available in their region (watersheds, aquifers, catchments). This means that governance structures and cultures at local and regional levels will inevitably have to play a role in long-term water solutions.

**Good water governance requires the participation of civil society.** An entire section of this report is devoted to the work of a special task force, the Civil Society Task Team, below.

## Dimensions of the Water Challenge

The American Water Works Association (AWWA) 2019 report summarizes the responses of over 2,000 water utility professionals. In their assessment, "aging infrastructure and infrastructure funding were still the most pressing issues, and access to capital had become more difficult. Extreme weather events were a critical concern." The professionals now list "long-term water supply availability" as their third-highest overall concern.[9] The top four "macro-scale" phenomena that threaten the water industry are given as extreme weather events, pollution, climate change, and political instability (p. 11).

The most recent report by the Organization for Economic Cooperation and Development (OECD) summarizes the central challenges under three headings:

1. **Infrastructure** is generally aging and requires upgrading, in some cases urgently and extensively. Prevailing financing mechanisms have historically been able to support the operation of existing infrastructure, while keeping water tariffs relatively low. However, they have been less successful at financing the upgrade or replacement of water-related assets, nor have they

6 In Abraham Maslow's famous hierarchy of self-actualization, access to water, air, and food forms the foundation of the triangle. "Maslow called the bottom four levels of the pyramid 'deficiency needs' because a person does not feel anything if they are met, but becomes anxious if they are not." (Neel Burton, "Our Hierarchy of Needs," Psychology Today, May 23, 2012; https://www.psychologytoday.com/us/blog/hide-and-seek/201205/our-hierarchy-needs.

7 See https://a4ws.org/download-standard-2/aws_standard_2-0_2019_final/.

8 Mark Dent & Liz Taylor, "Strategic developments that will support and strengthen the participation of local communities in improving water and sanitation management in South Africa," The Sustainable Water Resource Handbook – South Africa Volume 7 (Published by Alive2Green February 2017), p. 104.

9 AWWA, 2019 State of the Water Industry Report, p. 1. Thirty challenges to the water industry are ranked on p. 8. See https://www.awwa.org/Portals/0/AWWA/ETS/Resources/2019_STATE%20OF%20THE%20WATER%20INDUSTRY_post.pdf

provided incentives to adapt urban water management to changes in water availability or consumption patterns.

2. **Urban water management** faces emerging pressures, such as more-stringent health and environmental standards, diffuse pollution, competition to access water resources, increased intensity and frequency of extreme weather (affecting precipitation), and higher uncertainty about future water availability and demand. Cities in OECD countries face a particular challenge in that most are locked-in to specific technical trajectories, and retrofitting existing infrastructure to address new and emerging pressures is particularly expensive and technically difficult.

3. **Urban water governance** in OECD countries is hindered by several gaps, such as information asymmetries, sectoral fragmentation, and limited capacities. Moreover, institutional structures are changing, driven by national and international laws and regulations, territorial reforms, decentralization, and the reallocation of competences across jurisdictions. These changes affect the capacity of cities and other actors to manage water at the appropriate scale.[10]

## Four Guiding Questions (OECD)

1. Who should pay the water bill?

2. How can cities make the best use of innovative approaches to urban water management?

3. How can cities and their rural surroundings best cooperate?

4. How can cities govern urban water management?

## Aspects of Solution-Oriented Thinking

**Coordination.** "All cities share water resources with surrounding rural areas and increasingly have to coordinate with rural water users to reach their own water management objectives. Three specific water challenges would benefit from coordination between urban and rural communities – increased competition for water resources (scarcity), flood management (abundance) and freshwater quality conservation (pollution)."

**Cooperation.** "Cooperation allows water to be managed at the relevant spatial scale and provides a means of allocating risks to the parties best equipped to manage them. For instance, catchment protection programs rely on farmers' capacities to avoid pollution that would require costly treatments downstream."

**Trust.** "Building trust between the urban and rural communities is essential to the success of any approach, and governance arrangements should seek to foster such trust building through increased transparency, accountability and stakeholder engagement."[11]

The OECD identifies four features of countries that are making progress toward addressing the problem of water scarcity:

10 OECD, "Water and Cities Policy Highlights: Ensuring sustainable Futures," OECD, p. 1. The full report is available at https://www.oecd.org/environment/water-and-cities-9789264230149-en.htm.

11 Quotations drawn from the OECD report, "Water and Cities Policy Highlights: Ensuring sustainable Futures." This and other resources can be downloaded from https://www.oecd.org/environment/resources/7th-world-water-forum.htm.

1. A long-term vision of water challenges and opportunities for urban development
2. Business models for water utilities and land development that reflect water risks
3. Governance structures that co-ordinate urban water management with other dimensions of urban management and reach beyond city limits
4. Information campaigns to raise city dwellers' awareness of water-related risks and the liability costs resulting from short-term visions

Among the business models are public-private partnerships (PPPs). A PPP is a procurement choice that is available to the public sector. Five key characteristics of PPPs have been identified:

1. Long-term contract between public and private sector for a clearly defined project (5 to 30 years)
2. Includes private sector involvement in design, construction, financing, and implementation
3. Private party sources most or all finance required
4. Payment to private party based on agreed upon outputs
5. Requires risk transfer to private sector[12]

## The W12 Congress and The W12 Protocol

What follows is a description of the W12 Protocol and a presentation of the research and development that has contributed to this project, which is ongoing. Because the central goal of the W12 Protocol is to facilitate collaboration among cities facing water scarcity, the Preamble to the W12 Protocol will be presented to the city leaders who gather at the inaugural W12 Congress for their signatures. It is a statement of shared values and commitment to work together in pursuit of water security.

The description of the W12 Protocol below includes a selection of case studies on water-scarce cities and an explanation of how these studies and the key lessons they contain will appear in the electronic resource.

This document and the larger W12 endeavor continue the work undertaken at the "Cities Facing Escalating Water Shortages" conference, which took place at the University of the Western Cape (UWC) in January 2020. The conference produced six position papers on topics central to water security: technical science, natural science, politics, social science, civil society, and economics. Each paper was created by a dedicated task team consisting of mostly South African experts whose goal was to help frame discussions at the conference. The role of the position papers in this document is to provide the conceptual framing for the multi-sector approach explored during the UWC conference and reflected in the W12 Protocol. The position papers are lenses through which to view the issue of urban water security.

12 "An Introduction to PPPs in South Africa," published by The National Business Initiative; https://www.nbi.org.za/wp-content/uploads/2019/05/[illegible]ction-to-PPPs.pdf

# Preamble to the W12 Water Protocol

> "Water sustains human life and the environment; it connects people, cultures and economies. Water is indispensable for all economic and social development, food security, and ending poverty and hunger." (5th World Water Forum, Istanbul 2009)

We, the Ministers and Heads of City Delegations assembled for the inaugural W12 Congress, affirm the centrality of water for human survival and flourishing. Without clean water, cultures and economies cannot thrive. Without it, sickness, poverty, and hunger reign. We acknowledge that the quality of life in human communities depends fundamentally on access to clean water and sanitation.

At the same time, we recognize that access to life-giving water is under threat for a growing number of people. The world's population is expected to reach 10 billion in 2050, with almost 70% of people living in cities. Climate change will continue to reduce precipitation for vulnerable urban centers around the globe. Together, these forces will put unprecedented pressure on cities in their quest to supply water.

We affirm that "water is the most fundamental element and is essential to our survival… Water does not only mean life; it means civilization."[13] Recognizing that water scarcity exacerbates inequalities, we prioritize meeting the basic needs of our citizens, striving for universal access.

As signatories to this Preamble to the W12 Water Protocol, we share the goal of developing and managing city water resources in a sustainable manner. Our commitment is to supply safe water and sanitation for all of our residents—present and future.

We seek to remain informed about the most recent science on climate, hydrology, and resource management, and about affordable technologies for collecting, treating, transporting, and monitoring water. We desire to work with industry to learn about private-sector solutions and public-private partnerships, and with the finance sector to locate viable sources of funding, since many of our cities need major infrastructure updates and expansions.

We testify to the importance of learning about and implementing best practices in city water management, and we are ready in turn to share the best practices and solutions that we have developed in our own cities and regions. Achieving water security will require a deep understanding of the different types of water challenges and the specific solutions for each, drawing on the best available data and predictive models. We affirm the importance of a participatory, multi-sectoral, and multi-disciplinary approach to managing water resources.

Above all, as we gather for the W12 Congress, we proclaim the value of collaboration. Peer-to-peer relationships between city leaders are crucial. Cities around the world are developing

13 Former President of Turkey Abdullah Gül

sophisticated solutions to their water scarcity challenges, which means that their leaders can serve as stores of knowledge for their peers. As cutting-edge best practices emerge, communication and collaboration become vitally important, so that the solutions can be implemented in more and more cities around the world.

In recognition of these facts, we, the undersigned, affirm our commitment to work together in order to achieve water security for all the world's cities. We call on other cities and nations to join our efforts to generate a common vision, to share solutions, and to establish additional forms of support. May our efforts help to produce a global framework for addressing the world's water issues and to support cities in their quest for solidarity, adaptability, and water security.

Signed,
[*signatures to be added*]

# The W12 Protocol: Description and Preliminary Research

## Introduction

The W12 Protocol is an electronic resource for city leaders and decision makers as well as stakeholders from all parts of society who are interested in advancing water security at the level of city water governance. It is based on studies of water challenges that cities face and the solutions they are finding.

What the present document offers is a preliminary text version of the information that will be represented dynamically in the protocol itself. When the electronic resource is available, municipal utilities managers, public officials, and others will be able to select issues that apply to their city's water challenges and build their own city profiles representing interrelated issues. These issues will link in turn to relevant case studies from around the world. Each case study will include a list of solutions that have been proposed or implemented in the subject city, along with an analysis of steps that have or have not been effective. It will be possible to browse the database by case studies and by core issues and solutions.

Lists of core issue and solution "tags" are provided below, followed by a selection of case studies. These case studies and the tags associated with them are examples of the kind of information that the database will contain.

Numerous invaluable publications on city water management highlight best practices, factors of success, and other recommendations for achieving water security. There is remarkable consensus among water experts about what should be done. This document relies on and is indebted to the work of many of these experts. Building on their work, the W12 Protocol seeks to organize known solutions for city decision makers in ways that encourage and support implementation.

Therefore, the protocol will link issues and solutions to specific cases rather than presenting them as general recommendations. The tags that link case studies to each other are not prescriptions. Instead, they are a means of connecting users with options based on concrete experience.

This approach is meant to highlight the specific features of each city's situation and encourage integrated strategies for applying lessons learned in new contexts. Users will have the flexibility to explore solutions of interest to them. That flexibility, together with the focus on specific examples, will help leaders translate the solutions contained in this resource into policies and actions.

The number of case studies in the database will continue to grow. Over time, the W12 Protocol will provide users with an increasingly detailed and comprehensive view of how water scarcity challenges are being met in cities around the world.

## Core Issue Tags by Category

**Supply**

*These factors reflect material limitations on the availability of water. Consider a city's water sources, including recharge rates, in the present and under projections for the future, taking into account the best available climate models.*

Surface Water Scarcity
Groundwater Scarcity
Drought
Desertification
Flooding
Contamination and Pollution
Damage to Aquifers

**Water Use**

*These factors reflect increases or changes in demand for water, including changes of quantity or type of use.*

Population Growth
Displacement/Migration
High Per Capita Consumption
Urban/Rural Competition

**Inequality and Access**

*These factors reflect the social determinants of access, including equity and justice issues.*

Affordability
Unsafe Access Points
Distant Access Points

**Infrastructure and Service**

*These factors reflect limitations on a city's ability to utilize or maintain available resources*

Insufficient Data
Insufficient Capture Technology & Infrastructure
Insufficient Storage Technology & Infrastructure
Insufficient Pipe Systems
Insufficient Maintenance Capacity
Non-Revenue Water
Lack of Sanitation Services

**Governance**

*These factors reflect systemic barriers to planning and implementing needed changes. They refer to water governance in all aspects, including political and administrative processes.*

Insufficient Capacity & Expertise
Pipeline Barriers within Government Departments
Lack of Coordination between Government Departments
Lack of Coordination between Local, Regional & National Government
Lack of Coordination between Sectors
Lack of Public Awareness & Political Will

**Finance**

*These factors reflect barriers to funding needed changes, including inadequate funding and inability to access or apply funds that have been identified or allocated.*

Lack of Funds
Counterproductive Pricing Structures
Lack of Collateral for Loans
Uncertain Return on Investments
High Interest Rates
Barriers to Subsidies and Loans
Insufficient Revenue Collection

**External Factors**

*These are factors that lie outside the control of city and national governments and exert a negative influence on water security.*

Conflict

## Solution Tags by Category

**Data**
*Obtaining good data to facilitate progress in all areas.*

Research and Development to Generate Innovative Solutions
Understanding Local Conditions
Integrating All Water Sources into Water Cycle Analysis
Keeping Water Supply Data Up to Date
Consistent Monitoring of Rainfall and Water Demand
Learning from Temporary, Small-Scale Implementation Projects
Consolidated Information Repositories
Climate Models
Climate Vulnerability Assessments
Hydrological Models
Consumption Models
Groundwater Monitoring
Drinking Water Monitoring
Sanitation Monitoring

**Water Supply**
*Employing methods that make local environmental sense.*

Diversifying Water Sources
Wastewater and Storm-Water Capture, Treatment, and Reuse
Treating Contaminated Water
Desalination
Rainwater Harvesting
Groundwater Capture
Surface Water Capture

**Infrastructure**
*Building and maintaining sustainable systems.*

Continuous Supply
Consumption Metering by Zone
Reliability Standards for Infrastructure Investments
Pressure Management Interventions
Alternate Supply Methods in Informal Settlements
Water Transportation Between Cities and Between Urban and Rural Areas
Storage Infrastructure
Transitional Water Delivery Systems

**Finance**
*Obtaining needed capital investments in addition to a city's direct revenue sources (which are covered in other sections below).*

Sustainable Cost Recovery
Including Financial Feasibility in Project Feasibility Assessments
Private Investment
Regional & National Government Infrastructure Investment
Non-Governmental Investment
Intergovernmental Investment
Innovative Loans Structures & Other Finance Mechanisms

**Management Within City Governments**
*Ensuring efficient and accountable systems within a city's government.*

Water Department Organization
Coordination Among Governmental Departments
Attracting and Retaining Skilled Staff
Accountability
Water Management in Informal Settlements

**Coordinated Governance**
*Working together across parts of government.*

Consistency of Policies Across Jurisdictions
Consistency of Policies Over Time
Local, Regional, and National Coordination

**Planning**
*Strategic planning for long-term success.*

Integration of Water Planning with Urban, Regional, and National Land Use Planning
Integrated Water Resources Management (IWRM)
Accounting for All Water Access Options in Cost / Affordability Analyses
Funding Structures That Incentivize Realistic Timeframes
Planning for Realistic Timeframes
Flexible Water Restriction Policies
Flexible Financial Planning
Training in Procurement Processes

**Municipal Revenue Sources**
*Raising funds equitably for water supply.*

Tariff Structures That Disincentivize Water Waste
Sustainable and Just Enforcement Models

**Access and Equity**
*Ensuring access for all city residents.*

Subsidies to Assist the Low Income
Protecting Vulnerable Populations
Tiered Assistance Programs
Safe and Convenient Access Points

**Involving Stakeholders Outside of Government**

Concession Contracts
Public Private Partnerships (PPPs)
Community-Based Solutions
Building Capacity of Stakeholders in all Parts of Society
Involving Stakeholders in All Parts of Society in Water Related Decision Making
Issuing Guidance to The Public

**Building Trust**

Making Data Transparent and Readily Available to The Public
Ensuring Compliance with Laws and Regulations

**Water Cycle Management**
*Applying a systems approach to water.*

Conserving and Restoring Water Related Ecosystems
Increasing Water Productivity and Efficiency in Agriculture
Conservation Mechanisms That Can Be Easily Scaled Up in Times of Crisis
Groundwater Basin Rehabilitation
Using Treated Wastewater to Recharge Groundwater and Over-Exploited Aquifers
Coordination of Urban and Rural Use of Water
Conservation Zones That Protect Areas of Environmental or Hydrological Importance
Considering the Hydrosocial Cycle
Maintaining Lakes As “Soft Infrastructure” To Recharge Ground Water

**Reducing Water Loss**

Reducing Theft
Reducing Leaks
Reducing End-Of-Pipe Loss

**Reducing Water Consumption**

Public Awareness Campaigns
Systems Change
Integrated Perspectives on Urban Water Consumption

# Case Studies

## Amman, Jordan

**City Profile**

Jordan is one of the top four water-scarce countries in the world, with an annual water availability of 120–145 $m^3$ per capita, significantly less than the global average of 500 $m^3$ per capita (Hadadin et al. 2010). The nation's arid climate and its lack of natural surface water are the primary drivers of water scarcity. Current use of water resources in Jordan already exceeds the nation's renewable supply. Water scarcity is intensified by the fact that Jordan shares its three main water resources—the Yarmouk River, the Jordan River, and the Disi Aquifer—with its neighbors: Syria, Israel and Palestine, and Saudi Arabia, respectively (Ray, Kirshen & Watkins, 2012; Hadadin et al., 2010).

While most regions in the country are water-scarce, the problem is particularly acute in the nation's capital and its most densely populated city, Amman, which contains over 50% of the total Jordanian population (El Achi & Rouse, 2020). Situated in the highlands of northwestern Jordan, Amman has a Mediterranean climate characterized by cool, wet winters and hot, dry, and drought-prone summers (Ray, Kirshen & Watkins, 2012). Amman has grown rapidly in recent decades, and the population expanded from approximately 1.02 million people in 2000 to 2.17 million today (Potter & Darmame, 2010). In addition to the rapid natural population growth, the city has also experienced an influx of refugees in recent years from neighboring countries (e.g., Syria, Lebanon, Iraq, and Palestine), which has resulted in a nearly 20% increase in demand on Amman's water utilities (El Achi & Rouse, 2020).

Scarce water supply, rapid population growth, transboundary complications, limited financial resources, and 1,000 meters of elevation between the city of Amman and its water sources all pose challenges to water security (Ray, Kirshen & Watkins, 2012).

**Case Study: Transitioning to Continuous Supply**

Amman's water utility, Miyahuna, provides intermittent water supply (IWS) in the city. Users are allocated water for a total of 48 hours each week, and non-potable water is stored in water

tanks on top of buildings. Citizens in need of additional water typically buy it from private vendors. This practice is particularly common in the summer months when tourists and Jordanians living abroad visit the city (El Achi & Rouse, 2020). At the moment, Amman is reliant on the IWS provided by Miyahuna and the private vendors operating outside of the public water supply system. IWS poses significant barriers to adequate and safe water supply. Dirty and polluted water from a city's public network is typical of IWS systems worldwide (Potter & Darmame, 2010). Furthermore, Amman's water supply system experiences high rates of water loss, with non-revenue water (NRW) estimated to be between 38–48% of the total system, another characteristic typical of IWS systems (El Achi & Rouse, 2020).

IWS functions as a practical solution to water scarcity problems in resource-constrained cities, but it comes with many negative financial, infrastructural, social, and public health consequences. Achieving continuous water supply (CWS) requires significant capital investment in infrastructure, careful management of water resources, and a thorough understanding of the population dynamics that impact water management. Furthermore, transitioning to CWS using a total-system approach can be slow and costly.

Miyahuna has invested in a citywide renovation program to mitigate the degree of water loss in the system. To address the feasibility of transitioning to CWS using a gradual approach, researchers from the International Water Association (IWA), Nassim El Achi and Michael J. Rouse, created a theoretical model to propose a gradual (zone-by-zone) transition to CWS in a recently refurbished district of Amman (Tariq or DZ 27). The model proved to be efficient both technically and financially, highlighting that CWS is safer, ensures greater water security, and doesn't have to use more water than IWS systems. A gradual transition to CWS may be a feasible solution for water-scarce cities like Amman that currently rely on IWS.

**Background**

No centralized, urban water supply systems were intentionally designed to provide IWS. That is to say, urban water supply systems are all initially designed to provide CWS but, due to their inability to meet consumer demands, these systems are eventually switched to IWS—often considered a "practical" solution (Kumpel & Nelson, 2016, El Achi & Rouse, 2020). In IWS systems, supply periods are shortened, and water is not supplied for periods of time, meaning that pipes experience regular flow re-starting and draining (Kumpel & Nelson, 2016).

The regular flow re-starting and draining in pipes typical of IWS systems affects water quality by increasing the risk of microbial contamination in the water supply. Pipes contain stagnant water in IWS systems, which is conducive to microbial growth between supply cycles (i.e., when the water is turned off). Upon initiation of supply periods, this water is charged up, pressurized, and distributed to consumers throughout the system for the duration of the supply period. Therefore, microbial contamination, biofilms, loose deposits, and other water quality problems caused by intrusion and backflow into the system are all frequent occurrences in IWS systems (Kumpel & Nelson, 2016).

The degradation of water quality common in IWS systems frequently results in water-borne illnesses in consumers who depend on these systems for water supply (El Achi & Rouse, 2020; Kumpel & Nelson, 2016). The World Health Organization (WHO) considers IWS a major source of water contamination and a serious health hazard (WHO, 2016). Furthermore, IWS limits personal freedom, especially for women who are typically involved in household water collection; it is therefore associated with social inequality (El Achi & Rouse, 2020; Caprara et al., 2009; Majuru, Suhrcke & Hunter, 2016). Finally, in addition to the negative public health and social impacts of IWS, there are technical and financial challenges. IWS systems are frequently associated with higher operation and management costs, more NRW,[14] greater deterioration of infrastructure, and, ultimately, an increased gap between supply and demand in the water supply sector (El Achi & Rouse, 2020).

Despite the problems associated with IWS, many resource-constrained municipalities rely on it (Kumpel & Nelson, 2016; Franceys & Jalakam, 2010). This reliance on IWS is usually due to financial and infrastructural constraints that impede municipalities from switching to CWS, as well as due to the misconception that IWS leads to less water consumption (El Achi & Rouse, 2020). Achieving CWS is difficult when supply systems and infrastructure are badly degraded, as the transition requires significant capital investment. Furthermore, when switching from IWS to CWS, most municipalities have historically considered a total-system approach, wherein the entire system transitions simultaneously (El Achi & Rouse, 2020). However, it is logistically difficult to standardize such a large and simultaneous transition. These logistical difficulties, coupled with the financial burden, can result in situations wherein the pace of deterioration caused by the IWS system is more rapid than the transition to CWS itself (El Achi & Rouse, 2020). These challenges historically have made it difficult for resource-constrained cities to transition from IWS to CWS.

**Actions Taken**

In 2013, Jordan launched the Disi Water Conveyance Project to allocate water to Amman via 300 km pipelines from the fossil Disi aquifer that the nation shares with Saudi Arabia. The project aimed to provide enough water to Amman to ensure CWS. It succeeded in increasing IWS from 24 hours/week to 48 hours/week (El Achi & Rouse, 2020). However, Amman still relies on IWS.

More recent efforts by Miyahuna have focused on refurbishing the water network to reduce the high quantities of water lost through leaks in the system. These efforts consist of replacing the old meters with newer and more sensitive ones, renovating the distribution network, monitoring and detecting leaks, and rezoning the current district metering areas (DMAs) in the city's 44 district zones (DZs) (El Achi & Rouse, 2020).

14 Although IWS is typically employed as a response to water scarcity, studies from Northern Karnataka, India and Phnom Penh, Cambodia indicate that, if properly managed and monitored, the transition to CWS greatly reduces the amount of NRW in water supply systems. In the case of Northern Karnataka, NRW dropped from 50% to 7% after transitioning to CWS; in Phnom Penh, NRW decreased from 70% to 6% after transitioning to CWS (Hastak et al., 2017; Das, 2010).

**Existing Challenges**

Miyahuna and the city of Amman have increased supply and reduced overall losses in the distribution system, but transitioning to CWS remains a challenge. As a means of achieving a feasible transition to CWS, El Achi and Rouse propose in their 2020 article, a hybrid hydraulic model for the gradual transition from IWS to CWS in the city of Amman (El Achi & Rouse, 2020). The study investigates theoretical potentials for transitioning from IWS to CWS using a gradual approach, in which individual zones are transitioned to CWS, and the network is renovated instead of being totally replaced (El Achi & Rouse, 2020).

The zone-by-zone transition proposed by El Achi and Rouse is characterized by a balanced coexistence of IWS and CWS during the transition period. In such an approach, a certain zone (within a district) is supplied continuously with water while the surrounding zones remain rationed. Then the area of CWS continually expands until it covers the entire city. This gradual approach puts less pressure on water utilities in terms of operation, maintenance, and financing (El Achi & Rouse, 2020). It can have a positive impact on public opinion and citizens' acceptance of the transition project (as well as their willingness to pay more to finance such a transition). Once CWS proves successful in a small zone, word spreads throughout the city, and water users become more willing to consider the transition in their own districts and, if needed, pay more in water charges to obtain better service (El Achi & Rouse, 2020; Rouse, 2013). In contrast, a total-system transition requires more time to implement and a greater immediate capital investment, and it frequently leaves water users with an unclear idea regarding the transition itself and its impact on improving water access (El Achi & Rouse, 2020).

Taking advantage of the renovations currently underway in the city's water supply system, El Achi and Rouse used Tariq (DZ 27), a residential district whose pipes and water meters had recently been refurbished, as the basis for their theoretical model (El Achi & Rouse, 2020). DZ 27, located in the northeastern part of Amman, is subdivided into seven DMAs serving a total of 18,728 customers (El Achi & Rouse, 2020). When determining the order of DMAs for the theoretical transition, the authors prioritized DMAs with fully independent water pipes and serving low numbers of customers. (These DMAs were chosen due to the ease of separating them into the distinct "zones" necessary for a gradual transition.) It is necessary to note that while one DMA was continuously supplied with water, the rest retained their usual access to an IWS of 48 hours/week (El Achi & Rouse, 2020).[15]

Study results indicate that a 15% increase in water supply (a total of 381,696 $m^3$/month) would be needed to transition Tariq to CWS. Currently, there is a high rate of water loss in the system, estimated to be approximately 32% in DZ 27. Bulk readings at the reservoir indicate that it receives approximately 386,003 $m^3$ of water per month, meaning that there is

15 For a detailed account of the modeling process, please see:
El Achi, N., & Rouse, M. J. (2020). A hybrid hydraulic model for gradual transition from intermittent to continuous water supply in Amman, Jordan: a theoretical study. ***Water Supply***, ***20***(1), 118-129.

more than enough water theoretically available to cover the required increase in supply (El Achi & Rouse, 2020). Therefore, the increase in water demand necessitated by the transition to CWS could be compensated by reducing the system's overall NRW, whose current value (32%) exceeds the total amount needed (15%) for achieving CWS (El Achi & Rouse, 2020). Such a transition would be cost-effective, since the cost of rehabilitation would be limited to the price of the added pressure-reducing valves (PRVs), necessary for mitigating the water loss in the system (El Achi & Rouse, 2020).[16] Ultimately, the model developed by El Achi and Rouse showed that the transition from IWS to CWS is theoretically achievable in cities like Amman, which are constrained by their access to financial and natural resources.

The district of Tariq has features that make it particularly suited to the transition proposed (El Achi & Rouse, 2020). These features include the recent refurbishment of its supply network, the rezoning of DMAs and refurbishment of other key infrastructure, and because Tariq sources its water from a single reservoir. In districts with greater infrastructure difficulties, implementing a zone-by-zone approach would be more challenging (El Achi & Rouse, 2020). The authors highlight key factors necessary for a transition to CWS.

First, thorough data collection is required, specifically regarding elevations and numbers of junctions, number of households supplied per junction, maps of existing networks with DMAs, water supply (quantity and pattern), water resources, water tariffs, and NRW value (El Achi & Rouse, 2020). Second, modeling is required. Successful models are associated with two factors, namely, a single water source per district and the rezoning of DMAs (to adjust size, include areas of similar elevations, and be completely independent of each other). Finally, from a technical standpoint, certain kinds of infrastructure are necessary to make the transition possible, including water meters, PRVs, and a reliable (and cost-efficient) power supply (El Achi & Rouse, 2020). Currently, there is not good data on which of Amman's districts can meet these technical requirements and to what to degree.

In addition to the technical factors that make possible the transition from IWS to CWS, there are societal, political, and organizational factors involved. First, successful transition requires strong human resources capacities, robust organizational capacity (for project management, strategy and planning, and operation and maintenance), and political support. Behavioral change on the part of residents requires fostering greater public awareness of the water supply system, dispelling the myth that CWS requires more resources than IWS, and encouraging users to be willing to pay more for better service (El Achi & Rouse, 2020). Involving the public in the decision-making and implementation process can help ensure a smooth transition from IWS (El Achi & Rouse, 2020; Rouse, 2013).

Although gradual transition is feasible in economically constrained municipalities, and

16 In the case of Tariq, the cost of adding PRVs amounts to a total of 10,000 USD.

despite the fact that such an approach is less economically burdensome than a total-system approach, funding remains a primary challenge. Many residents of Amman buy water from private vendors at a cost greater than that of the water provider's tariffs, and people would likely be willing to pay more for better service (El Achi & Rouse, 2020). Future feasibility studies could consider potential reduction in NRW, consumers' behavioral development, and the future scenario of CWS (El Achi & Rouse, 2020). The sustainability of any long-term transition to CWS requires an integrated management of water resources with a focus on social equity, environmental sustainability, and economic efficiency (El Achi & Rouse, 2020). The challenges involved in transitioning to CWS are multi-faceted and require careful consideration. But as climate change intensifies water scarcity challenges in Amman, the goal of CWS will become increasingly urgent. Water resources management strategies implemented now will determine prospects for water security for future generations (Ray, Kirshen & Watkins, 2012).

## Core Issues Driving Water Scarcity in Amman

**Supply**

Surface Water Scarcity
Drought

**Water Use**

Population Growth
Displacement / Migration

**Inequality & Access**

Unsafe Access Points

**Infrastructure & Service**

Insufficient Pipe Systems
Insufficient Maintenance Capacity
Non-Revenue Water

**Finance**

Lack of Funds

## Sample Solutions for Water Security in Amman

**Data**

Keeping Water Supply Data Up To Date

Collect and regularly update data regarding the water supply system (including elevations and numbers of junctions, number of households supplied per junction, maps of existing networks with DMAs, water supply (quantity and pattern), water resources, water tariffs and non-revenue water value).

Hydrological Models

Build robust hydrological models on different levels within the city (i.e. city, district, zone, etc.).

**Infrastructure**

Continuous Supply

Transition refurbished water supply systems from intermittent to continuous supply gradually, using a zone-by-zone approach (based on robust models and after rezoning district metering areas).

Consumption Metering By Zone

Rezone district metering areas (by adjusting size, including areas of similar elevations and ensuring that zones are completely independent of each other).

Pressure Management Interventions

Reduce water loss to leaks (non-revenue water) by refurbishing the system to include sensitive water meters and pressure reduction valves.

**Building trust**

Making data transparent and readily available to the public

Enhance public awareness by making hydrological and water-stress related data readily available to the public.

**Appendix A.** "Main Factors for Proper Transition from IWS to CWS"

| Category | Conditions |
|---|---|
| Data | - Regularly updated:<br>○ Elevations and Number of junctions<br>○ Number of households supplied by each junction<br>○ Maps of existing networks with DMAs<br>○ Water supply (quantity and pattern)<br>○ NRW value<br>○ Water resources<br>○ Water tariffs |
| Modelling | - A single water source per district<br>- Rezoning of DMAs to:<br>○ Adjust size<br>○ Include areas of similar elevations<br>○ Completely independent |
| Infrastructure | - Water meters<br>- PRVs<br>- Power supply |
| Human resources | - Well trained employees |
| Organizational | - Management<br>- Strategy & Planning<br>- Operation & Maintenance |
| Social | - Myths *vs* reality<br>- Behavioral change<br>- Involving public in decision making |
| Institutional (Political) | - Political commitment |
| Economic resources | - Funding (sustainability) |

**Source:** El Achi, N., & Rouse, M. J. (2020). A hybrid hydraulic model for gradual transition from intermittent to continuous water supply in Amman, Jordan: a theoretical study. *Water Supply*, *20*(1), 118-129.

## Cape Town, South Africa

### City Profile

The City of Cape Town is the second-most populous city in South Africa, with a total population of 4.5 million people, amounting to approximately 64% of the Western Cape region's population (Macrotrends, 2019). Cape Town is the primary economic hub in the Western Cape and one of the fastest-growing metropolitan regions in South Africa (World Population Review, 2020). Cape Town is characterized by its Mediterranean climate and experiences hot, dry, and drought-prone summers and mild, rainy winters. The city is almost entirely reliant on surface water, which makes it vulnerable to drought and extreme climate events.

In 2015–2018, the Western Cape experienced a drought that caused a water shortage in Cape Town so severe that the city nearly ran out of water. The Cape Town water crisis drew global attention. It produced key lessons for water crisis management and informed the city's long-term strategy for achieving water security.

### Case Study: From Crisis Management to Long-Term Planning

The Cape Town water crisis was a period of severe water shortage in the Western Cape region of South Africa. The crisis began with the onset of drought in 2015 and lasted until 2018. As the crisis reached its peak between mid-2017 and mid-2018, Cape Town began to prepare for the point when reservoir levels would fall below the functional minimum of 13.5% capacity, and the city taps would close entirely. Had that occurred, residents would have been forced to queue to collect water from public Points of Distribution (PODs). The water conservation efforts of private citizens and businesses, together with improved data management, upgraded technologies, and the city's water management efforts, led to a radical decrease in water consumption.

As the crisis subsided and Cape Town moved out of immediate danger, the city began to focus on creating a long-term strategy to ensure future water security. The city's new Water Strategy is based on redefining Cape Town's

relationship to water, enacting institutional reform for a more holistic approach to water management, fostering resilience to climate change, and supplementing surface-water supply through risk-based deployment of water supply augmentation technologies.

**Background**

*Immediate causes of the water crisis*

In 2015, a period of severe drought caused dam levels in the Western Cape Water Supply System (WCWSS) to decline steadily. Water levels fell between 15–30% of total dam capacity between 2017 and 2018 (Ziervogel, 2019). The third consecutive year of drought, 2017, was characterized by unprecedented low levels of rainfall—the lowest ever recorded in the city since record-keeping began in 1928—which threatened to cut off water supply entirely for the city's 4.5 million inhabitants (Schreiber, 2019). As the drought intensified, Cape Town began organizing its response in 2016 and more intensely in 2017 when the drought peaked. The short time frame for formulating a response was a notable challenge of the crisis (Schreiber, 2019; Ziervogel, 2019).

*Long-term causes of the water crisis*

Over-reliance on surface water

The historical, or long-term causes of the water shortage are complex. The crisis itself was the result of an interplay of existing factors that made the region particularly vulnerable to water scarcity (Ziervogel, 2019; Schreiber, 2019). The city's reliance on surface water was the most notable of these long-term causes, as Cape Town obtained over 95% of its water from six reservoirs located throughout the Western Cape province (Ziervogel, 2019; Schreiber, 2019). The city was almost entirely reliant on these rain-fed reservoirs when the drought struck in 2015 (Schreiber, 2019).

Deteriorated infrastructure

Degraded infrastructure is another long-term factor that contributed to Cape Town's water crisis. Key catchment areas became overrun with thirsty, invasive vegetation. Other infrastructures—such as canals that transport water from nearby rivers to the Voëlvlei Dam—became clogged with sand and cracked, all of which contributed to overall water losses throughout the system (Schreiber, 2019; Ziervogel, 2019).

Lack of coordination among levels of government

Under South Africa's constitutional framework, the national Department of Water and Sanitation (DWS) is responsible for managing and providing bulk water supply—for municipalities and agricultural users—while cities, such as Cape Town, are responsible for water distribution to individual users and businesses located within their boundaries. The maintenance of catchment areas and canals within the Western Cape province is the responsibility of the DWS. Lack of coordination between these government entities has been cited as a factor in the water crisis (South African Water Caucus, 2017). Partisan politics compounded the challenge (Saunderson-Meyer, 2018; Serjak, 2020).

Climate change

A drought of this severity was unprecedented for Cape Town. More and better data collection could be used to build robust predictive models that take climate change into account. Re-

liable predictive models require sufficient data and must account for uncertainty in both data and predictions. Responding to climate change is an ongoing challenge in drought-prone areas like the Western Cape (Ziervogel, 2019).

**Actions Taken**

Water conservation efforts that have been central to Cape Town's water management program since the early 2000s proved useful in managing the water crisis (Ziervogel, 2019). In 2007, Cape Town put in place measures to repair leaks, replace pipelines, and maintain mild restrictions on water use even during wet years to prevent water loss in the system. These efforts prevented an increase in water consumption for more than 10 years, despite the 30% increase in population during that period (Schreiber, 2019).

*Scaling-up existing measures*

Having measures in place proved beneficial during the 2015–2018 water crisis, as Cape Town was able to scale up several readily available, existing efforts to reduce water demand when the drought hit. As a result, a number of water-saving interventions were strengthened, most notably: the installation of many more household flow regulators and water management devices to monitor leaks and water loss, previously installed mostly in low-income homes with high water bills; scaling up water reuse reclamation plants to increase the amount of water that could be offset; and efficient, organized portfolio and project management systems already in place that allowed for rapid procurement processes and afforded the city flexibility and agility in taking action during the crisis (Ziervogel, 2019; Schreiber, 2019). Among the most successful of these interventions were the city's aggressive pressure management efforts. By making pressure reduction responsive—that is, by offering high pressure at peak times and low pressure at off-peak times—and by improving leak detection throughout the supply system, the city was able to save 50 megaliters per day in the first three months of 2018. This success earned Cape Town an international award from the International Water Association in 2018 (Schreiber, 2019).

Cape Town had set up other measures in the past to ensure water security. The city had created transversal management systems years earlier—for example, the Water Demand Management Department—that historically relied on cross-department collaboration. The city also experimented with various approaches to reduce water demand, and cultivated relationships throughout the business sector and different spheres of government, all of which proved useful once the drought hit in 2015 (Ziervogel, 2019). Due to Cape Town's previous partnership with the Cities Support Program in the National Treasury, national and international experts were able to mobilize quickly to support the city as it tackled the impending crisis (Ziervogel, 2019).

*Implementing immediate (short-term) measures to combat the crisis*

When the crisis began, Cape Town implemented various short-term strategies, many of which were later integrated into strategic, long-term responses. First, water restrictions typically implemented during periods of low rainfall were gradually increased, with restrictions intensifying in 2017 (Ziervogel, 2019). Second, to for-

mulate its response to the drought, Cape Town created the "Water Resilience Task Team" (and later the "Water Crisis Management Committee"), consisting of many experts in different sectors and government departments. The experts created a plan that prioritized emergency action and defined tactical phases, which tackled both the immediate problem and prepared for worst-case scenarios by formulating the city's response in the event that the water supply was depleted (Ziervogel, 2019). This approach proved to be an effective practice, as it allowed the city to prioritize its responses and avert the worst outcomes.

The task team's successes were multifold. By bringing transversal water management on board early, the city was able to formulate a holistic response to the water crisis that accounted for different sectors, thereby making it more effective. Through effective financial planning and flexible leadership—the city froze certain posts entirely and reorganized their budget to free up money for combating the crisis—the city was able to secure enough funds rapidly to procure and implement a number of small-scale, affordable water augmentation projects.

These immediate responses included building temporary desalination plants and a temporary reuse plant, accelerating an existing project to use treated wastewater to recharge the Atlantis aquifer, and drilling boreholes into the Cape Flats and Table Mountain Group aquifers (Ziervogel 2019; Schreiber, 2018). The small-scale augmentation projects proved doubly successful. First, they provided an additional 40,000,000 l/day by July 2017, with the total rising to 80,000,000 l/day by December of that year. Second, these undertakings were cheaper and faster to implement than groundwater extraction projects (Schreiber, 2019).

Cape Town also cracked down on "water wasters" by increasing the cost of water tenfold for particularly heavy users (i.e., those that used tens of thousands of liters/month). If the property owners remained noncompliant with water restrictions thereafter, the city installed water management devices to shut off water automatically after 350 l/day had been used on such properties (Schreiber, 2019). Increasing tariffs was effective at promoting conservation (Ziervogel, 2019).

In addition to the city's response to the drought, numerous non-governmental organizations helped Capetonians survive the water crisis. Notably, the Groenland Water Users Association—an organization of fruit farmers from a region neighboring the city—donated a one-time "water injection" of 10 billion liters held in reservoirs on private farmland to Cape Town in early February 2018. This donation amounted to nearly 20 days' water supply for Capetonians (Schreiber, 2019).

Throughout the crisis, the city was successful in ensuring water for critical services—hospitals, schools, etc.—as well as providing free and subsidized water to many Capetonians who could not afford to pay for it (nearly 1/3 of the city's population) (Ziervogel, 2019).

*Turning immediate crisis-coping measures into long-term water management strategy*

Many of Cape Town's successful short-term drought and disaster management efforts were

later extrapolated into long-term strategies and integrated into Cape Town's overall plan to ensure water-sensitivity and resilience in the future. Cape Town's successful communications strategy was one such effort (Ziervogel, 2019; Ziervogel, 2018; Schreiber, 2019). Before the historic water crisis of 2017, water-supply related information was not consistently available to Capetonians (Ziervogel, 2019; Schreiber, 2018). As the water crisis approached, Cape Town enlisted a crisis communications consulting firm, which was able to produce a number of effective communications tools for the city.

The first of these tools was the term "Day Zero," the day when reservoir levels would fall below the functional minimum and the city taps would close, which the communications firm employed as a means of raising awareness and instilling a sense of urgency. Although effective in raising awareness, the term "Day Zero" had the unwanted consequence of reducing international tourism to Cape Town (Allsop, 2018). Other communications tools included the Water Dashboard (launched in November 2017) on the city's website, which gave weekly updates on dam levels and water use; the Water Map (launched in January 2018), which used green dots to show low water use per household; and the Water Outlook (made publicly available in January 2018), which provided a detailed description of the city's water management efforts. In addition, Cape Town provided free communications and resource packages of water-saving materials (e.g., leaflets, posters, hospitality materials, guides, etc.) on their website for the private sector, to stimulate involvement in raising awareness and conserving water (Ziervogel, 2018; Ziervogel, 2019). These efforts resulted in significant water demand reduction, highlighting the benefits of sharing information with the public in a way that is intelligible and accessible, so as build trust and citizen engagement in reducing consumption (Ziervogel, 2018).

As the crisis intensified, "micro"-sources of water—such as boreholes, rainwater collection tanks, greywater reuse systems, etc.—mushroomed across the city among private citizens and local businesses (Ziervogel, 2019). Although micro-sources were useful in reducing water demand on the public water supply system, they can pose a threat to public health if used improperly. To prevent a potential public health crisis, Cape Town created and distributed guidelines for the safe use of micro-sources (Ziervogel, 2018). This action helped resolve the immediate issue of water quality from micro-sources and informed a long-term strategy for micro-source use in the future.

Another key success was strengthening relationships outside of the public sector by engaging with various local NPOs, NGOs, and businesses to address concerns and identify areas for collaboration. These relationships took time to cultivate and are now a useful tool at Cape Town's disposal in the future (Ziervogel, 2018).

By creating an effective, multi-pronged and broad information campaign, improving data management, enlisting the support of private citizens and businesses (by cultivating relationships, building trust and ensuring transparency), as well as by upgrading technologies (relating both to demand reduction and supply augmentation), Cape Town was able to avoid

running out of water (Ziervogel, 2019). By the end of the drought, Capetonians had cut water usage by nearly 60% from 2015 levels (reducing consumption from 1.2 billion liters to 478 million liters per day), with each resident consuming little more than 50 liters/day. Out of the average reduction of 101 million liters used per day, 66 million liters of water were conserved as a direct result of aggressive pressure management, 11 million liters were conserved due to the forced adoption of water management devices in "wasteful" households, and 24 million liters were saved due to elective consumer change (largely the result of the communications campaigns) (Schreiber, 2019). As a result, Cape Town achieved one of the lowest per capita water consumption rates of any major city in the world, and the absolute lowest per capita water consumption of any major city without resorting to intermittent supply (Schreiber, 2019).

**Existing Challenges**

After the crisis, Cape Town shifted its focus to building long-term adaptive capacities for the future. The city published a comprehensive Water Strategy in February 2020, dedicated to increasing understanding of the water system and highlighting the need for better governance, among other things, to implement future responses using a collaborative approach. The strategy is defined by its dedication to enabling inclusion, resilience, and sustainability in the water sector through five main commitments: safe access to water and sanitation services for all, wise water use, sufficient and reliable water from diverse sources, shared benefits from regional water resources, and building a water-sensitive city (City of Cape Town, 2020).

*Restructuring the city's relationship to water*

Cape Town's Water Strategy seeks a paradigm shift in the water sector itself and Capetonians' relationship to water. To achieve this paradigm shift, the city will: optimize and integrate all water resources (surface water, groundwater, wastewater, and storm-water) into a single, holistic paradigm; value water and increase the efficiency of its use through water-sensitive urban design; and maintain healthy waterways and coastal waters, as well as ensure their inclusive and safe use (City of Cape Town, 2020). In accordance with its transition to water-sensitivity, Cape Town is redefining its Water and Sanitation Department, previously a traditional municipal engineering department, into a modern, holistic water services provider, in line with international best practices (City of Cape Town, 2020). The three main tools at Cape Town's disposal to realize its holistic transition into a water-sensitive future are economic and financial incentives, regulatory mechanisms, and direct investment in infrastructure (City of Cape Town, 2020).

In addition to continuing to reduce water demand through aggressive network management, the city has also expressed plans to manage all forms of water—storm-water, groundwater, greywater, blackwater, canals, rivers, etc.—in an integrated fashion, to optimize the sustainable use of water and reduce flood risk in the future. Some actions have been taken to ensure this, such as shifting the responsibility of storm-water from the Roads Department to Cape Town Water, while others are in the planning phase (City of Cape Town, 2020).

*Fostering adaptability and increasing robustness of responses*

Accurate predictive modeling that accounts for climate change is a goal of Cape Town's Water and Sanitation Department. Based on historical rainfall records, the 2015–2018 drought was a 1-in-590-year event, a fact that highlights the difficulties of planning for climate change based on extant data. In response to this challenge, the city plans to integrate additional uncertainties related to climate change into its future models and increase the robustness and adaptability of its planning mechanisms.

Measures taken to increase robustness and adaptability include monitoring rainfall and water demand, updating demand-and-supply reconciliations regularly, learning from temporary, small-scale implementation projects ("learning by doing"), increasing adaptability, undertaking project preparation in advance, and risk-based dispatch of supply sources (City of Cape Town, 2020). Risk-based (or demand-based) deployment of augmentation technologies and supply sources is particularly important, as it allows for the implementation of technologies on a stage-by-stage basis. Cheaper and easier solutions (the "low-hanging fruit" in water security projects) will be implemented first. Slower and costlier technologies will be implemented progressively, as needed, to meet certain demand targets. This means of planning for future water security allows the city to align its project pipeline and budget with the water demand curve, thereby ensuring water security without overstraining the municipality's budget or technical capabilities (Serjak, 2020).

*Augmenting surface-water with additional supply sources*

Investment in infrastructure—especially in new build infrastructure to ensure additional, diversified water supply—is already well underway in Cape Town. According to the 2020 Water Strategy, although rain-fed sources will still supply more than 75% of Cape Town's water for 10 years, the city will also commit to increasing available supply by more than 300 million liters per day over the next 10 years. Furthermore, the build program will be based on a higher reliability standard (99.5% assurance of water supply, as opposed to the 98% assurance standard of the past) that will ensure a diverse, reliable water supply without significantly raising the cost of water for consumers (City of Cape Town, 2020).

Cape Town (coupled with the DWS) has embarked on a substantial new build program, investing considerable funds into a variety of water augmentation projects, all of which are expected to produce their first yields of water at various points throughout the next five years. Among these are the Berg River augmentation scheme (responsibility of the DWS, and expected to yield 40 Ml/day), groundwater extraction from the Cape Flats aquifer (to yield 20–48 Ml/day), the Table Mountain Group Aquifer (to yield 15–45 Ml/day), and the Atlantis aquifer recharge project (to yield 10 Ml/day).

In addition, the city has committed to two water reuse programs, namely, the Reuse Demonstration Plant (to yield 10 Ml/day) and the Faure New Water Scheme (to yield 70–100 Ml/day). These programs, however, face potential social backlash, as consumers can be unwilling

to consume reused wastewater outside of emergencies (City of Cape Town, 2020).

Cape Town is investing significantly in water desalination plants. The city has commissioned two temporary desalination plants—the Strandfontein and the Monwabisi plants, each yielding 7 Ml/day—and are currently assessing the feasibility of constructing a permanent water desalination plant that would yield between 50 and 150 Ml/day, at a total cost of R6–7 billion (City of Cape Town, 2020). Desalination plants have drawbacks: they can threaten marine and coastal ecosystems because they produce significantly warmer water and higher saline content. (Roberts, Johnston & Knott, 2010).

The city has also developed an "adaptable" build program, wherein infrastructure projects can be brought forward or scaled back in the future, as needed (City of Cape Town, 2020).[17]

*Fostering a collaborative approach in management interventions*

In addition to infrastructure investment, Cape Town is exploring successful management interventions. Although many interventions succeeded at the municipal level in the past, the drought raised concerns among water professionals and city officials regarding the need to engage collaboratively with regional and national government bodies to ensure the effective management of shared water resources (Ziervogel, 2019). As a result, Cape Town has expressed its commitment to engage with the Western Cape province to protect shared water resources, maintain shared infrastructures, clear invasive alien vegetation in key catchment areas, and effectively manage the WCWSS in a way that is beneficial to all parties involved (City of Cape Town, 2020).

*Finance*

Cape Town's new Water Strategy notes that the committed new water program will require a capital expenditure of nearly R5.8 billion over the following 10 years, a sum that is within the municipality's total capital budget for water and sanitation services (City of Cape Town, 2020).

*Project pipeline challenges*

Many water projects proposed during the crisis were not completed. When the crisis ended, some projects remained, but delivery rates were low. Available funds were not flowing to projects.

The entire Cape Town water department was reorganized as a result. A capital projects branch now aligns the city's water tariffs and budget with project pipelines. A new project management office tracks performance against targets, looking at medium-term and ten-year budgets. This tracking will be aligned with the city's Water Strategy.

Ensuring project feasibility requires a realistic analysis of procurement processes. Project managers can be financially disincentivized to give realistic scheduling estimates for projects because their funding is usually tied to the proposed timeline of their projects. As a result, companies and utilities can underestimate the time needed for projects to be realized, there-

17 See Appendix B for a detailed breakdown of provisional water yields and costs of the committed 10-year program.

by creating unrealistic scheduling expectations among city administrators (Serjak, 2020).

The city has a long-term investment plan to meet growing needs and maintain extant infrastructures, to promote cost-effective spending within the municipality's water and sanitation budget, and to improve revenue collection with a fair and sustainable tariff model (City of Cape Town, 2020). The city plans to rely on capital grants to prioritize access to basic services, thereby continuing to ensure access to water for its most vulnerable citizens (City of Cape Town, 2020). Efficient, realistic, and sustainable capital and project management are essential for achieving water security (Ziervogel, 2019; Serjak, 2020).

*Inequality*

Although Cape Town was able to provide free and subsidized water to its lower-income citizens throughout the water crisis, the "Day Zero" campaign highlighted socioeconomic disparities. The collection of water from communal taps was already a reality for the 500,000 Capetonians living in informal settlements (Schreiber, 2019; Allsop, 2018). In that sense, the 2015–2018 drought had a smaller effect on nearly one-eighth of Cape Town's population, those living in informal settlements who use only 5% of the total water provided by the city's water supply system (City of Cape Town, 2020). Improving water and sanitation services for this portion of the population remains an urgent concern.

The city plans to work with communities in informal settlements to improve the daily experience of access to water and sanitation services, emphasizing the need for trust-building and increasing safety within these communities. Cape Town's Water Strategy cites the improvement of sanitation services in informal settlements as a higher priority than improving water supply services, due to the specific security and hygienic concerns these shared sanitation infrastructures pose to the communities that use them (City of Cape Town, 2020).

Challenges in informal settlements are multi-faceted. First, the high population densities of informal settlements make it impossible to construct and operate permanent infrastructures without relocating existing housing structures. Second, many informal settlements are located on privately-owned land or land that is otherwise unsuitable for residential development, thereby restricting the city's ability to develop permanent infrastructure (City of Cape Town, 2020). Although the issue of adequate service provision to informal settlements is complex, Cape Town has expressed its commitment to developing solutions based on building trust, social cohesion, and dignity (City of Cape Town, 2020). Logistical, technical, and physical barriers remain.

## Core Issues Driving Water Scarcity in Cape Town

**Supply**

Surface Water Scarcity
Drought

**Water Use**

Population Growth
High Per Capita Consumption
Urban/Rural Competition

**Inequality & Access**

Unsafe Access Points
Distant Access Points

**Infrastructure & Service**

Insufficient Data
Insufficient Capture Technology & Infrastructure
Insufficient Storage Technology & Infrastructure
Insufficient Pipe Systems
Non-Revenue Water

**Finance**

Counterproductive Pricing Structures

**Governance**

Pipeline Barriers Within Government Departments
Lack Of Coordination Between Local, Regional And National Government

## Sample Solutions for Water Security in Cape Town

**Data**

Consistent Monitoring Of Rainfall And Water Demand

Engage in consistent monitoring of rainfall and water demand.

Keeping Water Supply Data Up To Date

Update demand and supply reconciliations on a regular basis.

Learning From Temporary, Small-Scale Implementation Projects

Ensure robustness of data by learning from temporary, small-scale implementation

projects ("learning by doing").

Hydrological Models

Create robust, predictive hydrological models that take climate change projections into account.

Climate Vulnerability Models

Create robust, predictive models that indicate level of vulnerability to climate change-related extreme weather events (e.g. droughts).

**Water Supply**

Diversifying Water Sources

Diversify water sources so that municipal supply is not reliant on a single [type of] source.

Wastewater And Storm-Water Capture, Treatment, And Reuse

Supplement surface water supply with treated and reused wastewater.

Use public awareness campaigns to build support for integrating water treatment and reuse as a means of supply augmentation.

Desalination

Supplement surface water with desalinated seawater.

Groundwater Capture

Supplement surface water supply with groundwater.

**Infrastructure**

Reliability Standards For Infrastructure Investments

Base infrastructure-build programs on higher reliability standards to ensure reliability of supply and overall system resilience in the face of climate change and/or extreme weather events.

Pressure Management Interventions

Invest in pressure management interventions (i.e. household flow regulators, water management devices to monitor leaks and water loss) before crises occur to reduce leaks and water loss in the system.

Make pressure management reduction responsive by providing high pressure during peak hours of the day and low pressure during off-peak hours.

Water Transportation Between Cities And Between Urban And Rural Areas

Coordinate water transfers with external stakeholders (e.g. from surrounding rural areas) that have surplus of water to supplement municipal supply during crises.

**Finance**

Sustainable Cost Recovery

Implement effective cash collection policies to generate revenue from water users.

Including Financial Feasibility In Project Feasibility Assessments

Incentivize outcome-based grants to ensure more self-sustaining infrastructure and finance systems in water supply projects.

**Management Within City Governments**

Water Department Organization

Integrate all water resources—surface water, groundwater, storm-water and wastewater—into a single holistic paradigm by reassigning responsibilities within municipal agencies.

Coordination Among Governmental Departments

Restructure management systems to make them transversal (as opposed to silo-based), allowing for holistic water management.

**Coordinated Governance**

Local, Regional, And National Coordination

Cultivate relationships (and ensure coordination) throughout different spheres of government so they can be quickly mobilized in times of crisis.

**Planning**

Integrated Water Resources Management (IWRM)

- Encourage long-term perspectives in financial planning and management.

Funding Structures That Incentivize Realistic Timeframes

Create funding structures that incentivize realistic scheduling of engineering or infrastructure projects.

Ensure realistic project scheduling by creating funding structures that disincentivize underestimated project deadlines or schedules.

Planning For Realistic Timeframes

Undertake supply augmentation project preparation in advance and organize risk-based prioritization of supply source (technology) dispatch to ensure realistic timeframes and overall project implementation agility.

Flexible Water Restriction Policies

Implement a system of water restrictions that can be gradually intensified as necessary where baseline restrictions will almost always be in place to encourage wise water use and allow for population growth (without straining water resources).

Flexible Financial Planning

Design efficient and organized portfolio and project management systems to allow for flexibility in times of crisis.

Encourage flexible financial planning so that leadership is free to utilize finances read-

ily and flexibly in times of crisis (i.e. by re-budgeting money, temporarily freezing certain posts, etc.)

Training In Procurement Processes

Foster understanding of and training in procurement processes to ensure realistic expectations, schedules and project planning.

**Municipal Revenue Sources**

Tariff Structures That Disincentivize Water Waste

Address "water wasters" by drastically increasing tariffs for heavy users.

Design fair and sustainable tariff models that are able to generate necessary revenue for future infrastructure maintenance.

Sustainable And Just Enforcement Models

Address non-compliant "water wasters" (i.e. those who continue to use a lot of water despite tariffs) by forcibly installing water management devices that automatically shut off water on those properties after a daily water use maximum has been reached.

**Access & Equity**

Subsidies To Assist Low Income Population

Continue providing subsidized water for low income members of society even in times of crisis, so as to ensure universal access to water.

Protecting Vulnerable Populations

Continue providing subsidized water for critical services (i.e. schools and hospitals) even in times of crisis, so as to ensure universal access to water.

**Involving Stakeholders Outside Of Government**

Involving Stakeholders In All Parts of Society In Water Related Decision Making

Cultivate relationships throughout the business sector so they can be quickly mobilized when crisis strikes.

Cultivate relationships with national and international water experts—by joining resilience programs, etc.—so that experts can be quickly mobilized when crisis strikes.

Cultivate relationships with local NGOs and NPOs so they can be quickly mobilized when crisis strikes.

Issuing Guidance To The Public

Encourage safe use of micro-sources (e.g. rainwater, boreholes, etc.) by creating and disseminating standardized guidelines for use of these sources.

**Building Trust**

Making Data Transparent And Readily Available To The Public

Make data transparent, readily available and easily intelligible to citizens to raise overall awareness of water security.

**Water Cycle Management**

Conservation Mechanisms That Can Be Easily Scaled Up In Times Of Crisis

Put in place regulatory and financial mechanisms to ensure water conservation that can be readily scaled-up in times of crisis.

Using Treated Wastewater To Recharge Groundwater And Over-Exploited Aquifers

Invest in artificial aquifer recharge programs to supplement surface water supply with groundwater.

**Reducing Water Loss**

Reducing Leaks

Reduce system water loss to leaks through aggressive pressure management.

**Reducing Water Consumption**

Public Awareness Campaigns

Engage public in conservation efforts early on and not at onset (or in the midst) of a crisis through public awareness campaigns.

Design and implement comprehensive, informative and effective communications campaigns to engage the public and encourage conservation.

Create informational packages for the private sector to engage private business in water conservation efforts.

Create promotional packages for the private sector to utilize as a means of raising awareness about water security among their customers (i.e. among the public).

Systems Change

Increase the efficiency of water use through water-sensitive urban design to ensure future water security.

## Appendices

**Appendix A.** Restriction levels and timeline, 2005-2018.

| LEVEL | DATE | RESTRICTION | TARGET |
|---|---|---|---|
| Level 1 | 2005 | • No irrigation 10:00-16:00<br>• Spray nozzles for hosepipes<br>• No hosing down hard surfaces<br>• No dampening of building sand | 10% savings |
| Level 2 | 1 January 2016 | • Irrigation for 1 hour on Tue. Wed. Thurs<br>• No irrigation 9:00-16:00 | 20% savings |
| Level 3 | 1 November 2016 | • Buckets only for watering gardens<br>• Pool covers | 30% savings |
| Level 3B | 1 February 2017 | • No private car washing | 30% savings |
| Level 4 | 1 June 2017 | • No irrigation<br>• No topping up of private pools | 100 Litres pp/day |
| Level 4B | 1 July 2017 | • No topping up of public pools | 87 Litres pp/day |
| Level 5 | 3 September 2017 | Fines:<br>• Residential > 20kl/m<br>• Commercial: 20% less than same month previous year | 87 Litres pp/day |
| Level 6 | 1 January 2018 | • Households consuming more 10.5kl/m prioritised for WMD<br>• Non residential properties reduce by 45% less than pre-drought consumption (2015)<br>• Agriculture to reduce by 60% | 87 Litres unless targets continue to be missed in which case this will be reduced |
| Level 6b | 1 February 2018 | • Households consuming more than 6 kl/m prior fixed for WMD<br>• Punitive tariffs for >10.5kl/m | 50 Litres pp/day |

**Source:** https://newtulbaghhotel.com/wp-content/uploads/2018/02/Drought-crisis-info-for-SubCouncil-16-Feb-2018.edited.pdf
Found in Schreiber, L. (2019). Keeping the taps running: How Cape Town averted 'Day Zero,'

**Appendix B.** "Committed new water program over 10 years—provisional yields

| TABLE 1: COMMITTED NEW WATER PROGRAMME OVER TEN YEARS - PROVISIONAL YIELDS AND COSTS | | | | | | |
|---|---|---|---|---|---|---|
| Intervention* | First water | Effective yield | | Total capex | Unit capex** | Operation cost*** |
| | | Mℓ/day | Million kℓ pa | R million | Rm/Mkℓ | R/kℓ |
| Demand management | 2019 | 70 | 26 | 410 | 6 | 3 |
| Alien vegetation clearing | 2019 | 55 | 20 | | | ~1-2 |
| Management of WCWSS | n/a | 27 | 10 | | | ~0,2-0,5 |
| Cape Flats aquifer ph 1 | 2020 | 20 | 7,3 | 610 | 31 | 5 |
| Table Mountain Group ph 1 | 2020 | 15 | 5,5 | 375 | 25 | 5 |
| Cape Flats aquifer ph 2 | 2021 | 25 | 9,1 | 450 | 18 | 5 |
| Atlantis aquifer | 2021 | 10 | 4 | 290 | 29 | 8 |
| Table Mountain Group ph 2 | 2022 | 15 | 5,5 | 335 | 23 | 5 |
| Table Mountain Group ph 3 | 2022 | 20 | 7,3 | 326 | 16 | 2 |
| Berg River augmentation | 2023 | 40 | 15 | | | ~3-5 |
| Water reuse ph 1 | 2024 | 70 | 26 | 1 360 | 20 | 5 |
| Desalination ph 1 | 2026 | 50 | 18 | 1 650 | 33-40 | 9 |
| **Total, including WDM** | | 417 | 154 | 5 806 | | |
| **Total new supply** | | 347 | 128 | 5 396 | | |

* Timing and the capital and operating costs are best available engineering estimates. All schemes are subject to the outcomes of ongoing investigations (to determine optimal yield, siting and timing) and relevant approvals. ** Rounded to nearest million rand. *** Rounded to nearest rand.

**Source:** City of Cape Town. (2020). Our Shared Water Future: Cape Town's Water Strategy.

## Chennai, India

### City Profile

Chennai is the capital of the Indian state of Tamil Nadu. Located on the coast of the Bay of Bengal, it is home to migrants from other parts of the state and across India. The growing population now stands at 10 million. The city is home to India's automobile industry and a hub for information technology and manufacturing companies. Industry and population growth have strained once-abundant water supplies, leading to high government spending on desalination, long-distance water transport via train, and trucks to deliver water to individual neighborhoods. Chennai utilizes groundwater in part because flooding, drought, and contamination have made surface water sources unreliable. The city also relies on four main reservoirs (Palanichamy, 2019). These reservoirs regularly run low in times of drought; consequently, boreholes have been deepened to increase groundwater extraction at the cost of dropping the water table to a lower depth.

### Case study: Future Water Supply Solutions

Chennai can supply 830m3 of water per year/per capita, which is below the global norm of 1000m3 per year/per capita (Vivek, 2016). With a growing population and lack of immediate freshwater sources, Chennai has long employed groundwater extraction (Vivek, 2016). Chennai experiences heavy rains during the monsoonal season. These rains were once beneficial for groundwater and surface water recharge; however, due to urban development and the expansion of impermeable surfaces, rains now cause flooding and increased pollution of waterways with minimal groundwater recharge.

City water sources include four reservoirs (Poondi, Cholavaram, Red Hills, and Chembarambakkam), variable groundwater sources, and two desalination plants (Paul & Elango, 2018). Combined, these sources provide 108 liters per capita per day (lpcd), short of the 150 lpcd recommended by the World Health Organization (Paul & Elango, 2018; Vivek, 2016).

The Chennai Metropolitan Water Supply and Sewage Board (CMWSSB) utilizes trains and tankers to transport water from lakes and rivers hundreds of kilometers away to provide for the city during periods of drought (Vivek, 2016; Gupta, 2019).
2016).

**Background**

Urbanization in Chennai poses numerous challenges to maintaining an adequate water supply (Arunprakash et al., 2013). The total amount of water used in a typical, non-drought month is around 80% of the total supply, creating little storage capacity for months of drought (Palanichamy, 2019). Chennai's growing population, now over 10 million, is changing the natural landscape. Ponds, flood plains, and canals are being filled in to provide housing and resources. The removal of wetlands has reduced the rate of groundwater recharge and degraded water quality. Benefits derived from wetland ecosystems, such as the natural filtration of contaminants from surface water, have been lost. Lakes and ponds have decreased in size over the past 40 years, from 100.98 km2 to 91.31 km2 (The Hindu, 2019).

Causes of water contamination include direct emission of raw sewage, runoff during flood events, and hazards related to open defecation (Palanichamy, 2019). In 2019, all water samples tested throughout Chennai showed some form of contamination, which led to over 2,000 diarrheal cases (The Times of India, 2019). Floods and droughts exacerbate contamination, as pollutants from roadways, homes, and agriculture become concentrated in waterways. Chennai experienced an acute water crisis in 2019 (Lakshimi, 2019). During the crisis, reservoirs were only able to provide 530 mld (million liters a day), compared to the average 830 mld. Studies of water supply methods in Chennai have identified possible improvements, including augmenting the current system with an additional reservoir, increased desalination, and wastewater reuse (Paul & Elango, 2018).

**Actions Taken**

Actions taken to maintain Chennai's current
Actions taken to maintain Chennai's current
water supply and meet future demand include water transport, continuous rainwater harvesting, further investment in desalination, and wastewater reuse. The method of transporting water into the city can be effective in the short term for minimizing the impacts of groundwater exploitation. The Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) utilizes mobile water units across the city to distribute water. It employs trains from other cities like Vellore and Jolarpettai to bring millions of liters of water per day into the city (CMWSSB, n.d. and Gupta, 2019).

In the early 2000s, Chennai required that all buildings be fitted with Rainwater Harvesting (RWH) systems (Vivek, 2016). RWH increased supply and provided a form of water storage that could be used as needed for groundwater recharge (Vivek, 2016). An estimated 5% of the water collected by RWH systems is used for immediate consumption; the majority of captured rainwater is directed to groundwater recharge. Implementation of RWH throughout Chennai has increased groundwater recharge rates and involved residents in the management of water resources (Vivek, 2016). This kind of pub-

lic participation can be beneficial in generating new conservation efforts. Improved enforcement of water regulations is another area that could help prevent another water crisis (Palanichamy, 2019).

Desalination plants are another source of water. The first plant was put in place in 2005 (Ramesh, 2015). Currently, two plants operate in the city, providing 100 mld each, with two more plants under construction to increase the production of freshwater to 400 mld (Ramesh, 2015 and Lakshimi, 2019). Desalination is normally used in arid regions. Although desalination helps the city meet the demand for water in the short term, it is not an optimal long-term solution in a climate with abundant water resources.

Chennai pioneered wastewater recycling in India with the efforts of the Chennai Petroleum Company Limited (CPCL) (Narain, 2015). The company invested in a wastewater treatment plant to clean water for refinery use (Water World, 2006). This project not only minimized the refinery's use of the local water supply; it also protected much of the surrounding environment from further pollution (Water World, 2006). The project sets an example of how wastewater could be utilized more extensively. Paul and Elango (2018) suggest that 60% of the city's sewage is treatable for reuse. Treating that amount would generate 486 mld of water, which could be used in homes or directed back to rivers to recharge groundwater. In 2019, the state government began developing plans to create a new wastewater treatment facility to pump 500 mld back into the local groundwater supply (Viswanath, 2019).

**Existing Challenges**

As the population grows, urban development will also increase; meanwhile, climate change will intensify the risk of floods and drought. These pressures will continue to reduce groundwater recharge rates unless significant changes in water management are made.

## Core Issues Driving Water Scarcity in Chennai

**Supply**

- Drought
- Groundwater Scarcity
- Surface Water Scarcity
- Flooding
- Contamination and Pollution
- Damage to Aquifers

**Water Use**

- Population Growth

**Infrastructure & Services**

- Insufficient Capture Technology & Infrastructure
- Insufficient Storage Technology & Infrastructure

## Samples Solutions for Water Security in Chennai

**Infrastructure**

- Water Transportation Between Cities And Between Urban And Rural Areas

**Water Supply**

- Diversifying Water Sources
- Wastewater And Storm-Water Capture, Treatment, And Reuse
- Desalination
- Rainwater Harvesting

## Istanbul, Turkey

### City Profile

Istanbul, Turkey, is home to nearly 15 million people and spans over 5,000 km2 (2,000 mi2) on both the European and Asian continents. Istanbul experiences a Mediterranean climate, but due to its size also experiences more rainfall in the north and even snow in the east. In the last two decades, Istanbul has experienced multiple droughts. These droughts have affected the city's surface water resources, which are held in multiple reservoirs outside the city (Easton, 2017). The majority of the population in Istanbul lives on the European side, whereas much of its resources, including water, is stored predominantly on the Asian side. The growing population adds stress to an already water-scarce city, requiring further procurement of resources. Elaborate water transport systems span the city, under the Bosporus Strait and outside city limits, delivering water to the metropolis. Today, the water transport system in Istanbul spans 20,000 km (Öztürk & Altay, 2015). The city depends on a decentralized water management system. With increasing growth and water demand, changes are needed to make this system sustainable. The city is projected to continue to grow because of its bustling economy, constituting 55% of trade in Turkey. Migrants within Turkey, as well as refugees from neighboring countries such as Syria, continue to move to the city. According to current estimates, the population is expected to reach 21 million by 2050 (Cuceloglu et al., 2017).

### Case Study: Adapting Infrastructure to Serve a Growing Population

As the meeting point of Europe and Asia, IsAs the meeting point of Europe and Asia, Istanbul has been an economic and trade hub for centuries, allowing it to become the largest city in Turkey and all of Europe (Öztürk &Altay, 2015).

In the 1930s, groundwater wells were used for drinking water and for various industries like textiles, with and without official sanction. By the 1960s, many of the wells had run dry and become mixed with salt water or other contaminants (Demiroglu, 2019). This early overuse of groundwater led to reliance on water bodies outside the city. Today, 97% of Istanbul's supply comes from surface water, originating in reservoirs and lakes on both the European and Asian continents (Altinbilek, 2006; Öztürk & Altay, 2015; Yalcintas et al., 2015). Distant reservoirs and water transportation are associated with contamination at the reservoir sites, losses during transport, and shortages during periods of drought. To keep up with Istanbul's growing population and growing water demand, the government has developed further dams and procured further water resources outside of the city. The effects of climate change, coupled with a growing population, contamination, and significant water losses, will increase pressure on the system in the coming years.

**Background**

Istanbul has been a world empire three times over and is now the largest city in Turkey (van Leeuwen & Sjerps, 2016). It is known for its historical and cultural importance. Because the city was developed and has remained developed for 3,000 years, some natural resources in the region have been depleted. Istanbul is surrounded by water, but it lacks nearby freshwater sources. Groundwater was extracted and utilized during an earlier period, resulting in a shift to reliance on transported water, which itself is not a new practice in the city. From the Roman era to today, aqueducts have been built, torn down, and rebuilt to maintain the growing population. In the 1980s, about 43% of Turkey's inhabitants lived in urban areas. Today, 75% of the population lives in urban areas, particularly Istanbul, Ankara, and Izmir. Residential demand for water (2.9 million m3 /day) in Istanbul constitutes 80% of the total water supply (Yalçıntaş et al., 2015).

*History of Water Management in Istanbul*

When the Ottoman Empire ended in the 1920s, very little water infrastructure remained. This lack of water infrastructure can be attributed to the multiple wars that occurred before the establishment of the Republic of Turkey (Kilbaroglu et al., 2012). Dilapidated infrastructure produced poor water quality for urban and rural communities across Turkey. Between the 1930s and 1950s, Turkey began turning things around with the establishment of dams for hydropower, drinking water, and irrigation. Before the 1980s, water was managed primarily on the national level, and there was little collaboration with foreign actors, even when water bodies were shared (Kilbaroglu et al., 2012). The 1980s saw the beginnings of water management reform for Istanbul and all of Turkey. This decade was a time marked by economic transition, greater environmental awareness, and the development of municipal water service administrators (Kilbaroglu et al., 2012).

Turkey moved away from a singular, state-led economy to a broad market model, which was open to the global economy. This transition created space for decentralization and privatization (Kilbaroglu et al., 2012). This shift was initially apparent in the electricity and power sectors across Turkey, which sought to attract private investment.

With the development of the environmental movement in the 1970s and the Stockholm conference in 1972 highlighting the need for environmental regulation, Turkey enacted legislation including the Law on Environment in 1983 and the Water Pollution Control Bylaw in 1988 (Kilbaroglu et al., 2012). Legislation for environmental protections and clean water at the national level led to the development of the Ministry of the Environment in 1991 (Kilbaroglu et al., 2012). These initiatives gave the area of water management greater importance in the political sphere. Finally, it was determined that the nationalized style of water management that had existed in Turkey was unsuccessful in providing water to poorer areas. Therefore, management methods were altered to increase local responsibility and control. The city began the process of privatization and decentralization. The Istanbul Water Supply and Sanitation Administration (ISKI) was created (Kibaroglu et al., 2012). Decentralizing services gave local governments budgetary autonomy and the ability to seek international funding (Kibaroglu et al., 2012). Today, ISKI manages the 39 different municipalities within Istanbul, providing over 1 billion m3/ year of water from 17 different surface water resources with a network that covers over 19,000 kilometers (ISKI, n.d.). ISKI also manages the wastewater and water treatment facilities throughout the greater Istanbul area.

These developments in the 1980s were necessary for Turkey's growth; however, during the creation of new institutions, explicit lines were not drawn to distinguish jurisdictions. Too much decentralization and privatization can make systems less effective, especially in times of crisis. With this challenge in mind, national water laws were drafted in the early 2000s but not enacted (Kibaroglu & Baskan, 2011).

In 2009, Istanbul hosted the 5th World Water Forum of the World Water Council. This meeting brought together local and regional parties from 43 countries (WWC, 2009). The focus was on creating a platform for local governments and local authorities to tackle climate change and build water security. The forum resulted in the Istanbul Water Consensus (IWC) (IIWF, 2014). Highlighting the necessity of urban water management, the IWC has served as a template for over 1,100 towns and cities to enact positive change within their local water management structures (IIWF, 2014). The IWC called for collaboration across sectors, suggesting that knowledge outside of the specific area of water policy would be essential for water security and sustainable growth in the future.

*Governance*

At the national level, Turkey has long prioritized water distribution policy (Islar & Boda, 2014 & Mutlu, 2011). The Southeastern Anatolia Project (GAP, o Güneydoğu Anadolu Projesi) in Southeast Turkey launched in the 1980s, focused on the need not only for water, but also for development generally, including educational opportunities, infrastructure, irrigation, and energy. [18] The GAP remains the largest water project in the country's history (Kibaroglu et al., 2012 and Ozkahraman, 2017). Plans included 25 irrigation systems, 22 dams, and 19

18 Find information on the GAP project here http://www.gap.gov.tr/en/what-is-gap-page-1.html

hydroelectric power plants, many of which are completed (Ozkahraman, 2017). The GAP project continues to generate strain on relationships between Turkey and its neighbors Iraq and Syria (Jongerden, 2010). The damming project gave Turkey control over 50% of a shared water source due to its geographic location at the headwaters of the Tigris and Euphrates Rivers (Ozkahraman, 2017). The damming removed sources of drinking water and reduced the energy capacity of dams in Syria and Iraq.

Becoming a candidate for membership in the European Union in 1999 brought a new set of rules on water governance for Turkey to follow. The EU Water Framework Directive (WFD) requires developing river basin management plans, establishing monitoring systems, building widespread public participation, and achieving "good water status" [19] (Kibaroglu et al., 2012). Turkey has been working toward these goals, in particular by improving national legislation and infrastructure to deliver drinking water and remove wastewater (World Bank, 2016). Turkey's accession to the EU is currently at a standstill (European Commission, 2019).

*Increasing Population and Demand*

Istanbul is considered one of the 23 "megacities" in the world and continues to grow at a rate of 2.8% per year (van Leeuwen & Sjerps, 2016). There is significant internal migration to Istanbul from other areas of Turkey. As of 2016, 2.6 million Syrian refugees had migrated to Turkey, with 395,000 individuals moving to Istanbul (Kaya & Kirac, 2016). The largest city in Europe, Istanbul is expected to reach a population of 21 million in 2050 (Cuceloglu et al., 2017). The deficit between water supply and demand in Istanbul was around 682 million m3/year in 2010 (Bekiroglu and Eker, 2011). Even with the continuous addition of new resources, Istanbul is projected to experience a deficit.

Because of the increasing population, individuals and groups have settled outside of the city, occasionally near reservoirs (Güneralp et al., 2013). These settlements increase the risk of contamination and impede the city's ability to provide continuous fresh water. Some settlements in and around Istanbul had been legalized throughout the 1980s. With others expanding toward forests and water basins, the number of illegal settlements constructions in the area reached 200,000 in 2007 (Bekiroglu and Eker, 2011). This unregulated growth contributed to Küçükçekmece Lake, a former source of drinking water (80 million m3 capacity), becoming unusable due to varying levels of anthropogenic and natural contamination sources (Güneralp et al., 2013 and Turgut & Ceylan, 2012). The development of the area's shoreline, industrial waste polluting the waterway, and inadequate auditing by the authorities resulted in excessive contamination to the lake (Turgut & Ceylan, 2012).

Deficiencies in waste management infrastructure also contribute to the contamination of water sources. Updates to the sewage and wastewater systems have brought the percentage of wastewater treated to 95% (Altinbilek, 2006). However, some of the piping systems separating grey and black water still overlap,

19 Find the layout for the Water Framework Directive here: https://ec.europa.eu/environment/water/water-framework/index_en.html

allowing some of the untreated waste to reach water bodies, including reservoirs. Compared to the water delivery system, the wastewater management system in Istanbul is less developed (Ekrem Karpuzcu et al., 2019 and Yuksel et al., 2004).

*Insufficient Infrastructure and Usage*

The process of moving water from reservoirs to homes poses ongoing challenges. Between 2011 and 2014, more than 50% of water was lost through water transport to Istanbul (Yalçıntaş et al., 2015). Because of Istanbul's history, much of the city has ancient ruins and cultural sites that have the potential to be ruined with modern development. These sites create a logistical problem when trying to minimize the losses of water transport through old infrastructure or mismanaged connections. Due to the inconsistent nature of surface water supplies in Istanbul, minimizing losses within the system is a vital strategy (Yalçıntaş et al., 2015).

The city has engaged the public in efforts to promote conservation. Residential water usage constitutes 80% of Istanbul's water usage (Yalçıntaş et al., 2015). Implementing high-efficiency residential equipment can also reduce consumption.

**Actions Taken**

*Infrastructure*

Infrastructure projects have focused on reducing loss through renovations to pipe systems and obtaining greater supply through dams and reservoirs. Plans to draw water from additional surface water sources include the Melen River basin project (Turoğlu, 2016), which is estimated to be capable of supplementing Istanbul's water resources until 2071.

Implementing SCADA (supervisory control and data acquisition) technology across ISKI's jurisdiction aids in identifying areas of loss and collecting data in real time across various landscapes (ISKI, n.d.). This system collects data on pressure, flow, and points of illegal water use. This modernization of the current infrastructure is a step toward sustainability.

*Legislation*

Legislation to minimize the impacts of settlements around water basins helps maintain conservation zones. ISKI has created a tiered conservation zone approach, in which restrictions increase with proximity to the zone (Altinbilek, 2006). This approach reduces the amount of land available for development throughout the conservation zone, aiding in water quality and quantity protection. Despite the development of special teams to monitor these situations, enforcement remains a challenge in the face of continued growth (van Leeuwen & Sjerps, 2016).

The development of ISKI in the 1980s established a new method of management that has aided Istanbul's growth and set an example for other areas of governance. The tariff system used by ISKI charges a higher rate for industrial and commercial water use than for residential use. This system has been successful in generating revenue and maintaining financial stability for the industry while rewarding those who use less water with lower prices (Altinbilek, 2006). ISKI also employs a gradual tariff to household consumers who use more than 10 m3/house per month. Paired with awareness campaigns

highlighting opportunities for household water saving equipment, this economic tool is an example of a successful initiative to ensure that municipal revenue is maintained while increasing household-level water conservation (Öztürk and Atlay, 2016).

*Conservation*

Conservation efforts like the rehabilitation of the Golden Horn estuary are important projects for the city (van Leeuwen & Sjerps, 2016). This project highlighted the amount of time and money needed to rehabilitate an area affected by development, pollution, and increased use (Altinbilek, 2006). It highlighted the negative impacts of unregulated development and restored a valuable ecosystem to the city of Istanbul.

**Existing Challenges**

The population of Istanbul will continue to increase, as will its demand for water. Climate change will continue to reduce available water, and proximity to water sources will not improve; however, the city can invest in infrastructural changes to conserve and reuse its current supply. Expanding supply is also possible with efforts like the Melen River project. If the city decides to move forward with plans for a new bridge crossing the Bosporus and a new airport in the north, these expansions are likely to increase growth and generate more stress on the water system.

## Core Issues Driving Water Scarcity in Istanbul

**Supply**

- Groundwater Scarcity
- Surface Water Scarcity
- Drought

**Water Use**

- Population Growth
- Migration

**Infrastructure & Service**

- Non-Revenue Water
- Insufficient Pipe Systems

**Governance**

- Lack of Public Awareness & Political Will
- Lack of Coordination between Local, Regional & National Government

## Sample Solutions for Water Security in Istanbul

**Infrastructure**

- Water Transportation Between Cities and Between Urban and Rural Areas
- Pressure Management Interventions

**Water Cycle Management**

- Conserving And Restoring Water Related Ecosystems
- Conservation Zones That Protect Areas Of Environmental Or Hydrological Importance

**Municipal Revenue Sources**

- Tariff Structures That Disincentivize Water Waste

**Management Within City Governments**

- Water Department Organization

## Kigali, Rwanda

### City Profile

The country of Rwanda occupies a mountainous region in Africa's rift valley with a tropical climate. The Nile and Congo River basins cover the country and are valuable resources shared with Rwanda's neighbors, including Burundi, the Democratic Republic of the Congo, Uganda, and Tanzania. Rwanda is a water-rich country due to its location and climate. The country spans 10,000 mi2 with a population of over 12 million people.

Home to 1 million people, Kigali is the economic center of Rwanda. It became the official capital in 1962 when Rwanda gained its independence. The country has experienced continuous economic growth in the last decade. With this economic growth, the population has continued to increase throughout Rwanda, primarily in and around the capital city of Kigali. Kigali's landscape poses challenges to housing construction, which must work around steep slopes and multiple wetlands (Tsinda, 2018). Partly for this reason, 60% of the urban population in Kigali resides in informal settlements, which are generally in the lower valleys (Tsinda et al., 2020).

### Case Study: Progressing Toward Integrated Water Resources Management

Kigali is the capital and economic hub of Rwanda and home to the largest population in the country. Like much of sub-Saharan Africa, Rwanda faces significant water security challenges. Water resources in Rwanda as a whole are not lacking due to its tropical highland climate and its location in the African Great Lakes region. However, the infrastructure and management needed to maintain a continuous water supply for the entire population of the city of Kigali is still being developed. The threat of severe droughts and floods associated with climate change has led the government of Rwanda to propose new solutions for water security. The government has created a national framework for the development of integrated water resource management strategies (REMA, n.d.).

### Background

Kigali is located in a tropical highland climate at a little over 5,000 ft (1,500 m). The city ex-

periences regular rains (1,028 mm per year). Mudslides are a threat related to the city's topography. The Congo and the Nile Rivers feed smaller rivers that supply water throughout the country. Groundwater is a source of clean water for many rural areas across the country. The country as a whole is water-rich. Storage and monitoring practices have been implemented recently.

In Kigali, semi-rural areas, unplanned settlements, and old infrastructure are situated at the bottom of the ridges in the city. In contrast, the majority of wealthy inhabitants are located on top of them. Because of Kigali's growing population, fringe neighborhoods and unplanned settlements are abundant (Tsinda et al., 2020). Today, established water coverage is around 80% for the rural areas, but water is provided primarily through communal posts rather than residential taps (IFC, 2015). In periods of intermittent supply, those living at the top of ridges and hills are likely to experience increased shortages relative to those living in the lower valleys. This disparity is the result of an aging infrastructure that is unable to pump water to the farthest points during periods of shortage (Bizimungu, 2019). Non-revenue water is another problem related to aging pipes.

Much of the focus of the Water and Sanitation Corporation (WASAC) is on providing water to the urban areas of Kigali. Many private entities, including World Vision, Water for Growth, and others work in the semi-rural areas of the city (Bizimungu, 2019 & W4G, n.d.). In 2015–2016, WASAC provided an average of 15 water hours per day, increased the water network by 348 km, and attained 100% metering of all live accounts (WASAC, 2017). Currently, the city of Kigali needs 130,000 m3 of water per day, and total production in the country is 300,000 m3 per day. The private sector provides around half of this supply, much of which is delivered in rural areas (Bizimungu, 2019; World Vision, 2018).

Public-private investments are used in Rwanda to help increase the number of residents with continuous access to water. To manage the growing demand in Kigali, a public-private-partnership model was adopted for the Kigali bulk water project, which has the capacity to provide fresh, clean water to 500,000 Rwandans. In 2010, the Government of Rwanda and the International Finance Corporation joined to create the Kigali Bulk Water Supply Project (IFC, 2015). The Emerging Africa Infrastructure Fund (EAIF) is the lead debt financer for the project, providing over US $19 million (PRI, 2019). Pulling water from the Nyaborongo River, this project could contribute 40,000 m3 more water per day to Kigali and the surrounding area (PRI, 2019). Before construction begins, the EAIF must collect and analyze water samples and rain fluctuations for the basin.

### Actions Taken

Integrated water resource management was incorporated into Rwanda's national water management framework in 2011 with the establishment of Rwanda Natural Resources Authority (RNRA) (Aboniyo et al., 2017 and W4G, n.d.). In 2018, multiple goals within this framework were met, including developing community-led task forces, increasing water balances, and evaluating water storage capacity (REMA, n.d.). Continued plans

include monitoring, modeling, information management, and the development of a national water security plan—including conservation measures and water storage opportunities (REMA, n.d.). The private sector is involved in this transition. Groups like Water for Growth are assisting at the district level, primarily by developing catchment plans (W4G, n.d.). The Food and Agriculture Organization (FAO) is also involved with integrated management systems throughout Rwanda (FAO, 2019). The FAO is generating data using remote sensing and water auditing to create a comprehensive resource database. This transition, though lengthy, will complement investments like the Kigali bulk water supply project and help the country achieve better water management practices.

**Existing Challenges**

Rwanda has a complex governmental structure. Jurisdictions need to be clearly defined for operations and data collection (Umulisa, 2017). Greater coordination among levels of government would improve water management at the local level (Aboniyo et al., 2017). The multiple resources developed by partnering with the FAO, Water for Growth, and others could contribute to a central data repository containing the most up to date information.

## Core Issues Driving Water Scarcity in Kigali

**Supply**

Contamination & Pollution

Flooding

**Water Use**

Population Growth

**Inequality & Access**

Distant Access Points

**Infrastructure & Service**

Insufficient Pipe Systems

Insufficient Storage Technology & Infrastructure

## Sample Solutions for Water Security in Kigali

**Coordinated Governance**

Local, Regional, and National Coordination

**Planning**

Integrated Water Resources Management (IWRM)

**Involving Stakeholders Outside Of Government**

Public Private Partnerships (Ppps)

Incorporate private-public partnerships to generate funding for large-scale projects to supplement water resources and update overall infrastructure (see: https://www.unpri.org/pri-awards-2019-case-study-kigali-bulk-water-supply-project/4838.article)

Community-Based Solutions

Utilize non-governmental sector work for community led projects to assist in transitioning a city's management system

**Finance**

Innovative Loan Structures & Other Finance Mechanisms

Utilize innovative blended financing models for water infrastructure or service improvements to catalyze projects that traditionally would not be bankable.

# Appendix A

Possible restructuring model for Rwandan government to better execute integrated water resource management. Taken from Aboniyo et al., (2017).

**Table 5:** Proposed institutional framework of water resources management

| | Department | Function and Responsibilities |
|---|---|---|
| National level | Rwanda Water resources management authority (RWRMA) | • It will develop principles, guidelines, and procedures for the allocation of water resources;<br>• Assess and reassess the potential of water resources;<br>• Receive and determine applications for permits for water use;<br>• Monitor and enforce conditions attached to the permits for water use;<br>• Regulate and protect the quality of water resources from adverse impacts;<br>• Manage and protect catchment areas; determine charges and fees to be imposed for the use of water from any water source;<br>• Gather and maintain information on water resources from time to time in order to publish forecasts, projections, and information on water resources; and<br>• Work with other bodies for the better regulation and management of water resources. |
| | Transboundary Unit | • responsible for any conflict that would rise between shared resources between counties. |
| Catchment-level | RWRMA District offices unit | This will consist of government officials, water users, and communities. |
| | Catchment advisory committees' unit | Their role includes advising RWRMA officers at catchment level on:<br>• water resource conservation, use, and apportionment;<br>• the granting, adjustment, cancellation, or variation of any permit; and<br>• any other matter pertinent to the proper management of water resources. |
| | Water resources user groups unit | These will provide a forum for conflict resolution and cooperative management of water resources in designated catchment areas.<br>They will be responsible for conserving the watershed and advising the Catchment advisory committees on the available water that may be allocated or re-allocated to other water users. |

## Los Angeles, United States

### City Profile

Los Angeles, California, is located on the west coast of the United States. Spanning over 12,000 km2, the landscape of Los Angeles County consists of coastal plains, valleys, mountains such as the San Gabriel and San Bernardino mountains, and an extensive coastline along the Pacific Ocean. The area has a dry subtropical climate, experiencing less than 15 inches of rainfall a year. Wildfires are annual occurrences and have become more devastating in the past 10 years throughout the county, intensified by little annual rainfall and climatic events such as droughts. The county's use of fresh water is variable, and strict conservation limits have been set, especially during drought years. Freshwater sources used to run freely through Los Angeles; however, due to mass urbanization, many rivers were channelized, and whatever water remains runs out to sea. The city population of 4 million (around 10 million in the county) requires large amounts of water for consumption, industrial uses, and agriculture. The progressive effects of climate change on the area intensify the need for changes to water management.

### Case Study: Gathering Data on Water and Energy Consumption

The Los Angeles area draws over 167 billion gallons of water per year, primarily from three sources: the California aqueduct, the Los Angeles aqueduct, and the Colorado River aqueduct. The 10 million residents of Los Angeles County use over 100 gallons per capita/day. Much of this water comes from as far away as northern California (Colgan, 2018; Porse et al., 2017). The county of Los Angeles faces challenges associated with a lack of natural water supply, historic use and misuse of surface and groundwater, the demands of the dollar agricultural sector, and the large metropolitan population (Gumprecht, 2001; Porse et al., 2017). Extreme events such as droughts, wildfires, and floods put stress on water infrastructure across the state. Plans to move away from reliance on imported water are in development for Los Angeles. Obtaining data on how, and how much, water moves through the area can produce an accurate understanding of the scarcity situation and inform policies to address it.

### Background

Home to just under 40 million people, Califor-

nia has the largest population and agricultural sector in the United States. Los Angeles County contains 88 distinct cities, the largest being the City of Los Angeles (Porse et al., 2017). Even as a semi-arid, Mediterranean climate, the City of Los Angeles is a bustling metropolis, full of palm trees, ornate gardens, large ports, swimming pools, and multiple industries. In Los Angeles County, there are 100 agencies involved in the provision of water services (Porse et al., 2017). The demand for water in the county is high, and water reserves are low. In the past, Los Angeles had surface and groundwater resources, including the Los Angeles River (Fitzhugh & Richter, 2004; Gumprecht, 2001). This river was a primary source of water for the city until 1940. It was then rebuilt as a drainage system, directing any remaining fresh water out to sea (Gumprecht, 2001; Porse et al., 2017). In addition to the Los Angeles River, groundwater sources used to be plentiful (Hevesi & Johnson, 2016). In 2014, California passed the Sustainable Groundwater Management Act to minimize the impacts of an increasing population, agriculture, and previous overuse of groundwater resources. This act requires agencies and localities to maintain balanced groundwater systems and develop sustainability plans (GoC, n.d.). The water resources around Los Angeles have suffered from exploitation. Current urban infrastructure directs approximately 80% of rainfall into the ocean, instead of allowing it to replenish aquifers or be utilized for another purpose (Garrison, 2014).

The city has required resources beyond its borders throughout its history. Aqueducts were built hundreds of kilometers away in Owens Valley in the early 1900s, and again in the 1940s in the Mono Basin (Fitzhugh & Richter, 2004). Reliance on these distant resources threatens the surrounding environment and potentially the water supply itself (Fitzhugh & Richter, 2004). Today, the Los Angeles Department of Water and Power (LADWP) utilizes water from four main sources: two local (groundwater and recycled water) and two imported, coming from the Los Angeles aqueduct and the Colorado River aqueduct, which is managed by the Metropolitan Water District (MWD) (Garcia et al., 2019; LADWP, 2016). Between 2010 and 2015, LADWP purchased approximately 280 million gallons per day from the Metropolitan Water District. This water constituted 57% of LADWP's water supply for the five-year period.

In 2018, the city of Los Angeles' total water supply was 521,915 acre-feet (94% imported water, 4.2% local groundwater, and 1.9% recycled water) (OpenData, 2019). The reported supply and demand within the city are generally equivalent because the LADWP purchases supplemental water from the MWD when other sources do not meet demand; this is generally around 35% (LA City, 2017). For example, in 2018, 35% of LADWP's water was purchased from MWD, a total of 182,706 acre-feet of water needed to meet the demand in the city (OpenData, 2019). Projected demand for water in 2035 in the city of Los Angeles is approximately 710,800 acre-feet (LADWP, n.d.).

Measures that could reduce the city's reliance on transported water include increasing water reuse, improving water conservation, and refilling groundwater basins (Prose et al., 2017). Contamination, increased impervious surfaces, channelization, and saltwater intrusion also

affect the city's ability to utilize and replenish local groundwater sources (LADWP, 2016). Climate change continues to exacerbate water shortages in California by diminishing mountain snowpack, extending periods of drought, and driving extreme weather events.

**Actions Taken**

The flow of resources in and out of a city constitutes its "urban metabolism" (Kennedy et al., 2011). This concept can be applied to water, energy, imports and exports of goods, and even the movement of people.

To generate estimates of water use across Los Angeles County, teams from the Institute of the Environment and Sustainability at UCLA gathered publicly available data from county-wide water providers, including annual reports, management plans, and adjudication records (Porse et al., 2017). This information was then used to generate the Los Angeles Water Hub, an interactive data-driven website that aggregates available water data information in one location. This tool is open to the public. It identifies areas of loss and potential points of conservation (Garrison, 2014; OurCounty, 2019). Data compiled so far indicates that if Los Angeles County increased its annual storm-water capture by 300%, increases its ability to reuse, and reduced overall demand to 105 gallons per person/per day, the county could reduce its reliance on imported water by 30% (Prose et al., 2017). Further reductions could be made with greater conservation efforts, reallocating groundwater resources, and monetary investments in groundwater recharge (Prose et al., 2017). The collection of this data was instrumental in the development of the first Los Angeles County Sustainability Plan. One of the main goals of this plan is to source 80% of the county's water locally by 2045 (OurCounty, 2019).

**Existing Challenges**

Current water provision methods in Los Angeles externalize water stress to other regions. This stress could be avoided by minimizing losses associated with transportation, runoff, and evaporation, and by employing methods for local capture and reuse (Feldman, 2009; Hevesi & Johnson, 2016; Prose et al., 2017).

The comprehensive data needed to perform "urban metabolism" analysis is not always readily available and must be sought out. The combination of public and private ownership of the distribution of water throughout the county makes it difficult to bring all key players to the table (Pincetl et al., 2016). Additionally, due to the fragmentation of the Los Angeles area, data may lack consistency.

## Core Issues Driving Water Scarcity in Los Angeles

**Supply**

- Groundwater Scarcity
- Surface Water Scarcity
- Drought

**Water Use**

- Population Growth

**Infrastructure & Service**

- Insufficient Data
- Insufficient Capture Technology & Infrastructure

**Governance**

- Lack of Coordination between Sectors

## Sample Solutions for Water Security in Los Angeles

**Data**

- Consolidated Information Repositories
- Climate Vulnerability Assessments
  - Conduct climate vulnerability assessments to prioritize planning, development, and infrastructural changes to maintain appropriate water supply (see: https://ourcountyla.lacounty.gov/strategies/strategy-2a)

**Water Supply**

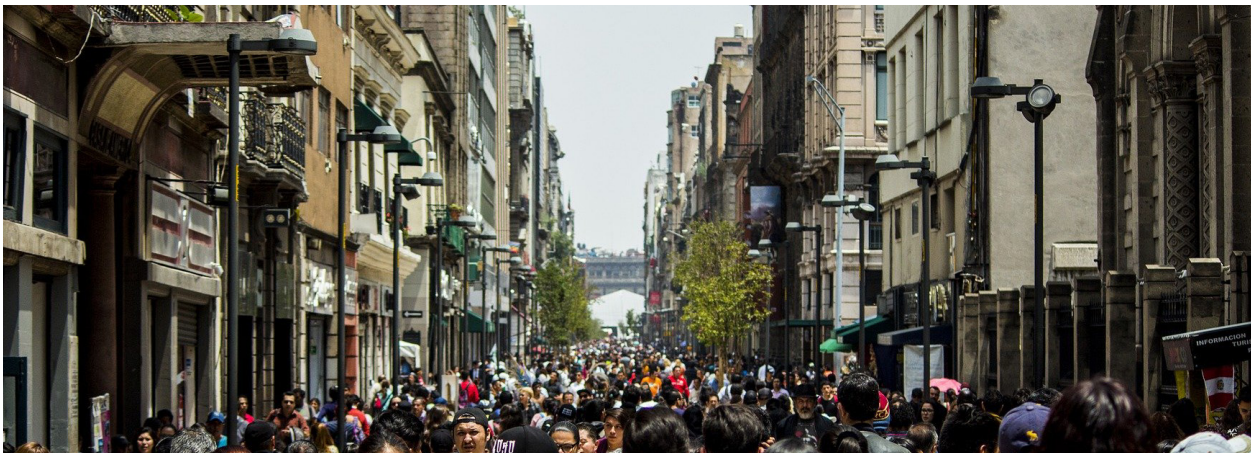
- Wastewater and Storm-Water Capture, Treatment, and Reuse
  - Increase investments for stormwater runoff capture technology and reuse in the local and surrounding area to supplement other water sources (see: https://safecleanwaterla.org/projects2/)

**Involving Stakeholders Outside Of Government**

- Building Capacity Of Stakeholders In All Parts Of Society
  - Minimize silos between public and private water providers

**Access & Equity**

- Tiered Assistance Programs
  - Aid small water systems that lack funding (see: https://ourcountyla.lacounty.gov/strategies/strategy-1e



## Mexico City, Mexico

### City Profile

Mexico City is one of the largest metropolises in the world and the second-largest metropolitan area in the Western Hemisphere (Macrotrends, 2019). The city itself has a population of nearly 9 million, and the greater Mexico City Metropolitan Area has a population of nearly 22 million. The population is rapidly growing and is expected to reach 30 million by 2030 (Freeman et al., 2020; Jiménez et al., 2020; Tellman et al., 2018). As the administrative and economic hub of Mexico, Mexico City has grown significantly throughout the last century, spanning across three states within Mexico. It consists of 16 boroughs in the city proper, 59 municipalities in the State of Mexico, and one municipality in the State of Hidalgo (CONAPO, 2005).

This urbanization has resulted in significant water stress in Mexico City and beyond (Engel et al., 2011; National Research Council, 1995). The city's vast water supply and distribution and storm-water and wastewater infrastructures are difficult and expensive to maintain and have degraded over time. Over-exploitation of scarce groundwater resources has resulted in high rates of subsidence (or sinking) throughout Mexico City, which puts the city at an increased risk of flooding and further degrades water infrastructure. Informal settlements are common throughout the city and are often located in environmentally and hydrologically crucial areas, which further exacerbates water security challenges. Residents of informal settlements grapple daily with water insecurity, as many lack consistent access to water supply from the formal distribution network. The situation in Mexico City is an example of an imbalance between water availability, population settlements, and production needs: it is one of the most naturally water-scarce areas in all of Mexico, yet as the country's primary economic hub, it has a much greater population and water demand than any other area (Gutierrez, 2019).

**Case Study: Urban Sprawl and Water Insecurity**

Water scarcity in Mexico City is driven by a cycle of land use and hydrological risk: urban sprawl and a growing population have produced water demand that exceeds the natural recharge rate of the area's aquifers, and changes in land use due to urbanization further inhibit aquifer recharge; overexploited aquifers result in high rates of subsidence; subsidence puts the population at greater risk of flooding; floods degrade infrastructure, and the degraded infrastructure makes water provision more difficult. Externalization of water demand to other basins puts the city in competition with other areas and leads to additional water stress.

All these hydrological issues are compounded by wealth disparities and the presence of informal settlements, in which many citizens lack access to the water supply system altogether and are at a disproportionate risk for experiencing flooding. Mexico City and the Mexican government have instituted a number of projects throughout the past two decades to fix degraded infrastructure, mitigate flood risk, cultivate new sources of water (including from rainwater harvesting), and ensure water security in the city. These solutions have produced successes but have also highlighted challenges, in particular those related to equitable water access in informal settlements and ensuring future water security in light of climate change and urban sprawl.

**Background**

*Governance*

Mexico's constitution and Water Law (of 2003) both recognize water as an inherent human right of all Mexican citizens (Gobierno del Distrito Federal, 2015; Gutierrez, 2019). Water is managed by the National Water Commission (CONAGUA), a decentralized agency of the Ministry of the Environment and Natural Resources (SEMARNAT). CONAGUA's tasks are the administration of national waters, the management and control of the overall hydrologic system, and the promotion of sustainable social development as pertains to water issues. The institution is further subdivided into regional administrations based on watershed boundaries. The Mexico Valley Watershed Regional Administration is responsible for managing the water in the region, and although the watershed encompasses a total of 116 municipalities, 92% of users are located in the Mexico City Metropolitan Area (Engel et al., 2011). Within Mexico City itself, the city's Environmental Secretariat, or SEDEMA, also plays a role in ensuring sustainable water management (Gutierrez, 2019).

The Mexico City water supply system is one of the largest hydro-engineering projects in the world. The task of adequately governing and distributing this water is a significant challenge for government institutions. The city employs private actors to assist governmental institutions in providing water to the city's many citizens. Although the semi-private system has produced successes in improving municipal water supply infrastructure, it has been criticized for not alleviating social inequalities. (Pierce, 2012; Watts, 2015; Van Dusen, 2016).

*Groundwater*

Mexico City is characterized by its subtropical highland climate, with warm, dry summers and mild, flood-prone winters. Despite

the frequent flooding, the area is naturally water-scarce, largely due to the city's complex historical relationship[20] with water resource management (Sosa-Rodriguez, 2010; Jiménez et al., 2020). Built on an old, drained lakebed, Mexico City—formerly known as Tenochtitlan, the once water-rich capital of the Aztecs—now sources nearly 70% of its water from groundwater pumped from the Mexico Valley Aquifer (National Research Council, 1995; Engel et al., 2011). The growing population of Mexico City drives over-exploitation of the region's groundwater resources, with an extraction volume three times greater than the basin's natural recharge rate, and an urban water demand that amounts to 173% of available renewable freshwater resources (Engel et al., 2011; Tortajada, 2006; Gutierrez, 2019). Groundwater use is a regional problem, as four out of the 14 aquifers in the Valley of Mexico Basin are currently overexploited (CONAGUA, 2017). The over-exploitation of groundwater has significantly lowered the water table in the region, resulting in high rates of subsidence in areas of Mexico City,[21] thereby further degrading municipal infrastructure and exacerbating flood risk in the city (Engel et al., 2011; Jiménez et al., 2020; Tortajada, 2006).

Population growth is not the only aspect of urbanization that strains the city's aquifers. The physical effects of urbanization—that is, the covering of pervious surfaces and soil with asphalt—impede the absorption of storm-water by the soil, a process necessary for natural aquifer recharge. This exacerbates the problem of groundwater over-exploitation and increases flood risk. Storm-water in the city overburdens and further degrades municipal infrastructure (Gutierrez, 2019).

*Surface-Water and Inter-Basin Transfers*

The second-most important water supply in the Mexico City is the inter-basin transfer from the Cutzamala and Lerma rivers, which are located west of the city and supply 43% of the metropolis' total water supply (Engel et al., 2011; Freeman et al., 2020). Externalization of water sourcing adds water stress to the regions from which the water is sourced (Tellman et al., 2018). In the area around the city, inter-basin transfers have facilitated further urbanization, despite the lack of water resources available to sustain further population growth (Tortajada, 2006; Engel et al., 2011). Studies across a variety of future climate scenarios indicate that the Cutzamala surface water supply system will not be able to continue to provide reliable water supply to Mexico City, meaning that one of the city's main water supplies will likely be threatened in the future (Freeman et al., 2020). Inter-basin transfers have also exacerbated tensions in the Valley of Mexico (Engel et al., 2011; Sosa-Rodriguez, 2010; Tortajada, 2006).[22]

20 For an overview of Mexico City's rich and complicated history related to water resources management, see Appendix B.

21 Accumulated subsidence over the past century has caused the city to sink more than 15 meters in some areas, and an average of 7.5 meters in downtown Mexico City (Martinez, Escolero & Perevochtchikova, 2015).

22 More specifically, tensions have resulted because significant transfers from the Lerma basin have resulted in decreased soil fertility and a dependence on rain-fed (as opposed to irrigated) agriculture, thereby threatening the livelihood of local farmers. In the Cutzamala basin, the biggest single source of Mexico City's fresh water, indigenous groups feel threatened by the constant use of their land and resources to meet Mexico City's needs, while homes in their own communities remain without potable water supply. All these issues raise concerns regarding the externalized effects of Mexico City's waters scarcity problems (Engel et al., 2011; Sosa-Rodriguez, 2010; Tortajada, 2006).

*Infrastructure*

The inter-basin transfers upon which Mexico City depends for much of its water supply require vast infrastructure networks that are difficult and expensive to maintain. Water from the Lerma and Cutzamala basins is transferred from a distance of 60–155 km and pumped to a height of more than 1,000 m to reach Mexico City, where it then enters the public water supply system. This process is both expensive and energy-intensive (Tortajada, 2006). The water distribution infrastructure itself is vast, old, and therefore difficult to maintain (Freeman et al., 2020; Gutierrez, 2019). [23] Regular flooding and subsidence, as a result of over-extraction of groundwater, further degrade the already decaying water supply infrastructure (Freeman et al., 2020; Tortajada, 2006). The degraded water pipelines result in degraded quality of the water they supply. Presently, although 88% of the water is chlorinated, only 60% is suitable for human consumption (Chelleri, Schuetze & Salvati, 2015).

Mexico City's water supply system currently experiences a high rate of water loss. Non-revenue water is estimated to be around 40% of the system's total water (Engel et al., 2011; Gutierrez, 2019). Some of this water loss is due to leaking caused by deteriorating pipes, but a large number of illegal connections in the supply system are also a significant factor (Gutierrez, 2019; Tortajada, 2006). Illegal water connections, government subsidies for water costs, and limited cost recovery for legal connections in the system have resulted in insufficient funds with which to repair the degraded infrastructure.

*Water Use and Access*

Mexico City has high average water use (320 liters per person per day), which is three times more than the UN recommendation (Gutierrez, 2019). This amount varies greatly between neighborhoods. Wealthy neighborhoods have unlimited access to water, including water for sprinkler systems irrigating lawns and golf courses (Watts, 2015). Water consumption is as high as 475 liters per person per day in some wealthy neighborhoods (González Villarreal, 2018).

Poorer districts (such as the Iztapalapa borough) receive less than 10 liters per person per day, usually only once a week (Gutierrez, 2019). Current estimates indicate that about 70% of the city has fewer than 12 hours of access to running water per day, while the most vulnerable areas—approximately 18% of the city—have to wait days for access to water (Watts, 2015). The use of intermittent supply in these neighborhoods degrades the piped water quality when the supply system does provide water, thereby raising public health concerns in such communities (Kumpel & Nelson, 2016). [24] The discrepancy in water supply and quality throughout the city's boroughs is indicative of significant wealth disparities (Gutierrez, 2019).

23 Due to the sheer size of Mexico City's water supply system—as well as due to the great lengths and elevations that the water transverses to reach the city itself—the city's water infrastructure is considered to be one of the greatest feats of hydro-engineering in all of Latin America. Paradoxically, its vastness makes the system extremely difficult to maintain, resulting in significant water loss and supply issues throughout the system itself (Gutierrez, 2019; Kimmelman, 2017).

24 For a more thorough analysis of the dangers of intermittent water supply, refer to the Amman Case Study or see:
Kumpel, E., & Nelson, K. L. (2016). Intermittent water supply: prevalence, practice, and microbial water quality. Environmental science & technology, 50(2), 542–553.

*Informal Settlements and Urban Sprawl*

Fifty-nine percent of Mexico City's population lives below the poverty line. An estimated 22% of the population lives in informal settlements, or slums, which are usually located in higher elevation areas of the city and are beyond the reach of the centralized water supply system (Bruce et al., 2020; Gutierrez, 2019; Chelleri, Schuetze & Salvati, 2015). The provision of water to informal settlements is sometimes logistically difficult. In other instances, water is rationed partly in order to discourage further expansion of informal settlements, which the authorities sometimes consider illegitimate and environmentally harmful (Gutierrez, 2019).

In the borough of Iztapalapa, for example, water supply is routinely suspended for long periods, sometimes for as long as 15 days (Gutierrez, 2019). As a result, residents of districts lacking access (or continuous access) to the public supply system resort to buying trucked water from private vendors—known as pipas—which can be 500 times more expensive than water from the municipal supply (Gutierrez, 2019; Bruce et al., 2020). The pipa system has led to sexual and financial exploitation in vulnerable communities (Bruce et al., 2020). The system can be unsafe for drivers of pipa trucks, as they run the risk of their vehicles being hijacked at gunpoint, particularly in times of acute shortage (Watts, 2015).

Informal settlements are also a driver of water scarcity. In 1992, Mexico City established a Conservation Zone in the southern region of the city, in the borough of Xochimilco, where the soil is naturally pervious and ideal for natural recharge of depleted groundwater aquifers. However, as urbanization rates declined in the majority of the city in the 1990s, expansion continued throughout Xochimilco. Increasing urbanization in the southern region resulted in more asphalt-covered land, encroaching on the Conservation Zone and impeding the aquifer's recharge by storm water (Gutierrez, 2019). It is estimated that for every hectare urbanized, recharge reduces by approximately 2.5 million liters per year (Gutierrez, 2019).

Currently, although 59% of Mexico City's territory is protected by Conservation Zones, formal and informal urban sprawl threatens these areas and further exacerbates the issue of aquifer depletion and thus the overall rate of subsidence in the city. This is particularly true of informal settlements, as approximately 80% of families living in informal settlements currently live on protected conservation land. Another 20% of these families live in dangerous places, such as riverbeds, where they are at increased risk of flood (Gutierrez, 2019; Sosa-Rodriguez, 2010; Tortajada, 2006). Despite regulations put in place to protect Mexico City's watershed, urban growth and the demand for settlements—both formal and informal—have outstripped the government's institutional ability to keep up. Managerial discrepancies between land-use and water management institutions, which have historically operated in silos, are one challenge to progress (Gutierrez, 2019).

These issues have combined to produce a cycle of urbanization, land use, and water management problems. Informal settlements, which use little to none of the public water supply, are most at risk from subsidence-related floods, caused by overexploitation of groundwater

resources for the public supply. These settlements, built on pervious soil, also exacerbate the issue of groundwater depletion by impeding the natural recharge of storm water into aquifers (Gutierrez, 2019).

**Actions Taken**

Mexico City has invested in a number of projects historically, including a citywide water conservation campaign in the 1990s and an Inter-American Development Bank (IADB)-funded sanitation project for the Valley of Mexico (UNEP Regional Office for Latin America and the Caribbean, 2003). More recently, Mexico City has invested in two large programs—the Water Sustainability Program and the Green Plan—to address the water security risks the city faces.

*The Water Sustainability Program*

The Water Sustainability Program (WSP) for tThe Water Sustainability Program (WSP) for the Valley of Mexico was a subproject of the National Water Program (NWP), a five-year program launched by CONAGUA in 2007 (CONAGUA, 2008). The goal of the NWP was to ensure water sustainability and security for all Mexican citizens and enable sustainable urban development in the future (CONAGUA, 2008). The multi-faceted program tackled some key issues, notably enhancing the provision of bulk water supply, storm-water drainage, and wastewater treatment in Mexico City for the period 2007–2012.

To enhance water supply, the WSP proposed importing groundwater from the nearby Tula and Mezquital valleys, where the water table had increased as a result of continuous irrigation with wastewater. The WSP promised to amplify water supply by exchanging treated wastewater for the clean water presently used for irrigation in the Vaso del Cristo area (IANAS, 2015). This is part of an overarching program by CONAGUA, known as the "Wastewater Reuse and Exchange Program," which is based on the transfer of treated wastewater from municipalities to rural areas to be used as irrigation, in exchange for first-use freshwater, to be used for water supply (IANAS, 2015). The program is an example of coordinated water management involving the national and sub-national levels. Finally, the WSP proposed the "rehabilitation" of extant resources through the expansion of the Cutzamala system and the integration of water from the Guadalupe Dam in Mexico State into Mexico City's water supply (IANAS, 2015).

Storm water drainage and wastewater treatment were also primary components of CONAGUA's NWP and Mexico City's Water Sustainability Program. The city's main wastewater collector, the Emisor Central tunnel, was built in 1975 to collect storm-water runoff and municipal wastewater. Ballooning urban populations, illegal connections, and consistent flooding and subsidence patterns have severely over-burdened and degraded the tunnel's infrastructure over the years. In response to these issues, CONAGUA committed to the US $1.18 billion construction of another drainage tunnel, the Emisor Oriente to relieve the older tunnel of some of its burden. The Emisor Oriente project was completed in 2014, and it is presently the seventh-longest tunnel in the world. It serves a population of 20 million people, running Mexico City's wastewater to six

new wastewater treatment plants, the largest of which is the Atotonilco Wastewater Treatment Plant in Hidalgo state (Water Technology, n.d.). The primary objectives of this program were to reduce flooding, enhance wastewater treatment (and enable reuse), and reduce leakages in the extant system.

The program was funded through a combination of private sector Build-Operate-Transfer (BOT) projects, federal funds from CONAGUA's budget, the National Infrastructure fund, loans from a state-owned investment bank, and a trust fund created by the Federal District, the State of Mexico and the Mexican federal government (IANAS, 2015; OECD, 2004).

*The Green Plan*

In addition to the National Water Program, Mexico City launched a US $6 million 15-year Green Plan in 2007, with the primary goal of sustainable development, focused on seven primary target issues, including water. Similar to the WSP, the Green Plan sought to reduce water losses in the overall system. In addition to this goal, the Green Plan outlines a strategy to achieve water equilibrium in over-exploited aquifers, reduce residential water consumption, increase wastewater treatment and reuse, and rehabilitate natural wetlands (Gobierno del Distrito Federal, 2007).

To achieve aquifer equilibriums, the Green Plan intends to reevaluate the use of springs, develop soil containment infrastructure in non-urbanized areas (i.e., areas where there is bare soil) to increase recharge rates and mitigate erosion, and enhance the protection of canyons by declaring an additional 12 areas of environmental value (Gobierno del Distrito Federal, 2007). Furthermore, the Green Plan promises to expand networks of absorption wells and encourage actions to increase infiltration rates in conservation areas.

As a means of reducing rates of consumption among citizens in line with the Green Plan's objectives, the city sought to implement metering for all users and increase coercive measures for delinquent users. It promoted the installation of low water use sanitary installations (e.g., toilets, sinks, etc.) and water-saving accessories in private homes. Finally, it implemented a permanent water campaign in 2008 to promote water-saving measures and raise awareness regarding water security among the populace (Gobierno del Distrito Federal, 2007).

To reduce water loss in the system, the city outlined plans for the full substitution of all damaged or outdated segments of the network by 2012 intending to address leaks and faulty infrastructure quickly. Finally, the city sought to identify and reduce illegal connections to the supply system (Gobierno del Distrito Federal, 2007).

In line with the Water Sustainability Program and the construction of the Emisor Oriental tunnel, the Green Plan outlined Mexico City's commitment to enhancing wastewater and storm-water capture, treatment, and reuse to augment overall water supply in the system. The Green Plan sought the restoration of natural ecological wetlands by creating parks around the Tláhuac and Xochimilco lakes in the city's southern districts (Gobierno del Distrito Federal, 2007). These areas are of ecological

and hydrological importance to Mexico City, and the rehabilitation of these natural areas is intended to serve as a natural means of restoring hydrological balance in the region by allowing for natural aquifer recharge.

If successful, the Green Plan will reduce overall water use by 25% and groundwater extraction by 10% in the Mexico City area

*Private sector participation*

Mexico City implemented an initiative to develop a fixed-tariff pricing system through private sector participation in various stages of the production, distribution, and sale of water (Sosa-Rodriguez, 2010). The initiative reassigned municipal responsibilities to the private sector, including distribution, metering, and maintenance of secondary networks, and billing and customer support (Sosa-Rodriguez, 2010; Pierce, 2012).

These actions alleviated some of the burden of maintaining the vast water supply network from the municipal government, allowing the water supply system to become more responsive to consumers' needs (Sosa-Rodriguez, 2011; Engel et al., 2011). Privatization was initially met with positive responses from many citizens and businesses, but problems with contract governance, regional coordination, and network extension suggested a need for more robust accountability moving forward (Pierce, 2012). Privatization also raised concerns about water security issues in the city's poorest and most vulnerable neighborhoods (Wilder & Lankao, 2006).

*Rainwater harvesting*

Due to the frequent flooding that many areas in Mexico City experience, rainwater harvesting (RWH) has been proposed as a logical solution for augmenting water supply and alleviating pressure on over-exploited aquifers (Engel et al., 2011). In its official Water Law, the city government committed to enacting rainwater harvesting programs throughout various parts of Mexico City to alleviate flooding and promote groundwater recharge (Asamblea Legislativa del Distrito Federal, 2009). The law also mandates that all newly constructed buildings—especially those near green areas—must have storm-water harvest and recharge systems, to promote infiltration and groundwater recharge (Asamblea Legislativa del Distrito Federal, 2009; Gobierno del Distrito Federal, 2015).

Rainwater harvesting has been implemented as a feasible and practical solution for families living in informal settlements or in other underserved areas of the city, which lack regular and safe access to water (Gutierrez, 2019). The NGO Isla Urbana focuses on the provision of rainwater harvesting and purification systems to Mexico City's southernmost (and most impoverished) districts, such as Iztapalapa, Xochimilco, Tláhuac, Milpa Alpa, and Tlalpan. Founded in 2009, the NGO has installed 15,000 RWH systems to date, benefiting a total of 90,000 people, and successfully capturing 600 million liters of water per year (Isla Urbana, 2020). Isla Urbana's RWH systems have succeeded in providing families in under-served areas with potable water for up to nine months of the year—amounting to a total of 40% of their annual supply—without having to rely on the municipal supply network or trucked water from

the pipas (Isla Urbana, 2020). It is estimated that, if implemented on a large scale, rainwater harvesting could provide 30% of Mexico City's water (Isla Urbana, 2020).

In 2016, Mexico City launched a rainwater harvesting campaign of its own, known as the Agua a tu casa ("Water to your house") project. One of the program's main goals is to consolidate the reuse of rainwater in the city, especially in underserved areas—such as Xochimilco and Iztapalapa—by installing RWH and water purification systems in private homes (Gobierno del Ciudad de México, 2017). In its first two years of operation, the Agua a tu casa program[25] resulted in the installation of 500 RWH and purification technologies, benefiting a total of 56,320 people, and capturing 117 million liters of water in total—75 million liters of which were converted into potable water supply (Gobierno del Ciudad de México, 2017; GOE, 2019). The social rainwater harvesting program offers a promising method for providing water access in informal settlements (Gobierno del Ciudad de México, 2017).

## Existing Challenges

*Infrastructure*

Despite ongoing projects and attempts to improve the water supply network's infrastructure, the problem of leaking pipes and illegal connections remains. Non-revenue water is estimated to be around 35–40% of the network (Gutierrez, 2019). Financing is part of the challenge. The price of water in Mexico City does not reflect the resource's total cost, which creates a discrepancy between water demand among users and the city's ability to provide water. To tackle this issue, SEDEMA, the city's environmental ministry, recommends charging users—especially in formal settlements—more for water provision to reflect the cost of operation and conveyance (Gutierrez, 2019). Increasing fees is a challenge in itself, as SEDEMA estimates that approximately 45% of registered users already don't pay for water use. This number does not include the thousands of illegal connections present in the water supply system, which are entirely excluded from the fee system (Gutierrez, 2019). As a result, funding cannot depend only on increasing water fees in the city but must also include improved fee collection among delinquent users. The city has been slowly introducing tariffs for particularly high users, both as a means of augmenting its financial resources and raising awareness (Martinez, Escolero & Perevochtchikova, 2015).

The high rate of illegal connections remains a burden on the water supply system. But many vulnerable communities depend on such connections as their only source of water. Eradicating illegal connections, therefore, must be accompanied by new methods of supplying water to those communities (Gutierrez, 2019).

*Wastewater treatment and reuse*

CONAGUA's "Wastewater Reuse and Exchange" program has exceeded its initial goals for the volume of wastewater treated and reused for irrigation or other non-consumptive purposes (IANAS, 2015). The program has encour-

25 As part of the city's overarching commitment to sustainable development, the ***Agua a tu casa*** program also has a social component, by promoting gender equality and empowering women who are victims of domestic violence by offering them training (and, subsequently) jobs in installing and maintaining RWH systems (GOE, 2019).

aged many businesses throughout Mexico City to use treated wastewater for industrial purposes, thereby saving scarce groundwater for consumption by citizens. Presently, at least 260 l/s of reclaimed water (treated wastewater) is used for industrial purposes in Mexico City (IANAS, 2015). The main constraint on increased use of treated wastewater in the city—particularly for irrigation or industrial purposes—is cost. The cost of treated wastewater is higher than the cost of first-use water, and businesses and agricultural users presently have no legal obligation to use treated wastewater (IANAS, 2015). Current estimates suggest that regulatory legislation could increase the volume of treated wastewater for industrial use by approximately 1,000 l/s (IANAS, 2015).

Mexico City also uses treated wastewater to recharge groundwater. At present, the city uses 1,200 l/s of this reclaimed water to recharge groundwater and another 2,000 l/s for recharging recreational lakes and irrigation. Another 600 l/s is used for ecological purposes, such as recharging what was once Lake Texcoco[26]. The remainder of the city's approximately 60,000 l/s of wastewater is untreated and is used for irrigation in the Valley of Tula (IANAS, 2015).

*Subsidence and the over-exploitation of groundwater*

Progress toward wastewater reuse has taken some of the pressure off over-exploited aquifers, but the city still draws more water from its aquifers than it recharges (Gutierrez, 2019). Over-extraction continues to drive high rates of subsidence, with areas of the city sinking at a rate of 40 cm/year (Cabral-Cano et al., 2012). Subsidence exacerbates flood risk in the already flood-prone city, putting many residents—particularly those living in informal settlements—in danger (Gutierrez, 2019; Engel et al., 2011; Freeman et al., 2020). Sinking continues to damage the city's infrastructure (Gutierrez, 2019).

*Externalization of water stress*

Externalization of water stress has produced tensions in both the Lerma and Cutzamala basins, which continue to escalate as a result of climate change and increased demand in Mexico City (Engel et al., 2011; Sosa-Rodriguez, 2010; Tortajada, 2006). The city is implementing a new project to transfer groundwater from the Valleys of Tula and Mezquital to Mexico City. There is not yet sufficient data to predict how this will affect the hydrological balance in these regions in the future (Martinez, Escolero & Perevochtchikova, 2015).

*The Green Plan and reformulating water management institutions*

Mexico City was able to accomplish 77% of the Green Plan's objectives in the first five years of the program. Some aspects of the plan related to water conservation efforts and enhancing overall system efficiency have yet to be realized (Chelleri, Schuetze & Salvati, 2015).

Challenges in the early years of the Green Plan's implementation relate to a lack of coordination and limited institutional cooperation, highlighting the need for careful integration of land use and water management planning. Private

26 The lake upon which Mexico City was built and which was drained by Spanish conquistadors in the colonial period.

and public sector engagement can lead to more effective and inclusive water management institutions (Chelleri, Schuetze & Salvati, 2015; Freeman et al., 2020).

*Rainwater harvesting and decentralized water management in informal settlements*

The city's Agua a tu casa rainwater harvesting program coupled with Isla Urbana's RWH efforts have succeeded in providing thousands of families in the city's most vulnerable areas with a safe and potable water supply. However, rainwater harvesting comes with challenges of its own. If not implemented carefully, RWH and purification systems create a risk of contaminated water. Furthermore, rainwater only provides water for up to nine months of the year (Gutierrez, 2019). While RWH enhances access to water and saves money for users in underserved or informal districts, users must resort to trucked water in dry months (Chelleri, Schuetze & Salvati, 2015).

However, SEDEMA has taken a renewed interest in RWH systems. The Secretariat has committed to installing 100,000 RWH systems throughout the city over the next six years to demonstrate feasibility (Gutierrez, 2019). This plan raises the question of encouraging decentralized water management systems in informal settlements as a means of enhancing access to water supply (Gutierrez, 2019). In areas of Mexico City such as Xochimilco and Iztapalapa, which are almost entirely excluded from the city's formal water supply system, decentralized management may prove to be a practical and feasible solution to compensate for the formal system's inability to provide water (Gutierrez, 2019). In particular, decentralized management systems enable informal and underserved communities to build resilience independently, regaining control of water resources from formal institutions that have previously neglected or been unable to serve them adequately (Gutierrez, 2019).

*Managing formal and informal urban sprawl*

The underlying driver of water stress in Mexico City is urban sprawl, both informal and formal. The city's consistent growth (both in terms of population and territory) has placed unsustainable demands on the water supply. As the city continues to grow, urban sprawl cannot be redirected to other areas of Mexico, due to demographic and economic dynamics (i.e., the immense disparity of capital and economic activity between Mexico City and the rest of the nation). The challenge is to organize growth sustainably (Coq-Huelva & Asián Chaves, 2019).

Water stress associated with urban sprawl disproportionately affects informal settlements, which are already largely excluded from the public system. Despite current solutions—such as decentralized water management and RWH systems—informal settlements remain at high risk of water insecurity as well as flooding (Jiménez et al., 2020).

*Climate change*

Mexico City faces an acute water crisis, which will grow with the effects of climate change (Zambrano, Pacheco-Muñoz & Fernández, 2017). Extreme weather events, such as droughts, are expected to become longer, more intense, and more frequent, which will threaten the surface-water on which Mexico City re-

lies for inter-basin transfers (Freeman et al., 2020). These events, in turn, will likely drive increased extraction of groundwater, resulting in increased subsidence patterns and putting the city at even greater risk of flooding in the future (Zambrano, Pacheco-Muñoz & Fernández, 2017). Like droughts, floods are expected to become more severe and frequent as a result of climate change, thereby further endangering many areas of the city—the city's most vulnerable districts in particular.

## Core Issues Driving Water Scarcity in Mexico City

**Supply**
- Surface Water Scarcity
- Groundwater Scarcity
- Flooding

**Water Use**
- Population Growth
- Displacement/ Migration
- High Per Capita Consumption
- Urban/Rural Competition

**Inequality & Access**
- Affordability
- Unsafe Access Points
- Distant Access Points

**Infrastructure & Service**
- Insufficient Maintenance Capacity
- Insufficient Capture Technology & Infrastructure
- Non-Revenue Water

**Governance**
- Lack Of Public Awareness & Political Will
- Insufficient Capacity & Expertise
- Lack Of Coordination Between Sectors

**Finance**
- Insufficient Revenue Collection
- Counterproductive Pricing Structures

## Sample Solutions for Water Security in Mexico City

**Data**

Climate Vulnerability Assessments.

Create robust predictive models based on thorough data collection to integrate climate vulnerability into future water and land use planning.

**Water Supply**

Diversifying Water Sources

Diversify water resources to avoid over-reliance on one [type of] source.

Wastewater And Storm-Water Capture, Treatment, And Reuse

Employ wastewater and storm-water capture, treatment and reuse, especially for agri-

cultural and industrial purposes.

Incentivize use of treated wastewater in industry or private businesses by regulatory, legal or financial incentives and mechanisms.

Rainwater Harvesting

Employ rainwater harvesting (RWH) and purification as a means of augmenting water supply and mitigating flood risk.

**Infrastructure**

Consumption Metering By Zone

Sectorize the water distribution network into distinct metering areas to ensure maximum control over the supply system (i.e. to allow for quick and targeted action when responding to leaks or faulty infrastructure).

Pressure Management Interventions

Install water-saving accessories and low water-use sanitary installations (in residences in formal settlements) to reduce water consumption.

Upgrade city-wide infrastructure to include pressure-reducing technologies and reduce water loss in the overall system.

Alternate Supply Methods In Informal Settlements

Employ rainwater harvesting (RWH) and purification in informal settlements as a means of ensuring water access and security.

Ensure proper training of individuals using and maintaining RWH systems to avoid public health hazards.

Water Transportation Between Cities And Between Urban And Rural Areas

If transporting water from different areas, consider all externalities that might be generated in those areas and try to prevent these (i.e. through groundwater recharge with wastewater).

**Finance**

Sustainable Cost Recovery

Implement meters and increase coercive measures for delinquent users (in formal settlements) to ensure payment.

Improve fee collection among delinquent users.

**Management Within City Governments**

Attracting And Retaining Skilled Staff

Build human resources capacities within municipal institutions to enable effective engagement with stakeholders (e.g. private sector, citizens, NGOs, other spheres of government, etc.) for water conservation efforts.

Accountability

Create regulatory structures that ensure accountability of private sector actors and disincentivize abuse of power, corruption, etc.

Water Management In Informal Settlements

Enable decentralized water management in informal settlements to ensure resilience, access and supply.

**Planning**

Integration Of Management Of Water Resources With Urban, Regional, And National Land Use Planning

Reformulate traditional municipal utilities and institutions to encourage a more holistic or integrated approach to water resources management (i.e. integrating land use planning into water resources management).

Work with land use agencies to sustainably manage urban sprawl.

Integrated Water Resources Management (IWRM)

Engage in integrated water resources management (IWRM) by encouraging regional cooperation (i.e. through treated wastewater and groundwater exchange programs).

**Municipal Revenue Sources**

Tariff Structures That Disincentivize Water Waste

Create tariff structure that disincentivizes water waste.

Increase cost of water to reflect true cost of service provision and allow for continuous and adequate maintenance of infrastructure.

**Access & Equity**

Subsidies To Assist Low Income Populations

Maintain subsidies in place for low-income users to avoid exacerbating water insecurity in vulnerable communities.

**Involving Stakeholders Outside Of Government**

Public Private Partnerships (PPPs)

Increase private sector participation to alleviate some of the financial and logistical burden from municipal utilities (allowing for enhanced maintenance and service capacity).

**Water Cycle Management**

Conserving And Restoring Water Related Ecosystems

Restore natural ecological wetlands to promote aquifer recharge and hydrological

equilibrium.

Using Treated Wastewater To Recharge Groundwater And Over-Exploited Aquifers

Recharge groundwater or over-exploited aquifers with treated (reclaimed) waste-water or stormwater.

Coordination Of Urban And Rural Use Of Water

Support both rural and urban development by engaging in water exchange programs (i.e. provision of treated wastewater to rural areas for agricultural use and provision of first-use groundwater to cities for consumptive use).

Conservation Zones That Protect Areas Of Environmental Or Hydrological Importance

Create conservation zones to protect areas of environmental or hydrological importance in the watershed (i.e. areas where soil is good for recharge).

**Reducing Water Loss**

Reducing Theft

Address water theft through legal means (while simultaneously taking care not to cut off vulnerable populations from their only source of water supply).

Reducing Leaks

Invest in upgraded infrastructure to reduce water loss due to leaks in the system.

**Reducing Water Consumption**

Public Awareness Campaigns

Reduce rates of consumption among citizens in formal settlements (and particularly in wealthy neighborhoods) through public awareness campaigns.

## Appendices

**Appendix A.** An overview of water resources management in Mexico City

| GENERAL INFORMATION | |
|---|---|
| Inhabitants | City (Distrito Federal): 8,851,080[6]<br>Total metropolitan area: 21,163,000[7] |
| Population density | 5,912 person/ km² - Mexico City 2009<br>668 person/ km² - Mexico state 2009 (CONAGUA, 2011) |
| Population growth | 15 %[8] |
| GDP (estimated in 2008, $bn at PPP) | US$ 390 billion (rank 8) (Hawksworth et al., 2008) |
| Contribution to national GDP | 33 % (IDB, 2008; Tortajada, 2006) |
| Area | 7,854 km² (CONAPO, 2005) |
| Climate | Temperate semi-humid, Arid & Semi-arid; Temperate humid (SMA, 2005) |
| Altitude | 2,240 m.a.s.l. (SMA, 2005) |
| Mean temperature | 16°C (SMA, 2005) |
| Mean annual rainfall | Arid – 50 mm; Temperate humid – 100 mm (SMA, 2005) |
| **WATER STATISTICS** | |
| Domestic water use (liter per capita) | 364 l Mexico City & 230 l Mexico state = 297 l on average in metropolitan area (Tortajada, 2003) |
| % households with water access | 98 % (Mexico City) (CCA, 2011) |
| % water loss due to leakage in pipe systems | > 40 % (Tortajada, 2003) |
| Water price for domestic households | Mexico City = CONAGUA tariffs for 20m3 (US$/month)9: Popular $3.50, Low $5.10, Medium $14.90, High $17.00 (CCA, 2011) |
| % households with sewerage services | Mexico City = 94 % (CCA, 2011) |
| % wastewater treated | Mexico City = 7.9 % (CCA, 2011) |
| Main water sources | Groundwater<br>Inter-Basin water Transfer from the Cutzamala & Lerma Rivers |
| Main water problems | Pollution<br>Groundwater over-extraction<br>Insufficient and leaking infrastructure<br>Subsidence → flood risk |

## Appendix B. Historical overview of water management in Mexico City[27]

Mexico City has a long and complicated history with water resource management. Present-day Mexico City was built on the ruins of Tenochtitlan, the former capital of the Aztec empire. Founded in 1324, Tenochtitlan was built on an island in the middle of Lake Texcoco, a shallow saline lake, with frequent exposure to droughts and floods and limited access to drinking water (Tellman et al., 2018). Lake Texcoco was part of a system of lakes and the Aztecs built a sophisticated infrastructural system of drains, canals, dams, dykes and aqueducts to regulate water flow and quality and to mitigate drought and flood risks (Sosa-Rodriguez, 2010). To provide food for their populous capital, the Aztecs engineered floating gardens known as chinampas, which were highly productive wetland agroecosystems (Jiménez et al., 2020; Gutierrez, 2019; Tellman et al., 2018). Tenochtitlan was designed in a way that ensured a harmonious balance between human settlements and the nature that surrounded them (Gutierrez, 2019).

When Spanish conquistadors conquered Tenochtitlan in 1521, they decided to build the capital of New Spain on the ruins of the old Aztec empire to symbolize their political domination (Tellman et al., 2018). The conquistadors were determined to subdue the water, in an attempt to create more livable land and expand human settlements in the area. They drained the lakes, replaced the canals and dykes with streets and squares and, ultimately, exposed the growing metropolis to increased flood risk, low water quality, outbreaks of waterborne illness and the subsidence of the city itself (Gutierrez, 2019; Sosa-Rodriguez, 2010).

As Mexico City grew, sanitation became a concern, and the government created the *Gran Canal* (Great Canal)—which is still in operation today—to remove storm-water and waste-water (Tellman et al., 2018). Expansion continued throughout the 19$^{th}$ and 20$^{th}$ centuries, and the period between the 1930s and the 1960s saw dramatic urbanization as informal settlements mushroomed across the cities. To facilitate rapid urban growth, the government of Mexico City regularized the informal settlements and developed a public subway system. Ultimately, this stimulated more urbanization, until it became clear, in the 1970s, that the city was facing serious environmental and water issues due to pollution resulting from urbanization. To address the water pollution, city administrators began creating Conservation Zones in the 1980s.

While the rate of urbanization declined throughout much of the city, it continued in the city's southern boroughs, encroaching on Conservation Zones established to protect the city's watershed (Gutierrez et al., 2019).

27 For a more detailed account of Mexico City's history with water management, please see: **Sosa-Rodriguez, F. S. (2010). Impacts of water-management decisions on the survival of a city: from ancient Tenochtitlan to modern Mexico City. International Journal of Water Resources Development, 26(4), 675-687.**

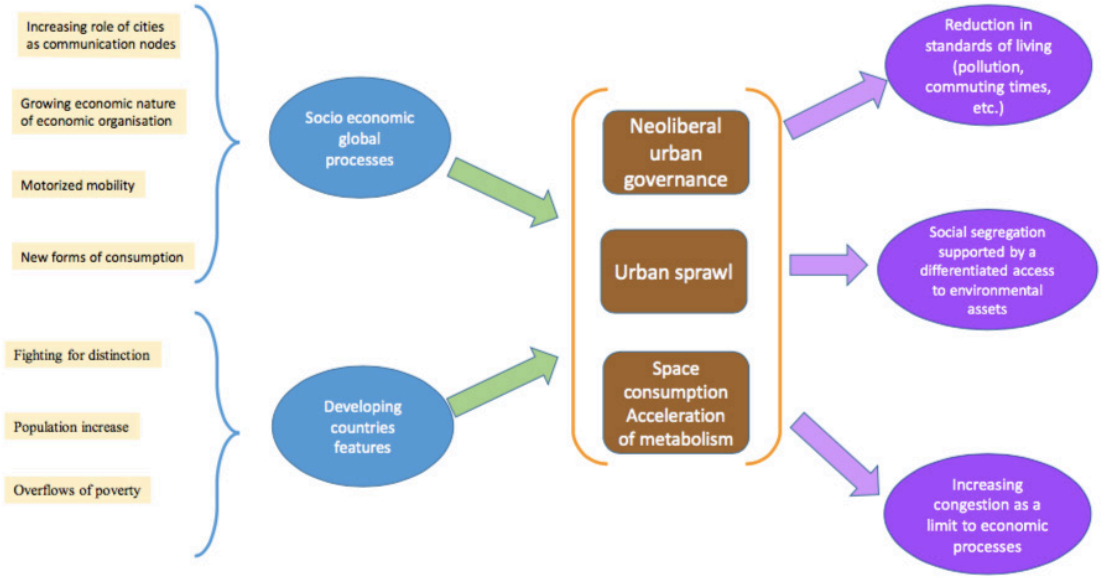
**Tellman, B., Bausch, J. C., Eakin, H., Anderies, J. M., Mazari-Hiriart, M., Manuel-Navarrete, D., & Redman, C. L. (2018). Adaptive pathways and coupled infrastructure: seven centuries of adaptation to water risk and the production of vulnerability in Mexico City. Ecology and Society, 23(1).**

**Appendix C.** Reasons SEDEMA provides for water scarcity

| Physical | Managerial | Institutional |
|---|---|---|
| • Lower aquifer levels<br>• Changing rain patterns | • 30-45% potable water lost to leaks<br>• Extraction surpasses natural aquifer recharge<br>• Not taking advantage of rainwater<br>• Pollution | • Growing population = growing demand<br>• For every hectare urbanized, recharge reduces about 2.5 million liters per year<br>• Irresponsible, wasteful use |

**Source:** Gutierrez, J. (2019). Water Scarcity and Supply Challenges in Mexico City's Informal Settlements.

**Appendix D.** Schematic representation of the environmental effects of urban sprawl.




**Source:** Coq-Huelva, D., & Asián-Chaves, R. (2019). Urban Sprawl and Sustainable Urban Policies. A Review of the Cases of Lima, Mexico City and Santiago de Chile. *Sustainability, 11*(20), 5835.

## Mostar, Bosnia-Herzegovina

### City Profile

Mostar—located in Herzegovina, the southern region of Bosnia-Herzegovina (BiH)—is characterized by a Mediterranean climate, hydrological richness, and karst aquifers. The water supply system in the City of Mostar is reliant on a combination of surface and groundwater, and the city's many rivers are popular for recreational use, attracting tourists and locals alike.

The city has been divided since the war that ravaged BiH in the 1990s. Prior to the war, ethnic Bosniaks, Serbs, and Croats lived in heterogenous communities. Today, the city is divided along ethnic lines on the banks of the Neretva river. The Bosniak population, a minority since the war (due to significant population loss caused by genocide and mass exodus), is concentrated on the eastern bank of the Neretva river, in Eastern Mostar. The Croat population, the newly formed majority, live in the territory on the western bank of the river, in Western Mostar. There is little contact between the two communities, and the political situation is characterized by complex consociationalism[28] and almost absolute territorial fragmentation (Bieber, 2006; Sherman, 2011). Many Serbs left the city during the war, and only a small Serb population remains today.

Ethnic tensions and divisions within the city have produced a political stalemate; the city has not held municipal elections since 2007. In the absence of democratic elections, Mostar has had the same mayor for the past 17 years.[29] The formerly elected city council has remained in power past its mandates as well. This impasse puts the city at odds with the constitution of BiH, which requires democratic processes (Pobrić, 2016). There is a lack of accountability and transparency within local government, as well as distrust between the government and the public (Pobrić, 2016; Sherman, 2011). The political situation has also exacerbated ethnic tensions in Mostar (Bieber, 2005)[30].

28 Consociationalism is defined as a system wherein there are major internal divisions along ethnic (or religious or linguistic) lines, which remains stable due to consultation among the political or ruling elites of these groups.

29 Mayor Ljubo Bešlić, representative of the Croat ethnonational party HDZ, was elected democratically for the first time in 2003, and again in 2007. He's remained in power since, despite lack of elections.

30 Bosniaks feel underrepresented in the City of Mostar, as the majority of political positions are held by Croat leaders from the HDZ party.

Mostar has recently emphasized the need for sustainability in city-planning, but complexities of the post-conflict setting create challenges (Djurasovic & Knieling, 2015). As a divided city, Mostar has two institutions for nearly everything, with five public utilities (divided territorially along ethnic lines), each of which must answer to one of the two reigning ethnonational political parties when deciding on a budget. The municipal landfill, one of the few shared utilities in the city, was the cause of much contention in 2019 and 2020, when an industrial carcinogen was discovered in the city's water supply. The carcinogen pyralene was traced back to the inappropriate waste disposal practices at the landfill. The presence of pyralene in the water supply is a serious risk to water security in Mostar, where the majority of residents consider tap water potable and use it for consumption, cooking, and hygienic purposes.

**Case Study: Water Governance in a Post-Conflict Scenario**

Mostar is a post-conflict city that is divided—territorially, societally, and institutionally—along ethnic lines. The city has two of nearly every public institution, with the municipal landfill being one of the few exceptions: that is, one of the few shared resources. Pyralene recently discovered in the public water supply has been traced back to illegal waste disposal practices at the municipal landfill. In response to the discovery, citizens have united across ethnic lines to call for greater environmental and water quality protections.

**Background**

Uborak, the municipal landfill, is among the only shared utilities in Mostar. In the past two years, Uborak has come under scrutiny due to the presence of large quantities of toxic sludge (from a water treatment plant) that has been illegally disposed of in the landfill. In the summer of 2019, water quality tests confirmed the presence of pyralene—a polychlorinated biphenyl (PCB) and known carcinogen—in the city's drinking water supply. The pyralene ended up in the river Sušica—a tributary of the river Neretva, one of the city's main sources of water—through storm-water runoff and leachate from the landfill, thereby contaminating the city's water supply.

Mostar is characterized by a karstic topography, which is vulnerable to pollution because of the unpredictable sinkholes, caves, and underground streams associated with karst aquifers. Currently, Mostar does not undertake groundwater quality monitoring, so there is insufficient data to determine to what degree improper waste disposal at the Uborak landfill degrades the quality of groundwater (Calo & Parise, 2009). Waste disposal at the Uborak landfill likely affects the local water supply in multiple ways, as the municipal water supply system depends on surface water as well as groundwater (Calo & Parise, 2009; Lukić et al.).

**Actions Taken**

The discovery of PCB brought attention to illegal waste disposal practices—the disposal of medical and industrial waste—at the Uborak landfill. The federal government had ordered the Uborak landfill site closed in 2014, when it was deemed that the landfill had reached maximum capacity, but it continued to operate. The discovery of PCBs in the drinking water caused many citizens of Mostar to organize in protest.

Led by a grassroots activist organization, "Jer nas se tiče" ("Because we care"), protesters blocked access to the landfill in the summer of 2019, and again in the winter of 2019–2020. The protests caused garbage to pile up in the city center (during periods of both intense heat and heavy rain) in an attempt to provoke a response from the city. In response, the city sent police to force access to the landfill in order to resume waste collection and disposal from the city center. The fact that water security issues were able to unite a divided population suggests the potential of improved water management as a mechanism for peacebuilding in post-conflict societies (Weinthal, Troell & Nakayama, 2014).

Mostar has commissioned a private consulting company to investigate the situation at the Uborak landfill. Public information about the investigation is limited.

**Existing Challenges**

Despite Mostar's natural hydrological richness, chemical contamination of the public supply causes water insecurity. Citizen groups and experts have proposed the closure of the Uborak landfill site. No alternative site has been formally identified by the city. Citizens have also requested chemical water purification in the river Sušica, to ensure that leachate from the Uborak landfill is free of harmful chemicals before entering the river Neretva and the city's water supply. That solution does not address the potentially harmful effects of leachate from Uborak on the groundwater and karst aquifers.

Environmental issues have been exacerbated by political ones, with the absence of democratic processes leading to a lack of accountability among officials. Limited government transparency weakens public trust. Political, social, and technical solutions are needed. Addressing the problem of contamination at the Uborak landfill site could involve the closure and possible rehabilitation of the site itself and the design of a new, more sustainable waste disposal site. Additional chemical purification of water in the public supply could be a benefit as well. Increasing monitoring efforts to include groundwater, and ensuring regular, adequate, and transparent data collection would be significant steps. Data transparency would foster public support and build trust between the government and the public (Gupta & Mason, 2014).

## Core Issues Driving Water Scarcity in Mostar

**Supply**
- Contamination And Pollution

**Governance**
- Lack Of Public Awareness And Political Will

**Infrastructure & Service**
- Insufficient Data

**External Factors**
- Conflict

## Sample Solutions for Water Security in Mostar

**Data**
- Groundwater Monitoring
- Drinking Water Monitoring

**Water Supply**
- Treating Contaminated Water

**Management Within City Governments**
- Accountability

**Building Trust**
- Making Data Transparent And Readily Available To The Public
- Ensuring Compliance With Laws And Regulations

## Pune, India

### City Profile

The city and district of Pune are located in the state of Maharashtra in Western India. Pune is the second-largest city and district in the state after Mumbai. In the district of Pune, there is one urban center, Pune City, with a population of over 5 million. In the rural area of Pune, the population is around 3.5 million, spread out in 13 rural centers, thousands of villages, and over nine thousand habitations (Census of India, 2011; Hui & Wescoat, 2019). The district of Pune covers over 15,000 km2. Its environment, economy, and demographics lie on a gradient from west to east, with rainfall, prosperity, and industry in the west and dry, rural, relatively poor habitations in the east (Singh et al., 2020; Udmale et al., 2016). Pune city receives its water from four major dams. Nearby rural areas that lack adequate piping gather water from unregulated wells, boreholes, and occasionally from surface water. The risk of contamination from these sources is high due to open defecation and inadequate waste management..

### Case Study: Water Quality Initiatives

India is one of the most groundwater-dependent regions in the world, using around 230 km3 of groundwater per year (Belita, 2015; Chindarkar & Grafton, 2019). Sixty-five percent of India's groundwater reserves irrigate large amounts of cropland and are also the sole source of water for 90 million rural households (Chindarkar & Grafton, 2019). Pune utilizes groundwater for domestic, agricultural, and industrial purposes (Siddiqui et al., 2018). Many sources are unregulated and can easily be contaminated by agriculture practices, industrial activity, and human waste (Dhawde et al., 2018; Jaiswal & Voon, 2017; Singh et al., 2020). These contaminants are detrimental to human and environmental health and add stress to the water supply in the region. Clean water sources have been difficult to manage in Pune due to the geographic spread of rural and peri-urban areas in the district and methods of individual access to groundwater. Most villages test their water four times a year and use bleaching powder as a purifying treatment (Sakthivel et al., 2015). Bleaching is effective for removing bacterial contaminants at the point of consumption, but it does not stop contamination at its source.

Initiatives to end open defecation across India and minimize human waste as a source of contamination are essential to achieving a clean water supply.

**Background**

The relationship between national and local levels of government in India is complex. The smallest level of government is a gram panchayat. This local advisory encompasses multiple villages, which in turn have multiple habitations. A habitation is the smallest denomination (Wescoat et al., 2019). Above the gram panchayats, there are district and state governments. Infrastructure for improved water, sanitation, and hygiene is not readily available due to the expansion of peri-urban and rural areas in Pune. One quick way for rural areas to access water is by tapping into groundwater systems with wells or boreholes.

These unregulated wells are susceptible to contamination by human waste. Open defecation is a major problem in India that contributes to poor water quality (George, 2008; Jaiswal & Voon, 2017). It occurs primarily because toilets are inaccessible. In some cases, toilets provided by the government have been converted for other household needs (George, 2008). Education campaigns about the use of toilets could help. Despite national programs to end open defecation, many rural areas in India struggle with this transition.

Contamination stresses the water system and the health system. Diarrhea, likely arising from contaminated water, is the cause of 500,000 deaths each year, (Jaiswal & Voon, 2017). Bleach is one effective way to purify a water source for the community utilizing it, but it does not protect other communities downstream (Sakthivel et al., 2015). Regular flooding exacerbates the effects of contamination. If one village contaminates a water source, the rest of the district and the state can feel the effects (Singh et al., 2020 and GOI, 2014).

Current water demands in Pune City are easily met in the city center, where the majority of water is piped through controlled, closed drainage systems from reservoirs on major rivers, with adequate wastewater management (Hui & Wescoat, 2019). Infrastructure in the immediate outskirts of the city is provided in part by the Maharashtra Industrial Development Corporation (MIDC), a project of the government of Maharashtra. Additional piping and wastewater management are needed in these areas, which are vulnerable due to their proximity to industrial sites, including wastewater treatment plants (Hui & Wescoat, 2019). At greater distances from urban and peri-urban centers, there are fewer piped systems, fewer closed drains, and less waste management infrastructure. Many rural villages are effectively charged with developing their own means of water management.

Unregulated groundwater extraction and continuous contamination of ground and surface water strain Pune's water sources. Extensive aquifer mapping and externally funded research for groundwater control has occurred at the national level; however, this information does not always reach the smallest communities (Belita, 2015). Under current projections, 60% of India's districts will see groundwater tables fall to critical levels within 20 years (Belita, 2015).

**Actions Taken**

The state of Maharashtra has experimented with ways to achieve state and national goals at the village level through statewide initiatives, external funding, and state and local collaboration efforts.

Under statewide water initiatives like the Sant Gadge Baba Sanitation Campaign, villages compete to achieve the title of "the cleanest village." These initiatives encourage responsible management at the local level to reduce open defecation, minimize animal presence near water sources, collect and dispose of waste, and develop community institutions. Competition winners are awarded monetary prizes. Maharashtra state initiatives inspired the national level Nirmal Gram Puraskar, or National Clean Village Award, which is awarded to the cleanest villages in India. These awards grant further funding from the national government for infrastructure and development of the local village (Sakthivel et al., 2015 and Shah, 2013).

Additionally, the state government of Maharashtra has negotiated loans from the World Bank to improve the overall quality of water services in water-stressed, polluted, and peri-urban villages (Singh et al., 2020 and World Bank, 2014). The Jalswarajya (JS1) project, begun in 2003 and completed in 2009, increased the percentage of households using sanitation facilities (toilets and washrooms) from 19% to 77% (in project villages), and increased the number of gram panchayats who provide potable water to their inhabitants to 76% (World Bank, 2010). This project identified the importance of engaging the gram panchayats in participatory processes as well as working across villages with similar social backgrounds, where word-of-mouth contributes to interest. A more recent project funded by the World Bank, Jalswarajya II (JS2), aims to improve capacity building, monitoring, and sanitation in rural and peri-urban villages through September 2020 (Singh et al., 2020 and World Bank, 2014).

Local champions play an essential role in building sanitation capacity in villages. Physician and social activist Suhas Vitthal Mapuskar saw the negative effects of open defecation on water quality in Dehu, Pune. He worked with villagers in Dehu to establish biogas toilets not only to contain waste, but also to generate energy (George, 2008 and Karelia, 2020). Each household contributed to construction, and in 1980 the village had installed toilets in 90% of households.

Another local champion in Maharashtra, dental surgeon Avinash Pol, noticed that villagers from poor areas were experiencing health problems due to poor sanitation. These individuals did not know about the initiatives provided by the state and national governments to build toilets in their villages (Katoch, 2016). Dr. Pol became a champion for over seventy villages in Maharashtra, distributing information, and initiating the first steps in building toilets and clean water systems (Katoch, 2016). Villagers who learned about government initiatives and other available resources through his work were then able to reach out to the gram panchayats on their own (Katoch, 2016).

**Existing Challenges**

Contamination remains a significant problem

in Maharashtra. Solutions include purifying water sources with bleach, building fencing around wells to minimize the risk of children and animals contaminating the source, and developing toilet facilities.

The state of Maharashtra and the district of Pune have been case studies for assessments of initiatives to improve water quality through local level planning. These assessments highlight the importance of capacity building at the local level (Dhawde et al., 2018; Hui & Wescoat, 2019; Wescoat et al., 2019). Capacity challenges remain, and an associated lack of good data at the village level is itself a barrier to developing solutions for water security (Wescoat et al., 2019 and Singh et al., 2020).

## Core Issues Driving Water Scarcity in Pune

**Supply**

- Groundwater Scarcity
- Contamination And Pollution

**Water Use**

- Population Growth

**Infrastructure & Service**

- Insufficient Data
- Insufficient Maintenance Capacity
- Lack Of Sanitation Services

**Governance**

- Lack Of Coordination Between Local, Regional & National Government

## Sample Solutions for Water Security in Pune

**Data**

- Drinking Water Monitoring
- Sanitation Monitoring

**Coordinated Governance**

- Local, Regional, and National Coordination

**Access & Equity**

- Subsidies To Assist Low Income Populations

**Involving Stakeholders Outside Of Government**

- Building Capacity Of Stakeholders In All Parts Of Society
- Issuing Guidance To The Public

## Quang Tri Town, Vietnam

### City Profile

Quang Tri is a town located in Quang Tri Province in the North Central Coast region of Vietnam. The town is the second largest in the province—after Dong Ha, the province's capital—and has a population of approximately 23,000 people. Quang Tri lies in the tropical monsoon zone and experiences a relatively harsh climate, with two distinct seasons: the rainy season, influenced by heavy rainfall and strong winds (from September to January) and the dry season (from March to August) (ADPC, 2003). Due to Quang Tri's climate, it experiences frequent droughts, which often result in saltwater intrusion in the province's rivers. To a lesser degree, Quang Tri is exposed to increased flood risk during the rainy season as well as a heightened risk of typhoons due to its tropical climate (APDC, 2003).

In Vietnam as a whole—and in Quang Tri Province specifically—rapid urbanization has resulted in significantly increased water demand and a need for expansion of the water supply network (P4G, 2019). The nation has set a target of ensuring 100% clean-water coverage in all of its urban areas. Achieving this goal requires investment in additional infrastructure and technology in the water sector in 79 municipalities in Vietnam, including Quang Tri (Grundfos, 2019). However, a primary concern for achieving this goal is the high rate of non-revenue water (NRW) present throughout Vietnam's water sector.

### Case Study: Sustainable Cost Recovery Infrastructure Investments

As in many countries in the Global South, the water supply network throughout Vietnam experiences high levels of non-revenue water (NRW): estimated to be around 30% nationally (P4G, 2019). In accordance with its goal of achieving clean water for all urban areas, Vietnam has committed to cutting the rate of NRW in half by 2025 (Grundfos, 2019). However, reducing NRW requires overcoming a number of institutional, technical and financial challenges. Most notable among these are financial barriers; the overall lack of financial resources for water and sanitation services creates a role for private sector investment. The private sector, however, is disincentivized from investing

in the water sector in Vietnam by the low water tariffs common throughout the nation (P4G, 2019).

In Quang Tri Town, a blended financing model enabled the implementation of pressure-reducing water infrastructure that resulted in water, energy, and cost savings for the water utility and had a cost recovery period of five years (P4G, 2019). Quang Tri Town is a potential model for the implementation of blended finance to enhance the efficiency of Vietnam's water sector.

**Background**

The water sector in Vietnam has historically shied away from private sector involvement, and water utilities continue to provide water to citizens at relatively low prices. Tariffs for water-related services are low in relation to the actual costs of services provided, willingness to pay, and prices charged in comparable countries. All these factors generate low revenue across the water sector and discourage utilities from investing in efforts to reduce water loss due to leakage throughout the system (P4G, 2019).

In 2007, due to increasing public debts and competing investment demands, the state instituted economic reforms that allowed for greater private sector participation throughout the water sector (P4G, 2019). As a means of facilitating the transition from public financing (including government money and foreign aid), increased privatization, equitization,[31] and public-private partnerships (PPPs) throughout the water sector have been encouraged by Vietnam's government. Yet despite the government's encouragement of partial privatization, it has been difficult to transition from public financing to private sector investment. One reason is that equitization—or joint-stock companies—place pressure on investors by obligating them to work with the government as a compulsory partner. PPPs are sometimes even less popular than equitization in the water sector, since PPPs demand more of private investors in terms of performance standards and behavioral obligations (P4G, 2019).

Although utilities (including state-owned companies, joint-stock companies, and PPPs) could borrow capital directly from financial markets through loans or sale of bonds, this form of financing is not commonly used in Vietnam due to the high levels of risk involved in investments (Smets, 2014; P4G, 2019). As a result, investors are typically unwilling to undertake risks to finance water sector projects. Investors lack confidence in sources of future revenue and in the ability of regulatory frameworks to protect investments; this lack of confidence constitutes one of the main impediments to private money entering the water sector. In addition to financing barriers and lack of confidence among private investors, institutional coordination remains a significant barrier to implementing business models in the water sector. Vietnam currently has a coordination strategy that is sub-sectoral and not national, which raises the concern that capital will not be invested in locations where it is most needed, and that regulatory actions will not adequately promote national policy objectives (P4G, 2019).

31 Equitization is defined as a process wherein a "state-owned enterprise is [transitioned] into a joint-stock company by selling equity to one or more private investors" (P4G, 2019).

These barriers have disincentivized both the private sector as well as utilities operators from investing in pressure management and leakage reduction technologies throughout the water sector. As a result, NRW levels remain high throughout Vietnam, including in Quang Tri Province, both due to technical loss in the system (i.e., leakage) and commercial loss (i.e., illegal connections and inaccurate meter reading) (P4G, 2019). In Quang Tri Town, the estimated leakage rate is approximately 28% of the water in the entire system, which indicates overall inefficiency in water management and poses a threat to the town's long-term water security (P4G, 2019).

**Actions Taken**

The organization Partnering for Green Growth and the Global Goals 2030 (P4G) funded and facilitated a partnership of four organizations to lead a study investigating the potential application of a blended finance model to reduce NRW and energy consumption in four distinct water networks in Vietnam. The study included two non-governmental organizations, namely, the Asia Society for Social Improvement and Sustainable Transformation (ASSIST)[32], a sustainable development NGO based in Southeast Asia, and the Vietnam Water Supply and Sewerage Association (VWSA)[33], a voluntary social-occupational organization of bodies and individuals involved with the water sector. Grundfos,[34] a private water solutions company based in Denmark, was enlisted as the project (or contracting) company in the P4G study. Finally, the Danish Investment Fund for Developing Countries (IFU)[35], an independent fund owned by the Danish government and specializing in the provision of advisory services and risk capital to companies seeking to do business in emerging markets, served as the donor institution.

P4G's study focused on four different water networks in Vietnam, including the Tri Phuong Water Plant, the Quang Tri Town Pump Station, the Quang Tri River Pump Station, and the Ca Giang Water Plant, all of which were operated by distinct public-private partnerships (P4G, 2019).

Grundfos served as the primary provider of pump technologies to reduce water loss in the respective networks. In Quang Tri Town, Grundfos refurbished all the water pumps to optimize pressure management and reduce NRW. While the company undertook 70% of the risk, the entire project was backed by capital from the IFU (an agency of the Danish government) (Mathiasen, 2020; P4G, 2019).

Through the combined efforts of the project company (Grundfos), the grant donor (the IFU), and the NGOs (ASSIST and the VWSA), the project met its goals. The Quang Tri Town pump—as well as two of the other pumps—were

32 For more information on ASSIST, visit their webpage: https://assistasia.org/.

33 For more information on VWSA, visit their webpage: http://vwsa.org.vn/.

34 For more information on Grundfos, visit their webpage: https://www.grundfos.com/.

35 For more information on the IFU, visit its webpage: https://www.ifu.dk/.

able to pay back the capital investment faster than expected, resulting in a technology cost-recovery period of only five years (Mathiasen, 2020; Grundfos, 2019). This quick cost-recovery was largely due to the savings in water and energy consumption that the Quang Tri water utility was able to accrue using its new, state-of-the-art pressure reducing pumps. Specifically, the implementation of a new pressure-reducing water infrastructure in Quang Tri Town resulted in an annual water savings of 20,985 $m^3$ and an annual energy savings of 100,981 kWh. In total, these savings amounted to a capital savings of US $14,203 per year (P4G, 2019). Without the blended financing model, the local water utility would not have been able to invest in this new infrastructure because it wouldn't have been able to overcome the finance gap resulting from low revenue (i.e., highly subsidized water) and a lack of willingness among private-sector actors to undertake high-risk investments. This experiment demonstrated that trust-building between public, private, and multi-governmental actors can result in the implementation of water management solutions that are both financially and technically sustainable (Mathiasen, 2020).

The benefits of pressure management systems are multi-fold, from a conservation standpoint as well as from the standpoint of both the water utility and customers. Such systems reduce water loss to leakage, improve energy efficiency, and reduce operation and maintenance costs. They reduce flow rates and result in significantly less water consumed, ensure a more efficient use of both water and energy, and reduce the frequency of bursts and leaks, which reduces repair costs and bad publicity for the water utility, and increases overall customer satisfaction (P4G, 2019). Cost recovery within a five-year period in Quang Tri Town—as well as in Tri Phuong and Ca Giang—demonstrated the financial viability of blended finance in these cases (P4G, 2019).

To assess the feasibility of this approach as a model for other applications, P4G undertook four key analyses, namely:

1. Assessment of pressure management as an approach for reducing water leakages and energy consumption;
2. Assessment of the magnitude and nature of different barriers to investing in NRW and energy consumption reduction in Vietnam's water sector;
3. Financial analysis regarding the development of blended finance models to promote investment in the water sector; and
4. Identification of challenges in implementing the recommended blended finance model (P4G, 2019).

The result of these analyses was a set of recommendations for blended finance models that P4G says could be used to scale up projects in Vietnam or other countries facing similar challenges (P4G, 2019).

First, P4G recommends minimizing the administrative and bureaucratic burden of projects, which can discourage water utilities and technology providers from undertaking projects. (P4G, 2019).

Second, they recommend project bundling as a means of attracting investors. Investors typ-

ically seek investments sufficiently large to reduce their administrative burden and distribute risks. Small projects can be unattractive to investors. This challenge can be circumvented by bundling a number of smaller projects into a single larger one (P4G, 2019).

Third, they recommend adequately defining incentives for all stakeholders involved: the finance model should include criteria relevant to individual stakeholders. For example, contractors require a viable business model, while donors require alignment with institutional policies and grant requirements (P4G, 2019).

Fourth, they recommend that the model ensures the highest possible leverage of donor funds by only providing support at the level necessary for utilities and contractors to establish a functional business model. Such an approach creates more room for future investments (P4G, 2019).

Fifth, they recommend developing finance models that can be scaled to fit networks of different sizes. Potential investors can thereby be encouraged to support projects in all types of networks (P4G, 2019).

Finally, they recommend developing the finance model with potential scalability and replicability in other sectors in mind (P4G, 2019).
Overall, P4G's experiment indicates that the model featured could serve as an effective tool for reducing NRW in other places facing challenges similar to those addressed in Vietnam.

**Existing Challenges**

P4G's study highlighted several challenges that must be overcome if blended finance models are to be implemented effectively on a wide scale. To begin, adequate incentive structures are necessary to ensure utilities' willingness to repay investments. Due to the high rate of subsidization of water and energy costs in Vietnam, savings resulting from reduced NRW and energy consumption don't translate directly into higher revenue streams. Finance models and performance-based contracts need to be structured in such a way that water utilities are incentivized to repay investments (P4G, 2019).

Grants must be justified to donors and designed to ensure sustainable revenue for private investors. That means determining an acceptable threshold for return on investment while also establishing standards to ensure that the donor's capital investment directly benefits the water utility and consumers. Blended finance models require a balance between the donor's requirements, commercial viability, and municipal processes.

Individual investments are often small-scale yet require significant documentation and approval processes, which may discourage utilities, project companies, and investors from undertaking these projects. On the other hand, donors may be reluctant to provide funding if they believe that their grants may be used to maximize commercial profits instead of benefiting the local utility. Projects and grants could be categorized based on specific characteristics, such as network size or performance objectives, to speed up the administrative process while retaining a level of transparency acceptable to donor institutions (P4G, 2019).

The report recommends that entities interested in designing or implementing blended finance models in the water sector investigate the size of savings necessary to secure interest among utility providers in the target area. Relatively low water and energy prices may skew incentives for utilities to maintain and develop their water provision infrastructure (P4G, 2019).

In addition to incentivizing utilities, the report recommends incentivizing private contractors and, furthermore, ensuring shared incentives between these two actors. In practice, different stakeholder incentives can be difficult to negotiate. P4G's report highlights the need to find common ground at the outset (P4G, 2019). Finally, the report recommends seeking external advice specific to the region in question to ensure that the model and all its underlying agreements comply with the laws and regulations of the country in which they are implemented (P4G, 2019).

**Conclusion**

The blended finance model designed by P4G in collaboration with ASSIST, the VWSU, Grundfos, and the IFU to refurbish water infrastructure in Quang Tri Town had positive financial and technical outcomes. The project replaced old infrastructure, significantly reducing water loss and energy consumption, and proved to be financially viable, achieving a cost recovery of five years (Grundfos, 2019). The Quang Tri Town experience demonstrated a way to overcome financial barriers, reduce NRW, and achieve financial sustainability.

Blended finance models have been subject to criticism as well. The involvement of private sector actors in traditionally governmental spheres raises concerns about potential conflicts of interests and the ability of the private sector to safeguard the public's sustainable development interests (Tan, 2019).

The model used in Quang Tri Town produced positive outcomes, but it is not "one size fits all." Local context, including the interests and incentives of all stakeholders, is essential to success.

## Core Issues Driving Water Scarcity in Quang Tri Town

**Supply**

Drought

Flooding

**Infrastructure & Service**

Insufficient Pipe Systems

Insufficient Maintenance Capacity

Non-Revenue Water

**Finance**

Lack Of Funds

Counterproductive Pricing Structures

Uncertain ROI For Investments

Barriers To Subsidies And Loans

Poor Revenue Collection

## Sample Solutions for Water Security in Quang Tri Town

**Infrastructure**

Pressure Management Interventions

Refurbish water infrastructure to introduce pressure-reducing technologies and mitigate water loss (NRW).

**Finance**

Innovative Loans Structures & Other Finance Mechanisms

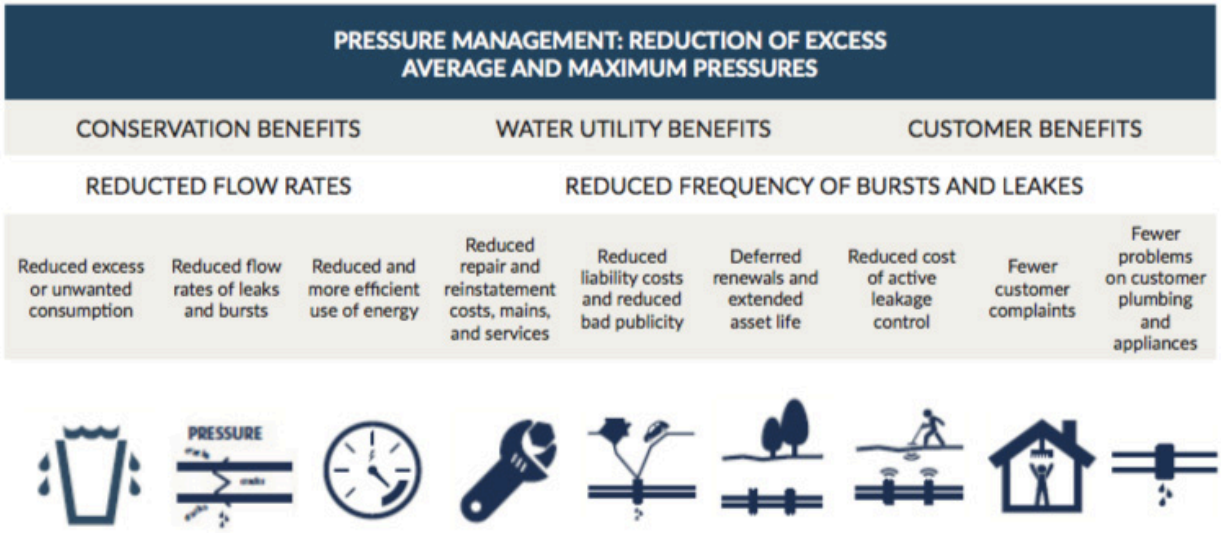
- Use a blended financing model to increase private sector participation and overcome gaps in public financing for investment in water sector infrastructure. [Specific recommendations for blended finance models below]
- Minimize administrative and bureaucratic burden of projects by standardizing the blended finance model as much as possible, to make projects more appealing to private-sector actors.
- Bundle smaller projects into 1 larger overarching project to make the project more appealing to investors.
- Accurately/adequately define incentives for all stakeholders involved by addressing criteria relevant to all individual stakeholders (e.g. project companies, grant donors, administrative bodies).
- Ensure highest possible leverage and maximum impact of blended finance model by only providing support at the level necessary for utilities and contractors to establish a functional business model, thereby creating more room for future investments.
- Develop the finance model to ensure adjustability (i.e. to be able to fit all networks

regardless of size).

- Develop the finance model in such a way that allows for scalability and replicability in other sectors, types of investments, regions and/or countries.
- Create adequate incentive structures to ensure utilities' willingness to repay investments.
- Justify grants in such a way so as to ensure acceptable profits for private-sector actors (i.e. investors).
- Quantify the grant level in such a way so as to ensure balance between donor's requirements, commercial viability and minimum bureaucratic processes.
- Investigate investment ability and appetite among utilities.
- Quantify and define best performance measures to establish a baseline and ensure credibility of results.
- Define the size of savings (in water, energy, and/or money) necessary to secure interest in use of a blended finance model amongst utility providers.
- Ensure shared incentives between utility and contractor on improving performance.
- Consider all of the donor's concerns and build the donor's perspectives into the model.
- Obtain external advice to ensure that the blended finance model and its underlying agreements are in compliance with local laws and regulations.

# Appendices

**Appendix A.** Benefits of pressure management



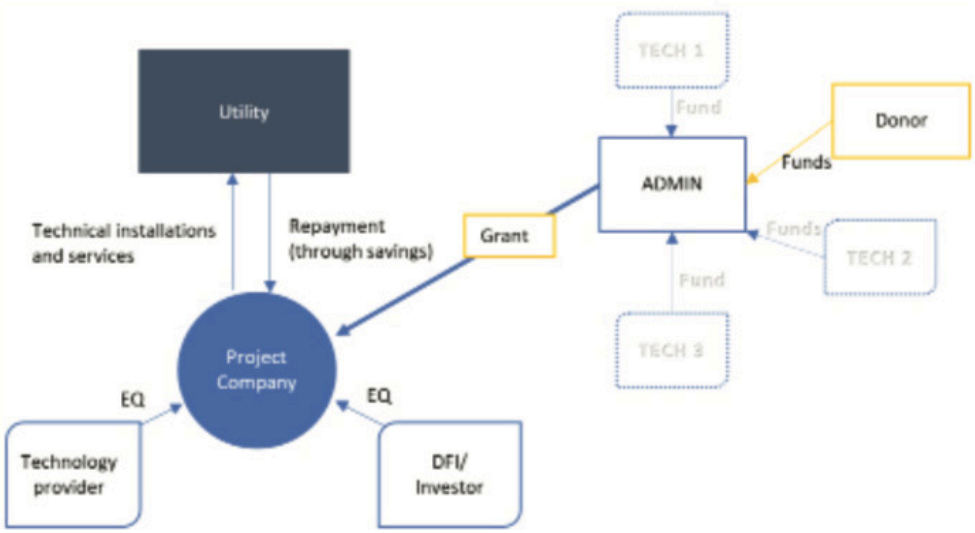

**Source:** Partnering for Green Growth and the Global Goals 2030 (P4G). (2019). Blended finance model to reduce non-revenue water and energy consumption in Vietnam (Rep.). Retrieved May 06, 2020, from https://p4gpartnerships.org/sites/default/files/2019-05/P4G_Blended%20Finance%20Model_Final%20report_20190423.pdf.

**Appendix B**. Key barriers for implementing business models in the water sector

| | |
|---|---|
| **Finance** | The provincial governments are responsible for planning and budgeting for water infrastructure in their localities. Projects are then implemented via bid for tender. However, the provincial governments usually do not have the capital, and thus are depended on the funding from the central government and international grants (the latter often requires state-backed guarantees, though). |
| **Private sector participation** | Lack of confidence on the sources of future revenue and in regulatory framework to protect the investment. Insufficient incentives to invest in risky and potentially unprofitable ventures, and thus attract fewer investments. |
| **Water tariff levels** | Vietnam has comparatively low prices and tariffs for water-related services, and thus generates low revenue across the water sector. The water-related services and tariffs are controlled by the Provincial People Committees. The tariff levels are set to either politically accepted or affordable for consumers, but not feasible in perspective of investments. |
| **Equitization process** | The Provincial People Committees who oversee water companies' activities become minority shareholders which means that they lose ability to manage and monitor the water sector. Also, assets in the water sector are slowly sold to private companies and the Government has little involvement in decision-making process. Currently most of investments are based on relationships, and informal contracts are acceptable for the Vietnamese investors but constrained for the international investors. |
| **Institutional coordination** | The current coordination strategy is sub-sectoral rather than national; hence there is a risk for the water sector not being invested in locations where needed most or regulatory actions are not promoting policy objectives |

**Source:** Partnering for Green Growth and the Global Goals 2030 (P4G). (2019). *Blended finance model to reduce non-revenue water and energy consumption in Vietnam* (Rep.). Retrieved May 06, 2020, from https://p4gpartnerships.org/sites/default/files/2019-05/P4G_Blended%20Finance%20Model_Final%20report_20190423.pdf.

## **Appendix C.** Recommended blended financing model




**Source:** Partnering for Green Growth and the Global Goals 2030 (P4G). (2019). *Blended finance model to reduce non-revenue water and energy consumption in Vietnam* (Rep.). Retrieved May 06, 2020, from https://p4gpartnerships.org/sites/default/files/2019-05/P4G_Blended%20Finance%20Model_Final%20report_20190423.pdf.

## Riyadh, Saudi Arabia

### City Profile

Access to freshwater is one of the primary challenges faced by the Kingdom of Saudi Arabia, a nation characterized by its hyper-arid climate and lack of perennial rivers and lakes. Naturally high rates of evapotranspiration[36] and low rates of rainfall result in extreme water stress. Currently, Saudi Arabia has fewer than 100 cubic meters of water per person per year—significantly lower than the 1,000 cubic meter benchmark used to define water scarcity—and the population is increasing at a rate of approximately 3% per year while water demand is increasing at a rate of 8.8% per year (Khalid & Ajbar, 2014; DeNicola et al., 2015). Rapid urbanization in recent years has created additional strain on water resources. Saudi Arabia now has the third-highest water consumption rate in the world (Kajenthira, Siddiqi & Anadon, 2012).

Riyadh, the capital and largest city in Saudi Arabia, has a population of 7.2 million people (approximately 22% of Saudi Arabia's total population). It is one of the fastest-growing cities in the world, with a population that has increased tenfold since the 1970s (Varis et al., 2006). Riyadh's water utility, or local Water Directorate, has successfully coped with an increasing population for years, covering 98% of the city with water supply infrastructure (Varis et al., 2006). The main sources of water supply for Riyadh are extracted groundwater (from the shallow aquifer around Wadi Hanifa, as well as the Minjur and Wasia-Biyadh aquifers) and desalinated seawater from the desalination plants in Jubail. In addition to non-renewable groundwater, Riyadh has a limited supply of renewable surface and groundwater sources—notably, the shallow aquifer Jubaylah—although these water sources are being used at a rate significantly faster than their rate of natural recharge (Chowdhury & Al-Zahrani, 2015). Riyadh also has 13 wastewater treatment plants, which treat slightly more than half of the city's generated wastewater and reuse only a fraction of it (Al-Zahrani, Musa & Chowdhury, 2016).

36 Evapotranspiration is the process by which water is transferred from the land to the atmosphere. This occurs by evaporation from soil and other surfaces and by transpiration from plants.

**Case Study: Desalination and Wastewater Reuse**

Riyadh relies on groundwater and, increasingly, desalinated seawater to compensate for the country's natural lack of surface water. However, desalination is an energy-intensive process, and despite a recent shift toward solar-powered desalination plants, fossil-fuel operated plants are still the norm in the country. Water professionals and experts have proposed increasing water reuse programs for non-potable purposes, as well as reducing consumption by increasing tariffs on water users. These suggestions have not been implemented on a large scale in Riyadh or beyond, but they may pose a solution to unsustainable dependency on desalination and groundwater extraction. Improved water management strategies and large-scale reuse of treated wastewater may need to become essential mechanisms to combat heightened water-stress due to climate change in the future, in Riyadh, and throughout the country.

**Background**

To meet increasing water demands, Saudi Arabia primarily relies on extraction of non-renewable groundwater and desalination of seawater (Al-Ibrahim, 1990; Kajenthira, Siddiqi & Anadon, 2012). Although the majority of water used in Saudi Arabia is sourced from non-renewable (fossil) groundwater aquifers, this water is largely used for agricultural purposes. Water for the municipal and industrial sectors is primarily sourced from costly and energy-intensive desalination processes. Desalination currently supplies more than 70% of Saudi Arabia's drinking water (DeNicola et al., 2015). Wastewater treatment and reuse, particularly for irrigation, has been proposed as a means of enhancing water supply in the water-stressed capital. Water conservation and demand management efforts will also become increasingly important.

**Actions Taken**

To minimize unsustainable extraction of groundwater from fossil aquifers, Saudi Arabia has invested heavily in desalination projects, primarily to meet domestic water needs in Saudi Arabia's largest cities, including Riyadh (Chowdhury & Al-Zahrani, 2015). Since the 1980s, Saudi Arabia has installed a total of 30 desalination plants to supply desalinated seawater (blended with groundwater) to domestic users in its largest municipalities. Currently, Saudi Arabia's desalination plants represent 30% of the world's total desalination capacity (Drewes, Patricio Roa Garduño & Amy, 2012). Jubail—the largest of these plants and the largest independent water and power project in the world—is located on the Arab Gulf Coast in eastern Saudi Arabia and supplies water to Riyadh via a 466 km pipeline (DeNicola et al., 2015). Presently, Riyadh gets more than half of its water supply from this desalination plant. The remainder is sourced from extracted groundwater (DeNicola et al., 2015).

Treated wastewater is an option for increasing supply in the city and surrounding suburbs. The 13 wastewater treatment plants in Riyadh treat and reuse only 13% of generated wastewater, all of which is used for agricultural and irrigational purposes (Al-Zahrani, Musa & Chowdhury, 2016). Increased reuse holds promise, especially when the result is

used for irrigation, which requires a lower degree of treatment than the potable water supply. Studies from other areas in Saudi Arabia indicate that proper treatment of municipal and industrial wastewater and reuse in irrigation can significantly reduce the agricultural sector's reliance on groundwater, thereby increasing water levels in both rural and urban areas (Al-A'ama & Nakhla, 1995).

**Existing Challenges**

Desalination is an effective means of water provision in water-scarce regions, but it has a number of limitations. First, the operational and maintenance costs of both desalination plants and the extensive pipelines used to transfer water from coastal areas to cities (often several hundred kilometers away) are high (DeNicola et al., 2015). Riyadh's Water Directorate receives only 2.5% of its revenues from water tariffs and faces increasing costs as the city's population grows (Varis et al., 2006; Dawoud, 2005). Therefore, sustainable long-term financing of desalination infrastructure is a primary concern (Dawoud, 2005; Khalid & Ajbar, 2014).

Second, desalination plants are energy-intensive. In the case of Saudi Arabia, they are almost entirely fueled by oil. According to current estimates, nearly 50% of the Saudi Arabia's oil production now goes to fueling desalination plants (Varis et al., 2006). The environmental costs of such large-scale fossil-fuel dependent operations are high, with greenhouse gas emissions contributing to climate change (DeNicola et al., 2015; Dawoud, 2005). Recent studies show that solar-powered desalination plants have a high degree of reliability and maintainability. As a step toward mitigating the environmental footprint of the nation's desalination projects, Saudi Arabia has shifted its focus toward solar-powered plants (Dawoud, 2005; Reif & Alhalabi, 2015). In 2018, Saudi Arabia commissioned the world's largest solar-powered desalination plant to be built in Al Khafji, near the Kuwaiti border. However, oil-fueled desalination plants remain a cheaper option, and most cities, including Riyadh, continue to receive desalinated water from such plants (DeNicola et al., 2015; El-Ghonemy, 2012).

Other drawbacks to over-reliance on desalination include damage to coastal and marine ecosystems (particularly related to increased salinity and warmer water temperatures), as well as the risk of being unable to respond to future population increases (DeNicola et al., 2015). The long-term ability of desalination to meet a continuously increasing water demand remains a significant concern in Saudi Arabia and particularly in Riyadh (Ouda, 2015). Ultimately, diversified water sources will be needed to meet the city's growing demand.

Water experts have been proposing wastewater capture and reuse in Saudi Arabia as a means of increasing water supply for decades, but these proposals have gained little traction and public support (Bushnak, 1990; Ghaffour, Missimer & Amy, 2013; Kajenthira, Siddiqi & Anadon, 2012). Presently, only 50% of the wastewater in Riyadh is treated. Untreated wastewater has the potential to contaminate groundwater sources (Chowdhury & Al-Zahrani, 2015). Furthermore, the

majority of the wastewater that is treated in Riyadh—nearly 90%—goes unused (Al-Zahrani, Musa & Chowdhury, 2016). This is due, in part, to technological and infrastructural insufficiencies that impede the collection, treatment, and recycling of wastewater (Al-Zahrani, Musa, & Chowdhury, 2016). Treated wastewater must meet certain biochemical and physical criteria if it is to be used for agricultural or other purposes (DeNicola et al., 2015). Results from a recent study analyzing the quality of effluent water from a wastewater treatment plant in Riyadh indicate that the water did not meet the necessary standards for agricultural use (Al-Hammad, El-Salam & Ibrahim, 2014). Careful management of wastewater treatment systems is needed to make reuse a viable option.

Increasing wastewater reuse will require efforts to win public acceptance. Currently, many people do not feel safe or comfortable using treated wastewater for any purpose (Al-Wabel, 2011; Al-Hammad, El-Salam & Ibrahim, 2014; Al-Ibrahim, 1990). Winning public support for reuse may require awareness campaigns or other efforts to encourage behavioral change. One proposal for reuse is a simple method of capturing, treating, and recycling ablution water from Riyadh's mosques for use as household greywater, which may be more socially acceptable than using treated municipal wastewater (Al-Wabel, 2011).

## Core Issues Driving Water Scarcity in Riyadh

**Supply**

Surface Water Scarcity

**Water Use**

Population Growth

High Per Capita Consumption

Urban/Rural Competition

**Infrastructure & Services**

Insufficient Capture Technology & Infrastructure

Insufficient Maintenance Capacity

**Governance**

Lack Of Public Awareness And Political Will

## Sample Solutions for Water Security in Riyadh

**Data**

Hydrological Models

Create robust hydrological models that take climate change into account.

Consumption Models

Create robust models of demand that take population growth and consumption projections into account.

**Water Supply**

Wastewater And Storm-Water Capture, Treatment And Reuse

Supplement desalination and groundwater extraction with wastewater reuse.

Desalination

Use desalination to supplement scarce surface water and groundwater resources.

**Reducing Water Consumption**

Public Awareness Campaigns

## São Paulo, Brazil

### City Profile

São Paulo (SP), located in southeastern Brazil, is the nation's largest city and its main economic, technical, and industrial hub. Current estimates approximate that the city proper has a population of 12 million people, and that the greater metropolitan area (the São Paulo Metropolitan Region, or SPMR) has a population of over 23 million people, making it one of the most populous metropolitan areas in the world (World Population Review, 2019). The metropolitan area's population has ballooned in recent years—largely due to migration from rural areas—and the demand for housing created by this growth has resulted in significant urban sprawl throughout the region. Presently, the SPMR covers a total landmass of approximately 1,500 km² and consists of 39 municipalities in the State of São Paulo. It is the largest conurbation in South America (Empinotti, Budds & Aversa, 2019).

São Paulo experiences a humid, subtropical climate with abundant rainfall and frequent flooding in the warmer, winter months, and relatively scant rainfall in the summer. The metropolitan area coincides nearly perfectly with the Alto Tietê river basin, which encompasses 99.5% of the city and is the largest river in São Paulo state (Formiga-Johnsson & Kemper, 2005; Empinotti, Budds & Aversa, 2019). The city sources 80% of its water from surface water, but water from the Alto Tietê alone is not nearly enough to meet the water demand of SPMR (Empinotti, Budds & Aversa, 2019). As a result, most of the city's water is sourced from inter-basin transfers from the Piracicaba-Capivari-Jundiaí (PCJ) watershed beyond the city limits, which supplies the Cantareira system (Empinotti, Budds & Aversa, 2019). The Cantareira system (located to the north of the city) supplies 45% of SP's water, while the Alto-Tietê (located to the east) supplies 20.5% and the Guarapiranga (located in the city's southern periphery) supplies 19% (Millington, 2018). The Cantareira system is, however, the city's main water supply and also the largest, serving a total of 9 million people (Empinotti, Budds & Aversa, 2019). There are eight water treatment plants through which all water in the distribution system must pass to provide potable water to São Paulo's residents (Braga & Kelman, 2020). Groundwater is estimated to contribute 20% to the overall system, although rates

of abstraction are neither monitored nor well-known (Formiga-Johnsson & Kemper, 2005).

SPMR's status as the economic and industrial hub of Brazil has drawn people to the city for decades and continues to do so. Significant growth in the metropolitan area has generated increasing pressure on the area's water resources, due both to increasing (and conflicting) demands from industrial, agricultural, and domestic users and to deteriorating water quality (Formiga-Johnsson & Kemper, 2005). Urban sprawl and gentrification continue to push lower-income residents to the city's peripheries (and, incidentally, towards the city's main sources of drinking water) to make room for middle- and upper-class residents in the city center (Formiga-Johnsson & Kemper, 2005). As a result, 50% of residents of the city proper live in "sub-normal housing," without access to adequate sanitation services (França, 2013).

In addition to the deterioration of water quality due to pollution and urban sprawl, São Paulo has faced significant water scarcity issues in the past, including an acute crisis in 2013–2015, when a historic drought struck southeastern Brazil, and many of SPMR's residents went without water (Cohen, 2016). The drought brought attention to inequities in São Paulo's social fabric, as it disproportionately affected low-income residents (Cohen, 2016). Other ongoing issues highlighted by the drought include inefficient water use and overuse, especially among residents living in formal housing.

The SPMR's heavy reliance on inter-basin transfers has resulted in conflicts with surrounding areas. The populations located in and around donor basins are expanding as well (Kelman, 2015).

## Case Study: Scarcity and Unregulated Land Use

### Background

Brazil is extremely water-rich and is frequently described as having the greatest freshwater reservoirs in the world, amounting to 12–16% of the world's total supply (Avins, 2015). Despite this abundance, Brazil's water is unevenly distributed, with 75% of the country's freshwater resources concentrated in the Amazon region and only 4% in the country's southeast, where 73% of the Brazilian population is located (Formiga-Johnsson & Kemper, 2005). This relative lack of water in São Paulo poses a problem for the metropolitan region, which faces increasing water demand and has experienced acute crises in the past.

São Paulo has taken several steps to enhance water security, including upgrading informal settlements and provision of sanitation services to mitigate pollution, as well as pressure reduction in the supply system to reduce rates of non-revenue water (NRW). However, each of these solutions was met with its own set of challenges, and the city continues to face issues associated with informal settlements, pollution, and inefficient water use. In addition to these issues, São Paulo faces the threat of future water scarcity, which is exacerbated by deforestation and unregulated land use outside of its boundaries. As such, while the city has taken certain measures to avoid acute crises going forward, some challenges must still be addressed to safeguard future water security in the megalopolis.

*Governance*

Historically, water management in São Paulo has been centralized and characterized by its top-down sectoral approach (Empinotti, Budds & Aversa, 2019). In 1991, however, the State of São Paulo enacted the Water Act, which redefined water management and marked the state's shift towards a decentralized, participatory, and integrated water sector (Barbosa, Alam & Mushtaq, 2016). Today, São Paulo's water sector is heavily decentralized and is, in theory, governed by a number of different actors.

The Water Act divided the state into 22 river basin units, which are the most basic units of water governance in the state (Barbosa, Alam & Mushtaq, 2016). In addition to the river basin units, the Water Act created consultative and deliberative collegiate bodies with representatives drawn equally from the state government, local government, and civil society (Barbosa, Alam & Mushtaq, 2016). However, the state's authority can supersede that of the basin governance units in a crisis.[37]

The state's partially privatized water utility, Companhia de Saneamento Básico do Estado de São Paulo S.A (Sabesp), is, in effect, the primary actor in the water sector (Cohen, 2016). Sabesp serves the majority of the state's consumers and provides water to 79% of SPMR's urban population (Cohen, 2016). The state owns a slender majority of Sabesp; the remaining 49.8% of the company's shares are privately owned and publicly traded on both the New York and São Paulo stock exchanges (Cohen, 2016; Böhm & Flores, 2015).

Proponents of privatization maintain that a privatized water sector can make water delivery more efficient and responsive to residents' needs (Parlatore, 1999). Critics have raised concerns about conflicts of interest, corruption, and negligence in times of crisis (Cohen, 2016; Böhm & Flores, 2015). They call for increased transparency and accountability from the state (Cohen, 2016; Empinotti, Budds, & Aversa, 2019).

*Pollution and Informal Settlements*

Informal settlements are one of the main challenges to water security in the SPMR. Presently, 50% of the city proper lives in "sub-normal" housing, including squatter settlements and illegal land subdivisions. In Brazil, these are commonly collectively referred to as favelas (França, 2013). These informal settlements are indicative of large wealth disparities throughout SPMR and Brazil as a whole, and they are characterized by the precariousness of their constructions[38] and an overall lack of adequate infrastructure (Cohen, 2016).

The migration of lower-income residents of the city from the center to the peripheries has resulted in the creation of a number of *favelas* right alongside the city's main sources of water (Formiga-Johnsson & Kemper, 2005; Cohen, 2016). Although high-density residential

37 During the 2013–2015 drought, for example, the state overruled the river basin units' committees in order to prioritize the supply of water to Sabesp, the state's water utility (Empinotti, Budds & Aversa, 2019).

38 ***Favelas*** are frequently placed alongside waterways or on hillsides and are, therefore, particularly vulnerable to flash floods and mudslides, which pose a serious threat to residents (Cohen, 2016).

occupation is prohibited by law in 53% of the SPMR (as a means of protecting water sources), city and state administrators have been unable to prevent the mushrooming of informal settlements in protected areas because informal settlements are, by nature, outside the law and difficult to regulate (Formiga-Johnsson & Kemper, 2005). In the Guarapiranga basin, for example, the legally-mandated protection area succeeded only in inhibiting industrial growth, because businesses were not able to obtain necessary permits (Formiga-Johnsson & Kemper, 2005). Informal settlements, on the other hand, faced no such restrictions. The result was an uncontrolled and disorderly expansion of residential structures (without water and sanitation access) throughout the Guarapiranga basin (Formiga-Johnsson & Kemper, 2005).

Presently, virtually all *favelas* in the SPMR Virtually all favelas in the SPMR have access to potable water provided by Sabesp (Kelman, 2015). For the most part, water is obtained without any payment, usually through informal, precarious, high-loss distribution systems that are illicitly connected to the public supply (Kelman, 2015). However, the majority of favelas in SPMR lack access to sanitation services, which poses a serious problem for water security both in the favelas themselves and in the SPMR as a whole. Lacking access to formal sanitation services—for example, wastewater collection and treatment—sewage from favelas is typically dumped directly into receiving bodies of water, many of which are important for the city's supply (Cohen, 2016; Kelman, 2015).

Sabesp has been working to overcome the deficit in sewerage coverage for decades. Over the past 25 years, the utility invested US $3 billion in sewage collection and treatment systems, but it has simply been unable to keep up with the urban sprawl, and the deficit in sewerage coverage persists (Formiga-Johnsson & Kemper, 2005; Kelman, 2015). This deficit is particularly evident in informal settlements, where the utility faces some distinct challenges that make provision of regular sanitation services difficult. Issues such as judicial disputes over land ownership (i.e., informal settlements have been built on private property) and environmental restrictions (i.e., informal settlements have been built on protected land) are common and complicate the provision of regular services by the utility (Kelman, 2015). The most common issue, however, is the impossibility of installing water supply systems and sewerage in neighborhoods that do not have any streets under which to bury the pipes (Kelman, 2015). Furthermore, several municipalities—those not served by Sabesp—have their own sanitation systems that do not provide any wastewater treatment, because Sabesp is the only utility in the basin with that capacity (Formiga-Johnsson & Kemper, 2005).

These issues make provision of wastewater collection and treatment in informal settlements extremely difficult and, in some cases, impossible. As a result, informal settlements in SPMR frequently resort to the disposal of raw sewage directly into waterways, which poses a number of health, water, and environmental security issues (Cohen, 2016). These actions, in turn, exacerbate tensions between the informal and formal settlements in São Paulo, because informal settlements are frequently blamed for water insecurity in the megalopolis (Cohen, 2016).

However, water quality is not degraded solely by informal settlements' sewage (Cohen, 2016). In addition to pollution from domestic wastewater, São Paulo's waterways are contaminated by industrial pollutants and solid waste. Therefore, the bodies of water surrounding the city are extremely degraded, with downstream waters characterized as "extremely low quality" (Formiga-Johnsson & Kemper, 2005).

Due to these pollution problems, it can be said that São Paulo faces "relative" water scarcity. Although the quantity of water is sufficient, its quality is not. That insufficiency forces the megalopolis to seek sources elsewhere (Kelman, 2015).

*Water Scarcity: Inter-basin Transfers and Water Conflicts*

São Paulo's increasing demand and high reliance on surface waters—as well as the Alto Tietê Basin's inability to meet this demand—have resulted in a reliance on inter-basin transfers to secure water supply (Formiga-Johnsson & Kemper, 2005; Barbosa, Alam & Mushtaq, 2016). Historically, this resulted in conflicts with the hydropower industry, which the city overcame to ensure use of water supply from the Guarapiranga (and, to a much lesser extent, part of the Billings) reservoir (Formiga-Johnsson & Kemper, 2005).

Presently, the SPMR relies largely on water diversions from the distant Piracicaba and Capivari rivers (Cantareira system) to the Guarapiranga system to meet its demand (Formiga-Johnsson & Kemper, 2005). In the past, use of this water has resulted in conflicts between the Piracicaba basin and the SPMR. Namely, as the Piracicaba basin grew and became urbanized, it developed an increasing water demand of its own. Local stakeholders believed it was unfair to have to use their water to supply SPMR while they remained unable to fully meet their own water demand (Kelman, 2015; Formiga-Johnsson & Kemper, 2005).

Similarly, a recent project to enhance supply using water from the Paraíba do Sul river resulted in a conflict between Rio de Janeiro, Brazil's second-largest city, and São Paulo (Kelman, 2015). The conflict between the two megalopolises centered around access to water from the 1,000 km long Paraíba do Sul, which runs through three states (including both São Paulo and Rio de Janeiro) (Kelman, 2015). As both metropolises expand and face increasing water demand, access to supply from the river became a topic of contention. São Paulo, still recovering from an unprecedented drought, found the inter-basin transfer from Paraíba do Sul to its PCJ basin attractive because it was a supply augmentation solution that would be the fastest to implement. Rio de Janeiro initially opposed the project—for fear of limiting its access to much-needed water supply—but ultimately relented (Kelman, 2015). Presently, water from the Paraíba do Sul is used to supplement both cities' supply systems without any conflict (do Encarnação Paiva et al., 2020).

Although the SPMR's users are nearly entirely supplied by surface water, groundwater is also used to a much lesser degree. Due to a lack of monitoring and control of groundwater use, it is impossible to quantify exactly how much is used, and extraction remains under-regulat-

ed (Formiga-Johnsson & Kemper, 2005). Relatedly, spring-, rain-, and well-water are neither adequately researched nor widely used in the SPMR as a means of supplementing surface water in the city's supply (Cohen, 2016).

The water supply system of the SPMR presently functions close to its full operational capacity, meaning that it is particularly vulnerable to changing fluvial conditions. The system is always on the brink of shortage and cannot withstand more significant reductions in the volume of rainfall (Torres, Côrtes & Jacobi, 2020). Ultimately, this means that the surface water-reliant SPMR water supply system is extremely vulnerable to drought.

The situation is further complicated by deforestation for agro-industrial production (e.g., of soya and cattle) both throughout the state of São Paulo and Brazil as a whole (Cohen, 2016). The "flying rivers" theory holds that forests—especially the vast rainforests, such as the Amazon, that are native to Brazil—evaporate huge amounts of water into streams of vapor. These large streams of vapor transport water from the Amazon to different parts of the country—such as to São Paulo in southeastern Brazil—where it falls as rain (Cohen, 2016). The "flying rivers" theory explains the high humidity in São Paulo and Rio de Janeiro relative to other areas at the same latitude (Cohen, 2016). The theory is supported by research studying land-use effects on water flows, which shows that forest coverage allows for the most water in surrounding systems, while pastures or farmland allow for the least (Ozment et al., 2018). Under this theory, progressive deforestation to make room for the soya and cattle industries makes São Paulo and its surrounding areas more susceptible to drought in the future (Cohen, 2016).

*Inefficient Water Use: Overuse and System Loss*

The fact that SPMR's water system always operates at nearly maximum capacity is indicative of virtually constant water stress (Osava, 2004). Nevertheless, the SPMR has an exceedingly high rate of average consumption, estimated to be around 180 liters per day per person (Osava, 2004). While this number is highly variable—largely due to the immense wealth disparities typical of SPMR (and Brazil in general)—this average is greater than the national averages of many hydrologically richer areas throughout the world (Osava, 2004). Historically, instead of promoting conservation, Sabesp has increased supply (mostly by externalizing SPMR's water stress to other basins), which has further promoted consumption (Osava, 2004).

In addition to inefficient use and water waste throughout the greater SPMR, there are inefficiencies in the water distribution system itself. Specifically, SPMR experiences exceedingly high rates of NRW, ranging between 30–35% in different areas of the city (Sánchez et al., 2020). The high rate of NRW is due both to water loss to leakage—estimated to be 18% of the total—and due to fraud or illegal connections (Braga & Kelman, 2020). Illegal connections are particularly prominent throughout informal districts and favelas in the SPMR, but they are not limited to informal settlements (Braga & Kelman, 2020; Kelman, 2015). In 2015 alone, 3.7 billion liters of illegal water consumption was identified in the SPMR (Braga & Kelman, 2020).
Overall, these inefficiencies in water use (both

related to individual overuse and systemic losses) exacerbate São Paulo's water stress and raise concerns regarding future water security in the megacity.

**Actions Taken**

*PROSANEAR-TAL: Enhancing Sanitation Services*

The Low-Income Sanitation Technical Assistance Project (also known as PROSANEAR-TAL) was a World Bank-funded project in Brazil seeking to enhance sanitation access for low income city residents (World Bank, 2008). The World Bank gave the Brazilian government a loan of US $23 million to help finance this large-scale sanitation project (World Bank IEG, 2008). Although the project was approved at the end of 2000, it went through a number of political and administrative changes at the federal, state, and municipal levels, which significantly delayed its implementation (World Bank, 2008).

TheobjectiveofPROSANEAR-TALwastoachieve integrated, participatory, and demand-driven water supply and sanitation service delivery to low income residents in Brazilian cities in participation with local government agencies and institutions (World Bank, IEG, 2008). To achieve this, the PROSANEAR-TAL aimed to:

- Increase the number of participating local government agencies that adopt and implement a participatory approach to water and sanitation service delivery;
- Increase the number of participating local government agencies that undertake integrated urban planning as a part of water and sanitation service delivery;
- Increase the number of participating local government agencies that implement clear and transparent cost recovery and subsidy policies for water and sanitation service delivery;
- Increase the number of participating local government agencies that establish multi-disciplinary teams to implement low-income sanitation projects;
- Achieve per beneficiary investment costs of less than US $100 for water supply coverage ($70 if only distribution and storage) and US $120 for sewerage ($80 if collection only) of PROSANEAR-TAL supported investment programs; and
- Increase the level of awareness and satisfaction among community groups, and municipal, state and federal officials regarding the PROSANEAR-TAL project approach (World Bank IEG, 2008).
-

Overall, the PROSANEAR-TAL project recognized the difficulties regarding water and sanitation access facing informal communities in Brazil, as well as the need for careful consideration of land use planning when designing water and sanitation projects. As per the World Bank's independent evaluation, the project outcomes were moderately satisfactory, as were both the bank and borrower performance (World Bank, 2008).

The project produced several valuable lessons, especially as regards the agility of project implementation in a decentralized water sector. First, the project showed that the complexity of decentralization in the water and sanitation

sector has a major effect on successful design and implementation of a project. Second, each change in counterparts at a different level of government brought significant challenges related to the level of prioritization and project implementation, thereby delaying the project. Third, continuing implementation while simultaneously redesigning a project can have significant impacts on the cost of supervision, can significantly impact measurability of progress and results, and can delay implementation significantly. Fourth, remaining inclusive of local actors and stakeholders necessarily implies introducing more complexity into project implementation, and will likely affect the agility of implementation. Finally, doing business in increasingly decentralized and politically complex environments requires both flexibility and adaptability, if projects are to remain relevant to the local context and stakeholders, but such flexibility will result in additional time and resource costs (World Bank, 2008).

*Upgrading Informal Settlements: Enhanced Infrastructure for Pollution Control*

The SPMR government has historically recognized upgrading informal settlements as an important means of pollution control and ensuring water security for the megacity in the future. By the end of the 1980s, it was clear that the environmental degradation threatening the Guarapiranga water basin was the direct result of disorderly, informal urban sprawl (França, 2013). In response, the state and municipal governments applied for a World Bank loan to combat the environmental degradation in the basin. One of the primary components of the project was upgrading informal settlements throughout the basin, 90% of which were located in the SP city proper, and housed 27,000 families (França, 2013). The upgrading itself focused on overcoming infrastructural shortages and enhancing accessibility and availability of public services, including sanitation systems (França, 2013). This effort was regarded as the first major informal settlement upgrading program in São Paulo, and the Guarapiranga program successfully upgraded 100 favelas and served as an example for future programs in SPMR (França, 2013).

More recently, São Paulo's Social Housing Department (SEHAB) adopted two significant commitments in 2005 that defined future informal settlement upgrading programs. Firstly, the city committed to investing in design quality (i.e., best architecture, urban design, and engineering practices) to ensure the success of SEHAB's projects. Secondly, the city committed to recognizing local cultures and territorial claims in favelas, especially with respect to incremental investments that families living in favelas have made over decades through self- or mutual-help processes (França, 2013). This second commitment is particularly important because it seeks to minimize government patronage, foster democratic leadership of housing programs, and ensure respectful attitudes towards residents and locals (França, 2013).

In 2005, São Paulo launched one of the largest informal settlement upgrading programs in Brazilian history. The program complies with the city's 2002 Strategic Master Plan, which guarantees the provision of suitable housing with adequate sanitary facilities, guaranteed habitable conditions, and which is met by essential public service, including water and sew-

erage, among others (França, 2013). The main priorities of favela upgrading include providing regular water and sanitation services, to "upgrade" informal settlements to formal parts of the city, relocation of dwellings in environmentally-sensitive areas (e.g., flood zones or steep hillsides at risk of landslides, etc.) to less precarious areas, and increased transparency of environmental, hydrological and housing-related information in the future (França, 2013).

As of 2010, São Paulo had 2,000 favelas in which 800,000 families lived. By 2013, 130,000 families had benefited from completed works or works in progress related to the informal settlement upgrading program (França, 2013). Aside from directly benefiting families living in favelas by upgrading their living conditions, São Paulo's informal settlement upgrading program also benefitted the megacity's overall water quality. By reducing the number of households without access to water collection or treatment, the program was able to mitigate a portion of the pollution entering bodies of water crucial to the city's water security.

*The 2013–2015 Drought: Responding to Acute Crisis*

São Paulo's over-reliance on surface water made São Paulo's over-reliance on surface water made it particularly vulnerable when the drought struck in 2013. Rainfall levels in 2013 and 2014 were the lowest in the region's recorded history, and drinking water reservoirs dipped to 5% of their capacity (Cohen, 2016). The drought lasted until the rains returned in 2015 (Cohen, 2016; Empinotti, Budds & Aversa, 2019).

Climate forecasts and hydrological monitoring had indicated an oncoming drought since at least mid-2013. The state government acknowledged the crisis at the beginning of 2014 (Torres, Côrtes & Jacobi, 2020). There were many plans by municipal agencies to increase water supply during the drought, but most were never implemented. Instead, the Cantareira system bore the brunt of the drought, as Sabesp used Cantareira's dead volume[39] to continue to provide water for São Paulo's residents (Cohen, 2016). Sabesp relied on pressure reduction and a pricing system to incentivize water conservation (and disincentivize waste) to combat the crisis (Braga & Kelman, 2020).

At the beginning of the drought, the state governor sought to avoid rationing (Cohen, 2016). However, Sabesp instituted de facto rationing, wherein pressure was reduced significantly, often resulting in dry taps for hours on end (Cohen, 2016; Empinotti, Budds & Aversa, 2019; Millington, 2018). While many residents were able to endure this shortfall with water stored in personal, small-scale reservoirs, lower-income residents (especially those living in favelas) were unable to do the same because they lacked access to water storage systems (e.g., small-scale reservoirs) (Millington, 2018). Pressure reduction resulted in supply cut offs for 60% of São Paulo's residents (Millington, 2018).

Sabesp had made reducing NRW a priority for nearly two decades and had, in partnership with

39 Dead volume refers to levels that were previously untapped, located below dams' existing floodgates and of very poor quality. The utility went to great trouble and spent tens of millions of US dollars to deploy new pipes and floating water pumps to extract the water from the reservoir (Cohen, 2016).

the Japan International Cooperation Agency, invested nearly US $960 million in NRW infrastructure projects[40] prior to the drought (Braga & Kelman, 2020). During the drought itself, Sabesp installed pressure control valves throughout the distribution network and decreased water loss from 35.8% to 30.6% (Sánchez et al., 2020).

As the drought progressed, Sabesp introduced tariffs to incentivize conservation (Empinotti, Budds & Aversa, 2019; Kelman, 2015). NGOs and grassroots organizations quickly developed initiatives to raise awareness about the water crisis and promote a culture of conservation (Torres, Côrtes & Jacobi, 2020). The state began to promote the importance of water conservation and created campaigns for conscientious water use (Kelman, 2015). These campaigns were criticized for lacking specific instructions on how to conserve water and how to capture, store, and reuse waste- and storm- water (Torres, Côrtes & Jacobi, 2020). However, the overall result of the campaigns was that domestic water consumption decreased by 24% from pre-drought levels (Braga & Kelman, 2020).

The water utility increased supply by supplementing the Cantareira system with new sources of water. Specifically, water was transferred from the Paraíba do Sul river—which the state of São Paulo shares with the states of Rio de Janeiro and Minas Gerais—as well as from the São Lourenço system, located 83 km away from SPMR (Ozment et al., 2018; Kelman, 2015; da Encarnação Paiva et al., 2020). The Paraíba do Sul project increased water supply by 15% in the SPMR and cost a total of US $170 million, while the São Lourenço system cost a total of US $500 million (Ozment et al., 2018).

The drought caused many drastic changes throughout São Paulo: water consumption was reduced by a fifth, water shortages resulted in frequent school closures, uncovered rainwater collection tanks tripled the rate of dengue fever infections, and water contamination resulting from pressure reductions caused a spike in dysentery among many of São Paulo's lower-income neighborhoods (Cohen, 2016).

The rains returned in 2015, but the drought left a significant mark on the megacity (Empinotti, Budds & Aversa, 2019; Cohen, 2016). The crisis brought to light a number of contentious political issues, raised concerns regarding governance, and highlighted social inequalities that left SP's residents unequally equipped to build resilience and handle crises in the future (Millington, 2018).

*Water Reuse: Potential Sources for Industrial Use*

Presently, water reuse remains limited throughout São Paulo, even though the cost of reused water is slightly less than the conventional rate (excluding transport costs) (Melo & Rodriguez, 2017).

Water reuse is typically considered a potential solution for industrial use in the SPMR, and the state has committed to increasing its use throughout the private sector. Aquapolo Ambiental, a new water reuse project, intends

40 These projects largely focused on reducing water loss due to leakage through upgrading infrastructure and, to a lesser degree, limiting non-physical losses due to connections or fraud, which amount to at least 9-10% of NRW (Braga & Kelman, 2020).

to promote sustainable water management in ABC Paulista, a highly populated industrial area in SPMR (Melo & Rodriguez, 2017). The project aims to produce high-quality industrial water from municipal sewage, saving around 2.58 billion liters of potable water per month and reducing pollution to the Tietê River Basin (Melo & Rodriguez, 2017). The amount of potable water saved by the Aquapolo Ambiental would be enough to supply 500,000 of São Paulo's residents with water for a month (Melo & Rodriguez, 2017).

## Existing Challenges

*Challenges of a Partially Privatized Water Sector*

Despite the success of São Paulo's informal settlement upgrading programs, challenges remain (França, 2013). New neighborhoods, lacking adequate infrastructure and of extremely low environmental quality, are built every day, outpacing the government's capacity to keep up (França, 2013).

São Paulo's Municipal Secretariat for Housing and Urban Development, SEHAB ("Secretaria da Habitação e Desenvolvimento Urbano"), has sought to develop a progressive and inclusive housing policy. The agency has adopted the view that informal settlements are not simply "sub-normal" housing, but rather communities that have invested their lives and savings to secure a place in the city, in the only locations to which they had access (França, 2013). Experiences during the 2013–2015 drought showed that there are significant inequalities throughout São Paulo's housing systems that make favelas particularly vulnerable to scarcity (Cohen, 2016). In particular, the water crisis highlighted the need to enhance access to water storage reservoirs throughout São Paulo's favelas (Millington, 2018).

Many favelas lack access to formal infrastructure for water, wastewater, sanitation and waste disposal, deficiencies that pose a public health risk for the favelas themselves and a security risk to SPMR's water supply (Cohen, 2016). After the 2013–2015 drought, minimizing water loss became a priority for SPMR. The state government of São Paulo launched a demand management initiative, which includes subsidies to help install water-efficient appliances (Braga & Kelman, 2020). Sabesp is currently focused on re-piping its water distribution network (and eliminating the maze of pipes scattered along alleyways of favelas) to enhance overall system efficiency and minimize water loss (Braga & Kelman, 2020).

*Water Scarcity: Potential for Future Conflicts*

São Paulo has been able to overcome past water-related conflicts between its metropolitan area and the many other basins (e.g., Paraíba do Sul, Piracicaba, etc.) from which it sources its water (Formiga-Johnsson & Kemper, 2005; do Encarnação Paiva et al., 2020). However, São Paulo's over-reliance on surface water makes it vulnerable to drought, which could exacerbate water conflict in the future. As São Paulo continues to externalize water stress by drawing water from distant basins, it poses a challenge to donor watersheds (e.g., São Lourenço and Paraíba do Sul) and other cities (e.g., Rio de Janeiro) (do Encarnação Paiva et al., 2020).

Water-related conflict with Rio de Janeiro may be of particular concern in the future. Although

Sao Paulo has so far managed to avoid a conflict with Brazil's other main megacity, that does not exclude the possibility of conflict in the future (do Encarnação Paiva et al., 2020). As both of Brazil's megacities continue to expand, so will their water demand, raising the question of how the Paraíba do Sul will continue to sustainably provide water for both, as well as for the other regions that depend on it (do Encarnação Paiva et al., 2020).

*Limited Access to Water and Sanitation Services in Informal Settlements*

Despite the conservation efforts undertaken by many of São Paulo's residents during the drought, water overuse remains an issue throughout the SPMR (Torres, Côrtes & Jacobi, 2020). This overuse likely occurred because many residents did not perceive the gravity of the crisis. (Torres, Côrtes & Jacobi, 2020).

In addition to overuse of water, water reuse remains scant throughout the SPMR. Reuse is limited to industrial supply, and even then, to a limited degree (Melo & Rodriguez, 2017). The capture, collection, treatment, and reuse of waste- or storm- water might be a useful component in reducing use of the potable supply, ensuring smart, integrated water management (Cohen, 2016). However, achieving this would require very careful planning and an active government role in ensuring the security and safety of these systems for use by private citizens or businesses.

*Deforestation: Degraded Natural Infrastructure and Droughts*

Finally, the ongoing deforestation throughout Brazil as a whole and São Paulo state specifically continues to contribute to water scarcity in SPMR by aggravating drought risk in the area (Cohen, 2016; Millington, 2018). Reforestation in general, especially in the Amazon, could return humidity and restore "flying rivers" in the region, making droughts less probable and severe in the future (Cohen, 2016).

In São Paulo, 75% of the forests surrounding the megacity's main drinking water system have been severely degraded or destroyed (Ozment et al., 2018). São Paulo recognized the need to combat deforestation and became one of the founding members of the Cities4Forests[41] initiative, in order to benefit from global experiences concerning the rehabilitation of forests as natural infrastructure to mitigate climate change and other environmental hazards in cities (Cities4Forests, 2019b).

A study by the World Resources Institute (WRI) has proposed targeted reforestation of these key areas as a solution to buffer against the impacts of droughts (and floods) and enhance water quality (Ozment et al., 2018). Restoring 4,000 hectares of these forests could reduce sediment pollution in the city's water supply by 36% and turbidity by 50% (Ozment et al., 2018). This targeted reforestation would result in lower water treatment costs and generate a 28% return on investment for the utility, thereby freeing up money for Sabesp to focus on other priority-problems (e.g., fixing leaks)

41 The Cities4Forests initiative is the result of a joint partnership between the World Resources Institute (WRI), based in Washington D.C., the Brussel-based communications agency, REVOLVE, and the Pilot Projects Design Collective, based in Montreal and New York. The initiative seeks to integrate the rehabilitation of forests into city development plans by catalyzing social, political, and economic support among a network of city governments (2019a). For more information about the Cities4Forests program, visit the initiative's website: https://cities4forests.com/.

(Ozment et al., 2018).

Furthermore, cloud forests that are native to the coastal mountain area of southeastern Brazil possess the unique ability to generate soil water and streamflow from fog, thereby potentially boosting supply (and increasing the likelihood of rain) in times of scarcity (Ozment et al., 2018). Data from global literature indicates that fog capture may account for up to 30% of annual water availability in cloud forests, although this is not presently well studied in the Brazilian context specifically (Ozment et al., 2018).

Areas for targeted restoration would be carefully selected via geospatial analysis—to reveal areas strategically important to São Paulo's water supply—and 4,000 hectares of forest could be restored at a cost of US $37 million (Ozment et al., 2018). This investment could generate a net benefit of US $69 million by avoiding future costs—for water treatment, water supply augmentation, etc.—of approximately $106 million over the next 30 years (Ozment et al., 2018).

However, the implementation of targeted reforestation necessitates further research to ensure the accuracy of data. Since the study was created based on data from global literature reviews, field research is required to ensure local, context-specific information about potential environmental and hydrological benefits (Ozment et al., 2018). Furthermore, the strategy proposed by the WRI calls for partnerships with farmers and rural landowners, as well as other key stakeholders (Ozment et al., 2018).

## Core Issues Driving Water Scarcity in São Paulo

**Supply**

- Surface Water Scarcity
- Drought
- Flooding
- Contamination & Pollution

**Water Use**

- Population Growth
- High Per Capita Consumption
- Urban/Rural Competition

**Infrastructure & Services**

- Insufficient Data
- Insufficient Capture Technology & Infrastructure
- Insufficient Storage Technology & Infrastructure
- Insufficient Pipe Systems
- Insufficient Maintenance Capacity
- Non-Revenue Water

**Governance**

- Insufficient Capacity & Expertise
- Pipeline Barriers Within Government Departments
- Lack Of Coordination Between Government Departments
- Lack Of Coordination Between Local, Regional & National Government
- Lack Of Coordination Between Sectors
- Lack Of Public Awareness & Political Will

**Finance**

- Counterproductive Pricing Structures
- Insufficient Revenue Collection

## Sample Solutions for Water Security in São Paulo

**Data**

<u>Research And Development To Generate Innovative Solutions</u>

Gather field data regarding cloud forests' water generation capacity relevant to the local context to better inform reforestation projects.

<u>Groundwater Monitoring</u>

Engage in regular groundwater monitoring so as to avoid unsustainable rates of extraction.

**Water Supply**

Diversifying Water Sources

Avoid overreliance on surface water to foster resilience against droughts.

Wastewater And Storm-Water Capture, Treatment And Reuse

- Employ wastewater treatment and reuse as a means of water provision for industrial purposes.
- Enable safe and efficient use of wastewater capture, treatment and reuse technologies to diversify water supply.
- Enable capture and treatment of industrial wastewater to avoid pollution of water supply.

Rainwater Harvesting

Encourage the safe capture, storage, treatment and reuse of rain-water to alleviate water stress in the overall system.

Surface Water Capture

When possible, avoid externalization of water stress to other areas due to inter-basin transfer of surface water (i.e. by carefully and equitably considering and involving all relevant stakeholders in the decision-making process).

Groundwater Capture

Enhance use of groundwater in a regulated and monitored fashion to supplement surface water.

**Infrastructure**

Pressure Management Interventions

- Install pressure reduction valves throughout the distribution network to minimize water loss in the system.
- When employing pressure management interventions, do so in a way that avoids shutting off the water supply completely (to avoid public health risks associated with cut-off supply).

Water Transportation Between Cities And Between Urban And Rural Areas

- Enhance water supply by diverting water from richer river basins to water-stressed cities while making sure not to threaten the water security of other areas that depend on the same resources.
- Involve as many stakeholders as possible when engaging in inter-basin transfers, so as to minimize the likelihood of endangering water security in other cities and regions.

**Finance**

Sustainable Cost Recovery

- Enhance cost-recovery capacities of water utilities.

Innovative Loans Structures & Other Finance Mechanisms

**Management Within City Governments**

Accountability

Coordination Among Governmental Departments

- Coordinate land use planning with water resources management to avoid unsustainable practices in both departments.
- Enhance solid waste disposal capacities (of the responsible department) to minimize pollution of water from solid municipal waste.

Water Management In Informal Settlements

- Increase sewerage coverage and ensure provision of sanitary services in informal settlements to avoid public health hazards, reduce pollution in surrounding waterways, and increase overall water quality.

**Coordinated Governance**

Local, Regional And National Coordination

**Planning**

Integration Of Management Of Water Resources With Urban, Regional And National Land Use Planning

When possible, integrate land use planning with water resources management policies to ensure holistic management of resources and protection of water bodies.

Planning For Realistic Timeframes

- Take into account complexities related to coordination between different spheres of government that may prolong project implementation when planning water-related projects.
- Take into account complexities related to changes in municipal, state or federal regulations or capacities that may prolong project implementation when planning water-related projects.

**Municipal Revenue Sources**

Tariff Structures That Disincentivize Water Waste

Create pricing structures that incentivize water conservation by giving discounts to low-users and surcharges for high-users.

Sustainable And Just Enforcement Models

Create sustainable finance mechanisms that simultaneously ensure revenue for utilities while fostering a culture of water conservation (especially in times of water stress).

**Access & Equity**

Subsidies To Assist Low Income Populations

Provide subsidies to low income populations for the installation of water-efficient appliances to ensure sustainable and equitable demand management.

Protecting Vulnerable Populations

- Ensure integrated, participatory and demand-driven water supply and sanitation service delivery to low income populations by:
  - Increasing number of participating local government agencies that adopt and implement a participatory approach to water supply;
  - Increasing the number of participating local government agencies that undertake integrated urban planning as a part of water and sanitation service delivery;
  - increasing the number of participating local government agencies that implement clear and transparent cost recovery and subsidy policies for water and sanitation service delivery; and
  - increasing the number of participating local government agencies that establish multi-disciplinary teams to implement low-income sanitation projects
- Upgrade informal settlements to provide better access to sanitation services.
- Relocate informal settlements in precarious areas (i.e. at heightened risk of flooding or landslides) to safer areas.
- Formulate a housing policy that provides suitable housing with adequate sanitation facilities, guarantees habitable conditions and is met by essential public services (e.g. water supply and sewerage).
- Enable access to small-scale water storage systems (i.e. household reservoirs) in low-income communities in order to build resilience and enhance water security in times of crisis or rationing.
- Institute crisis management solutions that are equitable and take lower-income residents into account so as to avoid disproportionately affecting low-income populations in times of crisis.
-

**Involving Stakeholders Outside Of Government**

Building capacity of all stakeholders in all parts of society

Involving Stakeholders In All Parts of Society In Water Related Decision Making

Issuing Guidance To The Public

Formulate information regarding safe and effective storm-water and wastewater (greywater) capture, storage and reuse to foster the integration of all available water resources into domestic supply (especially in times of water-stress).

**Building Trust**

Making Data Transparent and Readily Available To The Public

Ensuring Compliance with Laws and Regulations

**Water Cycle Management**

Conserving and Restoring Water Related Ecosystems

- Rehabilitate natural infrastructure, such as forests, to enhance water quality (i.e. by minimizing sediment pollution and reducing turbidity of the water supply).
- Rehabilitate natural infrastructure, such as forests, to enhance water supply and ensure water security (especially in times of crisis).
- Disincentivize deforestation for agro-industrial land use through regulatory or financial mechanisms.

Conservation Zones That Protect Areas of Environmental or Hydrological Importance

- Enforce protection of conservation zones by barring industrial or commercial permits in those areas.
- When possible, inhibit the construction of informal settlements in environmentally or hydrologically important areas.

**Reducing Water Loss**

Reducing Theft

Reduce water theft and illegal connections and consumption in a manner that does not threaten water security in lower-income neighborhoods.

Reducing Leaks

Invest in infrastructure upgrading to reduce leaks in the overall system.

**Reducing Water Consumption**

Public Awareness Campaigns

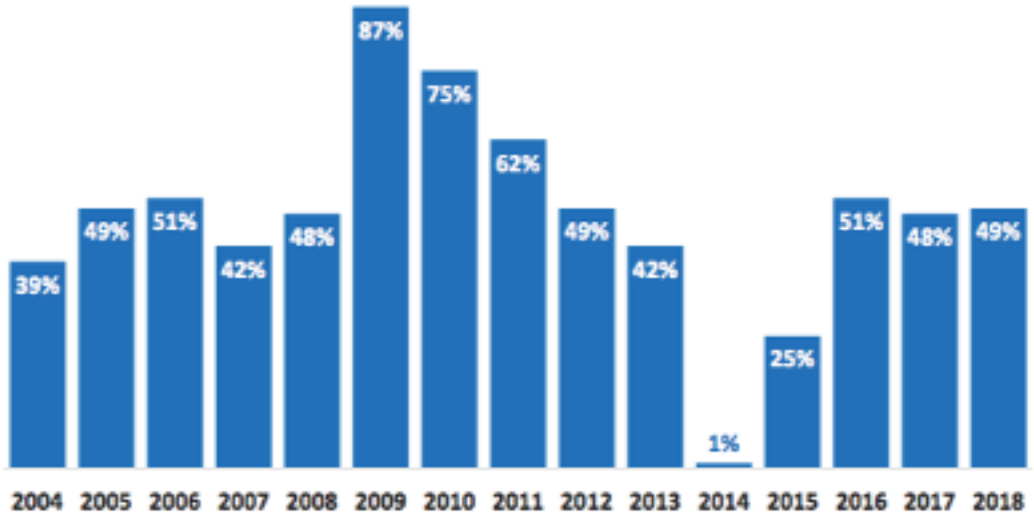
- Foster a culture of conservation in water-stressed cities by creating public awareness campaigns.
- Formulate information regarding how to save water clearly and make it readily available to the public (through communications campaigns, etc.).

Systems Change

Foster a culture of conservation by reformulating priorities in partially-privatized water utilities to incentivize water conservation.

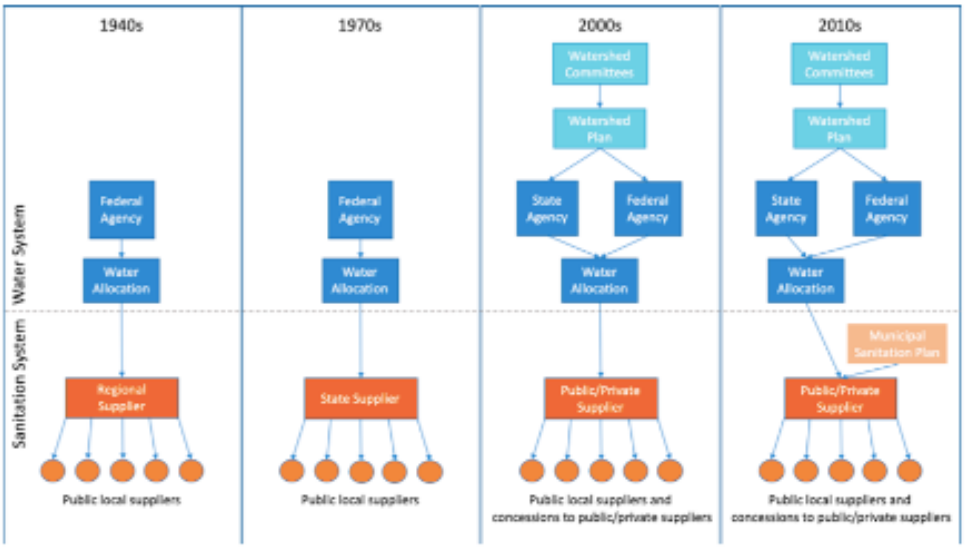
## Appendices

**Appendix A.** Total water storage in São Paulo Metropolitan Region reservoirs, 2004-2018 (%)



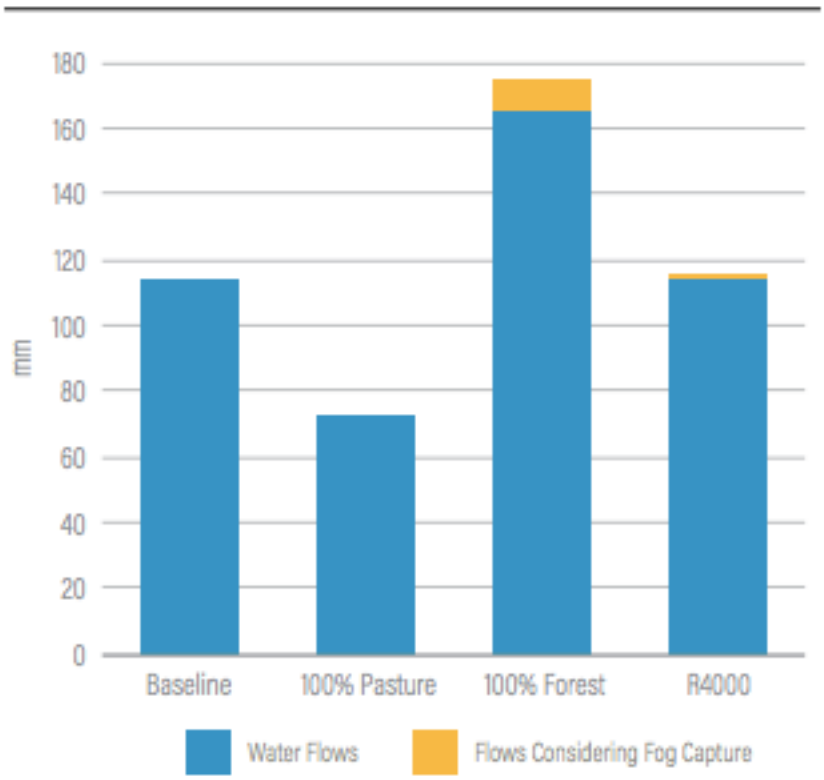

Source: Braga, B., & Kelman, J. (2020). Facing the challenge of extreme climate: the case of Metropolitan Sao Paulo. *International Journal of Water Resources Development*, *36*(2-3), 278-291.

**Appendix B.** Water access and distribution in the MSPR: Institutional arrangements over time




Source: Empinotti, V. L., Budds, J., & Aversa, M. (2019). Governance and water security: The role of the water institutional framework in the 2013–15 water crisis in São Paulo, Brazil. *Geoforum*, *98*, 46-54.

**Appendix C.** Land use effect on water flows, dry season (June – August)




**Source:** Ozment, S., Feltran-Barbieri, R., Hamel, P., Gray, E., Ribeiro, J. B., Barrêto, S. R., ... & Valente, T. P. (2018). Natural infrastructure in São Paulo's water system. *World Resources Institute (WRI).*

**Appendix D.** Current land cover in the Cantareira system.

| | SUB-BASIN | AREA (HA) | NATURAL FOREST (%) | PASTURELAND (%) | PLANTATION FOREST (%) | AGRICULTURE (%) | URBAN (%) | BARE SOIL (%) |
|---|---|---|---|---|---|---|---|---|
| PCJ BASIN | Jaguari Dam | 103,277 | 19 | 59 | 16 | 1 | 2 | 0 |
| | Jacareí Dam | 20,235 | 14 | 53 | 8 | 2 | 3 | 1 |
| | Rio Cachoeira Reservoir | 39,248 | 20 | 44 | 34 | 0 | 1 | 0 |
| | Atibainha Reservoir | 31,741 | 28 | 34 | 30 | 0 | 2 | 0 |
| ALTO TIETÊ BASIN | Paiva Castro Reservoir | 31,400 | 42 | 27 | 18 | 0 | 10 | 0 |
| | Águas Claras Reservoir | 2,321 | 59 | 15 | 13 | 0 | 13 | 0 |
| | **TOTAL** | **228,222** | **24** | **47** | **21** | **1** | **3** | **0** |

**Source:** Ozment, S., Feltran-Barbieri, R., Hamel, P., Gray, E., Ribeiro, J. B., Barrêto, S. R., ... & Valente, T. P. (2018). Natural infrastructure in São Paulo's water system. *World Resources Institute (WRI).*

**Appendix E.** Financing options to engage risk-averse investors in natural infrastructure.

**BOX 2 | FINANCING OPTIONS TO ENGAGE RISK-AVERSE INVESTORS IN NATURAL INFRASTRUCTURE**

Because natural infrastructure investments fall outside the traditional business activities of a water infrastructure operator, many projects have been stymied by water companies' hesitancy to engage. Innovative financing models can overcome this challenge. Some of these finance models are already being pursued in São Paulo.

**Leveraging seed funding early on:** Watershed investment programs often rely on seed funders to cover startup costs and demonstration projects and engage water utilities or city governments to invest only once a project is proven and is fully operational. It appears that programs in São Paulo are pursuing this strategy based on their reliance on corporate donations and government funding.

**Water funds:** The Latin American Water Funds Partnership has established 20 programs that pool funds from multiple water-dependent companies and public-sector actors so that each individual company's contribution contributes to a larger cumulative impact. The São Paulo Water Fund program is led by TNC and currently funded through the basin, private funds from the Green Blue Water Coalition, and other sources. The fund is searching for additional funding sources and finance mechanisms to use this successful strategy to sustain larger-scale activities.

**Leveraging private capital in a pay-for-success model:** Pay for success is an approach to contracting that ties payment for service delivery to the achievement of measurable outcomes. The DC Water Environmental Impact Bond represents one of the first applications of a pay-for-success model to environmental issues. In this case, private investors paid all up-front costs for the installation of green infrastructure to improve stormwater management, on the condition that the local water company would pay back their investment at an interest rate that would vary according to how well the green infrastructure performs (e.g., the more successful the project, the higher the interest rate—and vice versa).

A similar model might support natural infrastructure investments in the Cantareira or other basins throughout Brazil.

**Partnerships with finance institutions that have sustainable development missions:** Development banks have made significant investments in water resources systems in São Paulo State, and in river basins that border the Cantareira System. For example, the World Bank's Global Environment Facility contributed a $31 million grant to the states of São Paulo, Minas Gerais, and Rio de Janeiro for strategic restoration of water supply areas to increase carbon stocks and to promote ecosystem-based adaptation in the Paraíba do Sul Basin (GEF 2016). The Inter-American Development Bank (IDB) has also contributed funding to support TNC's water funds throughout Latin America, including the São Paulo Water Fund (IDB 2017).

While these grant funds have been essential to advancing forest restoration and natural infrastructure activities, there may be opportunities to engage development banks in larger, longer-term financing of these projects. IDB and the World Bank have both expressed interest in funding natural infrastructure alongside conventional water infrastructure projects as one way to advance their sustainable development agendas. However, these financing opportunities would likely require a funding level of $30 million or more, and be contingent on commitments from Sabesp or the government. They would likely require system-wide reporting of outcomes to evaluate whether benefits are being realized. Therefore, development bank investments in natural infrastructure (outside of grant funding) are likely not suitable for most of the natural infrastructure programs active in the Cantareira, at least not in their current form. Rather, tapping these opportunities would likely require programs to pool their efforts and operate at a system level and also engage Sabesp.

**Source:** Ozment, S., Feltran-Barbieri, R., Hamel, P., Gray, E., Ribeiro, J. B., Barrêto, S. R., ... & Valente, T. P. (2018). Natural infrastructure in São Paulo's water system. *World Resources Institute (WRI).*

**Appendix F.** Topics for further research to improve natural infrastructure planning.

## BOX 3 | TOPICS FOR FURTHER RESEARCH TO IMPROVE NATURAL INFRASTRUCTURE PLANNING

**Which natural infrastructure interventions are most cost-effective?**
While this study examines native forests as natural infrastructure, other forms of sustainable landscape management such as agroforestry, pastureland restoration, and rural road management can also achieve sediment reductions. Possibly more than half of the pasturelands in the Cantareira System are degraded, which reduces their productivity and increases their risk of sediment export. The São Paulo low-carbon agriculture plan already aims to restore 15 million ha of degraded pastureland (SAA 2016), so incorporating pasture restoration into natural infrastructure programs could unlock more funds as part of a larger natural infrastructure strategy.

However, further local research is needed to determine which interventions would be most cost-effective or attractive to program investors. These natural infrastructure interventions have been studied in other regions (Filoso et al. 2017), but the dearth of relevant local research data presents a barrier to evaluating their costs and benefits.

**How can natural infrastructure interventions address other water management objectives and provide social value?**
As discussed in Chapter 3, we found that there is a need for further scientific research regarding the impacts of natural areas on water availability. This is perhaps the most critical research area to address water managers' concerns about natural infrastructure strategies.

Nature-based solutions exist to address flood risk, rural sanitation challenges, and climate resilience, but further research can help determine which interventions will be most effective for the Cantareira. Managing water availability between extreme rainfall and extended dry periods is especially relevant in regions like São Paulo, where, some studies suggest, the primary water management challenge will be dealing with floods and siltation due to heavy rains (Nobre et al. 2010).

Assessing impacts on different income classes and genders could help in designing interventions to support rural poverty alleviation needs. Better understanding the impacts of natural infrastructure on land productivity and the rural economy could be particularly useful in engaging landowners in these programs.

**How can we ensure that natural infrastructure plans are feasible?**
Stakeholders emphasized that research is needed to confirm the practical feasibility of the interventions. Due to harsh terrain or a lack of willingness to participate on the part of key parties, it may not be feasible to bring some model-identified priority areas into the programs. Stakeholders should carry out additional spatial analysis and field studies to incorporate these parameters to prioritize which natural areas to target for restoration or conservation.

**What additional areas should be targeted for natural infrastructure interventions?**
While this study focused on natural infrastructure in the Cantareira System, that system is increasingly interlinked to neighboring watersheds. For example, São José dos Campos is located in the watershed where Sabesp will link the Jaguari Reservoir in Paraíba do Sul to the Cantareira. Also, stakeholders noted that the Cantareira experiences the lowest sediment pollution rate in all of São Paulo's source watersheds. Expanding this analysis to consider additional water systems could reveal more value and inform current investment decisions.

**Source:** Ozment, S., Feltran-Barbieri, R., Hamel, P., Gray, E., Ribeiro, J. B., Barrêto, S. R., ... & Valente, T. P. (2018). Natural infrastructure in São Paulo's water system. *World Resources Institute (WRI).*

# Conclusion and Next Steps

This W12 Framework document is being released in the midst of a health and economic crisis widely viewed as the worst global pandemic in over 100 years. Never has there been more awareness of the urgency of clean water and adequate sanitation. And yet in cities all over the world today, people lack flushable toilets and clean water for washing their hands. Experts tell us that rapid population growth, urbanization, and climate change mean escalating water crises for an increasing number of cities.

The W12 Framework and Protocol build on the efforts of countless leaders and water experts. The goal of the W12 project is to take what we are learning about water challenges and solutions and put this information in the hands of city leaders in ways that will help them implement solutions for their residents.

> **Step 1** was two years of preparatory work, partnership with six South Africa-based task teams, several conferences and consultations in the Cape Town area, and conference papers by the South African task teams, excerpts from which are included below.
>
> **Step 2** is creating and sharing a relational database consisting of case studies of challenges and solutions from around the world, each one "tagged" with the challenges it faces and the solutions it has implemented. We are grateful to the partnership with UNESCO that will help bring the W12 Protocol and database to a global audience.
>
> **Step 3** will be helping to build peer-to-peer networks between elected officials, water and sanitation staff, and water utilities managers in cities around the world. Beyond face-to-face meetings at the W12 Congresses, smaller trainings and visits between cities will be crucial.
>
> **Step 4** is multi-sectoral and long-term. Only partnerships between the public sector, the private sector, and civil society will suffice for the escalating water challenges that lie ahead. No one sector will solve the global water crisis alone.

The work is ongoing. The authors, supporters, and funders of the W12 project hope that, even in this relatively early stage of the work, other organizations and individuals will step forward to contribute their expertise and their financial support. Please direct inquiries to Ms. Ellie Leaning, W12 Project Lead, at the Institute for Ecological Civilization <eleaning@ecociv.org>.

# Cities Facing Escalating Water Shortages Conference Reports

Excerpts from the conference reports are provided below, covering the diverse fields of politics, economics, technical sciences, natural sciences, social sciences and humanities, and civil society. Full refereed versions of the position papers will appear in a special issue of a major journal.

# Politics Position Paper

***Reflections on the Politics of Water: Toward Urban Water Sustainability for the 21st Century***

*Initially prepared for the Cities Facing Escalating Water Shortages conference at the University of the Western Cape, January 2020.*

Lead authors: Larry Swatuk and Joanna Fatch

Version: January 20, 2020

## Executive summary

Water is an inherently political resource. As such, it is important to consider the ways in which our current political structures have given us the world we now inhabit and the importance of imagining a politics of water that is otherwise. Given the dramatic inequalities manifest across societies and the ways these inequalities manifest in urban environments, there has been a consistent over-reliance on technical, economic, and managerial approaches to urban water supply. Put differently, such approaches depoliticize water, articulating urban challenges as primarily a function of limitations on human, technical and economic resource capacity. Such a view has served both to stunt the dialogue regarding what may be done and to exacerbate the problems decision-makers ostensibly seek to solve. How to instill forms of collaborative decision-making that will yield benefits to all?

In light of both normal and abnormal challenges across differentiated physical, social, economic and political landscapes, the politics task team is centrally concerned with questions of:

- How to enhance the quality of life for all?
- How to deliver services to all where the physical, mental and socio-economic geographies are not only variable but disarticulated?
- Where vast inequalities of access and use of urban water resources are concerned, how to enhance effective stakeholder participation?
- How have select cities facing "Day Zero" responded to on-going political challenges?
- Is there evidence of cities having seized opportunities for best practice?
- What lessons can be learned from each city's experience?
- What lessons may be drawn from the wider world?

## Introduction

This paper focuses on the politics of water for cities. We provide a brief overview of water development with a focus on cities; the relevance lies in the general lessons to be learned.

The next section focuses specifically on water for cities, highlighting the politics underlying the inaction related to household water and sanitation. We then offer comparative data for several cities facing "Day Zero" scenarios. The final section presents lessons learned from the preceding sections and reflects on the necessary steps to develop the "political will necessary to act in support of environmental sustainability, social equity, and economic efficiency. This paper is meant as "food for thought" as we consider the ways and means of achieving urban water security.[1]

## Water Vision for 2050

A 2018 article from the BBC listed twelve cities facing "Day Zero" scenarios. A year later, an article in U.S. News and World Report provided a slightly different list. Beyond these candidates, one might list a host of others – indeed, all cities face challenges related to sustainability irrespective of their natural resource endowments, built environments, and human resource capacities. These challenges are well known and are captured in documents such as the Sustainable Development Goals (specifically SDG 11 – Make Cities and Human Settlements Inclusive, Safe, Resilient, and Sustainable and ICLEI's Resilient Cities, Thriving Cities: The Evolution of Urban Resilience. The point being made here is that no city is wholly prepared to meet the interrelated challenges posed by environmental, economic, and social actors, forces, and factors. At the same time, despite the massive sustainability challenges faced by all cities, there are successes, best practices, emerging networks of collaboration, and a shared perspective on the need to act now.

### Assumptions

Politics has been described as "the art of the possible;" it involves the authoritative allocation of scarce resources determining who gets what, when, and where. In the context of cities, we need to amend these definitions stating that urban politics decides what goes where. Given these definitions, it seems problematic to separate out "politics" from either economics or ecology: decisions affecting access, allocation, use, and management of water within cities are intertwined with questions of economics (e.g. "How to martial the financial resources necessary to build systems of delivery?") and ecology (e.g. "How does capturing a fugitive resource like water alter the character, and possibly the sustainability, of natural ecosystems?"). Recognizing the interrelationship among social, economic, and environmental factors, we focus our attention on decision-making in relation to questions regarding water and systems of supply:

- Whose needs are being satisfied? (the stakeholder question)
- What is the water for? (the demand question)
- Where does the water come from? (the supply question)
- How is it accessed? (the freshwater delivery question)

1 In Appendix 1 we present a short document meant to complement this longer paper, and to help guide our workshop deliberations.

- What is its quality? (the treatment question)
- What happens to it after it is used? (the wastewater conveyance question)
- How is the system financed, established, managed, and governed? (the governance question)
- What is the impact (social, environmental, economic) of the overall system? (the sustainability question)

Embedded in the answers to each question are trade-offs, compromises, the exercise of influence: in other words, the social relations of power. Urban water systems are organic, evolving through time as cities themselves evolve and change. Even a cursory review of available information reveals that the negative discourse surrounding urban water security. It goes something like this: 1) cities are growing rapidly, 2) water availability is limited due to First Order Scarcity (i.e. natural limits), Second Order Scarcity (i.e. poor management and limited human, financial, and technical resource capacity), or a combination of both, 3) the finances available for necessary infrastructure upgrades are limited, 4) the time for action is short, 5) and a changing climate makes planning for the future extremely difficult.

## Focal areas specific to water and cities

**Water and Power, Politics and Development**

Water is power. It drives industry. Its delivery to people wins elections, enhances authority, and builds legitimacy. Historically, humans settled around water, at the mouths of rivers, mid-stream, around lakes, springs, and wetlands. Over time, however, we have managed to reverse this flow, so much so that water no longer runs along its hydraulic gradient; rather, it flows toward money, people, and power. "As in all ages from antiquity to the present, the pattern of water distribution read like a map of society's underlying power and class structures."[2] So, while ancient Romans were among the first to treat water as a public good by building aqueducts to deliver fresh water to large urban centers, "Public basins and fountains used freely by ordinary people … received only 10 per cent of total aqueduct water."[3] But that 10% was more than enough to ensure the political legitimacy of the empire's ruling class.

The settled spaces we inhabit today are the result of relatively recent events in world history and largely the result of having discovered how to bend water to our will. Civilization is a direct result of a combination of human's ability to correctly predict water resource availability, and innovations to make more of it available when and where it was needed. Karl Wittfogel, in his 1957 classic, Oriental Despotism, proposed a causal link between the character of social organization and the extent of irrigated agriculture: the more complex the system of irrigation, the more likely you

2 S. Solomon, *Water: the epic struggle for wealth, power and civilization* (New York: HarperCollins, 2010).

3

would find an authoritarian regime whose leaders were able to command the labor of thousands in the service of the kingdom or empire.[4] Publicly available potable water and sanitation systems in ancient Rome were only possible because of slave labor and a highly militarized society. Wherever you look through world history you see the same pattern in river basins great and small: from the Nile to the Tigris-Euphrates, to the smaller river systems in Central America and Europe. In Western democracies such as the United States, the advent of two World Wars separated by a global economic depression and followed by the Cold War gave American policy-makers the nationalist motivation to drive industrial production and to create the infrastructure – particularly large hydraulic-works – to sustain that production. In that drive, came business and "the consumer society" along for the ride.

Today, China and India are engaged in a sustained, state-directed hydraulic mission. While this "mission" extends to many other parts of the Global South – often with the help of Chinese engineering companies – early 21st Century democracies everywhere are having a very difficult time generating either the social consensus or financial capital necessary for infrastructure maintenance, let alone new development. Given the challenges created by a changing climate, ensuring urban water security will require concentrated political commitment at the highest levels of government. How to fashion such a commitment is a key question to be asked by this task force.

**Hydraulic Societies: Draining, Damming, Diverting, Dumping**

Through history we have gradually developed our civilizations around four approaches to water management, which Conca labels "damming, draining, diverting and dumping."[5] Storing and/or moving water has historically focused on the often simultaneous need to move water, people, and things, and linked various resources to people and production, ultimately for consumption. All this activity has inevitably turned the vast majority of the world's waterways into "working rivers," which are a far cry from their "wild river" predecessors. There are many engineers who will tell you that any water that reaches the sea is "wasted" and should have been put to better use. Such an attitude derives from the high modern worldview that regarded it as "man's" (sic.) primary mission to tame nature. It is telling that of the more than 45,000 large dams built around the world between 1950 and 1990, following the spectacular success in the United States with the construction of the Hoover Dam on the Colorado River.

**Damming**

Dam building is a direct consequence of settled society. The earliest dams were constructed for flood control and to provide water for irrigation; while dams continue to be built, they remain highly controversial. The main arguments in support of dam building are tied to the expressed

4 Karl Wittfogel, *Oriental Despotism: A comparative Study of Total Power* (New Haven: Yale University Press, 1957).

5 K. Conca, *Governing Water* (Cambridge: MIT Press, 2006).

need for dependable flows of water for agricultural and industrial production and maintaining a steady supply of water for cities: thus, single and multi-purpose dams are regularly constructed in the name of irrigation, recreation, flood control, flow regulation, improved navigation, hydropower, and drinking water.

At the same time, there are many valid criticisms of dams, particularly large dams, defined as those more than 15 meters in height and/or with a capacity greater than 3 million cubic meters. These criticisms focus on negative impacts such as habitat degradation, loss of biodiversity, fishery destruction, de-oxygenation of waters, and destruction of cultural and social spaces to name several. Many environmental organizations, such as International Rivers, partner with marginalized social groups to raise public consciousness regarding the high social and environmental costs of dam building. Perhaps the most damning criticism of all, however, is that "dams displace democracy." This is a rather clever way of pointing out that the decision to impound water and to flood farms, forests, and even cities and villages is rarely if ever taken outside the main halls of political power.

Vandana Shiva is a well-known anti-dam advocate who has tirelessly worked to make the world aware of the social and environmental costs of, among other things, the Narmada Water Project in India. She has also worked very hard to mobilize citizens groups at local, national, and global levels to stand up to the powerful set of interests that drive dam development.[6] To paraphrase Ms. Shiva, the argument in support of large dams is invariably "improved agricultural production," but rarely is the question ever asked "to what end?" This is an important point, particularly in river basins where major cities are downstream (e.g. Chennai in India; Dar es Salaam in Tanzania) of significant agricultural enterprises, or in arid regions where the opportunity cost of irrigation is heightened vulnerability for human settlements.

Post-War economic reconstruction in Europe was complemented by show-piece project developments across the decolonizing world: Japan, China, and the newly emergent Soviet Union. By the mid-1950s, multi-purpose dams were synonymous with development. Some four decades later, large dam building projects had slowed to a trickle, mostly because social and environmental movements were better organized and more effective in challenging the claims made in support of these mega projects. In 1997 the World Bank and the IUCN helped convene the World Commission on Dams. According to their final report issued in 2000, "Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable. In too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers and by the natural environment." The Commission's final report provided a blueprint for dam building that would ensure the wrongs of the past would not

6 V. Shiva, ***Water Wars: privatization, pollution and profit*** (Cambridge: Southend Press, 2002).

be repeated. As shown, dam building projects such as the Lesotho Highlands Water Project, the Three Gorges Dam in China, the Belo Monte in Brazil, and the Xayaburi in Laos, the lessons of the past have not been learned.7

**Draining**

The United States Fish and Wildlife Service defines a wetland as "land where an excess of water determines the nature of soil development and the types of plants and animals … A continuum of environments where terrestrial and aquatic systems intergrade." An estimated 6% of the world's landmass is comprised of wetlands. Yet, wetlands have had a bum deal through human history. In 1576 AD, England's Queen Elizabeth I's chief architect, William Lambarde, described a wetland as "evil in winter, grievous in summer and never good." Several hundred years later, more than 50% of the world's wetlands have been drained, or, in the vernacular of development, "reclaimed" from nature and the land put to different, more "productive" use. The most spectacular example of this is Mexico City, which lies on the bed of the former Lake Texcoco. Today, many people recognize the value of wetlands, calling them "the kidneys of the biosphere," signifying their important water purification function. Wetlands have many uses in nature and to human communities: their rich soils are free organic fertilizer, their waters in flood provide free irrigation, and in recession good grazing and planting lands. They are biodiverse with their many species of flora and fauna providing such goods as food, wood, and fiber for building and handicrafts. Their complexity and multiple contributions to the natural environment and to livelihoods mean that they are generally treated as "commons," shared and co-managed as intact systems. Recently, environmentalists have tried to put a dollar value on the "ecosystem services" deriving from leaving wetlands as they are, in an effort to offset the economic arguments put forth by developers regarding the improved use to which wetlands could be put if drained: i.e., malaria and bilharzia free areas for large-scale commercial agriculture and/or urban and suburban development: compelling arguments, to be sure.

But every silver lining has its cloud: as with large dams, so too with wetland reclamation. While wetland areas, specifically river deltas, support millions of people worldwide, damming and diverting upstream, and draining have wreaked havoc on wetland communities. This is especially true where deltas have been divided up and turned over to private landholdings. In 1971, the Ramsar Convention on Wetlands of International Importance was signed into international law with the primary aim being the "conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world." Today there are 168 contracting parties to the convention, but like the WCDs, the rules and procedures guiding state behavior under its terms are breached as often as they are observed. Nevertheless, the fight continues. In the words of Fred Pearce, it

7 Larry Swatuk and Lars Wirkus, eds., *Water, Climate Change and the Boomerang Effect: Unintentional Consequences for Resources Insecurity* (London: Routledge, 2018).

wasn't that long ago when "wetlands" were simply called "swamps" and "bogs;" some progress has been made.

**Diverting**

With the rise of the industrial era, human settlement patterns have departed significantly from the logic of resource endowment in two fundamental ways. One, we often settle at the point of resource extraction (e.g. mining towns). Since most minerals are embedded in hard rock, and hard rock withstands weathering better than softer rock such as limestone and sandstone, minerals are most often found at the top of watersheds. In other words, at that point where rain falls and then runs away. Johannesburg is an extreme example of this: initially a haphazard mining town, it is today a metropolis of millions. Other less extreme examples of "top of watershed" settlements are burgeoning cities, such as Bulawayo and Harare in Zimbabwe, settlements that started off as small fortresses but then blossomed into administrative centers and eventually, in the case of Harare, a primate capital city – where the water runs away. Many other cities began as settlements close to freshwater springs, or along middle rivers where settled agriculture could flourish, or at coasts at the foot of river deltas where trade could flourish.

Canals, aqueducts, and other means of water transfer and transportation of people and goods have a long, proud lineage in human history. The Bridgewater Canal, named after the English Duke of Bridgewater, was built over 2 years, 1759-61, to ship coal from the Duke's Lancashire mine to its main market in Manchester. The success of this canal set off a major canal-building era in the UK. Predating the industrial era by more than 1000 years, the 1776km Grand Canal in China connects the high-flowing Yangtze River in the south with the lower-flowing Yellow River in the north. Today it is still considered one of the great symbols of the "hydraulic society," in which political will combined with perceived need and authoritarian rule makes just about anything possible. High modern examples of these historical practices such as the Central Valley Project in California and the Central Arizona Project, both in the western United States, stand as aspirational examples of what is widely regarded as a "successful hydraulic mission" to political leaders around the world. Given the complex needs of today's societies, it is difficult to argue against schemes which regulate flow and (mostly) reliably provide water for all uses – irrespective of their enormous energy footprints. The fact that these projects have made "the desert bloom" and cities such as Las Vegas, Phoenix, and Los Angeles arise from their arid environments, inspires political leaders, engineering firms, settlers, and farmers of all types around the world despite the serious and well documented problems associated with these projects.

As Tony Allan has shown us through the metaphor of the "hydraulic mission," our understanding of what water is and how it should be use, changes as we learn about resources and ourselves.[8]

8 Tony Allan, "IWRM/IWRAM: a new sanctioned discourse?" (OP 50, King's College London, 2003).

The complexity of water and the diversity of needs and wants ensure that decisions regarding access, use, and management are highly political. In an age of democracy, climate change, and highly networked globalization, arriving at consensus regarding large scale projects is more and more difficult: who will benefit, who will pay? Some years ago World Bank researchers Sadoff and Grey encouraged us all to look "beyond the river" and toward benefit sharing. Yet, it seems that for every step forward (e.g. accepting that water is a human right), there are two steps backward (e.g. land and water grabs by powerful global and local actors) that are particularly harmful to already marginalized social groups such as peasant farmers and nomadic groups dependent upon collective management of communal lands.

**Urban Challenges**

Providing adequate water and sanitation for the world's urban masses is perhaps the greatest challenge of the 21st century. According to ICLEI, "[t]he world has become predominantly urban, and cities are the place where the main challenges of sustainable development are being tackled. Although only occupying 2 percent of the land, cities are responsible for 70 percent of global GDP, greenhouse gas emissions (GHG), and global waste and over 60 percent of global energy consumption" according to UN-Habitat (2016). Not all cities are the same and face very different sorts of challenges. Those that arose out of the so-called first demographic transition fostered by the industrial revolution face significant challenges related to aging infrastructure: how to repair it, replace it, and upgrade it. This is primarily a so-called First World problem. Those cities that have arisen out of the post-WWII, post-colonial, second demographic transition face the primary challenge of meeting the needs of rapidly expanding populations that have overstretched existing infrastructure. In many cases, these cities exist in a sort of parallel peri-urban space: part of the greater metropolitan area, but largely unacknowledged by formal authorities.

The absolute number and percentage of people living in cities has increased dramatically over the last 60 years, with roughly half of all urban dwellers living in Asia. While Asia's urban population has dramatically risen as a percentage of total world urban population, Europe and North American percentages have fallen significantly. In addition, the size of the world's largest cities is also increasing dramatically (for a selection of major cities facing significant water-related challenges see Table 1).

**Table 1: A selection of major cities facing significant water-related challenges**

| City | Governance | Population (millions) | Geography | Precipitation | Water supply | Issues |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Cape Town | Party political | 3.74 | coastal | 515mm/a; winter rainfall (April-Oct) | Complex system of mainly surface water | Drought; Slums; Inter-basin transfers |
| Chennai | Municipal Corporation | 4.64 7.09 (GMA) | coastal (avg. 6.7masl) | | Surface water reservoirs; desalinisation plant; high groundwater table | Flooding; Drought; Slums; Downstream of agric. |
| Jakarta | Special Capital Region; elected governor, 106 councillors; 5 mayors and 1 regent chosen by governor; Water supply managed by 2 private corporations | 10 | coastal (-2 to 50masl; avg. 8masl) | 1816mm/a (Nov-May rainy season) | 80% surface water mainly from Citarum River and Jatilukur Reservoir; balance from ground-water | Subsidence; Flooding; Slums; Low % of household connectivity; 9% green space; Sewerage covers 1.9% of pop.; 4% housing covered by WWTP |
| Melbourne | Melbourne Water managed by independent Board of Directions & Minister of Water (Victoria); water responsibility falls to state government; waste management to councils | 5 | coastal | | Elaborate surface infrastructure; 3000km of sewerage lines; 1300kms of delivery; $3.1 billion desal plant | Drought; Low-density (sub)urban-isation |

| | | | | | | |
|---|---|---|---|---|---|---|
| Mexico City | Federal District; 13 boroughs; 'mayor' & directly elected reps (6 yrs/no reelection); party political; CONAGUA (Federal) + National Water Commission | 8.84; 21 in GMA | inland valley (drained lake bed; Lake Texcoco); 2240masl | 846mm/a (May-Oct) | Surface water 2/3; groundwater 1/3; long distance Cutzamate system; 11900km of pipes; elaborate drainage system | Flooding (17th century canals and tunnels); over-abstraction of groundwater; low recharge rate; subsidence (impacting wastewater management and runoff); deforestation; air pollution; 36% unaccounted for water |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sao Paulo | State-owned, publicly-traded, water and wastewater company, Sabesp, provides water and sewerage services in the city and across the state | 12.18 | Inland; 799masl; 70km from ocean | 1454mm/a (Oct-Mar but rains in all months); upper catchment forest cover | Cantareira System (1880s) provides 50% of water through surface system (6 reservoirs across 5 basins); 80% of all water from Alto Tiete Basin; 20% of water from groundwater; Iguape system being developed | 31% unaccounted for water; pollution; drought; flooding; Slums (20% of pop.); $22m in sediment management |
| Tokyo | Water managed by Bureau of Waterworks located within dept of Local Public Enterprises; wastewater by Bureau of Sewerage; Tokyo Metro. Assembly approves budget, revises water charges | 13.4 | coastal | | Surface water (14 dams); 27500km of pipes | Seismic stress on infrastructure; Drought |

Two major challenges identified by UN-Habitat are (i) providing water and sanitation and dealing with wastewater in the largest and fastest growing cities, especially in their informal settlements; and (ii) prioritizing water for low-income households.

It is a truism to say that access to improved water and sanitation is less about pipes and pumps and more about enabling the poor to help themselves. Put differently, non-resource specific interventions will go a long way to improving access to the water resource itself: better incomes through employment opportunities, the right to land and security of tenure, better information about citizen's rights, and better organized communities are all important elements of realizing access to improved water and sanitation.

A primary impediment to better water provision is poor state-civil society relations. Non-responsive or even repressive states are generally ignored or avoided by the very citizens they are supposed to serve. How to build trust where past experience engendered mutual suspicion is an important question for cities to consider. Participatory budgeting is regarded as one means of bringing the state and the citizenry closer together (e.g. Porto Alegre). But in many parts of the world, we are a long way away from transparent and accountable decision making as it relates to allocating resources to improve services for the poor.

Poor governance combined with incompetent public utilities led the rush toward private sector providers, particularly large multinational companies based in the UK, France, and elsewhere, throughout the 1990s and into the early 2000s. By and large, this extreme shift from public to private was an unmitigated disaster. It is rare to find a private sector provider that followed the terms in their contract. For most of the last 10 years, the donor world has been retreating from the private sector toward a middle ground where it is recognized that only oversight and regulation by a competent state authority will ensure a provider's delivery on contract.

For a while these public-private-partnerships, or PPP's as they are popularly known, were regarded as the best way forward, with relatively positive examples to be found in both Rand Water, as the bulk provider to major municipalities such as Johannesburg in South Africa, and Johannesburg Water, as an independent company with the City of Johannesburg as its sole shareholder, as the provider of water to consumers in the municipality. Johannesburg Water further sub-contracts many of its activities to private companies. This success stands in stark contrast to the negative social, economic, and environmental outcomes of privatization in Cochabamba, Bolivia and Jakarta, Indonesia.

Increasingly, municipalities have realized that PPPs are not enough, and that communities must be directly involved (e.g. civil society organizations). In highly unequal societies, such as South Africa or Brazil, with gini coefficients of income inequality nearing 0.6, differential service is regarded by the poor as a continuation of neglect and disrespect. Without community involvement, then, it is not possible to achieve buy-in regarding the possibilities for expansion and delivery.

While there are many issues related to under-performing utilities, it seems clear that both the

state (through goal setting, subsidies, incentives, and regulation) and the market (through responsiveness to consumer needs) have roles to play in ensuring that the provider or providers, have enough incentive to deliver as per the terms of their contract. It is a delicate balancing act. When it goes wrong, it goes very wrong as the so-called "water wars" in Cochabamba, Bolivia demonstrated. But when it goes right, as seems to be the case in Johannesburg, success tends to breed success as the state and civil society move closer together in building trust and social capital. Moving toward successful delivery of water and sanitation services then seems to require utility-state-civil society negotiation and improved relations.

Given the variability of settlement patterns particularly in the primate cities of the Global South, issues that require open conversations abound. These include: expansion through networked or non-networked systems, prepaid meters with automatic shut-off points, step-wise tariff structures, and adherence to global standards that may be beyond the technical and financial ability of the city. History shows that where non-transparent decisions have been made *on behalf of* the poor, problems arise; even the primary motivation is desire to help. The so-called "toilet wars" in Cape Town, South Africa are an excellent example of this.

## Case Studies

### Slums

Let us now turn briefly to a discussion of the ways and means of increasing and expanding improved water and sanitation to slums. Why slums? Because approximately 1 out of every 7 human beings lives in a slum. In addition, there is significant incidence of slum-dwelling as a percentage of urban living spread across most of the global south. It is also clear that the incidence of slums is on the rise, with massive increases in the last 30 years.

No two slums or informal settlements are alike. Hillside favelas in Brazil present very particular challenges. As do the densely packed shacks across an African plain, such as that in Kibera, which is part of Nairobi, Kenya. Squatting and informality raise challenges of access to water resources with sufficient quantity and quality to meet personal needs and because these are often unserviced areas, solid waste management is also a significant and related challenge. Blocked channels in rivers and streams result in standing water which can become breeding grounds for disease-carrying mosquitoes. Storm water run-off systems are often choked by solid waste; this creates persistent threats of flooding. In addition, where human and animal waste is poorly managed, flooding can result in widespread disease outbreaks (e.g. cholera). In order to deliver a service there are many and highly specific requirements, often times none of which are present in slum areas. So key questions arise:

- Enumeration: who is in the house? Apartment? Shack?
- Who in the dwelling will be responsible for payment?
- Who owns the land?

- Are there any official maps?
- Is there a register of households?
- Will the service depend on state support? Individual or community investment?

And challenges:

- The dwellings have no official addresses
- The geography of the settlement poses service difficulties
- There is no road access
- Landowners do not want squatters to receive services

What is clear is that the conventional model of in-house water delivery and water-borne sewage disposal will not work in slums. While it may work for part of a city, such as the high-income suburbs of Johannesburg, Jakarta and Sao Paulo, it may not work for all or parts of poorer areas. Moreover, it is these poorer areas that tend to become magnets for informal settlements and the expansion of squatters into very dangerous landscapes – such as hillsides or low-lying drainage areas that are particularly susceptible to the negative effects of extreme events. UN-Habitat advises a turn toward the unconventional. In their estimation, the conventional model of piped water into each dwelling and a sewer connection for wastewater and toilets, has managed to serve perhaps one-half of the world's population. Despite 30 years of global focus on making this a universal system, it has failed, and will continue to fail. Indeed, in many parts of the world, where large populations reside in arid environments, this is precisely the wrong type of system necessary.

Two very positive examples the authors put forward are PROSANEAR (the Water and Sanitation Program for Low-Income Urban Populations) in Brazil, and the Oranji Pilot Project, which focused initially on the neighborhood of Chisti Nagar, a slum area of the Pakistani city of Karachi, whose 2013 estimated population was 23.5 million. PROSANEAR was a World Bank and government of Brazil supported project rolled out across more than a dozen municipalities. Its aim was to ensure adequate water supply and sanitation for everyone in Brazilian cities. Given the massive economic inequalities in Brazil, this was no easy task. The innovation here was to involve un/under-serviced communities themselves in the design, planning, roll out, and management of what was termed "community provision."

The successes realized in Brazil were extended to other municipalities around the world. In the estimation of sanitation expert Duncan Mara, the Oranji Project was a beautiful example of South-South cooperation and knowledge transfer: devised in Brazil and successfully rolled out in Pakistan, where more than 850,000 were positively affected by community provision-oriented projects. These projects can only be as successful as the physical conditions in which they are rolled out. While the city of Cape Town, for example, has initiated a pilot project of water and sanitation provision in its high-density townships, extension of this provision to flimsily built shack

areas is not possible – at least not beyond a standpipe. Slum upgrading is therefore necessary, but it is often controversial.

"Decanting" areas in Kibera, where shack-dwellers are moved out of their residential spaces into government constructed housing, while their area is then demolished and rebuilt, is painfully slow. Such a government run scheme also smacks of paternalism (the state knows best) and is subject to all sorts of graft and corruption. Evidence suggests that new homes being built for people without displacing them is better received, especially if the new locations do not shift the residents too far away from where they have established themselves and feel comfortable. It still raises the question of "ownership" of the project by those ostensibly at the center of the initiative, i.e. the "beneficiary" of the new housing. Baan Mankong – Thai for "secure housing" – seems to offer an example of the way the state, the private sector, and the people can work together. Designed to reach 300,000 households, in 2,000 poor communities, in 200 Thai cities, the program channels infrastructure subsidies and housing loans through the national government agency directly to low-income communities who plan and manage the implementation of improvements to their housing and basic services. This not only improves provision of basic infrastructure, including water and sanitation provision, but also ensures a stable, legal relationship between households and water utilities by providing secure tenure for residents.

Without doubt, the world is rushing headlong into a brave new social order, an urban order with a vast array of challenges, threats, and opportunities. While the challenges are many, the continued failure to act by those with the capacity to do so is a serious threat in so many ways. From ill health to social disorder and violence, the evidence shows that the new urban reality presents many opportunities to rethink how we design and inhabit settled social spaces and interrogate our relationship is to the environment as we seek to satisfy our wants and needs.

What is very clear is that people need and deserve respect. Where the poor are consulted and made partners in problem solving, the innovations and results are remarkable. Where they are treated as either undisciplined children or a problem to be contained, the state's attempts will be met with contempt.

## Systems of Delivery

Savenije has described water for cities as "small water."[9] In other words, in comparison to the massive amounts of water that go into irrigated agriculture – i.e. some 70% of blue water – cities' demands for blue water pales in comparison. But this is not to imply that delivering water for cities is that much easier than delivering water for agriculture. On the contrary, providing water for cities is both complicated and contentious. While it is "small water," it is required on a 24-7 basis.

9 H.H.G. Savenije, 'Why water is not an ordinary good, or why the girl is special,' Physics and Chemistry of the Earth 27: 741-744.

On the face of it, the method of drawing water for cities is relatively straight forward: find a source of supply, collect, and, if necessary, treat the water before distributing it to various consumers (households, business and industry, public goods (e.g. parks), and other green spaces), collect it after it has been used, and treat it again before reintroducing it back to the source. We call this the system of supply. However, each step in the system of supply presents a wide variety of challenges.

Let us begin with the source of supply. What is the source of supply? Is it a surface water body such as lake? Is it groundwater, or both? Where is this source: a natural lake located upstream, groundwater directly beneath the city or a "well field" located some distance away? Is the source downstream? Out of the basin altogether? How much water is there? What is the flow rate of the resource, its recharge rate? How is its quality? Each of these questions has an associated number of issues related to them.

Questions regarding the source of supply reflect human settlement patterns. Where are the people? Are they at the top of the watershed? Is the city somewhere along a river's banks at midstream? Or is it a coastal settlement? No two cities or settings are exactly the same; each presents challenges that expected and unexpected. Bangalore – or Bengaluru as it is also called – and Johannesburg cities at the top of watersheds whose primary challenges stem from this location. Bangalore receives somewhere in the region of 1000mm rainfall annually and the bulk comes during a five month period, June-October. The average temperature stays quite warm throughout the year, meaning that evaporative demand in the dry season is much higher than that in Johannesburg, where the winters can be quite cold. In comparison, Johannesburg receives about 25% less precipitation than Bangalore, receiving the bulk of it during the warm summer months. Average temperatures are quite a bit cooler, however. What does this suggest for storage options in the two cities?

Urban growth has generally seen two dramatic spikes in recent history: the first great demographic shift followed the industrial revolution in Europe. People were driven off the land and into the towns. And wealth creation over time led to further immigration and natural population increase. The second demographic shift followed the end of the 2nd World War and the end of colonialism. Cities of the global South grew dramatically, in particular the capital cities, most of which have since achieved primate status, having between 10-20% of the total population of their countries residing in the greater metropolitan area. While Johannesburg (as a mining town) and Bangalore (as an historical settlement taken over by the British as an administrative centre during the colonial era) have modest origins, they have grown rapidly in recent years. Today they are home to several million inhabitants, their activities, interests, needs and so on. The pace of population increase has taxed even the most creative and well-equipped urban managers in terms of keeping up with necessary services such as water, sanitation, housing, electricity, transportation and so on. As a result, and as is typical across the global South, many of the residents of Johannesburg

and Bangalore reside in poor or un-serviced slums and squatter settlements. Moreover, the gini coefficients of income inequality in these two cities are among the highest in the world, illustrative of the fact that almost unimaginable wealth rubs spatial shoulders with equally unimaginable poverty.

So, what are the challenges facing these cities in terms of 'water in – water out'? Let us take a quick tour of each segment of the system. To provide water to people in a city, it must be collected from somewhere. Availability varies dramatically, as does the quality of the water available. The city of Halifax, Nova Scotia in Canada, is blessed with pristine lakes located upstream and far from any significant human settlement, industry, mines and so on. The delivery system utilizes gravity, so there are no expenses related to pumping water uphill (as there are in Bangalore, where water has to be pumped up to the plateau on which the city perches and much of it from a great distance). There are fewer water treatment costs for Halifax as well, given the initial state of the resource. This contrasts dramatically with cities such as Dhaka whose groundwater supply is contaminated with arsenic, or other downstream cities, such as Maputo who must deal with all sorts of effluent in their water that accumulates along the resource use chain by upstream cities and other users (such as farms and mines). This situation is not limited to the global South, of course. For example, lots of problems happen to the waters of the mighty Mississippi in the United States as it snakes its way through several states and many cities. Almost all urban water systems – even those in the deliberately constructed cities of fast-growing states such as China and Brazil – are cumulative and reactive. What this means is that the initial system was based on several assumptions such as the current and projected growth of the city.

Cities such as Johannesburg, Harare and Nairobi were deliberately laid out to reflect the contemporary political economy of settler-based colonialism. If one lived on the 'right side of the tracks' there would be every modern service imaginable. But if one lived on 'the wrong side of the track' – next to industry and so on – your access to services differed dramatically. In some cases, there were no services provided at all. This was deliberately done to discourage Africans from "settling" in these colonial centers of commerce, industry, and administration. So, high density housing estates were serviced by standpipes and shared latrines, while low density housing had in-house flush toilets and running, treated water. Following the end of colonial rule, and in the South African case, apartheid rule, people have crowded into the cities looking for economic opportunity and expecting access to water and sanitation as "their constitutional right."

Obviously, a system deliberately designed to serve the few continues to have a great deal of difficulty in serving the many. The same may be said for Bangalore, and pretty much any other city of the global South, be it large or small. So, people queuing at a public standpipe in Bangalore is hardly surprising; indeed, we seem to expect that this is the best we can do under the circumstances. But is it? Which leads us to distribution. Like collection and treatment, distribution faces many

of the same challenges.

Just because there was enough financial capital, political will, and human resources available to construct the initial supply and treatment system, be it a dam, or a system of well-fields where the water is moved either by gravity or diesel-powered pumps to a water treatment center where the resource is made ready for human use and consumption, does not mean that it was distributed equitably, efficiently, or sustainably. Initially, and across the post-colonial world, systems were constructed on "Western knowledge." Leaky pipes in temperate zones where there were upwards of 300 precipitation days per year (and free winter storage in the form of snowpack) were "good enough." Running the same pipes through the desert or across the tops of watersheds, however, meant that a great deal of *unaccounted for* water was in fact wasted and beyond the use of the people of that city. Some of these systems are now almost 100 years old, and in dire need of upgrading, extension, and so on. But how to do this? Cities are often bankrupt or run by corrupt officials and their cronies. Where will the money come from if people are to be properly served? Where is the human resource capacity? Who can afford appropriate technology if the mistakes of the past are not going to be replicated today and tomorrow? And all of this seems to be a race against time: before the system collapses under the weight of ever-increasing demands. In Bangalore there are some 10,000 km of water supply transmission and distribution pipelines, and another 7,000 km of lateral sewers and outfall sewers. As of 2006, there were an estimated 350,000 connections and 6,350 authorized public fountains (used by the poor and unserved of the city). How to keep these in good working order? At the same time, the costs of fuel used to pump the water up from the Cauvery River to the city bleeds the city almost dry. What is to be done?

Improved water metering is regarded as one way of ensuring the cost-effectiveness of delivery. In many parts of the world, pre-paid water meters have been introduced, particularly in high density settlement areas of cities. This system is often regarded as highly controversial, impinging on people's "human right to water." The city of Cape Town, for example, introduced a series of pilot projects to install meters which deliver 300 liters of government legislated "free basic water" to poor households. Once the limit is reached, householders must purchase additional water on a user-pay, pre-paid basis. There are many people in Cape Town's townships such as Khayelitsha who view this as an infringement on their right to water. But look at it from the City's viewpoint: water falls free from the sky, but systems of delivery cost a lot of money.

Where water is delivered into parts of the city that are unable to pay for it, not only is the water lost to other prospective uses, but the loss of revenue makes it doubly difficult for the city to deliver its existing services and to extend services to the historically disadvantaged. Yet, distribution based on cost-recovery seems somehow to remain a highly contentious issue across the global South, and in parts of the global North as well, such as in the scattered rural and aboriginal communities across much of Canada. How to get water to these folks without going bankrupt yourself? In some

cities, surveys reveal that people are happy to pay for water (and electricity and so on) if and only if the service is reliable: people want to pay for water that they can get when they need it and of good quality for those needs. They do not want to pay for erratic delivery of water that might kill them.

So, what happens to the water after it is used? In industry – is it treated to a quality that makes it unharmful to humans downstream (or, in fact, in the same city, if, as in the Zimbabwean city of Harare, the main source of water is a dam located downstream where water has to be pumped up into the city, used, and then it goes back into the system)? In households, is grey water separated out from black water? In slums, are people just dumping their "night soil" into the streams that feed the aquifers, rivers and lakes that hold the water for other users? We are back to the same old issues: appropriate technology, human capacity, and the cost of it all. Which leads us back to the source itself. As mentioned in regard to Harare, questions regarding the shape and condition of the water supply and distribution system become even more important if you are drawing from the same point into which you are then depositing liquid and solid waste. If the system draws water beyond the rate of replenishment then other sources and/or use practices will have to be found or devised. Water Demand Management (WDM) has become popular in the last two decades: we can make 'more' water by using wisely the water that we have. So fixing leaky pipes and ensuring that industry and households do not pollute the resource does not add an absolute amount to the system, but it does make more water available than would have been available had it leaked away or become unusable due to pollution. At the same time, there are important considerations as to who or what is downstream. Many cities simply dump their waste into their water systems and hope it floats away. Coastal cities face numerous problems because of this practice. In effect, they are destroying the very house in which they live. But those upstream often use the practice of 'out of sight out of mind' as a low-cost management strategy.

There is one more important aspect to our system: we often fail to adequately consider the water that enters the system informally, through natural processes. Most cities have decided that the best thing to do with this water, when it is not used as green water by the city's green spaces, is to remove it as fast as possible. Consequently, while we have devised a system of delivery for use, we have devised a parallel system of storm water management that regards this informal water as somehow problematic. This is understandable, in some ways, given where we have settled. Cities across the tropics face seasonal floods. Given that Bangladesh is a country in a floodplain, unless more than 40% of the city of Dhaka is under water, it is not considered a state of emergency. Flooding is part of life there but, even so, it is very poorly managed. But should it be made to run away as fast as possible? Should it not be integrated into the entire system of supply? In a country such as Bangladesh, where groundwater is contaminated with arsenic, does it not make sense to ensure that aquifers are as full as possible to dilute arsenic so that its presence is not deadly or harmful? Every year during the rainy season we channel storm water away from cities only to find

ourselves under a water advisory in the dry season. Why? Because most of our water is ground water and we've failed to replenish the source through a combination of stormwater 'management' and an increasingly hardened environment where impermeable concrete and asphalt have helped create the 'stormwater problem' in the first place.

To create an integrated system brings us back to capacity: human resources, finances, technology, and, the political willingness to depart from the "beaten path." In light of extreme events, heightened variability and climate change, it is time for a revolution in urban planning.

## Best Practices

Urban Water Security may be defined as citizens' freedom from want (i.e. having adequate amounts of water of appropriate quality for daily consumptive (household, economic) and non-consumptive (e.g. recreational, spiritual) needs; and citizens' freedom from undue risk from natural hazard and human use outcomes. To ensure urban water security for all, steps must be taken to (i) reduce risk (from external events); and (ii) reduce vulnerability (enhancing the character and strength of the people and the built environment). For example:

Reducing risk through appropriate individual and collective action

- Due to shortage (ensuring adequate supply)
- Due to pollution (ensuring fail safe systems of conveyance)
- Due to extreme events (improving the built environment)
- Reducing vulnerability through appropriate individual and collective action
- Through improved management of existing systems (at different scales)
- Through better governance and systems oversight (legal and institutional arrangements)
- Through adoption of new technologies (appropriate and affordable)
- Through knowledge mobilization and effective communication (learning from others)

There are many examples of "best practice" across the world's cities, including, for example:

- Low impact development
- Sponge cities
- "Pop-up" infrastructure and other community-centered approaches to service delivery
- Public-private-community partnerships
- Infrastructure upgrades

In terms of the politics of urban water security, one can glean several factors to understand how "best practice" emerges:

- Creative coalitions (citizen-led)
- "No opting out" due to collective effective of impending crisis
- Pressure from citizen groups
- Enlightened leadership
- Available finance
- Peer pressure (city to city; global governance systems)
- Smart partnerships

In relation to the politics of water for cities, the review of water in development and in human settlements reveals the following:

- Water use mirrors society back to itself. It is therefore unrealistic to expect equitable access to water, indispensable though it may be, in highly unequal societies.
- As cities continue to grow, there will be no substitute for supply-side solutions to scarcities and uncertainties; rather than moving away from 'Man over Nature' approaches to resource management, we continue to reinforce these high-modern, 'hydraulic mission' approaches.
- Demand-side management as well as improvements to existing systems of supply can greatly enhance the urban water endowment but these are politically sensitive, especially when asking citizens – some of whom already have limited access – to 'want less'.
- Authoritarian/Totalitarian political systems (where civil society is weak) provide equal space for misguided projects (e.g. Three Gorges Dam; Ilisu Dam) as well as creative innovation (e.g. large-scale desalination; 'sponge cities').
- Democratic political systems are prone to compromise and path dependence (e.g. urban sprawl that generates new revenue mixed with minor innovations such as green belts) due to financial limitations, social pressure and politicians' general unwillingness to take risks (that may have impacts at the ballot box).
- In the Global South, "big infrastructure" draws together political, economic and social power, squeezing out less influential groups, in particular the poorest citizens.
- In the Global South, where the urban poor are included it is because they have forced themselves into the public space through a combination of activism and external (NGO, IGO) support.

## Conclusion

One conclusion to be drawn from this review is that cities are deeply divided across many socio-economic fault lines. These divisions make every water-related decision inordinately political. How then to move toward improved practices and outcomes? Since 2000, when the Prince of Orange declared the world water crisis a "crisis of governance," there have been concentrated efforts along two fronts: improved governance (e.g. exposing and rooting out corruption, updating water

laws, developing water resource development, and management strategic plans) and improved management (i.e. integrated water resources management with a focus on the river basin as the geophysical unit of water use decision making). These efforts have been coordinated by several global and regional bodies, such as UN-Water. Donor states and international financial institutions have attempted to integrate these best practices into lending policies. On several occasions they have made very wrong turns (e.g. privatization of urban water systems).

There is no escaping the politics of water. It is manifest in decisions regarding reforms to governance and management. It is manifest in decisions regarding appropriate technologies. Some regard the widespread turn toward desalination to be a consequence of the fact that the endless ocean waters are not hemmed in by land tenure, communal rights, and contentious trade-offs between stakeholders as are land-based (surface and ground) water resources. Yet disposal of the brine effluent has ecological consequences which will no doubt have socio-political and economic consequences as well. Cities, through global processes such as Agenda 2030 and UNFCC COP, learn from each other. Moreover, these are collective social spaces occupied by civil society organizations who share strategies and tactics, and the private sector, who compete for markets and contracts. It is these groups coming together who will determine who gets what water, when, where, and how. It is our job as academics to understand why, and as activists to fight for the outcomes we believe in.

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# Economics Position Paper

Initially prepared for the Cities Facing Escalating Water Shortages conference at the University of the Western Cape, January 2020.

Lead authors: Charon Büchner-Marais
Co-authors: Cathie Lewis, Koen Verbist, Gregg Bill

Version: 20 January 2020

## Executive Summary

"Once unthinkable, water crises are becoming commonplace. Water stress creates ripple effects throughout societies and economies, as it poses serious threats to human lives, livelihoods and business stability."[10]

The Economics Task Team is one of six task teams that works alongside politics, natural sciences, technical sciences, civil society, and the social sciences in a multi-disciplinary approach, for the conference entitled "Cities Facing Escalating Water Shortages" scheduled to take place at the University of the Western Cape in January 2020. One of the strategic deliverables of the conference will be the creation of the W12 Framework as a living, open-access document, encapsulating best practices, principles, and goals. In addition, a desired outcome is to make action plans to develop resources for cities experiencing water shortages. The conference's aspiration is for policymakers, businesses, academia, non-governmental organizations, and concerned individuals to use this synthesized international best practice to find innovative ways to address water shortages in cities for the shared benefit of all.

The Economics Task Team includes representatives from industry, the agricultural sector, commerce chambers, economic development agencies, and economists from a broad local, national, regional, and international network to facilitate cross-sector collaboration among the multiple stakeholders, contributing to the compilation of the W12 Framework.

By recognizing the need for systemic responses to escalating water crises and imagining different structures and systems for the cities of the future, the Economics Task Team will provide long-term and holistically informed perspectives in an increasingly uncertain climate in which extreme events can disrupt water services.

10 World Resources Institute, August 6, 2019, https://www.wri.org/our-work/project/world-resources-report/wrr

In the spirit of collaborative governance, the Economics Task Team acknowledges that a collective effort is required to find robust solutions to regenerate and restore water security and build resilient economic, social, and natural ecosystems.

## Introduction

From Cape Town to Flint, Michigan, from rural, sub-Saharan Africa to Asia's mega-cities, there is a global water crisis. People are struggling to access the quantity and quality of water they need for drinking, cooking, bathing, hand-washing, growing their food, and meeting business needs. Less water for both developed and developing nations is a threat to the general well-fare of humanity and nature. The World Resources Institute reports that water withdrawals have more than doubled globally since the 1960s with no signs of slowing down.[11]

In most of the cities represented at the W12 conference, there is no question about the fundamental social and economic need of providing sufficient, safe water to its citizens and businesses. Nevertheless, insufficient funds available for water infrastructure and lack of skills to operate and maintain these systems at the local, provincial, or national levels hamper the ability of governments to provide water of sufficient quality and quantity to households and businesses, whilst maintaining sufficient water reserves to enable the provision of ecosystem services. When considering climate models and population and economic growth projections, it becomes clear that water scarcity will increase rapidly over the coming decades in major cities around the world; this will result insignificant economic crises. Economic and population growth will place further stress on infrastructure, government capacity, and water authorities. It is critical that we take ownership of the vulnerabiltities inherent to current economic systems as they encounter climate change. This will directly affect water supply, with concomitant impacts such as: devastating economic consequences in major cities, displacing millions of people, and disrupting entire ecosystems over the coming decades.

Climate change may affect people differently in different locations worldwide, but changes in water availability particularly, will become a major disruptor of people's livelihoods, economies, and ecosystems at all scales. In times of abundance, water is taken for granted; it is not fully appreciated as a valuable life-sustaining resource within "the Commons." In 2018, Cape Town became one of the first major cities after Sao Paulo in 2015, to come within weeks of "Day Zero" conditions. This is when piped water would have been cut off for the majority of businesses and citizens. These conditions emerged from drought conditions in Cape Town and surrounding areas that persisted over three years; reductions in rainfall of between 50% - 70% off the long-term average (Wolski, 2018) meant reaching the lowest precipitation values (recorded in 2017) since observations started in 1880.[12]

11 World Resources Institute, August 6, 2019, https://www.wri.org/our-work/project/world-resources-report/wrr 9

12 Wolski, P, 2018. "What Cape Town learned from its drought." Bulletin of the Atomic Scientists. April 16, 2018. https://thebulletin.org/2018/04/whatcape- town-learned-from-its-drought/

The significant reduction in rainfall suggests strong indications for anthropogenic influences on the drivers of the drought (Otto et al., 2018).[13] Although the reductions in precipitation between 2015 and 2017 were severe compared to historical observations, they seem to be in line with the projections for the region **(Figure 1).**

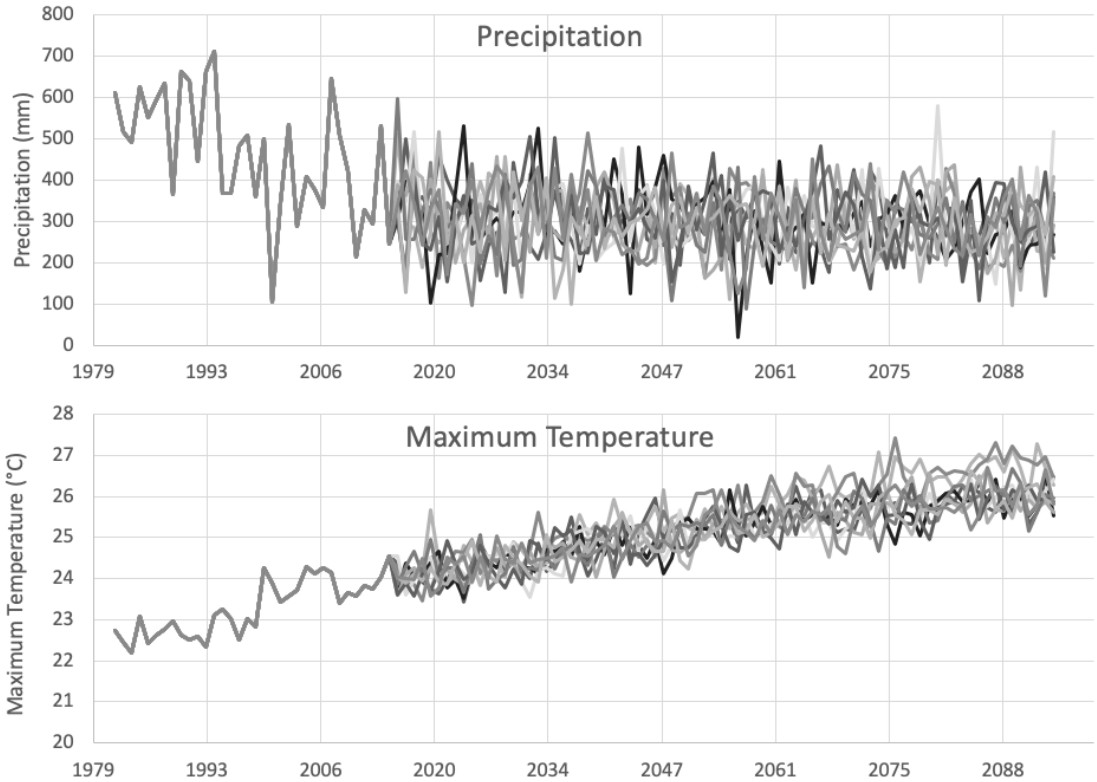


**Figure 1: Projections for precipitation and maximum temperature for a location in the Western Cape for a warming scenario (RCP 8.5) using the median projections from 43 Global Circulation Models (GCMs)**

These economic impacts with concomitant social implications need to be interrogated, analyzed, and critically questioned to find different economic approaches that incorporate different values and innovative solutions to alleviate hardship and suffering caused by persistent water scarcity. The Economics Task Team intends to find such alternative approaches, methodologies, and solutions to regenerate, restore, and maintain water security as part of "the Commons."

## Overview of Economics Task Team approach

The ultimate goal of the Economics Task Team is to find sustainable water security solutions, that

13 Otto, F. et al. 2018. "Anthropogenic influence on the drivers of the Western Cape drought 2015–2017." Environmental Research Letters, 13(12), p.124010.

include water scarcity and quality, while considering economic impacts. The approach will be predominantly climate risk informed decision analysis (CRIDA) based, influenced by value-focused thinking (VFT) as postulated by Ralp Keeney.[14] One of the benefits of using VFT is this approach is structured in a decision framework in which the ultimate goal is positioned at the pinnacle of the framework and supported by other fundamental goals. Each fundamental goal needs to be achieved in order to reach the ultimate goal. In addition, the third layer of the framework is comprised of goals that serve as a means to an end i.e. achieving the fundamental goals means achieving the end goals. Since this methodology is dynamic, it is likely that certain goals are structured as fundamental at the start of the process and morph into means-end goals or vice versa. This adaptability contributes to the robustness of the decision-making process, ensuring that the most appropriate decisions are developed and made. Greater detail of the various fundamental and/or means-end goals, as well as a brief description of the CRIDA-approach are set out below.[15]

One of the goals aims to bridge the gap between climate science and the global circulation model information and the concrete adaptation actions required on the ground. Identifying key thresholds for decision-making is conditional on the rate of climate change acceleration, providing a pathway to integrate climate change uncertainty into decision making.

Exploring, evaluating, and selecting adaptation pathways can provide a powerful planning tool and help consider uncertainty at all times. In particular, the Economics Task Team will deal with issues of water uncertainty/insecurity, water use management, and catchment-scale water stewardship practices. The task team will also seek out opportunities for public/private partnerships and other co-investment mechanisms to make and sustain shared commitments to improving water security.

The Economics Task Team will engage different economic models considering the roles of the public and private sectors, academia, and NGOs to consider their potential. Forecasting economic models with the economic effects of climate change on water supply is highly contentious due to the inherent levels of uncertainty: many of the core assumptions are disputed or are still being ground-truthed. Some models are potentially too conservative while others show that we are destined to run out of water in our lifetime.

The Economics Task Team will interrogate the prospects for developing collaborative governance frameworks to deal with water security issues in the economy.[16] Water is often viewed as an issue of "the Commons," but in reality it is highly complex and nu-

14 Keeney, R. "Value-Focused Thinking: A Path to Creative Decisionmaking." Harvard University Press: Cambridge, MA, London, 1992.

15 Verbist, Koen. "A Bottom-up Approach to Climate Change Adaptation: Towards Sustainable Water and Ecosystem Management in the Western Cape". UNESCO Project Concept Note in collaboration with Co-Go. August, 2019.

16 Büchner-Marais, C. "Transformative Collaborative Governance towards sustainability: the case of the Stellenbosch River Collaborative".

anced. The challenge is for the institutional barriers and inward-focussed governance approaches to consider the multi-faceted nature of this key resource and bridge the divide between stakeholders. A transparent and equitable approach is needed to ensure that governments and industry (as main stakeholders) engage meaningfully and proactively across sectors in a collaborative governance arrangement.

Collaborative governance comprises two distinct, but connected and interwoven aspects. The first can be described as intangible: dealing with ethics, values and culture. What to do is important, but equally important is how one goes about doing it. The values and principles that inform actions and engagements greatly affect decisions made and their ultimate impacts. In this instance the VFT approach will be beneficial because all decisions are value-based, which provides considerations in the decisionmaking process. The Economics Task Team will investigate, interrogate, and select the values and principles most appropriate to the task at hand, by bringing together all actors, affected by, and affecting water security. The task team will create an equal, non-competitive space in which the actors can engage with equal voices from their different perspectives, needs, and interests to ultimately find common ground and establish a mutually benefitcial outcome.

The second aspect is the tangible. This consists of the collaborative governance framework, supported by governance processes, systems, and procedures. Here collaborative governance becomes the enabler of flexible decision-making. The Economics Task Team will investigate and compare which frameworks, processes, procedures, and approaches are best suited to find and implement proper solutions to the risks of climate change and water scarcity. In this instance, the five-step CRIDA approach will form the basis of these frameworks, processes and procedures. In addition to the approaches descrived above, our approach also falls within the UN Global Compact (UNGC) framework guidelines. While the Sustainable Development Goal (SDG) framework was developed to guide governments towards sustainable development, the corporate world has also embraced this framework as part of their strategic processes.[17]

Water influences and is influenced by several, if not all, of the SDGs and is a powerful example of systemic connection. There is a growing insight that issues related to water and climate change cannot be served by goverments (top-down) alone, but require partnerships (SDG17) with non-state actors as well. Globally, the magnitude and complexity of climate change are amplified by the rapid and environmental degradation and deepening social and economic risks, carrying a growing cost. The primary concern is the impact of water crises on society, posing escalating and complex challenges for business and government.[18]

Sunscholar. December 2016, https://scholar.sun.ac.za/handle/10019.1/100298

17 The King IV Report on Corporate Governance for South Africa, 2016. The Institute of Directors of South Africa, NPC.

18 Büchner-Marais, C. "The Collaborative Governance Network for water security in catchments Distell report". Co-Go, August 2019.

## The UNGC framework guidelines include:

- Finding ways to integrate the Global Compact and its principles in terms of human rights, labor, environment, and anti-corruption into business strategies, culture, communication and actions resulting in sustainable socio-economic and environmental impact.
- Mobilizing a global movement of sustainable companies and stakeholders to create the world we want and future generations deserve.
- Networking and hosting dialogues locally and regionally to establish mutually beneficial relationships with like-minded organizations globally.
- Changing business operations so that the Global Compact and its principles become part of future strategies, culture and day-to-day decision-making.

An apt methodology most suitable to complement the collaborative governance approach is following a participatory (bottom-up) approach to climate change adaptation. This approach ensures inclusive solutions that engage all actors and affected parties, from the most vulnerable communities, to national regulators, and financially powerful organisations. It provides a phased process to bridge the gap between formal climate science and the global circulation model information with concrete on-the-ground adaptation actions required. Through a rigorous identification process, adaptation pathways can be identified, stress-tested and ultimately selected within the context of uncertainty. The CRIDA approach is a powerful planning tool that integrates the decision-making process and identifies key thresholds for decision-making. These threshholds are made conditional on the rate of climate change acceleration and provide a pathway to integrate climate change uncertainty in decision-making **(Figure 2).**[19]

19 https://unesdoc.unesco.org/ark:/48223/pf0000265895

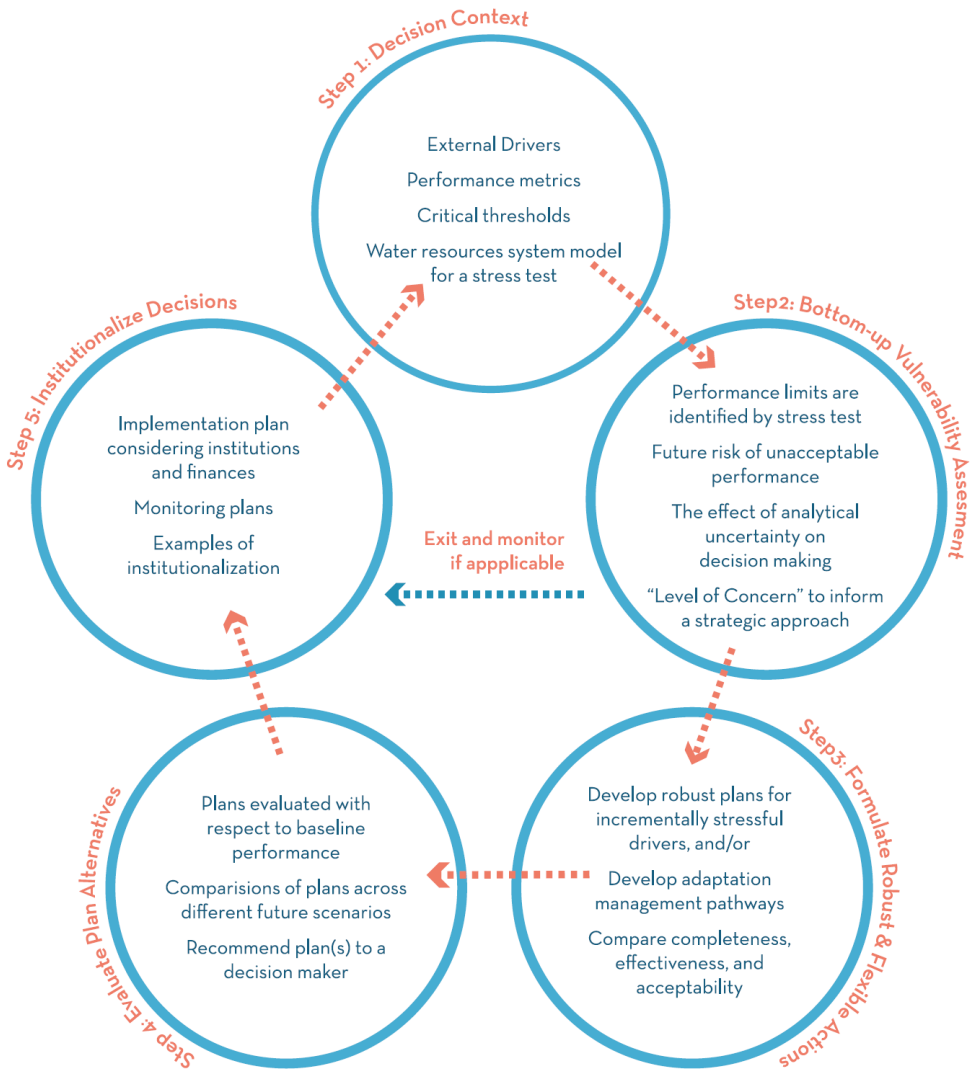


**Figure 2: CRIDA five step approach to climate change adaptation**

We propose the CRIDA, bottom-up approach to climate impact assessment on water resources through interactive dialogue with governmental agencies, academic institutions, private sector partners, agriculture, and civil society at every phase of the process. While strengthening the adaptive capacity of the Western Cape, the increased resilience to climate change needs to be adequately monitored and evaluated against current climate variability in the short-term and climate change impacts in the medium-term. A monitoring and early warning system must be developed to provide detailed information for flexible climate-informed decision-making, while identifying critical thresholds for action.

The approach is elegant and structured in five defined phases or steps to be taken, building sys-

tematically on one another. The phases (**Figure 2**) are described below:

**Step 1: Decision Context**

The focus of the climate change adaptation development needs to be clearly defined. This involves all-inclusive, stakeholder engagement to define key variables that need to be considered in subsequent steps. In practice, this step identifies the performance indicators that will be targeted in the adaptation process. These indicators will be selected by involving all relevant actors to ensure all required economic, social, and cultural elements are addressed. These consultations will also identify critical thresholds beyond which negative impacts are expected; these will be critical throughout the process. The development of a participatory environment is essential to ensure that the adaptation strategies adopted will address the needs of all sectors and give particular attention to the most vulnerable communities and persons.

**Step 2: Bottom-up Vulnerability Assessment**

Building on the critical indicators defined by the stakeholders in step 1, a detailed stress test will be applied to identify climate change impacts on the identified performance indicators, particularly, regarding water, food, and energy security. The stress test will start from the current condition by identifying the sensitivity of the region to climate variability and evaluate how climate change is expected to affect the performance indicators with respect to their critical thresholds. All 43 current Global Circulation Models (GCMs) will be used to assess uncertainty on the climate change projections. Combined with other uncertainties (e.g. population growth), the range of uncertainty will be accounted for in the subsequent steps of the process through the decision-making phase.

**Step 3: Formulate Robust and Flexible Adaptation Actions**

The recent water crisis demonstrated that potential adaptation actions have been identified: water basin transfers, additional groundwater extraction, and desalination (Ziervogel, 2019).[20] In the absence of adequate planning, however, the last two options could not be executed due to long implementation times and inflated costs. The CRIDA process identifies "adaptation pathways" that evaluate all potential options with respect to the results of the climate stress test in step 2, while incorporating uncertainty into the process. This helps identify those pathways as a combination of viable adaptation actions to provide solutions that ensure water, food, and energy security is met at all times.

**Step 4: Evaluate Alternative Adaptation Pathways**

20 Ziervogel, G. "Unpacking the Cape Town Drought: Lessons Learned." Report for Cities Support Programme Undertaken by African Centre for Cities. 2019.

While the previous step generated a portfolio of potential options to address climate change impacts, in this step a financial and institutional evaluation is developed to identify the best adaptation pathway under current conditions, combining robust and flexible adaptation actions. By identifying a long-term adaptation strategy, funding requirements can more easily be covered. Expensive solutions will likely be planned at a later start date in comparison with easier options in the short-term. Nevertheless, putting these costs in the planning process allows fundraising efforts to start earlier; this ensures viable implementation when contributions to offset climate change impacts is required. In this step, critical milestones are defined that require decisions to be made that are conditional to external drivers (e.g. rising temperatures or decreasing precipitation levels).

**Step 5: Institutionalise Decisions**

The last step of CRIDA ensures the integration of the decision framework into operational plans at the institutional level. This requires an effective mapping of governmental roles, mandates, and a review of financing options. Monitoring and evaluation are key components to ensure effective implementation of the adaptation pathway approach.

## Water Vision for 2050

The Economics Task Team's vision for water for 2050 highlights a need to shift how we value, use, and manage this key resource to ensure economic water resilience and sustainability in the province. As such, the aim is to achieve the following goals:

- The Western Cape has enough water to maintain and grow the economy, manage current water demand in all sectors, and plan for future demand to allow for survival and growth of the Western Cape economy. This is a balancing act between supporting augmentation programs and promoting water-use efficiency practices and technologies across economic sectors.
- Businesses value water as a finite resource, leading to world class water efficiency while maintaining/improving productivity. Understand that water is a finite resource and may become an even scarcer commodity under uncertain future climatic conditions. The whole of society should encourage sustainability, promoting a circular economy, technologies, and behaviours to ensure that we protect and manage our water resources efficiently and equitably.
- Businesses can be independent from municipal water supplies when necessary. Promote off-grid systems, hybrid centralized-decentralized systems in times of extreme water shortages, and limit the negative effects of water shortages. These off-grid systems should be feasible and sustainable as to refrain from negatively impacting other economic, social, or natural systems.
- All new builds incorporate water efficiency, storage, reticulation, treatment, and management into designs and build encouraging all new developments and construction projects

to incorporate aspects of water resilience, including the ability to store certain volumes of water, implementing efficiency systems, and technologies where appropriate. In addition, where possible, developing their own water reticulation and treatment facilities. Retrofitting water efficiency, storage, reticulation, treatment, and management systems into existing buildings should be a priority.

- Water-sensitive design and construction projects are the norm, stimulating the demand for water sector related products and services. Consider how we design and build our cities and towns to promote the use of ecological infrastructure, permeable materials, and the use of different water supplies to augment existing water supply and storage systems. These include concepts such as: sponge cities and the treatment and use of stormwater and effluent as alternative water supplies.
- The Western Cape hosts and attracts large-scale local manufacture and adoption of new or innovative water-related technologies, products, and services promote and attract the development and market for local water technologies that address water resilience not only in the Western Cape, but also nationally. All water-related products sold and services delivered in the Western Cape are as water efficient as possible.

## Assumptions

Economics is central to our understanding of value systems and guide us to make informed choices and decisions. Economics plays a fundamental part in the process of finding sustainable solutions to cities affected by escalating water shortages and will contribute to the body of research to be included in the W12 Framework. An economy is influenced by the choices made in the production, distribution, and consumption of goods and services. In essence it involves decisions and choices of all roleplayers in the economic ecosystem about how their value systems, needs, interests, and expectations can be fulfilled using the resources (i.e. financial, human, renewable or not) available to them.

While economic factors are also central to analyzing and addressing escalating water crises around the world, economy is more associated with extraction for maximum (personal) gains and less for providing stewardship; this is evident in the mounting social and environmental issues. After years of only incremental change in the corporate response to mitigate and contain risks to business-as-usual, there is an emergent shift to take the responsibility for working together with many different stakeholders to find a solution to a complex problem.[21]

## Focal areas specific to water and cities

The recent water crisis has reportedly resulted in the loss of 37,000 jobs in the Western Cape

21 Büchner-Marais, C. "Transformative Collaborative Governance towards sustainability: the case of the Stellenbosch River Collaborative". Sunscholar. December 2016, https://scholar.sun.ac.za/handle/10019.1/100298

Province and an estimated 50,000 people being pushed below the poverty line due to job losses, inflation, and increases in the price of food. This led to further social problems such as civil unrest and violence. Many of these job losses occurred in the agricultural sector which was obliged to cut its water use by 60% in 2017 and 2018. They were allotted 17% of the on field crop water requirements quota, causing smaller yields and an estimated economic loss of R5.9 billion (US $400 million), affecting 30,000 jobs and reducing exports by 20%, leaving many farming businesses vulnerable to bankruptcy.

The situation evidently calls for action, confirmed by diverse interested parties including national (e.g. DHSWS), regional (e.g. Western Cape Government), urban (Cape Town) and local actors (e.g. Stellenbosch River Collaborative). There is a clear need to address water resource challenges using a climate change adaptation framework, given the demonstrated anthropogenic influence on the drivers of the water crisis (Otto, et al., 2018), and the expectation that these climate change influences will further exacerbate (DEA, 2019).[22][23]

Concerns are emerging from various economic sectors that have already started witnessing the effects of climate change on production and operations. The insurance sector in South Africa confirms that some of these impacts are immediate (e.g. lower agricultural yields, declines in production and manufacturing due to less water supply/reduced water pressure) and this is therefore something businesses need to address in their current plans and strategies (NBI, 2018).[24] This will require businesses to use different design and investment criteria, adapt their business models, and design their organisations to be more responsive to variability, change, and ultimately become more economically resilient.

While some impacts of and responses to strengthen economic water resilience are generic to all businesses and economic sectors, certain economic sectors are more intense water users; consequentially, some are more vulnerable to water scarcity than others. In this light, it is important to understand and reduce water-related needs and risks to existing businesses in specific economic sectors in order to both reduce pressure on municipal water supplies and maximise opportunities for both existing businesses and new investments in these sectors (or sub-sectors). This not only enhances the water resilience of businesses, cities, and towns (water-stressed or not), but also increases the competitiveness of specific sectors and businesses. In addition, efforts to strengthen economic water resliance promotes the transition to a greener economy.

22 Otto, F. et al. "Anthropogenic influence on the drivers of the Western Cape drought 2015–2017." Environmental Research Letters, 13(12): 2018. p.124010.

23 National Planning Commission. "Our future - make it work. National Development Plan 2030." Department of the Presidency, South Africa, 70 p.

24 National Business Initiative, 2018. https://www.nbi.org.za/reports/nbi-iar-2016-to-2018/

When businesses start addressing their water-use issues, they invariably identify and resolve energy and material use issues as well. They start to look at their business differently and realize how they use resources and identify possible wasteful practices. This often leads businesses toward improved resilience overall, not just water resilience. This practice of resource auditing increases efficiency, promotes greater competitiveness—which can drive innovation for efficient technology and practices, and could drive down demand for water and other resources.

Despite many successes and areas of progress, both globally and locally, the economy remains locked into unsustainable resource supplies, systems, practices/operations, and investments. The move towards decoupling economic growth from increasingly degraded and scarce natural resources is still a long way from being realised. The latest International Panel on Climate Change (IPCC) report (2018)[25] indicates that global net human-caused emissions of carbon dioxide (CO2) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050. As part of this, renewables would need to supply 70 - 85 percent of electricity by 2050 to avoid the worst impacts of climate change. The changes required mean that we have only a decade left to completely rewire the global economy.

By not embracing a transition to a green(er) economy is essentially not an option for many local and regional economies in South Africa given increasing resource security challenges and costs, imminent waste crises, very high inequalities, increased urgency to mitigate and adapt to climate change and the poor state of many environmental factors. The green economy provides the Western Cape economy with a path towards building resilience to these and other challenges and, in the process, has the potential to provide significant economic growth and development opportunities. This pathway toward a greening of the economy will only be possible with multiple, committed partners and stakeholders.

## Best Practices

In order to promote and enhance best practice around economic water resilience in South Africa, WWF-SA (2017) suggests a number of measures:

1. South Africa needs to become a water-conscious country with sufficient knowledge and skills in the water sector.
2. Implement strong water governance with resilient stakeholder partnerships that advance the more explicit second phase of the National Development Plan to achieve water security under climate change.
3. Manage water supply and demand regulations more rigorously and protect water resources.
4. Become a water-smart economy and a leader in Africa in commercializing low-water technologies for industry and agriculture.

25 https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

The most significant risks facing society are the interconnected and unprecedented nature and impact of social and ecological systems. Failure of climate change mitigation and adaptation have strong links to extreme weather events, and water and food crisis, causing biodiversity and ecosystem collapse, natural disasters, manmade environmental disasters, migration, public health issues (spread of infectious diseases), loss of human life, livestock, and food security. The failure of regional, global, and national governance structures to deal with large scale social instability and conflicts, and unemployment and underemployment will reach a tipping point with unforeseen and unprecedented consequences. One such consequence is the migration factor as the drought takes its toll on the agriculture sector, causing more pressure on cities as more people will be crammed into shrinking tracts of habitable urban space.[26]

## Geographical scope for the case study/s: Western Cape

Situated on the south-western coast of South Africa, the Western Cape is the fourth largest province of nine provinces in South Africa covering an area of almost 130 000 square kilometres. It is also the third most populous province with an estimated 6.6 million inhabitants, of which two thirds live in the metropolitan area of Cape Town. The Western Cape Province governance is structured under a provincial government, its metropolitan municipality (City of Cape Town) and five district municipalities representing the Cape Winelands, West Coast, Overberg, Garden Route and Central Karoo, with 24 municipalities. The main river basins in the province are the Berg-Olifants-Doorn rivers catchment which includes the Eerste river catchment in the Cape Winelands, and the Breede-Gourits river catchment in the Overberg, and Garden Route. [27]

The City of Cape Town is the largest contributor to the provincial economic output (72.5 percent in 2016) while the districts of Cape Winelands contributed 11.2 percent. The private sector accounts for over 60 percent of the provincial economy and growth in 2016 was led by finance, insurance, real estate and the business services sector (+ 2.3 percent) followed by the wholesale, retail trade, catering and accommodation sector (+ 2.2 percent). This stands in stark contrast with the economic output in the agriculture, forestry and fisheries sector which declined by 7.2 percent, partly explained by droughts. The agricultural sector is a vital contributor and integral to the Western cape economy, playing significant role in generating value added to the economy, linking catchment wide upstream inputs and processing industries in the urban and municipal areas downstream. In 2017, fruit and wine exports generated around R37 billion in foreign income, making up about 30 percent of the total value of goods exported from the region. The agricultural value chains are key contributors to employment with 400 000 workers in the agriculture and agri-processing sectors, which also drives migration flows and population growth. The Western Cape is experiencing net immigration, and migration is expected to be strongly driven by stronger

26 The Global Risks Report 2019, 14th Edition. http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf

27 https://en.wikipedia.org/wiki/Western_Cape

economic outlooks, lower unemployment rates and less poverty compared to the rest of South Africa. Expectations project that approx. 1.3 million people will be added to the Western Cape´s population between 2018-2030, representing a total growth of 20 percent over 12 years, at an average of around 57 000 people each year, mostly from the Eastern Cape, abroad and Gauteng.[28]

The challenges caused by water shortages in the Western Cape are not confined to city boundaries. The Cape Metro is part of a much wider interdependent water system, which impacts on livelihoods, jobs, food security, natural systems and the economy .29 This water system includes key catchments such as the Berg, Eerste, Olifants, Doring, and Breede Rivers. These rivers and their catchment management areas are in local government jurisdictions such as the Stellenbosch, Drakenstein and Breede Valley municipalities, which are in close proximity to the City of Cape Town, as well as other municipalities falling within the Western Cape provincial boundaries. The different communities represented by the various local and district municipalities in these different water management areas all depend on and thrive from agri-related economic value creation in tourism and the export of their products.
Drought and declines in rainfall, as well as pollution of our freshwater systems[30] are ubiquitous and are a complex challenge31 in the Commons. These challenges require rallied action and initiatives to partner and cooperate to manage our water security. However, most of these initiatives and partnerships suffer because of budget constraints and budget cycles, clashing political agendas and election cycles and top-down government management approaches.[32] A Time article on Cape Town's water crisis claims that "the Cape Town crisis stems from a combination of poor planning, three years of drought and spectacularly bad crisis management".[33] There is a desperate need for a multi-actor, cross-sector collaborative governance network that can access and allocate funds[34] to implement and sustain bottom-up stakeholder-driven solutions within communities.[35]

The Western Cape Government (WCG) 2019 budget summary[36] cites the impact of climate

28 Provincial Treasury, 2018: Provincial Economic Review and Outlook 2018. Provincial Treasury of the Western Cape. https://www.westerncape.gov.za/assets/departments/treasury/Documents/Research-and-Report/2018/2018_pero_revised.pdf ISBN: 978-0-621-46680-5

29 Smith, Carin. "Poor water management is risk to land reform, agriculture forum hears." fin24 City Press, August 29, 2019, https://www.fin24.com/Economy/poor-water-management-is-risk-to-land-reform-agriculture-forum-hears-20190829

30 Kings, Sipho. "50000 litres of sewage flow into SA's rivers every second." Mail & Guardian, July 21, 2017

31 Lindow, Megan. "The many layers of Cape Town's water crisis." RE.THINK Feature, May 17, 2018, https://rethink.earth/the-many-layers-of-cape-towns-water-crisis/

32 Van der Merwe, Marilise. "Explainer: Everything you (n)ever wanted to know about the Cape's water crisis." Daily Maverick, May 18, 2017

33 Baker, Aryn. "What It's Like To Live Through Cape Town's Massive Water Crisis." TIME, 2018, https://time.com/cape-town-south-africa-water-crisis/

34 Felix, Jason. "Appeal for more drought funds." Cape Argus, December 7, 2017.

35 Smith, Carin. "Community input important in big business contribution to Africa's water challenges - Coca-Cola executive." fin24 City Press, May 18, 2019, https://www.fin24.com/Economy/community-input-important-in-big-business-contribution-to-africas-water-challenges-coca-cola-executive-20190515

36 Western Cape Provincial Treasury, 2019. The Western Cape Government 2019 Budget Summary, https://www.westerncape.gov.za/provincial-treasury/files/atoms/files/e2019%20Budget%20Summary.pdf

change (and the energy supply crisis) on agriculture and agri-processing sectors as one of the biggest risks to the provincial economy. Water supply directly impacts the sustainability of viticulture and the wine industry which contributes the lion's share to the Western Cape economy, considering the value chain that also links tourism to heritage sites and wine producing farms and private wine cellars.

The latest GreenCape Market Intelligence Report (MIR)[37] states that although agriculture contributes a relatively small share (2.5 percent) to the total gross domestic product (GDP) of South Africa, it is important in providing employment and bringing in much-needed foreign currency. This sector is estimated to contribute about 12 percent to the national GDP, taking into account the whole agricultural value chain. The agriculture sector was also the main contributor to overall GDP decline for South Africa, and can be larger considering the wider value chain, as agriculture is interconnected with the rest of the economy, as a large portion of agricultural output is used as intermediary production in other sectors such as food and beverages.

Estimates show that gross value added in the agriculture, forestry and fishing sectors shrunk by 21 percent in 2018, which also negative impacted on the directly linked agri-processing sector, which recorded a contraction of 8.4 percent in the period. The WCG responded to these identified risks, allocating millions[38] towards enabling the promotion and stimulation of a greener economy and a water-secure province by supporting the creation of opportunities for growth and jobs in agriculture and agri-processing sectors. However, the prolonged effects of the drought continued to impact the province that resulted in lower than anticipated economic growth, income and job creation The slow economic growth places pressure on an already constrained fiscal and business environment, especially in the tourism and agriculture sector .[39] The water dependent agriculture sector and related industries are extremely vulnerable and pressure to implement efficient water-use strategies are mounting on stakeholders, notably highly water-intensive companies, such as Distell.

## Distell case study

Headquartered in Stellenbosch in the Cape Winelands District, Distell is a global business with roots in South Africa and in joint venture and associate partnerships in countries such as Tanzania, Zimbabwe, Angola and Mauritius. Distell produces and markets a diverse portfolio of alcoholic brands, including Amarula, Savanna, Hunter's Dry, Durbanville Hills and Nederburg. Distell is one of South Africa's alcohol beverage producers with a global distribution network that

37 Kuschke, Inge and Cassim, Adila. 2019. "Sustainable Agriculture." The GreenCape 2019 Market Intelligence Report, https://www.greencape.co.za/assets/Uploads/SUSTAINABLE-AGRICULTURE-MIR-2019-WEB-01-04-2019.pdf

38 Western Cape Provincial Treasury. 2019. The Western Cape Government 2019 Budget summary, (https://www.westerncape.gov.za/provincialtreasury/files/atoms/files/e2019%20Budget%20Summary.pdf)

39 Western Cape Budget 2019/2020 at: https://www.westerncape.gov.za/provincial-treasury/news/western-cape-budget-201920

is supported by local production capability in South Africa, Scotland, Angola, Kenya and Nigeria. As of Financial Year 2019, 694 million litres were sold from more than 20 product categories.

Distell is highly water dependent throughout its supply chain, especially its manufacturing operations and therefore vulnerable to water quality and shortage of rainfall in the longer term – directly linked to the water-related vulnerabilities of the agriculture sector. Climate change and extreme weather events have a major impact on the South African grape and apple production and water crises disrupt production operations. A total of 90 percent of the wine used by Distell is sourced from cooperatives, with the remainder produced at Distell-owned farms.[40] The quality and quantity of its various water sources are key economic inputs, whichmaterially influence all the steps within the company's value creation model: from its business processes, resulting in its products and waste, the outcomes of those products and ultimately the impact on its collective stakeholders. Distell was materially affected by the extreme drought and is an example of the systemic approach taken to address both mitigation and adaptation to the water quantity and quality challenges. Key highlights of Distell's comprehensive water continuity plan[41] are provided below:

- An integrated water savings and behavioural change programme initiated at all manufacturing, distribution facilities and office facilities across the Western and Eastern Cape.
- Large investments made in water recycling and recovery technology at manufacturing plants.
- Contingency plans made for manufacturing and distribution facilities, based on local groundwater supply and, if required, transportation between facilities.
- All facilities and offices in the Western and Eastern Cape to be supplied by a group negotiated potable water contract, which includes the supply of water during a 'Day Zero' scenario.
- Alternative water supply solutions to be developed, including long lead time parts procured at the Stellenbosch office facilities.
- Flexible working assessed and addressed by local management, with concomitant policies and guidelines.

Suppliers are being risk assessed with mitigation actions to address such identified risks.

Distell is furthermore acutely aware of the importance of the health of the rivers it depends on for its operations and appreciates that the company is one of many parties dependent on this sensitive ecosystem. They understand that the complex challenge of water security and health needs a combined collaborative approach. Consequently, Distell collaborated as co-founder and anchor

40 LeongSon, Eric. "Distell company snapshot." Distell, 2018.

41 LeongSon, Eric. "Distell Water management & business impact." Distell Presentation, June 11, 2018

member of the Stellenbosch River Collaborative (SRC) with a variety of other stakeholders equally dependent on the river. The SRC is a group of diversified organisations and people, comprising business, academia, community, agriculture, non-profit organisations and government departments and agencies. They share the vision of restoring and maintaining the health of the rivers in the Eerste River Catchment and eliminating or mitigating the social and environmental risks of the degraded ecosystems for the communities, agricultural and other businesses and civil society dependent on the catchment.

The SRC formulated a bottom-up collaborative governance framework within which a wide group of stakeholders can create collective, fair and equal value through enabling transformational partnerships in a non-competitive space. This Collective draws on its broad range of skills and expertise, using sound research and science, to identify critical thresholds in, and drivers of change for the ecosystem. A bottom-up vulnerability assessment forms the basis the methodology to identify and develop alternative solutions which assists with robust decision-making.

The water quality issues, aggravated by the drought crisis, mobilised civil society and civic participation in the SRC, and new ways emerged in which the local people and organisations came together with government agencies to take action to restore the water quality in the rivers in and around Stellenbosch. This prepared the SRC stakeholders and members to be more resilient and collaboratively respond to the complexity and challenges of the drought crisis.

Key to the SRC's milestones and learning journey is the vision to develop a collaborative governance framework for influencing policy and enabling sustainable water stewardship strategies that is not limited to the Eerste River Catchment but across the province and eventually southern African region. The ongoing and unresolved pollution issues exposed the limitations of traditional top-down water quality governance models. The severity of the water crisis and crisis management (i.e. to ensure that water continues to flow from taps) proved that the existing formal governance structures struggle to engage people more deeply in sharing a collective sense of responsibility for water. This existing system is hardly capable of enabling action or supporting the implementation of innovative interventions without political strife and public distrust in the agendas.

In this context, the SRC already proved its value and successes to engage with and encourage multi-stakeholder collaboration to effectively enable local water governance as was intended through Catchment Management Agencies (CMAs), prescribed in the National Water Act of 1998. This resulted in the Collaborative Governance Network for water security in the Eerste River Catchment, as one of the new forms of water governance that have started to emerge against the backdrop of water quality issues and in the new context of the drought crisis.

## The Stellenbosch River Collaborative (SRC): Save our freshwater resources

Launched in 2013, the SRC brought together like-minded organisations and people to deal with the impact of the deteriorating water quality on society, economy and the environment in the catchment collaboratively. The rivers in the catchment have many sources and courses and are interweaved in the social and economic fabric of Stellenbosch. Dealing with the deteriorating water quality is therefore the responsibility of many different stakeholders, from every sector of the Stellenbosch community, to work together to find solutions to a very complex problem. Distell and Spier (a local winery) recognised this responsibility and not only stepped up as co-founders and key players in the SRC, but also as co-chairs of the SRC. This brought together industry, government agencies, a water board, conservation and community-based organisations, academic institutions, NGOs and NPOs.

Governance systems play a prominent role in sustainable development trajectories, but the traditional methods and transactional approaches are incompatible with sustainable governance requirements. We draw on narrow understandings of governance to deal with the intractable sustainability challenges that we are currently facing when looking for responses to governing the problems of the commons. Public-private partnerships are the preferred vehicle to deal with this challenge when the private sector and public sector join forces to collectively address issues such as drought. This means that the two sectors meet each other from their respective 'self-preservation' understandings, in a top-down approach, and at best in a polycentric approach which has its limitations in certain contexts.

The private sector actors frame their responses in terms of risk mitigation with an emphasis on sustaining business, strictly keeping to compliance criteria while avoiding political dramas and agendas. The state and relevant government agencies also frame their responses in terms of risk mitigation, with an emphasis on mandate, control and sanction rights when an issue flares up or a crisis strike, which translates to punitive/higher tax rates, crisis management, costly public relations events and media releases, re-prioritising election undertakings and re-allocating budget and supply – all of which are a root cause for deep distrust by businesses and communities towards the government's ability and capacity to execute and deliver within budget, and on time. And the outcome is almost always short of what was aimed for, because budget and funding falls short, a new election is underway. Some legal processes (e.g. environmental impact assessments (EIAs)) are very expensive and can be lengthy, implementation therefore cannot be completed within the same budget cycle, new issues become more important, and public blame shifting and a high turnover of staff in the public sector further erodes trust in the public sector.

The SRC was framed to bridge the divide between the two approaches. A governance approach was framed collaboratively by private sector and the relevant public sector agencies to collectively take full responsibility for the water quality issues in rivers in the Eerste River Catchment.

By framing the catchment and its rivers as a biosphere-based understanding of sustainability enabled the actors from the public and private sectors to collaboratively develop a governance response that draws on the socio-ecological systems (SESs) thinking and complex realities.

Sustainable development challenges cannot be limited to contain and control strategies and the only way is to collaborate in ways we see fit to develop sound relationships and trust in order to combine resources to overcome the gaps in our understanding created by fragmentation. In polycentric systems, relationships among multiple levels and different spatial and temporal scales determine whether SESs are sustainable or unsustainable. top-down governance approaches that work well in homogeneous settings. A polycentric governance approach assume legitimacy, which is a fundamental requirement for multiple stakeholder cooperation.

Based on these limitations a bottom-up, cross-sector Transformational Collaborative Governance (TCG) response and approach was justified based on a relational transformation process between the public sector and private sector actors. A TCG response is more suitable for the developing country context where SES stakeholders from heterogeneous systems do not necessarily enjoy a formalised representative legitimacy.

Since its launch, the Collaborative has gone from strength to strength, increasing its efforts to not only drive river rehabilitation with research projects, but also transformational relations research projects between government agencies and communities at Stellenbosch University. Key to the SRC's success is the ambition to develop a collaborative governance framework for influencing policy and enable sustainable water stewardship strategies, not limited to the Eerste River Catchment but across the province and eventually South Africa. This led to the launch of Co-Go, the Collaborative Governance Network initiative at the Stellenbosch University Water Institute in November 2018.

## Co-Go: The Collaborative Governance network mediating collaboration for water security in river catchments

Co-Go focus on place-based transformational partnerships that bring together a broad network of stakeholders under a common purpose. Clean rivers in water stressed environments requires a coming together of different resources, and community activations and knowledge exchanges. Co-Go is about bringing together civil society, municipalities, academia and the private sector in a non-competitive environment in partnerships within specific water catchment areas to create fair and equal value for the benefit of a broad range of stakeholders.

Co-Go provides a collaborative space within which decision-makers and community leaders across sectors and industry can connect and engage to take action in our river catchments. Co-Go uses

science-based learning platforms and community of practice to inspire innovative solutions, develop new ideas, relationships, and commitments to turnaround strategies with sustainable links between environment, society and government within specific water catchment areas. Distell is an anchor founder with the Stellenbosch University Water Institute (SUWI) for the Eerste River Catchment area, setting the tone for collaborative governance in/of the commons using corporate investment for sustainable social impact (in the Commons).

The ambition is to formalise Co-Go by means of the establishment and registration of a cooperative in terms of the Co-operatives Act, 2005, as amended by the Co-operatives Amendment Act, 2013, which legal entity will house the members and shareholders of the collective, and lay down the provisions according to which Co-Go will operate. Since Co-Go is focused on creating water security within a specific river catchment area, thus being place-based, the ambition includes the expansion of the unique collaborative governance approach, to many other river catchment areas, which will result in the organic growth of the Co-Go model with the registration and establishment of further Co-Go's in regions across South Africa, and potentially wider.

## City conclusions

Cape Town narrowly avoided a Day Zero scenario. Many cities around the world are facing a similar fate. The fear of realising Day Zero introduced drastic measures and expensive technology accompanying an aggressive water rationing and behaviour change campaign as well as pressure management measures. While Day Zero mitigation strategies saw the development of very necessary innovative solutions, Capetonians also experienced how different sectors of society struggled to understand each other's viewpoints, frustrations and ideas, especially as dams and rivers ran dry and the rate of water withdrawal jeopardised our natural freshwater resources, and food security.

The severe impacts of prolonged drought in the Western Cape in 2017 and 2018 (and still persists in 2019 in many parts of the province) highlighted the vulnerability of the Cape Town area to water scarcity, a condition which is expected to worsen considerably under projected climate change scenarios which see a hotter, drier and windier future. The analysis, one year after almost reaching 'Day Zero', indicates a cogent need to include climate change impacts across short-, medium- and long-term water planning.

The Agricultural sector as major water-user, was also extremely affected by the drought. Water restrictions were implemented in the Western Cape due to the severe drought experienced in recent years which caused extremely low capacity in dams throughout the Province. During the 2017/2018 season the urban water allocations from the Western Cape Water Supply System to the urban sector, including the City of Cape Town, was curtailed by 40 percent and to the agricultural sector by 60 percent from the System. Due to the fact that agriculture must carry the losses in the

rivers used as conduit for irrigation, actual restrictions in the Berg River allowed only 17 percent of the on field crop water requirement quota.

The water crisis created significant concerns for and impacts on businesses across many economic sectors in the Western Cape. By example, due to the impact on the agricultural sector, some agri-processing businesses were forced to import their raw materials from outside of the Western Cape (at increased cost), others closed down production lines in order to meet the water restrictions imposed.

Water has a large input into the agriculture value chains. The increasing demand for water resources has implications for agriculture in particular. This is because water for human consumption and for industrial production is perceived as a higher value use of water that requires increased levels of supply assurance. During drought years agriculture is the first industry to face abstraction reductions. This has implications for the higher production rates brought about by the use of irrigation with a chain reaction to food production, processed food security and exports. The effect of water shortages with resulting reduced agricultural production can lead to less products or lower quality products for processing and value adding.

The agriculture and agri-processing sectors are highly dependent on a consistent supply of water for the production of goods and services. This water needs to be of a high quality, and in many cases, the use of non-potable or low quality water is not permitted due to health and hygiene standards. The high level of impact as a result of the drought was of great concern, with many being acutely aware that water challenges may be the new normal given climate change projections.

Water resilience in the economic context entails agriculture as a business having: enough water for economic growth; sufficient water security to maintain current operations, maintain and grow economic competitiveness and provide sufficient investor confidence; and improved adaptive capacity to be able to stave off future water shortages.

The City of Cape Town joined the cities of Amsterdam and Jakarta, partners from business, religious groups, government, NGOs and the Amsterdam International Water Week to participate in a value-driven dialogue about water in times of climate change. This dialogue was hosted by the Vrije Universiteit and the Ecumenical Patriarch in close collaboration with the United Nations interagency taskforce on religion. The City delegation was represented by the City, UCTs Future Water Institute, SU's Water Institute, Archbishop Thabo and the Western Cape Government. Worldwide, as in South Africa, it is clear that governments now rely on partnerships for funding and the successful development and implementation of initiatives.

## Conclusion

The mandate of the South African Government to deliver better quality of life and to ensure that all citizens have access to adequate services provided and managed within a sustainable environment, remains one of the government's biggest challenges. While it is essential for policy- and decision-makers to understand and take action on water stress at a national level, water is inherently a local and regional issue as the recent drought in the Western Cape showed us.[42] Furthermore, a lack of capacity and skills, and even at times political will, has restricted the government at all levels in its ability to effectively enable local water governance as was intended through Catchment Management Agencies (CMAs), prescribed in the National Water Act of 1998.

It is increasingly clear that we have to reconfigure everything we know, understand and do regarding our water. Globally, there is a rise in efforts at collaborative governance to navigate these complex challenges together at the local level. These initiatives are diverse and are initiated by various parties, with industry emerging as a key participant. The old ways and systems of governing the commons within society do not work anymore. Our transactional approaches are failing us in addressing the persistent challenge of 'governing the commons'. The rate of change is now driven more rapidly by cohesions of various forces including civil society, entrepreneurs, progressive corporations, a progressive state, and innovators and investors who are emerging new institutional forms that are neither market-centric or state-centric.[43]

The ultimate goal of the Economics Task Team is to produce a position paper which will be used to develop the consolidated W12 Framework document. The main agenda of the Economics Task Team will be to synthesise and analyse responses to the position paper into a set (or sets) of best practices or principles that can help promote collaborative work within industry and the agriculture sector in interaction with the other sectors mentioned above.

42 World Resources Institute, August 6, 2019, https://www.wri.org/our-work/project/world-resources-report/wrr

43 Prof Mark Swilling response to Greenpop, Spier, 23 July 2019.

# Technical Science Position Paper

*Initially prepared for the Cities Facing Escalating Water Shortages conference at the University of the Western Cape, January 2020.*

Lead authors: Kirsty Carden and Jessica Fell

Version: January 07, 2020

## Executive summary

Water scarcity is increasingly prevalent in cities around the world, driven by multiple intersecting factors such as climate change, rapid population growth, and pollution. There is an urgent need for an alternative water resource management and planning paradigm that entrenches sustainability, resilience, and integrated approaches in day-to-day city water practices. Water secure cities move beyond the goal of simply ensuring the provision of water services, to the creation of diversified, resilient water systems and livable urban spaces with due consideration of the urban environment, and the catchments contributing to these systems.

The Technical Sciences task team focuses on the technical elements of ensuring water security in cities within the context of escalating water shortages. This is centered on the provision of resilient, sustainable, equitable, diversified, and regenerative water services. A holistic definition of water security is adopted that incorporates both technical and non-technical elements, i.e. "*water security is not simply a state of adequate water but rather a relationship that describes how individuals, households, and communities navigate and transform hydro□social relations to* ***access the water that they need*** *and in ways that* ***support the sustained development of human capabilities and wellbeing*** *in their full breadth and scope.*"

The Technical Sciences task team's vision for 2050 incorporates a paradigm shift in water resource planning and management to ensure urban water security. Five positions related to technical elements and capacities that are crucial for cities facing escalating water shortages are presented:

1. A clear vision and detailed water strategy are vital to building resilience.
2. Planning and managing an integrated water system is a fundamental in the face of an escalating water crisis.
3. Access to appropriate and timely data is imperative for predicting and managing escalating water crises.
4. An enabling governance, political, and legislative environment is needed to support the tran-

sition to water secure cities.

5. Sufficiently capacitated transdisciplinary teams with adequate technical skills and representation are required to manage water secure cities.

The concepts and principles of "Integrated Urban Water Management," "Water Sensitive Urban Design/Water Sensitive Cities," and "IWA Water Wise Cities" are used for their integrated approaches. We consider the multiple and interdependent drivers of scarcity in the following terms: quantity, quality, access, and economics.

Various questions have been categorized under the five positions, and provide cities with a means of prioritizing challenges and actions when facing an escalating water shortage. These include: "Is end-of-pipe treatment outdated?", "How can technology be utilized to add value to and upgrade existing systems, particularly around asset management?", and "What stakeholders need to be involved when developing a water vision and strategy?" We present case studies from a selection of cities that are facing/have faced water shortages and the approaches they have adopted. These include some of the lessons learned from Cape Town's response to the water crisis, China's "Sponge Cities" approach, Singapore and their WSUD philosophy that incorporates the notion of "Four taps," the wastewater reclamation/direct potable reuse scheme in Windhoek, Namibia, and a stormwater to potable system in Australia.

## Introduction

Water scarcity is increasingly prevalent in many cities around the world. Climate change is shifting the regional availability of water, along with the impacts of industry, agriculture, and non-existent or dysfunctional sanitation systems. Shifting population dynamics and land use changes complicate already complex water challenges facing cities who strive to ensure water security. In this age of uncertainty marked by escalating water shortages, there is an urgent need for a new water resource management and planning paradigm that entrenches sustainability, resilience, and integrated approaches in day-to-day practices (Taing *et al.,* 2019). To ensure urban water security, responsive and adaptable water resource systems need to be built upon a foundation of sound technical principles and elements. This includes an integrated view of the entire urban water cycle and a new relationship with water that moves away from centralized water provision its related management models. The creation of water secure cities moves beyond the goal of the provision of water services, to the creation of diversified resilient, water systems, livable urban spaces, and due consideration of the urban environment.

Taking this view of a water secure city, the Technical Sciences task team focuses on the technical elements of ensuring water security within the context of escalating water shortages. This is centered on the provision of resilient, sustainable, equitable, diversified, and regenerative water services (hereafter referred to as "resilient water services"). A holistic definition of water security

is adopted that incorporates both technical and non-technical elements, i.e. "*water security is not simply a state of adequate water but rather a relationship that describes how individuals, households, and communities navigate and transform hydro-social relations to* ***access the water that they need*** *and in ways that* ***support the sustained development of human capabilities and wellbeing*** *in their full breadth and scope"* (NPC, 2019).

## Water Vision for 2050

The Technical Sciences task team's vision for 2050 is for a paradigm shift in water resource planning and management to incorporate resilient water services and ensure water security. With this vision in mind, and drawing heavily on the lessons learned from the Cape Town drought, the following technical elements and capacities are crucial for cities facing escalating water shortages:

1. A clear vision and detailed water strategy are vital to building resilience.
2. Planning and managing an integrated water system is fundamental in the face of an escalating water crisis.
3. Access to appropriate and timely data is imperative for predicting and managing escalating water crises.
4. An enabling governance, political, and legislative environment is needed to support the transition to water secure cities.
5. Sufficiently capacitated transdisciplinary teams with adequate technical skills and representation are required to manage water secure cities.

## Assumptions

### Overview of task team approach

The technical elements of ensuring water security include: the provision of water services, identifying and developing future water sources for growing populations, operation and maintenance of water and sanitation infrastructure, water quality management, water conservation and water demand management, and climate change resilience. These elements are considered in the context of the five technical elements and capacities indicated above (i.e. a water vision and strategy, optimized technical water resource management, access to data, an enabling governance, political and legislative environment, and skilled transdisciplinary decision-makers).

The team considers water scarcity not only as it relates to resources that are insufficient to meet demand (i.e. quantity) but also related to the scarcity of water of suitable quality for its intended use. We consider the scarcity of access to water and highlight the need for equity as a necessary principle to build sustainable water systems (Taing *et al.*, 2019). Economic water scarcity is also addressed: human, institutional, and financial capital factors limit access to water despite its local and natural availability to meet human demands (Molden & de Fraiture, 2010). Thus, identifying

ways to ensure water security involves developing a high assurance of supply in the face of climate change, the management of water quality, the consideration of equity and access issues, and the human, institutional, and financial capital factors necessary for water services.

Our approach is closely linked to the concepts and principles of "Integrated Urban Water Management" (IUWM)[44], "Water Sensitive Urban Design/Water Sensitive Cities" (WSUD/WSC)[45], and "IWA Water Wise Cities."[46] These approaches emphasize addressing uncertainty through building resilience into water management systems and the need to plan for extreme events as a "new normal." They speak to the need to integrate planning and management mechanisms; i.e. planning for uncertainty involves developing new water supplies, enhancing governance systems, and exploring innovative approaches. The notion of diversifying a city's water supply to build resilience by including alternative water sources such as groundwater, desalinated seawater, and treated effluent to reduce dependence on a single supply source is central to our approach. We incorporate social and environmental factors, addressing attitudes and behaviors toward water to ensure the management of environmental and ecological elements are addressed. In addition, our approach accounts for the integration of urban sectors such as such as land, housing, energy, and transport, and the linkages therein.

In order to illustrate the potential pathways towards resilient water services, the urban water transitions framework posited by the concept of WSUD, is presented **(Figure 1)**. The framework highlights the transitions of a city on the journey to becoming a water sensitive city. This is a useful roadmap to show the dominant socio-political drivers and service delivery functions of each state and the way previous states influence and shape subsequent states. As a city moves from one state to the next, particularly from a "Drained City" onward, there needs to be a socio-technical overhaul of conventional approaches (Wong & Brown, 2009). This echoes the new water resource management and planning paradigm that entrench the sustainability, resilience and integrated approaches advanced by the Technical Science Task Team throughout the position paper.

44 IUWM combines the management of water supply, groundwater, wastewater and stormwater (Fletcher et al., 2007), and considers the roles and interactions of the various institutions involved in management of the urban water cycle (Rogers, 1993).

45 "In its broadest context, WSUD encompasses all aspects of integrated urban water cycle management, including water supply, sewerage and stormwater management. It represents a significant shift in the way water and related environmental resources and water infrastructure are considered in the planning and design of cities and towns, at all scales and densities. WSUD is now often used in parallel with the term water sensitive cities. However, there is a subtle but important distinction between these two terms; WSC describes the destination (the objective), while WSUD describes the process" (Fletcher et al., 2014)

46 The IWA Principles for Water Wise Cities ensure that water is integrated in planning and design in cities to provide increased resilience to climate change, livability, efficiencies, and a sense of place for urban communities. The ultimate goal is to encourage collaborative action, underpinned by a shared vision, so that local governments, urban professionals, and individuals actively engage in addressing and finding solutions for managing all waters of the city. See https://iwa-network.org/projects/water-wise-cities/

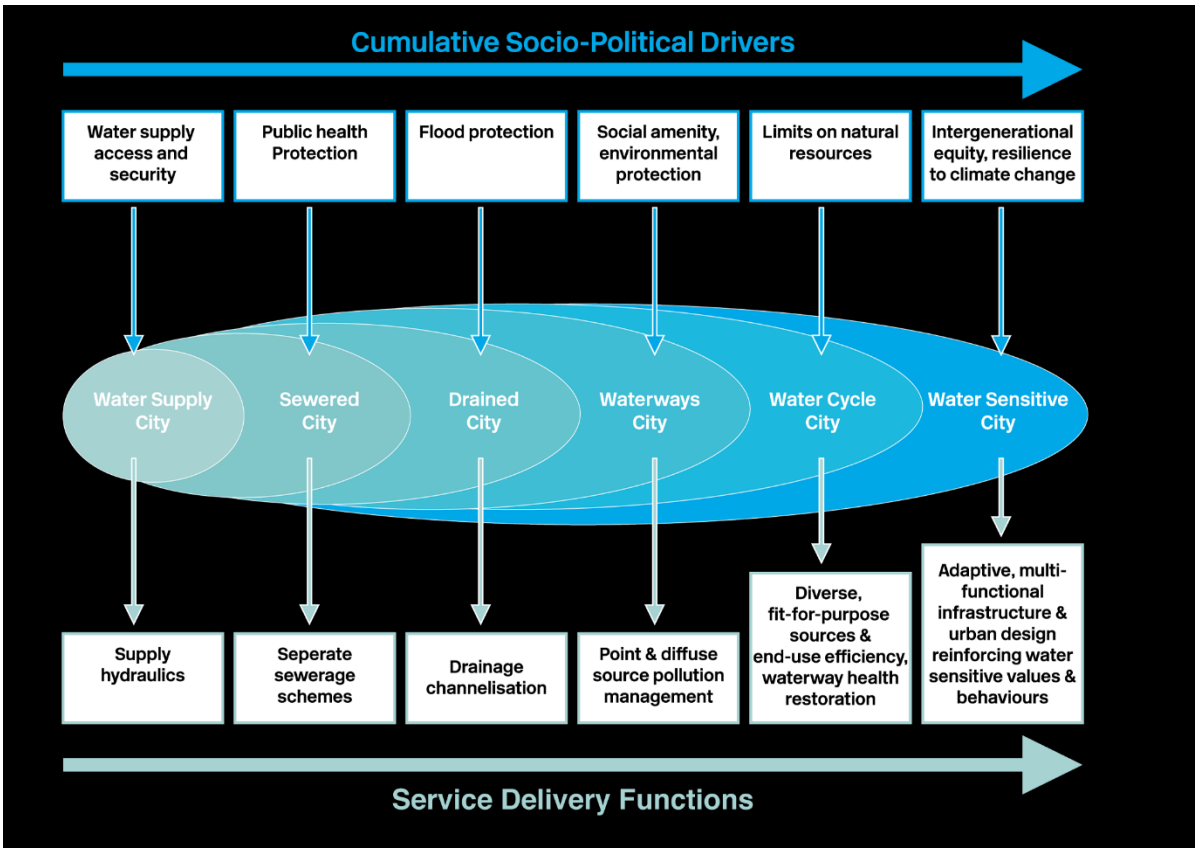


**Figure 1. The urban water transitions framework (Brown *et al.*, 2009)**

## Drivers of water scarcity

The provision of adequate water services in an age of climatic and land use uncertainty, alongside complex social, political, economic, and environmental factors, is undoubtedly challenging. The global prevalence of urban water scarcity, including the scarcity of quantity, quality, access and economics, is driven by many interrelated factors. This is due, in part, to the fact that water scarcity is a complex phenomenon to define and monitor, given the many types of scarcity. For instance, there are four types of drought (with drought constituting physical water scarcity): (1) Meteorological drought, which is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period; (2) Hydrological drought, which is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e. streamflow, reservoir and lake levels, groundwater); (3) Agricultural drought, which links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and so forth; and (4) Socio-economic drought, which associates the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought (University

of Nebraska National Drought Mitigation Centre. Types of Drought, n.d.).

Given the complexity of water scarcity, some prevalent drivers include: population growth and demographic changes, rapid urbanization, rapid economic growth, and rising income levels–with a growing middle class being "thirstier" than lower income classes, increased demand for energy and food, leaks and losses from the water system, climate change and its impacts on quantity and quality, and the socio-economic risks of climate change (Brears, 2016)(Figure 2). Ensuring water security through resilient water services in the face of such complex and interrelated water scarcity drivers, thus calls for an integrated approach. Also, as we move towards resilient water services, there is an increasing complexity of water systems with more feedback loops. For example, if treated effluent is used as a potable water supply source, the acceptable levels of risk begin to change (and need to be meticulously managed), and issues of perception and acceptance come to the fore. It is imperative that these new considerations and risks are given due attention in order to facilitate the necessary water paradigm shifts.

**Definition of water security**

UN Water defines water security as "*the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.*" Several other definitions have been put forward, however all are characterized by common strands that include a focus on (NPC, 2019):

- Access to a reliable source of potable water for basic human needs or domestic use ensures resilient communities. In South Africa, this is enshrined in the Bill of Rights in the Constitution and forms part of the definition the Reserve
- Provision of adequate water supplies for productive activities and livelihoods
- Environmental sustainability, preservation of ecosystems, and continuation of services that nature and people require—including the provision of freshwater. This also forms part of the Reserve and is a Constitutional right
- The risk associated with the presence or absence and reliability of water supply

The team recognizes that water security incorporates both technical and non-technical aspects and thus adopts the following holistic definition:

*"...water security is less about obtaining water, and more about fostering* ***human capabilities as they relate to wate****r... We thus ask: What are the social, cultural, and political relationships with water resources and flows that advance a life that fosters human dignity? And, how are those relationships secured to facilitate the freedom to achieve wellbeing, fulfilling social*

*arrangements, and human flourishing? … water security, then, is not simply a state of adequate water – however defined – to be achieved, but rather a relationship that describes how individuals, households, and communities navigate and transform hydro-social relations to* ***access the water that they need*** *and in ways that* ***support the sustained development of human capabilities and wellbeing*** *in their full breadth and scope"* (Jepson *et al.*, 2017).

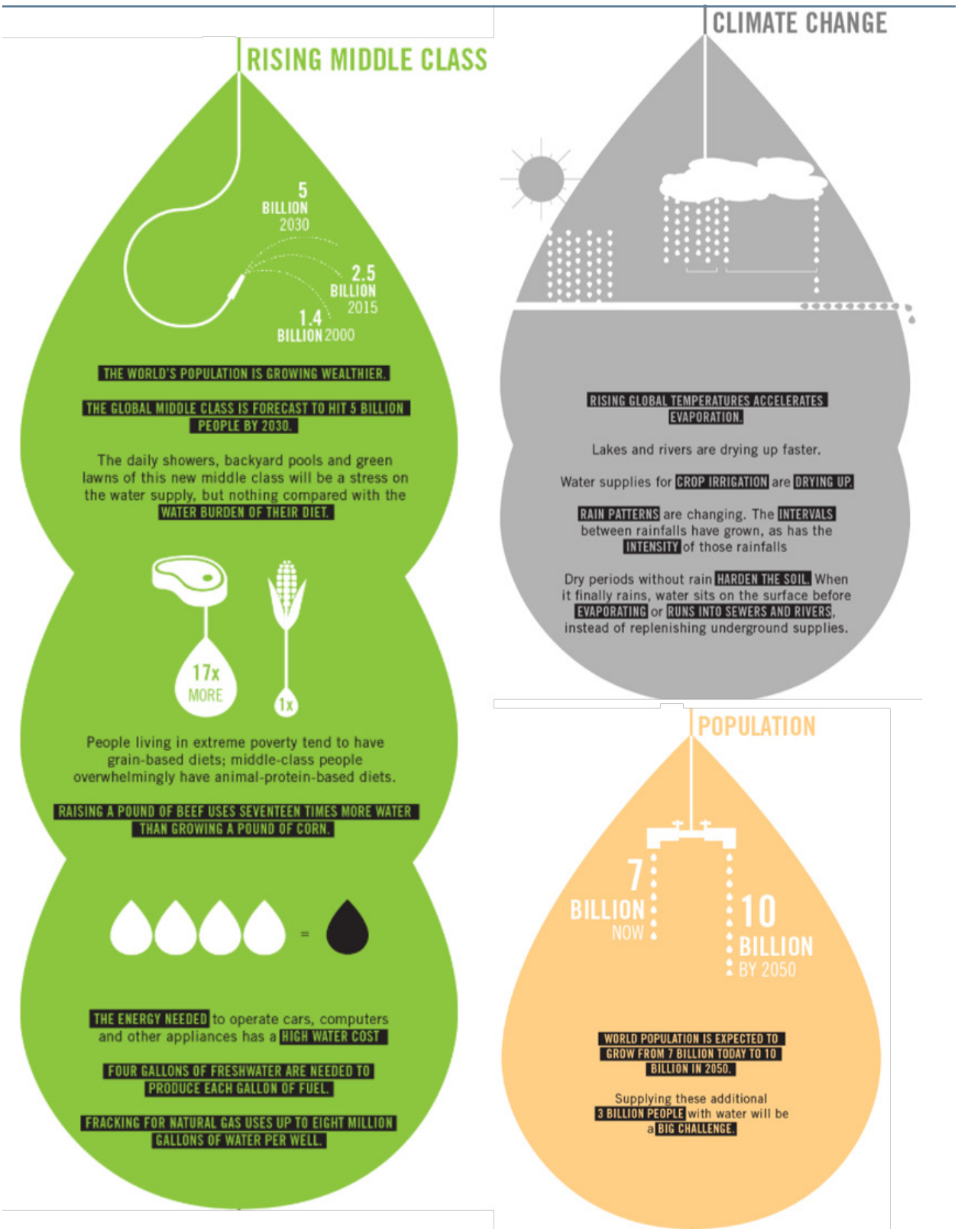


**Figure 2. Selection of water scarcity drivers (Adapted from Siegel, 2016)**

## Five positions crucial for cities facing escalating water shortages

The Technical Sciences task team suggests the following five positions that need to be adopted by cities in order to address escalating water shortages.

**Position 1: A clear vision and detailed water strategy are vital to build resilience**

A clear vision as well as a detailed water strategy are both necessary to articulate water resource planning and management approaches, including the operationalization of a WSC, and planning for the management of demand at different levels of risk (e.g. through a disaster risk response plan). A shared vision underpins the transition to resilient water services. The IWA Principles for Water Wise Cities identify a shared vision as one of the five building blocks to deliver sustainable urban water systems. The document outlines three points pertaining to a shared vision: (1) a shared vision moves stakeholders from defending solutions for their own specialties, to defining a set of common drivers for the greater benefit of the urban community, (2) a shared vision is an essential prerequisite for ensuring sustainable reforms and implementation of new policies and strategies, and (3) a resilient city vision that incorporates water enables people to work together at different scales and across disciplines. It supports the political will needed to invest in long-term measures. It provides consistency beyond political cycles (International Water Association, 2016).

With a clear shared vision, a detailed water strategy outlining key actions to plan and manage a city's short and long-term water needs can be created. A strategy articulates how to provide secure water services in an age of uncertainty, with primary focus on water supply security but also broader social, economic, environmental and governance issues. The strategy must apply to all parties responsible for water management at different scales (e.g. municipal/local government), catchment-based, and national government. The roles and responsibilities of the many role players and different stakeholders need to be carefully formulated. Within the strategy, attention should be given to the specific context of the city, including considerations of a hydrological nature as well as exploring social, economic and governance perspectives. Governance perspectives and processes, in all spheres of government, are particularly important in ensuring a water strategy gains traction within a city.

A strategy requires a clear roadmap with realistic timelines for implementation and operationalization purposes. This roadmap and timeline have to be effectively communicated to relevant stakeholders. For example, the City of Cape Town has recently developed a new, progressive water strategy with five main commitments (see text box below) and long-term goals based on the best available current data but yet to develop an implementation framework for the realization of these commitments (CoCT, 2019). In addition, there remain many different stakeholders, including government (particularly national government); roles and responsibility mandates need to be carefully formulated to ensure implementation.

## Cape Town water strategy - FIVE COMMITMENTS

1. **Safe access to water and sanitation.** The City of Cape Town metropolitan municipality1 will work hard to provide and facilitate safe access to water and sanitation for all of its residents in terms of well-defined minimum standards. In particular, the City will work with communities in informal settlements and with other stakeholders to improve the daily experience of access to water and sanitation, with an emphasis on building trust and increasing safety within these communities through this process.

2. **Wise use.** The City will promote the wise use of water by all water users. This will include promoting water conservation behaviour through (a) pricing water based on the cost of providing additional supply, while retaining the commitment to provide a basic amount of water for free for those not able to afford this; (b) revising by-laws and planning requirements, and using other incentives to support water efficiency and the treatment and reuse of water; (c) supporting active citizenship by substantially improving customer management and engagement; and (d) managing the water network effectively to reduce losses and non-revenue water.

3. **Sufficient, reliable water from diverse sources.** The City will develop new diverse supplies of water – which could include groundwater, water reuse and desalinated water, cost-effectively and timeously to increase resilience2 and substantially reduce the likelihood of severe water restrictions in future. The City is committed to increasing supply by building affordable new capacity of approximately 300 million litres per day over the next ten years, and in suitable increments thereafter, in a way that is adaptable and robust to changes in circumstances.

**4. Shared benefits from regional water resources.** The City will work with key stakeholders and partners, including other urban and agriculture water users, and other spheres of government, to make the most of the opportunities to optimise the economic, social and ecological benefits of regional3 water resources, and to reduce the risks. The City will do this through collaborative processes.

**5. A water sensitive city.** The City will actively facilitate the transition of Cape Town over time into a water sensitive city with diverse water resources, diversified infrastructure and one that makes optimal use of stormwater and urban waterways for the purposes of flood control, aquifer recharge, water reuse and recreation, and is based on sound ecological principles. This will be done through new incentives and regulatory mechanisms as well as through the way the City invests in new infrastructure.

As will also be outlined in further detail in the sections to follow, it is suggested that the following aspects be considered and included in any City water strategy:

- Incorporation of circular economy approaches
- Consideration of aspects of redundancy (of water resource infrastructure, for example) over long periods
- Multiple feasible back-up plans on how to provide potable water when taps are close to running dry
- Development of a holistic and integrated city-wide water balance which also highlights the potential to use the city as a catchment, if appropriate - including the inclusion of alternative

water sources and multi-functional infrastructure that supports hybrid (i.e. both centralized and decentralized) water supply systems that ensure livable cities whilst protecting the environment.
- Models for revenue generation that ensure financial sustainability when demand from the reticulated potable system decreases as a result of people and companies switching reliance onto alternative, decentralized water resources
- The inclusion of fourth industrial revolution (4IR) technologies; e.g. for performing informed maintenance on water infrastructure and assets
- Support for an engaged citizenry that is educated on water
- Targeted and digestible communication strategy based on high resolution smart data to foster trust
- Plans for working within the bounds of governmental bureaucracy at all levels
- Technical details of alternative water resources; specifically, wastewater re-use and how to plan for a city that re-uses wastewater
- Consideration of the economic value of water and ecosystems as ecological infrastructure, whilst acknowledging issues of equity and human rights.

**Position 2: Planning and managing an efficient integrated water system is fundamental in the face of an escalating water crisis**

As will be discussed in further detail later in this paper, one of the most important lessons to emerge from the Cape Town water crisis was that the current water management paradigm of linear technology-centred and resource-intensive approaches needs to shift to more water sensitive approaches that are cyclical and human-centred. This includes the development of new governance mechanisms and the diversification of water supplies to provide resilience to potential climate shocks (Taing *et al.*, 2019).

Integrated Urban Water Management (IUWM), Water Sensitive Urban Design/Water Sensitive Cities (WSUD/WSC) and the IWA Principles for Water Wise Cities are examples of approaches that have been formulated in response to the complexity of urban water management challenges worldwide. They all address the technical and institutional aspects of planning and design, with the key to their success being collaborative actions underpinned by shared visions, and integration at each stage of the planning process. This means that technological solutions for water management can be advanced while the attitudes and behavior of individuals and society towards scarce water resources can be simultaneously modified (Brears, 2016). The concept of IUWM has already been well-established in many cities around the world where it is acknowledged that "*implementing efficient and flexible urban water systems and adopting a holistic view of all components of the urban water cycle (water supply, sanitation, stormwater management) is essential for providing environmentally sustainable growth and access to better services…*" (Jacobsen *et al.*, 2017).

In particular, these approaches recognize that actions that improve urban water systems extend beyond just improving water quality and managing quantity to maximizing water's many environmental, economic and social benefits equitably. These include: improving water supply and demand efficiency (including through water conservation and water demand management, WCWDM); ensuring adequate drinking water quality and wastewater treatment; improving economic efficiency of services to sustain operations and investments for water, wastewater and stormwater management; developing high assurance of supply by using alternative water sources; engaging communities in the decision-making process of water resources management; establishing and promoting water conservation and other water education programs; and supporting capacity development of personnel and institutions that engage in water services management (Brears, 2016).

In line with similar recommendations for programmatic areas of intervention to address water security for the Gauteng City-Region (Muller et al., 2019), the following are some of the aspects that should be considered when adopting an integrated water management approach in cities:

- Whilst water "consumption" is an accepted term as an indicator of demand, it implies that water is 'consumed' whereas it is not; almost all water that is used is available for re-use, theoretically indefinitely. The key consideration is not so much water quantity but quality, making 'water use' a more accurate term. Given adequate control of water quality, there is adequate water quantity for all forever through recycling. Diversification of supply sources to allow for the use of treated wastewater, stormwater, groundwater etc. must therefore follow a 'mass balance' approach to support water quality modelling to guide policy interventions.
- Urban water demand should be significantly reduced – both in terms of per capita water use (which is unsustainably high in many regions of the world), as well as from losses in the reticulation system between source and the final supply. Ultimately, a target per capita use in the order of 100 liters (net) per person per day is achievable – as has been demonstrated in Cape Town since 2017. The reduction of unaccounted for water should be made a key priority for all cities with a view to keeping losses to less than 10%.
- Comprehensive city water balances need to be developed to enable better understanding and management of existing infrastructure and resources, whilst also highlighting opportunities for augmentation with alternative sources of water.
- Reconsider conventional wastewater and stormwater treatment and technologies; consider dispersed, decentralized systems with options for source separation and resource recovery (wastewater), as well as infiltration and fit-for-purpose use (stormwater).

**Position 3: Access to appropriate and timely data is imperative for predicting and managing escalating water crises**

Access to quality data that is appropriate and timely is vital in terms of strengthening the technical aspects of water resource planning and management. A paradigm shift towards resilient water services hinges on a data-based era driven by innovation. The UN's data revolution report, 'A World that Counts' aptly states that "*data are the lifeblood of decision-making and the raw material for accountability. Without high-quality data providing the right information on the right things at the right time; designing, monitoring and evaluating effective policies becomes almost impossible*" (UNIEAG, 2014).

Water monitoring provides essential information to guide law and policy-making, understand the effects of climate and land use change on hydrological systems and estimate hydrologic extremes. Without accurate data, the status of water resources cannot be sufficiently evaluated, effective water management and reuse programs cannot be executed, and program success cannot be judged. Access to data is not only important, there is also a need to be able to process and transform the data into useful and actionable information, i.e. through decision support systems (DSS). Fully integrated monitoring systems that collect data, upload data to a front-end platform, analyze and report on actionable information are essential. Four types of water data are critical in the face of escalating water crises:

1. Data on trends; for example, how population growth rates, water use and the systems in place to meet those needs interact.
2. Predictive data of projected future changes; for example, decreases in net precipitation, information about surface water availability and increases in population numbers.
3. Monitoring (quality and quantity) of water resources and water infrastructure; e.g. groundwater abstraction volumes as well as pipeline monitoring for informed maintenance, and responses of wastewater treatment works (WWTWs) to reduced flows. Monitoring data is imperative for transitioning to water wise or water sensitive cities with diversified sources and increased efficiency. Data can provide information on the types of alternative water resources as well as the quality, providing an important public health function.
4. Smart meter data as a communication tool to promote collaborative decision-making, foster awareness and influence water use behaviors. This data is particularly useful in the face of short-term water supply risks (see best practice section for a case study on Cape Town's highly effective information, education and communications campaign).

The Fourth Industrial Revolution (4IR) is a major enabler when discussing the importance of data in water resource management and planning. 4IR marks a new innovation chapter for the water sector, with innovations like the Internet of Things (IoT), artificial intelligence (AI), blockchain and big data, unlocking an abundance of previously inaccessible water data and opening up new ways of ensuring water security (World Economic Forum, 2018) (Figure 3). 4IR-enabled technol-

ogies allow for the acquisition of big water data, the ability to view variability in real time and at high resolution, the facilitation of rapid, targeted and data-driven decision making, the creation of early warning systems, the ability to perform predictive analytics and more.

To effectively harness 4IR for water will "*require a transformation of the 'enabling environment', namely the governance frameworks and policy protocols, investment and financing models, the prevailing incentives for technology development, and the nature of societal engagement*" (World Economic Forum, 2018). Innovations needs to be encouraged, supported and incentivized to optimize water resource planning and management. However, it is important that innovation needs to extend beyond alternative water resources and new 'buzzy' approaches to fundamentals such as asset management, infrastructure maintenance and water treatment. New models for raising money for innovation incentives and subsidizations need to be employed. For example, if stormwater harvesting is to become a viable water supply source, funds need to be provided to innovate on storage, treatment and distribution. Fisher-Jeffes & Armitage (2013) suggested that one way of achieving this would be via a proposed stormwater management fee or a stormwater 'tax', based on an Equivalent Residential Unit or Residential Equivalent Factor to raise funds for stormwater management.

In order to adequately support innovation, appropriate testing and demonstration sites need to be prioritized. To take an innovation from the ideation phase through to prototyping, testing and implementing requires testbed or incubation sites to demonstrate proof of concept and provide data to support business cases. An example of such a site is the Water Hub in Franschhoek, South Africa. The primary aim of the Water Hub is to demonstrate state-of-the-art techniques and technologies for water treatment suitable for African sanitation and water supply challenges. The site demonstrates various nature-based water treatment approaches and acts as a learning environment for researchers, entrepreneurs, and other stakeholders. It allows researchers to experiment with low cost, nature-based approaches that supply fit-for-purpose water for a range of uses and linked to the generation of sustainable livelihoods, in order to address conditions of poverty and inequality in South Africa.

| | Obtaining a complete, current and accessible picture of water supply and demand | Providing access to and quality of WASH services | Managing growing water demand | Ensuring water quality | Building resilience to climate change |
|---|---|---|---|---|---|
| 3D printing | | | | | |
| Advanced materials | | | | ● | |
| Advanced sensor platforms | ● | ● | ● | ● | ● |
| Artificial intelligence | ● | ● | ● | ● | ● |
| Bio-technologies | | | | | |
| Blockchain | | ● | ● | ● | ● |
| Drones and autonomous vehicles | ● | ● | | | |
| The internet of Things (IoT) | ● | ● | ● | ● | ● |
| Robotics | | | | | |
| Virtual, augmented and mixed realities | | | | | |
| New computing technologies | ● | ● | ● | ● | ● |

**Figure 3. Addressing water and sanitation challenges through 4IR-enabled innovations (World Economic Forum, 2018).**

**Position 4: An enabling governance, political and legislative environment is needed to support the transition to water secure cities**

The complexities around technical water issues are often linked to the ways in which the right technical decisions and approaches can be made, and the supporting governance, political, and legislative environment that enables these actions. An enabling governance, political and legislative environment provides the framework for stakeholders to work together and facilitate a paradigm shift to a resilient water system.

Strong inter-governmental relationships across national, provincial and municipal entities are required to provide the necessary support, both financial and technical, to provide water services. The differences in responsibility (and power) between different levels of government for the provision of water-based services need to be more clearly defined and adhered to. Technical experts within government need access to legislative processes and the institutional environment in which water is provided and managed. Lobbying voices are needed to help communicate common needs. Furthermore, a shift needs to take place away from treating water users as clients to one where all residents have rights and hence responsibilities.

An enabling governance, political and legislative environment needs to strongly consider financial elements and allow for adequate financing, especially in the face of an escalating crisis like "Day Zero." Complexities around funding issues, tender processes and procurement need to be understood and, in turn, optimized to make available sufficient resources, particularly for emergency water schemes. Related to this, cities must consider the impacts that reduced water demand, especially during periods of restrictions, have on municipal income. Current funding models often do not encourage sustainable water use and alternative funding mechanisms may be required.

Shifts also need to occur between political cycles and water resource management cycle to allow for the integration of sound technical management. A water strategy that involves water services and infrastructure for a whole city is generally planned around a time frame of around 30 years, which does not align with political cycles that can be anywhere from 2 to 5 years and are often beholden to poor governance or a lack of stability. Other mechanisms and institutional structures need to be explored. The planning, tendering and construction processes involved in water provision services for a city should occur over time scales longer than political cycles. For example, the planning for the Western Cape Water Supply System[47] (WCWSS) has a 20-year time frame working towards 2035 – to account for the design, tendering and construction processes involved with large dam or desalination schemes. Politics and water resource planning and management need to be decoupled to allow for government technical staff in water departments to effectively

47 The Western Cape Water Supply System (WCWSS) is a complex water supply system in the Western Cape region of South Africa, comprising an inter-linked system of six main dams, pipelines, tunnels and distribution networks and a number of minor dams, providing water to the City of Cape Town, surrounding small towns and agricultural users.

provide water infrastructure and services and to encourage continuity in policies, institutional memory and trust. This is applicable to all spheres of government.

In developing countries there are many other competing pressures which makes balancing spending on large, capital projects a challenge. Redundancy must always be built into systems, even in countries where basic social services such as education or health systems are not working well.

**Position 5: Sufficiently capacitated transdisciplinary teams with adequate technical skills and representation are required to manage water secure cities**

Implementing a paradigm shift in water resource management and planning needs to be underpinned by a sufficiently capacitated transdisciplinary management, planning and operations team, that in particular, has adequate technical skills. All water sources (freshwater supply, rain, rivers, sea and wastewater) are interconnected with each other and other urban systems (parks, roads, energy, waste etc.) so that efficiencies and synergies arise from a coordinated approach (International Water Association, 2016).

It is imperative that cities facing escalating water shortages retain and nurture existing skills through policies and actions. Failure to ensure adequate technical skillsets is one of the single biggest strategic risks to ensuring water security. In other words, there needs to be an increased focus on education and on retaining skills, as well as on the development of technical capacity in institutions. Additionally, consideration needs to be given to the issue of the age profile of experienced decision-makers. This issue is particularly pertinent in South Africa where a lack of capacity and relevant skills hinders the technical services of municipalities and utilities (e.g. Lawless, 2007), and ultimately the fostering of trust. This includes a technical divide which exists between management and customers (water users) as well as vested interests which obstruct technical innovation.

Technical skills are crucial in water resource planning and management, but it is important that they are embedded in an integrated interdisciplinary team where they are exposed to multiple disciplines daily. This is particularly important to ensure that technical decisions are socially just, and that all geographic areas and socio-economic classes receive the same level of service. Interdisciplinary teams bring in multiple social, environmental, economic and political perspectives that enable the creation of resilient water systems. It is widely held that technical and engineering skills alone will not address water scarcity, and a balanced and holistic team is necessary to build water security in an equitable manner.

## Focal areas specific to water and cities

When considering the technical elements that cities facing escalating water shortages should prioritize, the technical task team suggests that cities refer to the following questions, categorized

under the position statements mentioned previously:

**Position 1: A clear vision and detailed water strategy is vital to building resilience**

- What is the value and role of a water vision and/or detailed water strategy in a city?
- Which stakeholders need to be involved when developing a vision and strategy and benchmarking a city's readiness to transition to water sensitivity? (see Appendix for best case example of the City of Gold Coast Water Sensitive City Transition Strategy (CRC, 2019))
- What is the most effective way to operationalize a water strategy to ensure water security?
- What is the best form and outcome for knowledge sharing between cities on how to operationalize visionary strategies?

**Position 2: Planning and managing an efficient integrated water system**

- Given the vital role of water resource planning, how much redundancy can be built into water systems, specifically in developing countries where there are other competing basic needs, e.g. in contexts where health and education systems are barely functioning?
- How can the notion of a water sensitive city with diversified water sources be operationalized?
- In the face of water scarcity and climate change, there is a need for resource recovery and ultimately, a shift towards a circular economy. How can water reuse be operationalized? What technical issues have to be addressed first; i.e. quality of the wastewater and disposal of fecal material / sludge?
- Is "end-of-pipe" treatment outdated? Can treatment take place on site, instead of having to rely on centralized systems?
- What is the impact of poorly or unserviced (i.e. informal / unplanned) settlements on water quality and environmental protection?
- How do spatial geographies influence solid waste management, water quality and pollution and water resource planning in general?

**Position 3: Access to high quality data**

- How can data on trends and predictive data of projected changes, be accessed to strengthen technical aspects of water resource planning and management?
- How can citizen science (e.g. through mobile applications) be used to promote communication with water users and other stakeholders, to ensure collaborative decision-making?
- How can technology be utilized to add value to and upgrade existing water systems, particularly around issues of asset management?
- How can an innovation culture be fostered, making use of 4IR to promote new ideas, processes and products to enhance water security?
- What are appropriate funding and support mechanisms to encourage, incentivize and subsidize innovation?
- How can independent bodies that support data gathering, interpret trends and perform anal-

yses for policy support be developed?
- How can a transformation of the 'enabling environment', namely the governance frameworks and policy protocols, investment and financing models, the prevailing incentives for technology development, and the nature of societal engagement, be brought about?

**Position 4: An enabling governance, political and legislative environment**
- How can complex political arrangements between municipal, provincial and national government be optimized to ensure the provision of water services, especially in a country like South Africa where access to free basic water is a Constitutional right?
- How can longer water resource planning and management cycles be accounted for in the face of considerably shorter political cycles, particularly in an age of climatic and land use change? What legislative, policy or working agreements could be forged between municipal water provision staff and politicians to support this?
- How can social and developmental pressures be accounted for in the budgets for large capital projects for water?
- What model do cities work towards to allow the cross-subsidization of tariffs, so that the wealthy are subsidizing the provision of water to the poor in a way that is acceptable to all residents?
- What is the true 'value' of water? How much are people willing to pay in order to cross-subsidize indigent households – for example in the South African context where all residents have a right to free water?

**Position 5: A sufficiently capacitated transdisciplinary team**
- What type of policies and actions can be implemented to retain and nurture existing skills? How can this be done in cities that are in a state of austerity with limited capacity?
- How can appropriate training institutions be developed that provide skills to technical water professionals in a transdisciplinary manner with a focus on social equity? How can such institutions contribute to education and training to mid and late career professionals through short courses and workshops?
- How can transdisciplinary Communities of Practice be formed and supported to facilitate knowledge sharing and dialogue amongst the broader water sector?

## Best practices

This section outlines various case studies from around the world that demonstrate best practice with regards to planning, managing and operating resilient water services to ensure water security.

**Cape Town's water resources and the City's response to Day Zero (Taing et al., 2019)**

In principle, water is considered a "shared responsibility" in South Africa, divided between the

three spheres of government: (a) resources and bulk management are the domain of the national Department of Water and Sanitation (DWS), the country's water custodian; (b) supply infrastructure and service delivery are the responsibility of municipal authorities; and (c) provincial governments provide support when needed to municipal authorities and the agricultural sector. Significantly, DWS manages the water resources that the City of Cape Town municipality supplies to its citizens with support from Western Cape Province. Cape Town's potable water supply primarily comes from six dams that form the Western Cape Water Supply System (WCWSS), that also meets some of the demands of the province's agricultural sector (approximately 29%) and nearby small towns (approximately 7%). Cape Town households and businesses receive the bulk of the province's water (approximately 64%) and the per capita water use in 2012 was around 223 ℓ/c.d. The City had managed to contain total demand to around 1999 levels despite population growth of 50%, in part due to reducing losses from leakages, and as a result, Cape Town has one of South Africa's lowest percentages (15%) of "unaccounted for water" (typically losses due to leakage, meter under reading and theft). The national government officially plans water resources at a 1 in 50-year level of assurance, which means that there might be inadequate supply to meet demand once every 50 years. Although current climate risk models show the future potential for significant drying and extreme weather patterns in the Western Cape – translating into both severe droughts and floods (Cullis et al. 2015) – they also indicated that Cape Town would not be significantly impacted until around 2025. Cape Town, however, experienced well below-average rainfall three consecutive years commencing 2015 – including the two driest recorded by many gauges. Consequently, in September 2017, DWS instructed the City to reduce water use to 500 Mℓ/d until dam water levels recovered to 85% capacity. Thus, between September 2017 and September 2018, the City's response – which ultimately averted the disaster of "Day Zero" in the short-term - targeted both demand and supply in a three-pronged strategy that was aimed at: 1) drastically reducing per capita demand (to 50 ℓ/c.d) through implementing restrictions, limiting supply, reducing water pressure, increasing tariffs, and employing a communications and education campaign; 2) carefully monitoring and managing the levels of water in the dams that make up the integrated WCWSS; and 3) augmenting supply with alternative sources; i.e. small streams and springs, groundwater from local aquifers, seawater desalination, and treated wastewater.

**City of Cape Town Pressure management (Ziervogel, 2019)**

The City of Cape Town instituted aggressive pressure management from January 2018, which made a significant contribution to water use reduction. An ongoing program was accelerated through a contract with the private sector to isolate the network into zones that could be pressure managed. Pressure in these zones was drastically reduced, with an estimated saving of 50 million liters per day, in the first three months of 2018. Through this process, using both automatic pressure reduction valves as well as manual controls, the city was able to reduce water use at the same time as retaining a 24/7 pressurized system.

**City of Cape Town Water Map (Ziervogel, 2019)**
A novel Water Map was developed and launched in January 2018 that used green dots to show low water use per household for free-standing houses. This helped citizens to see how their water use was faring compared to the restrictions, their neighbors and other homes across the city.

**Cities as catchments – "Sponge" cities (Fuldauer, 2019)**
Sponge cities are designed to absorb large quantities of water and disperse it back into the environment in a slow manner. Like sponges, they are made of porous surfaces and spaces capable of keeping water. Permeable roads and sidewalks, green roofs, wetlands and natural vegetation absorb, infiltrate, store, purify, drain and manage rainwater. The system mimics the natural hydrological cycle to avoid flooding and is not only capable of dealing with a sudden excess of stormwater but also reuses it to help to mitigate the impact of droughts. A Sponge City is more than just its infrastructure; it is a city that makes urban flood risk management central to its urban planning policies and designs. There are planning and legal frameworks and tools in place to implement, maintain, and adapt the infrastructure systems to collect, store, and purify excess rainwater. The concept of sponge cities has been put into practice on a large scale in China. In 2015, the Sponge City pilot project was launched by the government, with thirty cities taking part. By 2030, the aim is that 80% of urban areas should absorb and reuse at least 70% of rainwater.

**Atlantis Water Recharge Management Scheme (Kotze, 2019)**
At Atlantis, the recharging of stormwater and treated wastewater into the aquifers via the sandy soils started in 1979. Unusual for the time, it was also to here that town planners and engineers turned their attention when novel plans had to be made to ensure a secure water supply for the town. They shifted their focus to recharging and recycling water in order to increase the yield of the aquifer sufficiently to meet the long-term water needs of the town. Currently, the Atlantis Water Resource Management Scheme (AWRMS) uses treated domestic effluent, all of the domestic stormwater, and most of the industrial stormwater for recharging the aquifer through a Managed Aquifer Recharge (MAR) system. MAR is an indirect water recycling method through the transfer of surface water underground and the subsequent storage in an aquifer either via infiltration from basins, dams or ponds or through injection boreholes. In this way water can be stored during wet periods or when there is a surplus and abstracted during dry periods. Because it is stored underground, minimal water is lost to evaporation, and in addition the water is relatively safe from contamination and the porous medium (in this instance, sand) through which it infiltrates acts as a filter for improving water quality.

The layout of the town allows for the separation of stormwater from the industrial and residential areas as well as separate treatment of domestic and industrial wastewater. Stormwater and industrial wastewater are channeled into separated systems to each undergo sufficient treatment. Domestic wastewater undergoes full treatment and is sent towards a series of maturation ponds.

Stormwater from the residential areas is collected in a system of detention and retention basins and blended with the treated domestic wastewater before being discharged into the main recharge basins for artificial recharge of the Witzand wellfield. Stormwater from the industrial area is more saline and is discharged into different recharge basins along the coast, from where it seeps into the ocean through the subsurface. This also helps to mitigate potential seawater intrusion into the aquifer. Water for the town residents and industries is then abstracted from the Witzand and Silwerstroom wellfields. The first contains a blend of natural and recharged water, and the second contains natural groundwater. It is estimated that the groundwater abstracted as part of the AW-RMS represents a blend of 30% water derived from recycling and 70% natural groundwater. The performance of the water recycling system at Atlantis has shown itself to be relatively robust with respect to the elimination of contaminants, and based on present knowledge, the recycling of the water does not present a threat to the drinking water supply.

**Singapore – 4 taps strategy (Singapore Public Utilities, 2019)**

As a small island that does not have natural aquifers and lakes and with little land to collect rainwater, Singapore needs to maximize whatever water it can harvest. Driven by a vision of adequacy, reliability and sustainability in water, Singapore has been investing heavily in research and technology. The nation currently has a robust, diversified and sustainable water supply from four different sources known as the Four National Taps (water from local catchment areas, imported water from Malaysia, reclaimed (waste)water known as NEWater, and desalinated seawater). By integrating the system and maximizing the efficiency of each of these four taps, Singapore has ensured a stable and sustainable water supply capable of supporting the country's continued growth.

**WSUD Case Study: Kallang River Bishan Park, Singapore (Dreiseitl, 2012)**

Bishan Park is one of Singapore's most popular parks and has more than 3 million visitors annually. As part of a much-needed park upgrade and plans to improve the capacity of the Kallang River along the edge of the park, works were carried out simultaneously to transform the utilitarian concrete channel into a naturalized river, and to create new spaces for the community to enjoy. This project formed part of the 'Active, Beautiful, Clean Waters' (ABC Waters) Programme of the Public Utilities Board in Singapore, which manages the country's water supply and drainage – a long-term initiative to transform the country's water bodies beyond their functions of drainage and water supply, into vibrant, new spaces for community bonding and recreation.

At Bishan Park, a 2.7 km long straight concrete drainage channel has been restored into a sinuous, natural river 3 km long, that meanders through the park. Sixty-two hectares of park space has been tastefully redesigned to accommodate the dynamic process of a river system which includes fluctuating water levels, while providing maximum benefit for park users. Three playgrounds, restaurants, a new look out point constructed using the recycled walls of the old concrete channel, and plenty of open green spaces complement the natural wonder of an ecologically restored river

in the heartlands of the city. In addition, the park provides generous open spaces for recreational activities and the soft, planted river banks allow people to get close to the water. In the case of heavy downpours of rain, the park land next to the river doubles up as a conveyance channel, carrying the water downstream. Bishan Park is an inspiring example of how a city park can function as ecological infrastructure, a smart combination of water source, flood management, biodiversity, recreation, and thanks to personal contact and an emotional connection with water, increasing civic responsibility towards water.

**Wastewater reclamation in Windhoek, Namibia (Veolia, 2018)**

"*In Windhoek, every drop of water counts*" - this is WINGOC's motto. It manages one of the few facilities in the world producing drinking water from wastewater. In 2001 the consortium signed an operating contract with the city of Windhoek aimed at improving wastewater treatment processes and increasing the site's production capacity. Recycling wastewater increases the amount of drinking water available, but also has a twofold benefit for the environment; it avoids tapping into natural resources and significantly reduces pollutant discharges.

Namibia is one of the most arid countries in Africa: the average rainfall is 250 mm per year, but the heat causes 83% to evaporate - only 1% of rainwater infiltrates into the ground. Consequently, the water supply of Windhoek - located in central Namibia - depends mainly on boreholes and three dams located 60 and 200 km away. To cope with shortages, the city has sought alternative solutions to secure its water supply. The various treatment processes, coupled with rigorous bio-monitoring programs, guarantee high quality, safe drinking water. The current system also allows for MAR processes to 'bank' excess treated water in the aquifer as a resilience strategy.

**Orange stormwater to potable: Building urban water supply diversity (CRCWSC, 2018)**

The drivers for securing urban water supplies in the town of Orange, New South Wales included:

- Critical water shortages - faced with continuing dry conditions and uncertainty of future rainfall, alternative water supplies were required.
- A willing community – continued high level water restrictions resulted in the community wanting the local Council to do something quickly to provide more water for the city.
- Local Council leadership and innovation - Council wanted a water security solution that would provide long term benefits and considered all elements of the urban water cycle.

The decision was thus taken to implement the first large scale, indirect-to-potable stormwater harvesting project in New South Wales. In this project, urban stormwater is being harvested for potable uses; this was feasible due to existing infrastructure (such as pipelines, storage facilities and water treatment plant) and the ability of the urban catchment to generate adequate runoff.

Orange City Council develop a Review of Environmental Factors which set the operating rules and helped to gain stakeholder approval for the use of stormwater for potable uses. Recycled water is fully allocated to Cadia Valley Operations (one of Australia's largest gold mining operations) and stormwater is used as an alternative water source in the dual pipe system included in homes built in the Ploughmans Valley and North Orange area. Outcomes from the project included:

- Creation of 4 stormwater treatment wetlands which slow and treat stormwater flows as well as provide important urban habitat
- Conversion of weedy drainage corridors into constructed wetlands has created high amenity landscapes which are now valued by the community
- Peak flows reduced in creeks reducing risk of erosion
- Harnessing the power of large impervious surfaces in urban environments for generating more reliable water supplies
- Up to 25% of the drinking water in Orange supplied by stormwater
- 29% of drinking water replaced with treated stormwater via dual water systems in homes in Ploughmans Valley & North Orange

## Conclusion

Transitioning to resilient water services is imperative to ensure water security within cities in this age of uncertainty. As climate change, rapid urbanization, population growth, and deteriorating water quality, impede the ability of cities to ensure water security, a new paradigm of water resource management and planning is essential. The different types of water scarcity, i.e. quantity, quality, access, and economics, are important to consider, as are the multiple and interdependent drivers of scarcity. Water security must be viewed holistically, and with due consideration to both the technical and non-technical elements around it.

The approaches and concepts of "Integrated Urban Water Management," "Water Sensitive Urban Design/Water Sensitive Cities," and "IWA Water Wise Cities" provide guidance on planning, managing, and operating water services in a new manner, and were drawn upon extensively by the Technical Science task team. The team presented five positions, related to technical elements and capacities to achieve the 2050 vision and ensure water security. The positions drew heavily on the lessons learned from the Cape Town water crisis and included:

1. A clear vision and detailed water strategy are vital to building resilience.
2. Planning and managing an integrated water system is a fundamental in the face of an escalating water crisis.
3. Access to appropriate and timely data is imperative for predicting and managing escalating water crises.
4. An enabling governance, political, and legislative environment is needed to support the tran-

sition to water secure cities.

5. Sufficiently capacitated transdisciplinary teams with adequate technical skills and representation are required to manage water secure cities.

Developing these technical capacities and elements, which are intertwined with other social, economic, political, and environmental factors, underpins all efforts in moving towards a water secure future.

## Acknowledgements

The authors extend thanks to the following colleagues and members of the Technical Sciences task team who provided useful inputs and support towards the drafting of this position paper:
Dr K. Winter; Dr A. Abrams; Ms S. Harigobin; Ms M. Lintner-Strauss; Mr R. Brown; Dr L. Fisher-Jeffes; Dr J. Cullis; Mr A. Janse van Rensburg; Ms G. Maree; Prof H. Jacobs; Mr W. Enright; Mr C. Compion Ms B. Oueweneel.

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# Natural Science Position Paper

*Initially prepared for the Cities Facing Escalating Water Shortages conference at the University of the Western Cape, January 2020.*

Lead authors: Jenny Day, Gail Cleaver-Christie, Liz Day, and Louise Stafford

Version: January 09, 2020

## Executive Summary

This paper deals with interactions between cities the natural environments they inhabit. We explore the ways in which water stress exacerbates or mitigates these effects. In its current form it is largely a case study of the effects of the recent (2016-2017) drought in Cape Town. Cape Town provides a very useful case study because it is one of the most biodiverse cities in the world; its managers face particular challenges when human water requirements compete with the water requirements of the natural environment under severe drought conditions.

## Introduction

We deal with biodiversity in general terms in conjunction with the conservation of biodiversity in modern cities; we emphasize the consequences of natural hydrological cycles on both terrestrial and aquatic ecosystems. We then attempt to outline the consequences for natural ecosystems of a shortage of water at city level, including modified behavior of city managers. Finally, we discuss potential ways of minimizing the negative effects of water shortages in the long term. The current version of this document deals largely with the recent drought in Cape Town; experiences of other cities will be included as information becomes available at the Cities Facing Escalating Water Shortages Conference in January 2020.

## Water Vision for 2050

The environmental setting in urban areas is extremely altered from conditions prevailing before urbanization. The most appropriate goal of city managers concerned with the natural environment is therefore to maintain, as far as possible, the functions and services of ecosystems with a minimal loss of diversity. Well managed cities have in place an Environmental Management Strategy that sets conservation goals supported by appropriate bylaws.

## Assumptions

<u>Hydrological cycles and their effects on the natural environment</u>

Cycles of wet and dry periods are familiar to us in terms of seasonal rainfall and longer term cy-

cles of wetter and drier periods that can last for several years. The plants and animals native to any area has adapted over millennia to the prevailing conditions (e.g. tropical forests, deserts, or swamps) in which they live. Environmental conditions change over the course of time but generally the changes are slow enough that most of the species are able to adapt little by little to the changes and survive. Species that are unable to adapt will become extinct. It is important to remember that over the course of Earth's history, far more species have gone into extinction than are alive today; extinction is natural and expected. A significant aspect of the Earth's current climate change is the rapid rate at which it is happening—a rate much faster than the rate at which adaptation by natural selection acts on most species.

Some of the most significant effects of urbanizing environments are changes to the natural hydrological regime. Areas that were once wetlands have been drained and developed: rivers are often canalized and subject to increasing pollution, runoff from rainfall is directed into stormwater drains, and temporary wetlands are made permanent or obliterated. The overall effect is that less water is available in drier times, and in other times flooding is becoming increasingly common. Plants and animals living in cities encounter water in less predictable ways, what water does occur is more polluted, and the quantity of water is often more extreme than in the past.

Natural hydrological cycles and the development of cities

Until recently, these cycles were fairly predictable and were used to estimate the amount of water available from season to season and from year to year. In conjunction with a knowledge of the water demand of a city, hydrologists and engineers would decide on the most suitable water sources to supply that demand. In mesic areas, where rainfall is consistently high, run-of-river water would be adequate, and small reservoirs were constructed to deliver water to reticulation points for purification and distribution. In drier areas, larger reservoirs would be needed so that river water could be stored between rainy periods. The larger the population of a city, and the drier the region, the larger the reservoirs and the greater the effects on the rivers downstream. Ground water has often been the primary source of water for cities in regions with few rivers, or with inadequate sites to build reservoirs. As climate change has brought extreme consequences, rapidly expanding cities are facing challenges of providing sufficient water for their populations even during periods of "normal" rainfall. Given that one of the consequences of climate change is longer and more frequent droughts, it is not surprising that several cities have faced, or are facing, water crises.

While these topics will not be directly addressed in this paper, It should be noted that the effects of damming and pollution have extreme consequences on water sources. Damming rivers has severe effects and often completely changes the nature of a river below the dam wall by reducing biodiversity and sometimes stopping the river from flowing altogether. The topic of "Environmental Water Requirements" is not dealt with further in this paper but a good review of the topic can be

found in King & Brown (2018). A further effect of human settlements on aquatic ecosystems is pollution. It is important to note, however, that levels of pollution are likely to increase considerably under drought conditions because there is less water to dilute or flush away pollutants, and because waste-water treatment plants (WWTWs - sewage works) receive much more concentrated sewage than normal, putting pressure on the WWTWs and often resulting in inadequately treated effluents leaving the works. These effluents are discharged either to rivers or to the sea.

## Focal areas specific to water and cities

The case of the City of Cape Town: a biodiversity "hotspot"

The Cape Floristic Region (CFR) is the smallest of the World's six Floral Kingdoms. This biodiversity hotspot, less than 80,000km$^2$ in area, has the highest concentration of terrestrial plants in the world: about 9,500 species. More than two-thirds of these do not grow anywhere else on earth – i.e. they are endemic to the CFR. Despite this remarkable diversity, and the small area involved, less than 10% of the CFR is formally protected in nature reserves or National Parks. Because of the great importance of the CFR for biodiversity, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) has declared the CFR to be a World Heritage Site.

Within the CFR, the City of Cape Town occupies an area of exceptionally high biodiversity and is thus "the most biodiverse city in the world" according to Thomas Elmqvist, leader of the UN's City and Biodiversity Outlook Project and Swedish expert in natural resource management and urban landscapes. The City of Cape Town itself hosts over 3,000 plant species and 20 vegetation types within its boundaries. Of these, six of the vegetation types and approximately 200 plant species are endemic, being found only within the city boundaries. (The whole of the British Isles boast 52 endemic species.). Thirteen plant species are classified as globally extinct, with a further 660 on the IUCN Red Data List for plants.

In addition to its rich terrestrial biodiversity, Cape Town supports a variety of rivers and wetlands. Many of these were naturally seasonal, particularly on the lowlands, where some rivers flowed for only a few months of the year, retreating into seasonal pools that dried up in the summer. Isolated perched wetlands also occurred in some areas, as well as wetlands that link to groundwater, and are seasonally inundated when the water table rises in winter. Many of the seasonal, isolated wetlands support communities of aquatic invertebrates with high rates of endemism, particularly among crustacean zooplankton taxa. Cape Town's rivers and wetlands have been highly modified by urbanization, however, many wetlands having been infilled or drained, while rivers have been canalized or channelized. As a consequence, marshy seasonal wetlands are now far more rare. Nonetheless, part of the False Bay Nature Reserve has been declared a Ramsar Wetland of International Importance for Waterbirds, and the City has very recently applied to become one of the first Ramsar Cities.

Pollution, mainly treated and/or untreated sewage effluent, has affected many of these systems. Treated effluent from sewage works discharging into the rivers and stormwater runoff, have led to many of the remaining systems receiving far more water than before, resulting in changes from seasonal to perennial systems and leading to fundamental changes in ecosystem function. The rivers that supply Cape Town with water lie largely outside of the City, and ironically these, too, have been impacted by large-scale abstraction and associated issues such as downstream, salinization.

Predictions of the effects of climate change (CC) for Cape Town suggest reduced rainfall, together with an increased likelihood of deep droughts and intense floods at unpredictable intervals. Until very recently, for its water supply Cape Town has been almost exclusively reliant on six rain-fed reservoirs ("dams") located mainly outside the City of Cape Town boundaries and part of the Western Cape Water Supply System (WCWSS). The City owns three of the six reservoirs, the others being owned by the national government's Department of Water and Sanitation (DWS). The WCWSS is managed by DWS in partnership with the City of Cape Town. Cape Town's Water Strategy (CCT 2019) aims to develop diverse water resources, including ground water, water reuse, and desalination. In the context of climate change, a mix of resources will be more reliable and more resilient than the reservoirs alone.

According to the 2019 Water Strategy, "The City will actively facilitate the transition of Cape Town over time into a water sensitive city with diverse water resources, diversified infrastructure and one that makes optimal use of stormwater and urban waterways for the purposes of flood control, aquifer recharge, water reuse and recreation, and is based on sound ecological principles. This will be done through new incentives and regulatory mechanisms as well as through the way the City invests in new infrastructure." This strategy includes protection of ecosystems such as strategic water catchments, as well as urban rivers and stormwater systems. Clearing alien vegetation and maintaining alien-free land has been recognized as the "least cost" method of increasing yields. In this regard, the City is committed to working with partners in the WCWSS to clear priority catchments of aliens and to investigate mechanisms for financing the initial clearing and long-term maintenance of cleared areas. Clearing invasive alien vegetation has additional social and economic benefits, mostly job creation. From an environmental point of view, it is important to ensure that clearing invasive vegetation is embedded in a restoration program that incorporates appropriate handling of biomass, active restoration where necessary, integration of fire as a control method, and best-practice management.

Effects of climate change

South Africa is not safe from the effects of climate change. In 2015, the country recorded its lowest annual rainfall since 1904. In the same year, Cape Town also recorded the highest temperature in the last 100 years at 42°C. The lack of rain, together with abnormally high temperatures, contrib-

uted to some of the worst fires the city has seen. And in 2017/2018, the Western Cape experienced its worst drought in decades, threatening our water security. Climate scientists predict that the Western Cape will become drier and experience moderate to strong warming over the next 100 years. By 2050, the rainfall in the Western Cape is likely to have decreased by about 30% from current levels. The specter of Cape Town as a perpetually water-stressed city is unquestionable.
The Western Cape Government is playing its part in the global effort to reduce greenhouse emissions, especially since the Western Cape is one of South Africa's provinces most vulnerable to climate change. There are strategies in place, like Cape Town's Climate Change Response Strategy, which aims to reduce greenhouse emissions and to help citizens adapt socially and economically to climate change. One of the successful outcomes of the city's approach to climate change was the development of a Western Cape Climate Change Response Framework and Implementation Plan for the Agricultural Sector, better known as SmartAgri. As our agricultural sector is vulnerable to changes in climate, it is vitally important to provide guidance to farmers and others in the sector on how to prepare for the impacts of climate change in order to protect their livelihoods as well as our food security. SmartAgri helps farmers from different parts of the Western Cape reduce their greenhouse gas emissions and protect their farms and businesses from the effects of climate change.

"The City of Cape Town needs to prepare in earnest for a drier warmer future over the next decades. While there remains uncertainty in the climate science, the evidence for drying and warming is strong and planning that ignores this evidence is at significant risk of vulnerability to a changing climate. There is now sufficient science evidence to motivate for serious consideration of climate adaptation planning and implementation in the city."

Effects of the drought and subsequent actions taken by the City
Drought conditions were somewhat alleviated during the winter (rainy season) of 2019 in Cape Town. However, despite dams being fuller than they were in the previous two years, seasonal wetlands systems have not fully recovered because groundwater levels have still not returned to pre-drought conditions. The long-term effects of the drought on natural ecosystems within the City have not yet been studied, and there seems to be no intention of instituting a monitoring system to evaluate these effects.

As a result of severe water restrictions imposed on Cape Town's residents, and the associated major efforts made for on-site domestic recycling of water, less water flowed in the sewers than under non-drought conditions, making them more vulnerable to blockages and overflows into stormwater systems leading to watercourses, including Cape Town's three most important recreational lakelets (Rietvlei, Zandvlei and Zeekoevlei). On the other hand, the feeder streams were also subject to reduced flows from their respective catchments. Combined with the regular but unintended sewage spills and other factors leading to the on-going eutrophication of our watercourses,

water quality within the urban context remains a challenge. Zandvlei was closed to recreational users for several short periods in 2019; and in late 2019 to early 2020, while Rietvlei experienced its second toxic blue green algal bloom in three years. Unlike the quasi-estuarine Zandvlei, which does receive a certain amount of sea water over the year, Rietvlei, an artificially excavated lagoon, has neither overflowed nor had any significant flushing since 2011.
A consequence of increased emphasis on water re-use as a result of the drought was reduced flows of treated effluent into downstream rivers, estuaries, and wetlands. This could have been beneficial because these systems are naturally perennial and retain vestiges of such function. Interestingly though, in some cases, such as the lower Diep River, treated effluent was at times almost the only water passing through this naturally perennial system, which has been highly impacted by upstream abstraction in agricultural areas. Increasing re-use of effluent may thus reduce water availability in the lower river reaches. The estuary itself has historically been influenced by too much effluent water, changing its salinity. Balancing these counter-impacts is a challenge for resource managers.

Other unintended consequences of the drought include the City's Biodiversity Management Branch not undertaking any planned burns in 2017 and 2018. This had operational impacts on work programs and resulted in having to plan a large number of burns in the 2019/2020 summer season. The impact on the environment appears to be minor at this stage. The positive aspect of the drought was finding ways of undertaking operations with limited or even no potable water and planned burns and firefighting now rely largely on non-potable water sources. Offices of the City's various nature reserves have become water-wise and in some cases have developed permanent ways of operating with the minimal use of water, while a soon-to-be built multi-purpose center at one of the City's Nature Reserves will recycle all its water and may not need to rely on municipal water at all.

The City of Cape Town has pioneered the introduction of Water Sensitive Urban Design in South Africa, and has encouraged (through both policy and legislation) increasing use of measures to reduce peak runoff at source, through measures that encourage infiltration and flow retardation. However, during the drought, many homeowners, developers and commercial centers moved away from water-thirsty lawns and planted areas, to the use of artificial grass and pavement. Not only do these increase runoff in non-drought periods, but also result in increased temperatures. The degree to which either of these issues have long-term implications for urban ecosystems is not yet clear.

<u>The National Water Act and other legislation</u>
In the South African National Water Act (NWA, No. 36 of 1998), the "Reserve" is defined as the quality and quantity of water required to ensure appropriate protection of water resources, so as to secure ecologically sustainable development and use. The Reserve is composed of "basic

human needs" (free water provided to every individual in order to cover personal daily needs) and the "Ecological Reserve," that is, water allocated to aquatic ecosystems (rivers and wetlands, estuaries, and ground water) to ensure the long-term sustainability of aquatic and associated ecosystems. During severe droughts ecological and agricultural releases may be compromised in order to protect the limited water supply for human use. The drought has had a significant impact on agriculture, livelihoods and communities. Estimates are an economic loss of R5.9 billion in agriculture in the Western Cape alone, with a resultant 30,000 job losses and exports dropping 13-20% due to reduced farming outputs and additional income losses as export volumes declined. The lack of integrated catchment management plans has been identified as a shortcoming in the protection and rehabilitation of catchments on which we rely for good quality and quantity water entering rivers, wetlands, dams, estuaries and aquifers. In South Africa, government funding cycles typically operate over a three-year budget cycle. This does not allow for the long-term funding needed for water security in catchments that may require maintenance for at least 20 to 30 years, depending on the state of the catchment. To address this shortcoming the Provincial Department of Environmental Affairs and Development Planning (DEA&DP) has developed the Western Cape Ecological Infrastructure Investment Framework. This framework will create strategies for, among other things, wetland rehabilitation, tackling invasive species and improving ecological infrastructure in the province, and ultimately improving water security.

Modification of regulations during the drought period

DEA&DP is the legislative authority responsible for the approval of Environmental Impact Authorizations in the Western Cape Province. Because of the increasing severity of the drought, a "Section 30A" Directive was issued to the City of Cape Town in June 2017 allowing the City to bypass certain regulations in order to be able to address the water supply shortage at the time. The Directive was valid for as long as the City was declared a disaster area, and until such time as the City could demonstrate its ability to provide adequate water supply to all areas that fall within its jurisdiction. Note that although the Directive permitted augmentation schemes to proceed without unnecessary delays, it did not exempt the City from compliance with the South Africa National Environmental Management Act (NEMA) or any other applicable legislation. In addition, the projects were required to comply with the general duty of care which aims to protect the environment and ensure compliance with applicable legislation.

In terms of National Water and Environmental Legislation, the act of drilling a borehole does not require a formal EIA process. Duty of care still applies to the drilling operation, though. For example, environmentally sensitive areas must be avoided and all disturbance minimized, while the construction or introduction of any associated infrastructure or services beyond the limited drilling area such as powerlines, roads and pipelines, usually require an EIA authorization. However, careful consideration of alternative approaches or sites is not required in terms of the Directive, leading to sensitive areas being targeted for activities such as borehole drilling and abstraction,

on the basis of land ownership.

Use of additional ground water resources

Often, one of the easiest ways of increasing water supply is by exploiting ground water. The Cape Town area is underlain in parts by aquifers close to the surface and therefore easy to access, but potentially affected by the drought if recharge does not take place (as is likely in deep drought conditions). The City is also located on a series of major and very deep aquifers of the Table Mountain Group geological formation (which, despite its name, extends for several hundred kilometers along the coast towards Port Elizabeth). Investigation into the potential use of the Table Mountain Group Aquifer for the City of Cape Town started in 2005, with various studies conducted to better understand both the geological and potential ecological impacts of large-scale abstraction of water from the aquifer. With the drought, this precautionary approach was set aside. More than 200 potential borehole sites were identified by the City of Cape Town for exploration and potential abstraction. In order to fast-track the process, a desktop screening tool was developed by CapeNature, the Provincial entity responsible for conservation. Once the desktop screening process had been undertaken, some sites could be excluded based on environmental sensitivity. The boreholes identified as potentially useful were then assessed on-site by botanists, freshwater specialists and geohydrologists to further refine risks and concerns. One of the key impasses during this process was that the best sites from a geohydrological perspective were, and still are, the most ecologically sensitive areas, with negative impacts of long-term large-scale groundwater abstraction on highly sensitive freshwater ecosystems highly probable.

The City of Cape Town identified areas for groundwater abstraction that include parts of the Cape Floral Region Protected Areas World Heritage Site (CFR PAWHS). One of the City's focus areas for the development of a production wellfield falls within the Steenbras Nature Reserve, a formally recognized protected area and part of the core of the Kogelberg Biosphere Reserve. Environmental Authorizations for activities in protected areas and biosphere reserves require approval by the National Department of Environmental Affairs (DEA), which was given for a wellfield within the Steenbras Nature Reserve water utility zone; this wellfield is still under development.

Due to the internationally recognized status of the CFR PAWHS and Kogelberg Biosphere Reserve, concerns were raised by citizens about potential impacts of large-scale groundwater abstraction from the Table Mountain Group Aquifer. A particular concern relates to the potential for irreversible damage to the environment, while DEA has been questioned why a formally protected area of great biodiversity importance has been targeted for production wellfields. Concerns were raised as to why the City was not prioritizing other water resources with potentially less environmental risk, such as water reuse, a permanent desalinization plant or catchment restoration, before targeting groundwater, particularly the Table Mountain Group aquifer and particularly in a sensitive Nature Reserve.

As a condition of the water use license issued by the Department of Water and Sanitation, an Environmental Monitoring Committee was established by the City of Cape Town with representatives from government, tertiary institutions and other interested and affected parties. This committee will assist in the design of a long-term monitoring program for the Steenbras Nature Reserve wellfield and other sites in the Table Mountain Group Aquifer, to assess monitoring information to detect changes in the water table and changes in freshwater ecosystems that can be linked to groundwater abstraction. This monitoring group will focus on effects on both wellfield development and production.

Despite the City of Cape Town disaster status terminating on 30 September 2019 and the dams feeding the Western Cape Water Supply Scheme at 84% capacity (on 14 November 2019), the Section 30A Directive remains effective "until such time the City can demonstrate its ability to provide adequate water supply to all areas which fall within its jurisdiction." This means that they may continue with the approved intervention plan and fast-tracked EIA processes for the foreseeable future. Due to the improved water situation in the City, however, the City's Section 30A directive is currently being reviewed by the relevant Provincial and National Departments.

Nature-based mitigation against the effects of future droughts

Investing in ecological infrastructure (naturally functioning ecosystems) is the most cost-effective long-term solution for securing water. Nature-based solutions require a fraction of the cost of engineering solutions such as desalination, groundwater exploration and water-reuse. Well-conserved catchments provide replenishment of ground water and surface water reservoirs, while increasing ecosystem resilience against climate change. Water Funds are organizations that design and enhance financial and governance mechanisms which unite public, private and civil society stakeholders around a common goal to contribute to water security through nature-based solutions and sustainable watershed management. The Greater Cape Town Water Fund (GCTWF) Business Case was launched in November 2018, with support from local partners, to make the case for ecological infrastructure in a clear and transparent manner. The GCTWF Business Case showed that investments in nature-based solutions, including controlling invasive alien plants and rehabilitating wetlands, can generate 55 billion liters of water gains per year, within five years – equivalent to two months of Cape Town's current supply needs – and 100 billion liters within 30 years. Such water gains can be achieved at one-tenth the unit cost of alternative supply options and can create up to 350 jobs. Ensuring the sustainability of these activities through a clear sustainable funding strategy will improve water security for the entire Greater Cape Town region and its 4.4 million people.

An important issue that needs to be discussed is the control of future development, so that the additional water resources freed up by more efficient water use and re-use does not simply lead to an expanded footprint of the City, with the result that there are no "additional" water sources

to draw on in times of drought.

## Best Practices

Lessons Learned from the Cape Town experience

It is important to acknowledge the context (i.e. working in an exceptionally high biodiverse system).

- The importance of having good spatial data in particular was highlighted – the City of Cape Town had invested in the production of GIS datasets showing the extent and importance of remnant terrestrial areas as well as wetlands and rivers. Better spatial data showing areas of surface/groundwater linkages would have been useful in decision making. Emphasis on collecting long-term data that will inform interventions in the next drought is important. Data are key in making decisions: having good long-term monitoring information prior to a disaster can assist in ensuring that good decisions are made and in minimizing long-term risks, which may have unintended consequences.
- Once the natural scientists, geohydrologists, engineers and planners became involved there was improved and faster decision making: establishing multi-disciplinary teams across scientific disciplines as early as possible helps to solve problems and find win-win solutions Rules of engagement are also important, however, so that ecological concerns are not downplayed in search for emergency water supplies.
- Share data and trust each other to use the data for the intended purpose right up front. Without all the information, poor decisions may be made and the time taken to make decisions may be needlessly increased.
- Many of the solutions take years to implement, so early planning and implementation is the only way to avert disasters. Cities need to recognize the time lag for water interventions to be established, and implementation of interventions should take place well before the disaster stage.
- Cities need to recognize the impacts of climate change and the unpredictability of rainfall where there is an over-reliance on surface water.
- In South Africa, directives are issued under the National Environmental Management Act in response to an emergency situation, and allow the applicant to proceed with a listed activity without an environmental authorization. Misuse of such directives must be avoided at all costs and there should be stringent and timeous independent auditing to ensure that necessary environmental mitigation measures are implemented and environmental considerations are not ignored.
- A challenge is the fact that approaches to drought must be adaptive, so that new technology can be taken advantage of. However, new technologies must also be adaptive and able to respond to unforeseen ecological or other impacts associated with their use.

- Avert disaster. Plan ahead: prevention is better than cure.

## Conclusion

Opportunities and Successes Resulting from the Cape Town experience

- The Greater Cape Town Water Fund brought partners together to plan collectively, monitor progress and impacts, and pool resources to achieve the highest return on investment.
- Removal of alien invasive trees has been going on for over 20 years. The drought and the Water Strategy (CCT 2019) have accelerated this. The remaining aliens in two catchments should be cleared within three years, and the City is at present working on a restoration plan for both areas.
- The City has recognized the importance of owning important water-providing catchments.
- Protection of the main recharge areas of the Atlantis Aquifer in the Dassenberg Coastal Catchment Partnership (DCCP) was an important contribution to protecting the water supply to Atlantis.
- The City's nature reserves have been proclaimed under the National Environmental Management: Protected Areas Act (No. 57 of 2003; NEM:PPA). The Protected Areas norms and standards should ensure that these areas remain well managed.
- The inclusion of Catchment Management in the City of Cape Town Water Strategy, and recognizing investing in catchment management as one of the ways to increase water supply.
- The development of the Ecological Investment Framework and Invasive Alien Strategy for the Western Cape Province.
- The development of the desk-top tool for analyzing groundwater augmentation proposals.
- The City recognized skills gaps and has, for example, employed a geohydrologist in the Bulk Water Department, adding huge value to the team.
- With many urban watercourses having been impacted by too much water in the past, leading to changes in their hydroperiod that resulted in large-scale biodiversity loss, strategic harvesting of effluent from these areas might create opportunities to improve ecosystem function.
- The drought has created a need for knowledge and learning across various disciplines, and research projects should be set up to include baseline data and monitoring needs. Existing data on water quality should be analyzed to track the effects of the drought on aquatic ecosystems, including rivers and wetlands.
- A greater understanding of the long-term impacts of large-scale groundwater abstraction on sensitive ecosystems is required. This topic had been investigated for several years but the findings need to be made public and long-term monitoring is required.
- An emphasis on effluent re-use / recycling could have major benefits for rivers and wetlands, including important recreational areas currently impacted by excessive effluent. However, the emphasis should be on direct effluent recycling, and not treatment of groundwater or surface water after it has received the treated effluent, as this means these systems remain contaminated. Education of politicians and local communities about effluent re-use is an important

long-term activity to make effluent re-use a norm.

## Further Reading

Cape Floristic Region World Heritage Site: https://whc.unesco.org/en/list/1007/

Cape Town Bioregional Plan 2015: https://resource.capetown.gov.za/documentcentre/Documents/Bylaws%20and%20policies/Bioregional%20Plan%20for%20City%20of%20Cape%20Town%20-20(Policy%20number%2044854)%20noted%20on%2019%20August%202015.pdf

Cape Town Water Strategy 2019: https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies,%20plans%20and%20frameworks/Cape%20Town%20Water%20Strategy.pdf

City of Cape Town Biodiversity Report 2018: http://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/CCT_Biodiversity_Report_2018-07-27.pdf

Environmental Water Allocations
King, J., and C. Brown. 2006. Environmental flows: striking the balance between development and resource protection. Ecology and Society 11(2): 26 and http://www.ecologyandsociety.org/vol11/

iss2/art26/
Western Cape Climate Change Response Framework and Implementation Plan for the Agricultural Sector, better known as SmartAgri:
https://www.greenagri.org.za/

Western Cape Climate Change Response Strategy 2014:
https://www.westerncape.gov.za/text/2015/march/western_cape_climate_change_response_strategy_2014.pdf

# Social Science Position Paper

*Initially prepared for the Cities Facing Escalating Water Shortages conference at the University of the Western Cape, January 2020.*

Lead authors: Mafaniso Hara, Darlington Sibanda and Bongani Ncube

Version: 20 January 2020

## Executive Summary

Urbanization is a growing challenge all over the world. In former colonies in Africa, Southeast Asia and South America, cities are increasingly attracting people from rural areas who come in search of jobs in the formal economy, better economic opportunities and improved lifestyles. However, during times of drought and water stress, the poor and vulnerable communities, particularly in cities, are usually the hardest hit. We argue for the importance of a spatial planning approach by cities that takes into account the importance of the rights of the urban poor, marginalized and vulnerable citizens in terms of addressing their rights, tenure and access to water and sanitation. In our view the water vision for global cities should be: ***Well-governed inclusive cities whose planning is human-centred with an ability to provide adequate water services for the poor and marginalised.*** There are global, continental and country plans in place which all recognise the need to address equity and social inclusion. Our contention is that the problem of water scarcity for the urban poor is a social issue. The problem, therefore, is not only prevalent during times of water shortages in cities, but that it is ever present. The key causes of social scarcity are historical and economic dispossession, flawed governance of water resources, informal economies, lack of recognition of 'the right to the city' for poorer segments of urban populations, and the politicization of the hydro-social contract.

## Introduction

In South Africa, the removal of the apartheid era influx controls has meant that Black South Africans are no longer temporary residents in cities, but citizens who have equal rights to the cities and therefore have greater degrees of freedom to establish their own homes within or outside of the ambit of the state and/or the residential property market in cities (Thompson and Tapela, 2018). The implications and consequences of this have been an increase in the number of households in urban areas and a hyper-growth of the demand for housing and social services. The state (particularly Municipalities and local government), as a result, struggles to deliver services to meet these burgeoning needs and demands. In South Africa, the net effect has been an increase in backlogs of historically disadvantaged individuals/households trapped on waiting lists or databases and/or dependent on informal rental and tenure markets.

There has also been an increase in the number of households residing in backyard shacks. While metros show the greatest increase in informality of housing and tenure, findings show that this urbanization trend is spreading to non-metropolitan cities and towns and smaller towns across South Africa (Thompson and Tapela, 2018). Once people move into urban areas, the next step is trying to "move up the ladder", which includes access to free government housing, informal settlement upgrades, formalization of tenure and tenure security. For residents living under informal tenure, infrastructure upgrade provides an opportunity to link housing upgrades with secure and improved water and sanitation as part of progressive realization of the constitutional (human) rights to secure access to water and sanitation services. Unfortunately, the reality is that cities find themselves continuously struggling to provide space and services. In a study on the impacts of urban land use planning for climate adaptation Anguelovski et al (2016) found that 'in a comparison of eight cities land use planning interventions for adaptation can disproportionately impact low income and minority groups by creating or exacerbating different forms of socio-spatial inequality.'

## Water Vision for 2050

Global effort towards addressing access to water and sanitation and ensuring sustainable development has been ongoing for several decades. The United Nations (UN) declared the period 1981-1990 as the International Drinking Water supply and Sanitation Decade. In 1987, the United Nations Commission on Environment and Development defined sustainable development as "development that meets the needs of the present while safeguarding Earth's life-support system, on which the welfare of current and future generations depends". This subsequently led to the Millennium Development Goals (MDG) based on the Dublin Principles (ICWE,1992). Water and sanitation were embedded in MDG 7 (Ensure Environmental Sustainability) and the main target was to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation.

One of the aspirations of the African Union's Agenda 2063 is a 'prosperous Africa based on inclusive growth and sustainable development'. Inclusivity as shown under Sustainable Development Goals (SDGs), is in recognition that there are already sections left out, be it the rural poor or urban poor. The Agenda further aspires to an 'Africa whose development is people-driven, relying on the potential of African people, especially its women and youth, and caring for children'. Inequality and gender remain key challenges in most countries across Africa. In formulating a vision for global cities, this needs to be taken into consideration.

In South African one of the key aims of the flagship National Development Plan (2012) was to eliminate poverty and reduce inequality. With recognition of the need to address inequality South Africa also revised the National Water Resource Strategy (NWRS2, 2013) with the major focus on '*sustainable, equitable and secure water for a better life and environment for all.*' Access to

water and sanitation were seen as important contributing factors in achieving these aims. Unfortunately, the NWRS2 has also failed to bring water to the resource poor, and the government has now come up with a Water and Sanitation Master Plan (2019) which includes a Call to Action document which sets out the critical priorities to be addressed by the water sector in the period from 2018 –2030. Plan to Action provides the basis for, and a more detailed analysis of the key issues and Schedule of Actions. Water experts believe *the government and stakeholders in the water sector cannot achieve the plan alone or by trying to manage the proposed actions in the traditional top-down approach.*

The Western Cape provincial government developed its own Western Cape Sustainable Water Management Plan (2017-2022). Unfortunately, the 2014-2018 drought left the province and the city reeling under severe water shortages. One of the glaring causes of the failure to manage water shortages was the lack of integrated planning between the provincial government, the city and the national government. The result was a blame game that remains unresolved, although efforts were made to jointly find solutions when the Department of Water and Sanitation (DWS), in partnership with the Western Cape Government, hosted a high level Water Indaba in 2017. After the drought the City of Cape Town became more aggressive in dealing with water issues. The strategic water vision for the City of Cape states that: *Cape Town will be a water sensitive city by 2040 that optimizes and integrates the management of water resources to improve resilience, competitiveness and liveability for the prosperity of its people (City of Cape Town, 2019)*

While the principles spelled out in the City of Cape Town's water vision explicitly mention 'inclusivity' and 'work together across boundaries', the city remains starkly divided. Access to services such as water and sanitation remain heavily skewed with informal settlements and backyard dwellers on bottom levels of the water ladder. The big question is, therefore, *"What types of mechanisms of access to water and sanitation services (within the mix of formal and informal tenure arrangements) in cities will ensure that inclusive engagement and participation of the urban poor and marginalised is achieved?"*

As already shown there are global, continental and country plans in place which all recognise the need to address equity and social inclusion. In our view the water vision for global cities should be: ***Well-governed inclusive cities whose planning is human-centred with an ability to provide adequate water services for the poor and marginalised.*** This global water vision will place the poor at the centre of water provision while ensuring inclusivity through effective engagement and participation. We believe this can be achieved if cities like Cape Town adopt water sensitive planning that includes the city, its environment and all its people.

## Assumptions

Our contention is that the problem of water scarcity for the urban poor is a social issue. The

problem, therefore, is not only prevalent during times of water shortages in cities, but that it is ever present. Thus the adage of "Social Scarcity of Water" (Tapela, 2012) is an apt descriptive reference to this existing situation regarding water for the poor in cities. The disjuncture between people's multiple-use of water and water services governance suggests that social water scarcity can be seen as a product of social exclusion. This is influenced by political, economic, social and power dynamics underpinning the institutions that structure social relations, rights and security of access to water (ibid). Thus water social scarcity revolves around issues of inequality (social, economic, political), governance and governing systems (formal and informal), markets, transparency and accountability, systems of rights/tenure (type of rights, bundles of rights, etc.).

The social science task team will mainly base its arguments on the political economy of water provision and water services in cities in developing countries. Our main focus at this stage is on Cape Town in South Africa as a city where water scarcity and the threat of day zero recently made global headlines. There is a need to look at what drives social scarcity of water in post-colonial cities and persistent skewed spatial planning and resource allocation related to water and sanitation. What role does policy development and water governance play in providing access to water for all? What are the roles and limitations of global (e.g. Sustainable Development Goals (SDGs), regional (for example the (Southern African Development Community (SADC) water protocol) and national (including urban/city) policy development processes in catering for the poor and marginalised?

The key questions that will help to develop policy and implementation and enable city officials and other key stakeholders to deal with water and sanitation service delivery challenges emerging from the rapid urbanization and de-agrarianisation socio-economic landscape are as follows:

1. What challenges does rapid urbanisation in developing country cities present? How do colonial, post-colonial and apartheid histories influence how to deal with the challenges?;
2. What are the patterns of access to water and sanitation services within the mix of formal and informal tenure arrangements in cities (including engagement and participation of the urban poor and marginalised)?;
3. What are the challenges of provision of water and sanitation for informal settlements and dwellings in cities?;
4. What challenges do informal and unrecognised tenure arrangements present in terms of equitable access to water and sanitation for the urban, marginalised and vulnerable groups?;
5. What are the gender and livelihood issues associated with challenges of access to water and sanitation services in the mix of tenure and access rights arrangements that are found among vulnerable marginalised urban populations?; and
6. What lessons can we draw from Cape Town (and other African cities currently facing similar problems) and the way the city dealt with (or other cities are trying to deal) the drought and water shortages from a sociological perspective?

## Conceptual Framework

This review paper uses the 'Hydro-social Contract' as the key conceptual framework for analyzing and understanding the social issues around the provision of water and sanitation in cities.
A 'hydro-social contract' refers to an implicit contract that exists between the State, Society and Markets (Lundqvuist, 2001). The term refers to the pervading values and often implicit agreements between communities, governments and business on how water should be managed. Turton and Meissner (2002:2) define the hydro-social contract as:

"The unwritten contract that exists between the public and the government that comes into existence when the individual is no longer capable of mobilizing sufficient water for their own personal survival, and that acts as a mandate by which the government ultimately takes on and executes this responsibility. This hydro-social contract thus acts as the basis for institutional development, and also determines what the public deems to be fair and legitimate practice such as the desire for ecological sustainability, to which politicians react."

While the hydro-social framework is useful in defining the key elements that require scrutinisation when analyzing the social issues in relation to water and sanitation delivery for the poorer and marginalised sections of urban populations, it is important to note that the framework assumes de-politicization of the issues and the implementation approach, which is far from reality. For example, the South African hydro-social contract has not been shaped by the dominant cultural perspective and historically embedded water values, but has been molded by a racially based historical political economy governing resource allocation (Thompson and Tapela, 2018). Given this political history, the complexity of dealing with equity in resource allocation and service delivery should not be under-estimated. Equally, the colonial history in most developing countries has resulted in class stratification, which also politicizes and skews resource allocation and service delivery in urban areas.

Secondly, the conceptual point of departure in understanding the hydro-social contract is that there are underlying unequal power relations in the exercise of rights and responsibilities, and also the framework is not value free, in terms of ethics, principles, ideologies, interests and motivations (*ibid*). Thirdly, the hydro-social contract is transacted through the socio-ecological fabric of space through time. Space, in this context refers to the linkage between land, housing, water resources, water and sanitation infrastructure and social constructs (particularly property rights) that the state, markets and society craft (Thompson and Tapela, 2018 ). Without security of tenure, investment in hydraulic infrastructure becomes untenable and/or insecure. Recognised tenure is key-most among common denominators that determine the patterns by which citizenry practically negotiate and attain (or not) secure access to water and sanitation services (*ibid*).

## Focal areas specific to water and cities from a social science perspective

**Causes and challenges of social scarcity of water in cities**

Here, we outline some of the key causes and consequences of the social scarcity of water in cities. These are as a result of historical and economic dispossession, flawed governance of water resources, informal economies, lack of recognition of 'the right to the city' for poorer segments of urban populations, and the politicization of the hydro-social contract.

**Scarcity as a consequence of historical and economic dispossession**

The perpetuation of social, economic and political inequality in South Africa and developing country cities in general is a result of the colonial past, apartheid and current neoliberal policies. Li (2009) argues that current policies amount to 'let live and let die' among social groups in society. The water issue is often conflated with other issues, such as housing, infrastructure, planning, land, informal settlements, etc.

There is a need to understand how urbanisation has happened in the global South cities. For example, in 1994, at the time of South Africa's first non-racial democratic elections, an estimated 1.06 million households comprising 7.7 million people lived in informal settlements. Socio-political control through the state driven, racial discrimination policy of apartheid firmly entrenched the underlying South African urban structural form. The apartheid policy's implications heavily weigh on the current relationship between state, citizenship and space (Robinson 1997). In effect, the unequal access to water services was inherited from a colonial and apartheid past in the case of South Africa and colonial past for other former colonies both in Africa and beyond. In South Africa, rapid urbanisation post-1994 has reinforced the spatial segregation instituted under apartheid (OECD, 2011:17).

Rian Malan (2000) paints a rather pessimistic view of the rapid rate of urbanisation in South Africa (taking Cape Town as a case in point) and how this relates to provision of water and other services. (Davies, 2006:60-61)

*"After…the hated pass laws were scrapped, it was as if a distant dam had broken, allowing a mass of desperate and hopeful humanity to come over flooding over the mountains and spread out across the Cape Flats. They came at the rate of eighty, ninety families a day, and built homes with their bare hands, using wooden poles, tin sheeting, bits and pieces of trash rescued from landfills and plastic garbage bags to keep out the rain. Within two years, the sand dunes had vanished under an enormous see of shacks and shanties, as densely packed as a mediaeval city, and populated by fantastic characters-bootleggers, gangsters, prophets, rastafarians, gun dealers and marijuana czars, plus almost a million ordinary people*."

Another dimension which has seen a tremendous growth in South African cities is the backyard housing sub-sector. The census for 2011 indicates that the proportion of backyard renters consti-

tutes 25% of all households (SALGA, 2013). Given this massive and unplanned growth in informal housing and demand for water, sanitation and other services, the number of people utilising toilets, taps, drains and cooking facilities on a specific site across neighbourhoods can stretch the carrying capacity of the existing infrastructure. In such contexts, the importance of the informal water economies in any urban (or rural) setting become prevalent. Thus self-dug wells/boreholes, informal vendors and sharing of water become important in the provision of the multiple uses and users of water - certainly for those without proper access to public supplies (and those who cannot easily afford water from public supplies). The numbers and proportions joining this informal water economy are bound to have increased massively with increased urbanization. It is no wonder that the last decade has seen growing unrest and violent demonstrations against lack of or/and poor service delivery in South Africa (Tapela, 2014; Sibanda, 2018). Despite the foregoing, formal households use the lion's share of the water in Cape Town at 55% in 2016/2017 financial year. Retail businesses and offices were the second biggest consumer at 12.8%. Informal settlements used only about 3.6%.

In other African cities, for example Harare, the growth in the number of self-dug wells/boreholes is a response to a deepening water crisis (Manzungu and Chioreso, 2012). The ability to respond is however dependent on the socioeconomic status of the households; the situation remains precarious for poorer households (*ibid*).
Lack of basic services has sometimes been blamed on 'informality' of informal settlements in the context of legality (or illegality) of such dwellings. For example, for Kibera, one of the largest informal settlements in Africa (Mutisya and Yarime, 2011: 203)

"*The Kenyan government owns all the land upon which Kibera stands, though it continues to not officially acknowledge the settlement; no basic services, schools, clinics, running water or lavatories are publicly provided, and the services that do exist are privately owned.*"

Even beyond the problematic land-water legalities, strict legal approaches and policy formulations on water service delivery easily end up in criminalization that hits the poor hardest. The question becomes 'what forms of policy review and (gendered) government support could stimulate whatever works and prevent negative excesses in water governance and service delivery?' Royston and Narsoo (2006) allude to this fact by stating that invisibility and lack of recognition carry the risk of side-lining many vulnerable people, households and communities from development opportunities.

Research findings by Sibanda (2018) indicated that informality leads to poor access to water and sanitation services. This is because the 'package' of services are normally linked to formal property titles. In some cases, municipalities do not provide services to informal settlements on private land or disputed tenure settlements (Sibanda, 2018). The quality of water services was also

affected by the geographic location of some of the informal settlements. Taing's (2017) research in Cape Town showed that officials preferred providing informal settlements with un-sewered or waterborne sanitation because ground conditions on which the settlement is located was not ideal due to various reasons, among them high capital costs for construction of new sewer and treatment plants and that informal settlement occupants might interpret this as unofficial tenure rights. This is also the case with water services.

The blanket approach to water and sanitation services delivery which the state followed after 1994 ignored serious pertinent issues for people in different tenure arrangements (Sibanda, 2018). It is important to address pertinent questions such as; how does the right to adequate housing, water, sanitation and others coalesce or contradict each other? Given that tenure arrangements are fluid and complex in urban and rural settings, how do they impact other rights such as basic services?

**Governance challenges**

Key to explaining water governance are rules and norms that govern institutions. These both include 'formal rules and informal rules', transparency, accountability and influence of externalities such as market forces and how these affect not only access to water and other services but also how they are perceived by urban communities living on the margins, how governance is enforced (or not) in different contexts and the impact therefore on overall water governance in cities. While literature views governance overwhelmingly as the exercise of political, economic, administrative and legal authority in the management of a nation's affairs (World Bank, 1994), Bang and Esmark (2013) consider governance to be an empirically observable politico-administrative way of making public policy-making, reforming and organising.

Poor governance appears to be the hallmark in some if not most of the African Cities. Cities that are dynamic need adaptive governance to accommodate rapid urbanisation and population growth to enable 'social mobility' among the poor (Turok, 2012). In addition, in the context of shared water points, as is the case in informal settlements in most cities in South Africa and most African cities, the issues and questions are: what type of access rights exist? What are the rules for access? How is access governed? How can the constitutional human rights be exercised and enforced? Who conceives all these? Who enforces these? and How are they enforced?

Boundary (physical, social, economic, political, etc.) rules according to Ostrom (2013) determine who can access a particular service and at which times. The role of socioeconomic boundaries is demonstrated by Manzungu and Chioreso (2012). The rules might or might not be written down. In some instances, as research has shown, access to water for tenants renting in someone's house might depend on the rules the landlord put in place (Sibanda, 2018). Likewise, research done by Tapela et al (2015) as well as Sibanda (2018) showed that sharing water points such as community standpipes can involve a complex mix of rules and processes. In both studies researchers found

some stand pipes with a lock, indicating restricted access or some form of access arrangements. Governance is therefore key in determining access to water services in African cities.

Since 1994, South Africa has failed to provide equitable services to the poor, in both the rural and urban sectors. The new Water and Sanitation Master Plan (2019) proposes a paradigm shift that includes recognition that in order to achieve water security there will be a need to "*ensure equitable access to the limited water resources and to deliver reliable water and sanitation services to all.*" Unfortunately, according to one of the top University of Cape Town scholars and water professional, the master plan may not go far enough to address the impending water crisis (Kevin Winter: https://www.news.uct.ac.za/article/-2019-03-20):

*"DWS (Department of Water and Sanitation) and stakeholders in the water sector cannot achieve the plan alone or by trying to manage the proposed actions in the traditional top-down approach. The challenge is too big."*

The Policy Draft for the City of Cape Town (2013:1) acknowledges that; 'although the City has made good progress in decreasing the service delivery gap in informal settlements, the organic growth and form of informal settlements, makes it difficult to provide municipal utility services such as water, sanitation, electricity and waste removal at the required minimum basic national standards'. In addition, the City claims that 'informal settlements are characterised by lack of formal tenure, lack of public space and public facilities, inadequate access to municipal services, and non-compliance with planning and building regulations' (City of Cape Town Draft policy for 2013). The situation is similar to cities such as Lusaka and Harare, although the historical and political narratives may be different.

One of problems in South Africa are the dual and overlapping and sometimes unclear governance mandates for water resources and water and sanitation services, which causes persistent confusion between the national Department of Water and Sanitation (DWS) and the cities. For example, water resources management is a function of the national government, while water services provision is a function of municipalities (and cities) and local government. The Cape Town Water Supply Systems is located outside the jurisdiction of the city and the system is governed by the DWS. In times of crisis like the recent drought, the DWS response was slow and while the City of Cape Town might have needed to take more responsibility, they were limited by their mandate (Ziervogel, 2019). Thus, during the Day Zero in Cape Town:

*"Officials' frustration with DWS included delayed responses including announcements of restrictions and delays in funding infrastructure projects as well as national's lack of leadership on the drought".*

Other areas of confusion include unclear regulatory and governance mandates for alternative wa-

ter sources, such as authorisations required for boreholes and rainwater harvesting.
In Zimbabwe the provision of water services in cities was a traditional function of municipalities, but political play started to interfere with the systems. Manzungu and Chioreso (2012: 121-122) reiterate:

*"Because the national government wanted to take over control of revenue from the profitable water account, it (the central government) took over the provision of water and sanitation services in local authorities in the early- to mid-2000s".*

*"The decision by the government to return water and sanitation to local authorities in February 2009, provided yet another twist in the relationship between central and local government. The new councils that were elected in March 2008, found themselves saddled with a giant malfunctioning water and sewer reticulation system."*

The political play between central government and municipalities has resulted in the total destruction of the water and sanitation system and untold suffering, especially for the poor and marginalised. The Zimbabwe Peace Project says SDG Goal 6 'remains a pipe dream unless there is more commitment and political will on the part of local and central government to improve the situation

**Informal water economies**

As cities continue to face water scarcity, it is the poor who are affected most. It is important to start recognising the growth of the informal water economies in any urban (or rural) setting. Self-dug wells/boreholes, informal water vendors and sharing of water could well provide for more than half of the multiple-use water users, certainly for those without proper access to public supplies (and those who cannot easily afford public water). Both the numbers and the proportions are bound to massively increase with the growing and projected future urbanization. In Harare for instance, the failure by the City to provide portable water has resulted in many households drilling their own boreholes and selling water to those who need and can afford it (Nhapi, 2009, Manzungu and Chioreso, 2012). Similar examples are found in Dar es salaam (Smiley, 2013), Nairobi (Smith School of Enterprise and the Environment, 2014) and Lusaka (Dagdeviren, 2008).
For Cape Town, Ziervogel (2019) argues that a 'systems approach' is required. This approach includes for instance, that during the drought in Cape Town 'many citizens and organisations installed their own "micro"-water sources, including boreholes, rainwater tanks and greywater systems' (Ziervogel,2019:17). Even beyond the problematic land-water legalities already mentioned, strict legal approaches on water service delivery easily end up in criminalization that hits the poor hardest. A good example being the need to register boreholes in the City of Cape Town and the national Department of Water and Sanitation guidelines for all borehole and WellPoint use gazetted and effective from 12th January 2018 (Government Gazette No. 41381 (Vol. 631)).

The question therefore remains - what forms of (gendered) government support could stimulate whatever works and prevent excesses?

**Rights to the City**

The Lefebvre (1996) 'rights to the city' discourse presents a platform for the masses to claim the enjoyment of full rights in urban spaces like anybody else. This also plays into water issues, particularly in the context of water shortages as the poor would continue to view this as denial of access to adequate and quality water. Those who perceive to be excluded from such citizens' rights have different ways of expressing the need for their rights to be recognised. In South African cities, various ways of protesting have happened. McFarlane and Silver (2016) argue that rallying around the poor sanitation issue and responding to this through throwing human waste in public spaces such as Cape Town International Airport as happened on 25th June 2013 (https://www.iol.co.za/news/faeces-fly-at-cape-town-airport-1537561) becomes *politics* of human waste. This means that services such as water and sanitation cease to be just tangible and physical elements, but they start representing other ways of 'seeing' (McFarlane and Silver, 2016) and they become sites of contestation and symbols upon which the excluded rally to demand their rights.

Thompson and Tapela (2018) argue that the institutional and governance issues are compounded by the analytical/ideological bias in policy analysis towards 'Cities without Slums', rather than the Rights to the City approach. The authors provide the example of the City of Ethekwini (South Africa) where this ideology found concrete application in the Slum Eradication Policy. Another example is 'Operation Murambatsvina ('Drive out the rubbish' or 'Restore Order')', implemented by the Zimbabwean government in 2005. According to Potts (2006), the campaign 'was designed to eradicate 'illegal' housing and informal jobs'. Unfortunately, the results were negative impacts on the livelihoods of 'hundreds of thousands of poor urban residents.' The author further points out some of the root causes of the campaign as being 'an ideological adherence to modernist planning and the associated image of a 'modern' city; and a desire to decrease the presence of the poorest urban people, by driving them out of the towns, because of an incapacity to provide sufficient and affordable food and fuel for them'.

The policies around slums and informal settlements in cities across the world therefore require grappling with the political content of the hydro-social contract.

**The politicized nature of the Hydro-Social Contract**

While municipalities and local governments in South Africa generally claim to be addressing the backlogs to water and sanitation, housing and infrastructure provision, such pronouncements need to be viewed through the analytical lens of the hydro-social contract. In South Africa, the politicised nature of the hydro-social contract has led to socio-economic distortions, which have been reinforced by global structural inequalities. In this context, the dual economy (formal and

informal economic sectors) policy lens fails to take cognizance of the fact that the vast majority of the marginalised poor are not so much excluded as included on highly adverse terms (Thompson and Tapela, 2018). The problem is, more often, not that the poor are excluded from particular institutions, resources or larger processes, but that they have been included on inequitable or invidious terms. This is because the institutional arrangements governance practices depoliticize the contract, in effect falling to sufficiently deal with and address the underlying structural distortions.

Boelens (2008) suggests that contrary to the depoliticized assumptions of the hydro-social contract, water rights are in most instances generated, constituted and distributed according to the prevailing class, gender (Goldin, et al. 2016) and ethnic relations and contradictions in both intra-community and wider socio-political arenas.

## Case Studies

Here, we provide case studies of some cities in terms of waters and sanitation provision. Two (Singapore and Perth) are probably what one could call examples of best practice, while the others (Santiago, Lusaka and Nairobi) could be examples of challenged practices to water and sanitation provision.

**Singapore**

Historically, Singapore was forced to rely on Malaysia for its water supply due to limited land mass and storage capacity. When the state intentionally planned to ensure national water security there was widespread public support on the initiative. Subsequently, the approach was to establish a diversified, clean, safe and sustainable water supply that is sufficient to meet the country's growing demand for water (INSEAD, 2013).

Singapore established the Public Utilities Board which was given a 'high degree of autonomy in designing policy and spearheading initiatives aimed at ensuring an efficient, adequate and sustainable supply of water' (INSEAD, 2013). According to Tortajada (2006), Singapore adopted the four-pronged approach to establish a robust, diversified and sustainable water supply. This is referred to as the 'Four National Taps' which consists of; (1) local catchments; (2) imported water from Malaysia; (3) recycled water, brand named 'NEWater'; and (4) desalination.

The World Bank (2006) highlights the following areas as having positive impact in the current water resource management strategy in the Singapore:

- Political will
- Institutional Integration
- Integrated Land Use Planning
- Enforcement of Legislation

- Public education
- Application of advanced technology

**Perth, Australia**

Perth is known as one of the best water-wise cities in Australia. The biggest threat to the city's water is persistent drought caused by climate change. According to the Department of Water and Environmental Regulation (2019), since 1975 Perth's rainfall has fallen by 15% and temperature has risen and continues to do so. This has resulted in drastic changes being made, including having drinking water being supplied exclusively by rainfall runoff and ground water for other purposes. In the 1970s it was a completely different picture. Currently dams supply only 10% of drinking water, 40% comes from ground water, 48% from desalination and 2% from ground water replenishment.

- Perth's water vision has been presented under four themes which include;
- Fostering stewardship of the system
- Protecting and enhancing the wellbeing of people and the environment
- Integrating and engaging with the built and natural landscape
- Sustaining the long-term use of Perth's resources (Hammer, Rogers, Chesterfield, 2018)

The approaches that Perth has adopted include rain water harvesting, public awareness, technological innovation such as installing dual meters are used to monitor demand and detect leaks in both scheme water and borehole water among other initiatives (Department of Water and Environmental Regulation, 2019).

**Santiago, Chile**

Santiago is a megacity which encompasses 52 municipalities of 'the city region' in an area that shares one water supply and one administrative jurisdiction and exhibits profound socio-spatial segregation (Gallagher, undated). Critics argue that Pinochet's government marginalized the opposition and came to revere expert-led positivist science at the expense of citizen participation in public decision-making (Zunino 2006; Paley 2004). The military dictatorship left a lasting impact through the commodification, marketization and privatization of water supplies which currently affects the water policy (Borzutzky & Madden 2011). Like other Latin American cities, Santiago is characterised by high levels of urbanisation and inequality. In addition, there are high levels of resource consumption, unequal access to resources and services, inadequate housing conditions and weak institutional control mechanisms. From a resources perspective, unlike cities like Perth and Cape Town, Santiago's contributing watershed has enough water to satisfy current demands from the municipal and industrial as well as the agricultural sectors in normal to wet years (Krellenberg, Kopfmüller& Barton, 2010).

**Lusaka, Zambia**

Lusaka Province which constitutes the capital city of Zambia (Lusaka) had a projected population of about 3 million people in 2017 (zamstats.gov.zm). The increase in the population is accompanied by increase in the demand for water, like in any other big city. In the late 1980s Zambia implemented reforms for commercialization and privatization of water and sanitation services. Families in low cost housing were to pay less than those in higher income housing. However, the unintended consequences were that water tariffs were low but still unaffordable to the majority. As a result, the quality of access to safe water in the urban sector has declined and poor households rely on public taps, boreholes and wells rather than water supply through residential pipes (Dagdeviren, 2008). Most of the residents depend on the shallow well water because of proximity and lower costs. As a result, there is greater incidence of water-borne diseases among residents who use such water (Levy et al, 2017). The poor quality of water is directly related to poor sanitation. Kennedy-Walker et al (2015) found that 'the level of sanitation access, safe management of excreta, sanitation service provision and associated knowledge in Peri-Urban Areas (PUAs) of Lusaka was poor.' It is also in these areas where 60% of the population resides and 90% of them use pit latrines *(ibid)*.

Since the late 1980s and early 1990s Zambia embarked on water sector reforms to "address a number of challenges including poor institutional and legal framework, deterioration of water and sanitation services, inadequate human resource capacity, low coverage of water and sanitation services, inadequate stakeholder and community participation, limited and ever-decreasing capital investments, and the need to adapt to emerging international trends in water management" (Chitonge, 2011). However, the Zambian water governance system has remained highly sectorial, with insufficient institutional and legal frameworks. The structure is centralized and lacks effective stakeholder participation (Uhlendahl et al, 2011), resulting in a large sections of the population remaining without safe water and sanitation services.

**Nairobi, Kenya**

Due to rapid urbanization, the City of Nairobi is expected to spill into neighbouring urban areas with a prospect of becoming a metropolis. The City consists of around 26% of the total urban population in the entire country (Ministry of Planning and National Development and Vision 2030). Nairobi is an economic hub for East Africa with a population of 3,5 million, which is growing rapidly due to rural-urban migration. It has the largest population density in Kenya at 4,515 per square kilometre (National Council for Population and Development NCPD, 2013). Besides the major water supply deficit, Nairobi faces unpredictable droughts and flooding. According to the Smith School of Enterprise and the Environment, the city's current water supply is 23 per cent lower (170,000 $m^3$per day) than water demand and this is expected to increase to 63% deficit by 2035. Non-revenue water is as high as 42% due to aging infrastructure and illegal connections (Smith School of Enterprise and the Environment, 2014). Due to insufficient and unreliable supply, most households and enterprises invest in their own alternative sources of water supply.

Estimates indicate that of the over 3,500 boreholes located in Nairobi County less than half (47%) have abstraction permits, nearly two thirds (63%) are unmetered, and four in five (78%) users do not pay for water (Smith School of Enterprise and the Environment, 2014). In addition, as a result of informal settlements relying on pit latrines, ground water is contaminated and largely unsafe for domestic use.

## Conclusion

In this position paper, we argue that the recognition of the urban poor should take cognisance of the importance of addressing their rights, tenure and access to water and sanitation. While the Hydro-social contract provides a framework for analysing these issues, de-politicisation of the framework is not practical/realistic. Also, water problems faced by most cities have a lot to do with distorted and disjointed policy and legal frameworks that persistently fail to address historical imbalances and inequities. The challenges faced by the urban poor are numerous, but for this the position paper we have focused on issues that we feel are critical and should be addressed as a matter of urgency. These are as follows: the social costs of water, water governance, security of tenure, inclusive spatial planning, and effective engagement/participation of communities. These issues cut across most cities, especially those in developing countries.

We recognise that most cities see water as a source of revenue, but there is a need to consider the plight of the poor and marginalised. The city of Cape Town and many other (African) cities try to provide free water for the poor, but there remain huge structural, planning, governance and infrastructural challenges. There is also the question of what are the best practices for provision/access to water and sanitation services within the mix of formal and informal tenure arrangements in cities; and how to achieve inclusive governance through engagement and participation by the urban poor and marginalised. Another question is 'What models of water and sanitation provision should the cities adopt for improved water and sanitation services delivery and sustainable utilisation of water resources?

Our overall recommended vision for water and sanitation services cities is:

"the need to develop ***well-governed, inclusive cities whose planning is human-centred with an ability to provide adequate water services for the poor and marginalised."***

However, there is a need to have a common understanding of the root causes of the marginalisation that continue to worsen in most developing country cities before we can come up with effective strategies to address the challenges. Some of the key causes could be as follows:

- The global, regional and national **frameworks and policies** have so far failed the poor and marginalised. Access to clean water and sanitation services is still a

dream in most African cities (including Cape Town). There are gaps in most frameworks, which are probably a result of the failure to include the poor and marginalised in the development processes of the frameworks.

- Water scarcity in most developing country cities is a consequence of the **historical and economic dispossessions.** The water problems faced by African cities have a lot to do with distorted and disjointed policy and legal frameworks that persistently fail to address historical imbalances.

- Water scarcity for the poor is more a social scarcity. Lack of **inclusive spatial urban planning** has kept the poor in the social, political and planning peripheries of the cities.

- Lack of **recognition of 'the right to the city'** for poorer segments of urban populations and the politicization of the hydro-social contract has kept the poor out and at arm's length regarding their issues, problems and challenges.

- Poor and unclear water structuring of the **water governance systems** have left the poor and marginalised outside. These include 'formal rules and informal rules', transparency, accountability and influence of externalities such as market forces and how these affect access to water and other services, and also how they are perceived by urban communities living on the margins. This includes how water regulations are enforced (or not) in different contexts and the impact of these on overall water governance in cities.

- Formality and security of tenure are major determinants of the provision of water and sanitation services in most cities. The **recognition of informal tenure in its various contexts** would be important step in the right direction. this would begin to deal with the question of what models of service provision should cities adopt in order to provide services to informal and unrecognised tenure holders in order to achieve equitable access to water and sanitation for the urban, marginalised and vulnerable groups.

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# Civil Society Position Paper

*Initially prepared for the Cities Facing Escalating Water Shortages conference at the University of the Western Cape, January 2020.*

Lead Authors: Ernst Conradie and Jeremy Fackenthal

Version: 19 January 2020

## Executive Summary

This paper will examine the role of civil society in addressing the escalating water shortages that we face now and in the future. While there are many lenses through which to examine water scarcity (e.g. politics, economics), civil society offers a wide breadth of resources (e.g. arts, morality, and religion) for us to address these fundamental issues. This strength is found in its multitude of perspectives and the moral depth that grounds and informs the ways that citizens, households, and grassroots organizations articulate and respond to water shortages. Civil society plays a critical role in motivating and encouraging long-term changes to systems and structures that have led to water crises, and contributes to long-term planning for conditions where such a crises can be avoided, anticipated, or handled in the best way possible.

## Introduction

**What does long-term, escalating water shortages require of civil society?**

Civil society has many referents in different contexts. For this context, it may be helpful to note that it is typically distinguished from government, business and industry, but also from jurisprudence, formal education, the formal health sector, the media, and the arts. Though one may include individual citizens and households, it may be best to focus on the way people organize themselves around social goals and institutionalize such efforts in organizations that cannot be included under any of the above. At the same time, inasmuch as civil society is comprised of citizens, it may be said that civil society underlies other sectors, whether government, business, etc. From inside civil society a distinction is typically made between non-government organizations (NGOs), community-based organizations (CBOs) and faith-based organizations (FBOs). From the government's perspective, such structures are typically referred to as non-profit organizations (NPOs) and are distinguished from business organizations for tax purposes.

NGOs are sometimes quite large and internationally deployed, with extensive budgets and staff. CBOs are typically much smaller and operate at a local level. They are often dependent upon outside funding but may also be more resilient given roots in local communities. FBOs are typically initiated from within faith communities but then become independent as the institution grows

and specializes. This also allows registration as an NPO. Their staff are often highly committed and some draw on volunteer work. One may distinguish such FBOs from organized religious groups and institutions (churches, mosques, synagogues, temples, monasteries) since these operate also as voluntary associations and contribute to civil society on this basis. These local religious communities typically, but not necessarily, form part of national denominational structures and sometimes of global ecumenical networks.

In addition, there are also broad social movements that form part of civil society initiatives. These may be well organized, but not necessarily institutionalized. One example is widespread student protests on climate change such as "Fridays for the Future" and "Extinction Rebellion". Such activist groups tend toward a flatter organization model, with or without official designation as an NPO. Nevertheless, some such groups contribute widely to the advocacy type work of civil society. The activities of such organizations cover a very wide array of initiatives – in the fields of food security, education, health care, various other forms of caregiving, education, arts, environmental concerns and so forth. Not surprisingly, there is a need to engage with the relevant formal sectors but there may be resistance against being taken over by the formal sector given perceived needs and strengths. In some contexts, challenges become overwhelming and government services break down and a need for emergency services and disaster relief arises.[48] This is often done with the help of large global organizations operating in civil society.

For the purposes of this task team, the term civil society will include NPOs, NGOs, CBOs, and FBOs, but will also consider perspectives from various arts – music, drama, literature, poetry, puppetry, the visual arts and the like. It will also make reference to ordinary households of different shapes and sizes, but from the perspectives of citizens and not from the social sciences.

The term civil society is sometimes used in a normative sense, i.e. to refer to civil virtues, civil rights or civil duties. This stands in contrast to "uncivil" behavior like: stealing water, conflict over water, or wasting fresh water. The term civil society will not be employed in this way here, although moral issues will indeed come into play. Moreover, the term civil society can sometimes be used in a way that excludes those who are not citizens and thus players in electoral processes. In response, the category of "the common good" has been used instead.

Organizations in civil society have ready access to grassroots needs and sentiments, are able to

48 Clive Pearson (Charles Sturt University, Sydney), one of the task team members, reports: "We are experiencing an absence of water in Sydney; it hasn't really rained for such a long time: we are due to get some storms this week as cyclones have begun to move over the west coast of Australia and this excess of water raises different problems, including contamination of water and loss of soils on denuded landscapes). But the thing which strikes me is that here we cannot separate our talk about water from our talk about fire (and heat), and quality of air (we are now all talking about 2.5mm particulates in the air which hardly any of us knew existed before). We are seeing how the 'elements' (water) are inter-related with fire and air and land. We are seeing how these things working together compromise our 'creatureliness' through so many animals / insects lost through fire (extraordinary numbers) and our connection with plant life is not what it was (how do you manage a garden: which plants do you choose to keep alive?). Our normal language of environment, sustainability, responsibility perhaps is giving way to 'emergency services', 'disaster relief', a lostness for words. Yesterday we saw a blue sky for the first time since late November, but even so the sun this morning rose orange and who knows what it is 'hidden' and 'unseen' through pressure of water and air."

reach ordinary citizens on a regular basis, and they can draw on volunteer support and tap into community based sources of inspiration (e.g. sacred texts, indigenous wisdom, myths and rituals). A diversity of conflicting interests is seen as a strength but can foster a lack of consensus from (not speaking with one voice). On the other hand, organizations in civil society can also be divided amongst themselves; they are often prone to infighting and political divisions, can suffer administrative weaknesses, become undemocratic, can be led astray by charismatic leadership, are often prone to corruption if not well resourced, and vulnerable to funding constraints.

## Initial Questions

To start a conversation, the civil society task team raised the following questions for discussion amongst participants:

- What contributions from organizations in civil society are necessary for the other sectors (especially politics, business and industry) to be able to address escalating water shortages? "What is it that you cannot do without us?"
- What would organizations in civil society do if and when politics and economics fail to address escalating water shortages, which is likely to happen at least in some contexts in decades to come? "What will we do when you fail, which we think may well happen?"
- What does civil society require from the other sectors to continue to operate at least at a minimal level? "What can't we do without you? / What do we need from you?" (this will be different e.g. for NGOs and for CBOs)
- What are the underlying weaknesses of civil society that may cause a failure to respond to escalating water shortages? "What makes it difficult for us to get our own act together?"

## Water Vision for 2050

Moral vision is a crucial source of inspiration for groups in civil society. This is expressed in various ways in different contexts, but the following core aspects are widely accepted:

- Cities should ensure that potable water is available for every (human) citizen. At best, this should be given at no cost and provide for all drinking and cooking needs; access to water is an inalienable right.
- Organizations within civil society require local governments, policies, regulations, and law enforcement to prevent water source contamination through mining, fracking, toxic waste management, agricultural effluent, sanitation infrastructure, industry, and business.
- Depending upon local circumstances and the reasons for escalating water shortages, organizations in civil society expect governments to maintain a long-term focus, be well-informed on current challenges, maintain transparency, and be regarded as partners in cultivating a responsible use of water.

## Assumptions

**Some broad parameters for engaging with water scarcity.**

Based on information and insights gathered the following conclusions were reached:

**Rights and Justice**

Citizens, households, and organizations in civil society tend to treat access to clean water as a right. They assume that water is not a commodity (except for bottled water) or a utility.[49] They believe that water does not belong to the municipality and that access to water cannot be privatized by any company.[50] They would regard water as part of nature's bounty, God-given, sacred, or belonging to the whole community of life, including plants and animals. Such rights not only include the rights of citizens (e.g. access to potable water), but also the rights of non-human animals and of biotic systems (rivers, mountains, lakes, wetlands and so forth). Access to water is therefore often a matter of struggle and of justice, especially distributive justice.[51] The Prophet Muhammad (SAW) declared: "Excess water should not be withheld so that the growth of herbage may be hindered."[52] Groups in civil society view water scarcity accordingly.[53] In other words, a lack of access to water is a matter of unequal distribution, poor governance, and management issues; not simply a limit imposed by nature.

49 See the comment by Leonie Joubert & Gina Zievogel, *Day Zero: One city's response to a record-breaking drought,* http://dayzero.org.za/ (accessed 7 October 2019): "The City's choice of wording in this ad campaign shows up one of the fault-lines in the municipality's efforts to meet its service delivery need across one of the most socially and economically unequal cities in the world: some see water as a 'commodity', a product to be bought and sold by those with the means to trade in it; but many others see it as a basic human right and part of a common good resource, something that we need to share fairly, regardless of who has the means to buy it and who doesn't" (p. 11).

50 See Anderson H.M. Jeremiah, "Privatization of Water – A Theological Critique and Ensuing Challenges for the Church", *Reformed World* 57:1 (2007), 3-16.

51 See V.J. John (ed), *Water Struggle* (Kolkata: Bishop's College, 2007); Susan Kim & Maike Gorsboth (eds), *Ripples in the Water: Success Stories of Churches Striving for Water Justice* (Geneva: WCC, 2014); Nadia Marais, "#rainmustfall: A theological reflection on drought, thirst, and the water of life". *Acta Theologica* 37:2 (2017), 69 – 85. Christiana Zenner, *Just Water: Theology, Ethics and Fresh Water Crisis* Maryknoll: Orbis Books, 2018); Jaia Kauma Issac, "Water as Divine Gift for Holistic Wellbeing: Perspectives from Orthodox Earth Ethics in the Context of Commodification of Water Bodies", *Hekamtho: Syrian Orthodox Theological Journal* 4:2 (2019), 69-87.

52 Muslim:1993. Vol3A: 38 no. 1566.

53 The South African National Water Security Framework recognises this by adopting the following definition of water security: "…water security is less about obtaining water, and more about fostering human capabilities as they relate to water... We thus ask: What are the social, cultural, and political relationships with water resources and flows that advance a life that fosters human dignity? And, how are those relationships secured to facilitate the freedom to achieve wellbeing, fulfilling social arrangements, and human flourishing? … water security, then, is not simply a state of adequate water – however defined – to be achieved, but rather a relationship that describes how individuals, households, and communities navigate and transform hydro-social relations to access the water that they need and in ways that support the sustained development of human capabilities and wellbeing in their full breadth and scope." See the Draft National Water Security Framework Version 0.5, 15 January 2019, Executive summary. See also Addendum A.

## Focal areas specific to water and cities

### Differing Perspectives on Rights

Households and organizations in civil society express this right in different ways, depending on economic positions. The affluent may be willing to pay for the right to fill their swimming pools, while the desperately poor focus on access to clean drinking water. All would recognize the need for water for personal hygiene (washing one's body, sanitation, clothes) and to grow food. The right to potable water may be absolute but the expression of such rights remains relative.

### A Sense of Responsibility

In the context of water scarcity most households would recognize the need to use water responsibly even if some individuals, households, companies, and organizations do not always act accordingly. Using water responsibly is not the same as reducing water usage: for the sake of basic human dignity some need to use more water than they do, others less. Without this common sense of responsibility, any political, economic, or engineering efforts to address water scarcity will be futile. Organizations in civil society can play a crucial role in cultivating such a sense of responsibility by strengthening the moral fabric of society. Religious traditions can also play a crucial role here given their long-term history and vision.[54]

Such a sense of responsibility is typically undermined through apocalyptic, worse-case scenarios like the images associated with "Day Zero" when taps will run dry.[55] Such imagery leads to either moral paralysis (fear) or opportunism (fending for oneself), at worst to violent conflict over water. The role of an attractive guiding vision towards the future is crucial in this regard.[56] As has been remarked, "Martin Luther King did not say, 'I have a nightmare'. He said, 'I have a dream, and he

54 The so-called Böckenförde principle is relevant here. It holds that the moral fibre of modern (Western) societies rely on moral sources that such societies cannot themselves guarantee or sustain. The moral fibre may be explained in generic categories (values, virtues, visions, duties) but the sources of inspiration behind them are particular and cannot be captured through a generic sense of religiosity. They are typically embedded in the archetypes, symbols and belief systems of religious traditions. To sustain such moral sources, the particularity of such traditions therefore has to be taken seriously.

55 See Joubert & Ziervogel: "With hindsight, it's clear that this was a double-edged sword: on one level, it stoked public panic, which drew some criticism as a communications strategy; but at the same time it did drive down daily water use drastically" (p. 20). They add: "With hindsight, it turns out that the release of the disaster plan became the single biggest catalyst for change in water users' behaviour. But with it came the use of the term 'Day Zero', which was controversial. There was a swell of alarmism, panic, and distrust, reflected in an ever-more shrill mediascape. Would these water cut-offs result in outbreaks of violence at water distribution points? What would happen if the sewage system shut down? What about outbreaks of diseases, and death?" (p. 25-26).

56 Jonathan Sacks argues that the biblical stories highlight an attitude of emunah (trust), hope (as a journey) and hesed (love). Hope here highlights the crucial role of time. Complex issues, that involve also or primarily a change of the way we look at the world, require time for a process of transformation. A key question then is how not to get lost while being on the way. How to keep the candle of hope burning. The Exodus-narrative emphasizes the crucial role of the institution of a public Sabbath or Utopia Now here. [Reference to be added.]
Another institution derived from this narrative is that of the covenant. During the recent water symposium in Amsterdam (6-7 November 2019), a covenant of hope was designed and signed by parties from business, finance, religion, government, academia and NGO. See the text of this covenant in Addendum B.

created a movement."[57]

There is also a need to recognize limits to responsibility. One can only take responsibility for what is within one's locus of control. This differs significantly depending upon positions of power in a household, a community, and an organization. It is important to clarify; a burden of responsibility should not be placed upon those who cannot exercise such responsibility. This could infer a false sense of guilt that precisely undermines the exercising of responsibility. This is obviously important in contexts with high degrees of inequality, especially in the global South.

### Fostering a Sense of Responsibility

Given disputes over water allocations and depending on the severity of water shortages at different times, it remains necessary to mobilize citizens, households, and organizations around responsible water use. It matters how this is done. For citizens it all too often sounds as if strategies are devised to change their behavior without recognizing that citizens are moral agents and should be respected as such.

Theories of moral formation are relevant here. Three strategies may best be used in public campaigns as they can complement each other.[58]

a) It is possible to emphasize rules and regulations and the duties of citizens to comply. Authoritarian rules will be less persuasive than sensible rules that citizens can articulate moral responsibility. Failure to abide by such rules can be subjected to penalties, but fear of penalties without understanding the rules will not suffice.[59] One may also suggest that oftentimes individuals distrust messages from municipalities because they may not support the political party in power. By contrast, they may be more inclined to trust messages from a faith leader.

b) It is also possible to emphasize the common good and the well-being of all citizens and all living creatures. Individual actions should be aligned with the common good and need to avoid common ills. The "Day Zero" strategy used in Cape Town in early 2018 was effective because citizens recognized the need to avoid a common catastrophe and collectively aligned their actions.[60] By contrast, those affluent households who find alternative access

57 Quoted by Maarten Hajer, former director of Netherlands Environmental Assessment Agency (PBL) (2011:28). [Reference to be added.]

58 See also the discussion in Gina Ziervogel, Unpacking the Cape Town drought: Lessons Learned, https://www.africancentreforcities.net/wp-content/uploads/2019/02/Ziervogel-2019-Lessons-from-Cape-Town-Drought_A.pdf (accessed 7 October 2019).

59 This is well illustrated by the novel by John Irving *The Cider House Rules*, and the film based on that. See also the comment by Joubert & Ziervogel: "Through the course of the drought, the City used a few carrot-and-stick approaches to get people to be more water-wise: price hikes for the bigger water users, restrictions, installing water shut-off devices in the homes of bigger residential users who were ignoring restrictions, fines, the threat of naming-and-shaming greedy water users, and behavioural 'nudging' messages through the City's utility billing system" (p. 28).

60 See again the comment by Joubert & Ziervogel: "One of the key take-home messages is that if people know

to water (e.g. through drilling new boreholes) may not recognize the common good since water in aquifers cannot be privately owned.

c) Another approach is to emphasize and cultivate virtues and to counter vices. The four "cardinal" virtues of wisdom, justice, courage, and temperance are all relevant for water usage. One may add the role played by the virtue of hope – which may be contrasted with optimism, pessimism and cynicism.[61] One may also recognize the role of kindness, hospitality, generosity and so forth in providing access to water for others in need of water.

This task of moral formation takes place in households, in moral communities (including schools), and in faith communities. The arts and culture also play a crucial role in moral formation. Moral leadership cannot rely on information and education alone because a sense of belonging to communities, role-plays, stories, songs, and proverbs are all required to cultivate such virtues over a longer period of time. These are typically culturally specific but commonly appear across a wide array of cultures and traditions. It may be taken for granted that Western, Eastern, and indigenous virtues can all contribute uniquely to such moral formation. Without the assumption of such virtues, any call for responsibility will fall on deaf ears. The cultivation and expression of such virtues follow a different rationality compared to an instrumental logic with which water-related issues are typically managed.

At the same time, the possibility of malformation should be considered. Often moral disintegration follows the fragmentation of moral communities – i.e. due to high levels of crime, corruption, and gangsterism. This is a pertinent problem on the Cape Flats due to the long-term consequences of colonialism, subjugation, and apartheid, but is easily applicable elsewhere. Faith communities have resources to cultivate respect for water (e.g. Muslims for prayer, Christians for baptism). Therefore, the sacredness of water can be emphasized in cultivating appropriate virtues.

their efforts to save water are working, and that their small efforts are contributing toward a greater good, they'll be more likely to do that than to 'free ride' at other people's expense and selfishly use up the resource … If the media keeps pushing the message that residents are selfish in their water habits, … it's more likely to trigger panic and selfish hoarding behaviour. If people feel that their small daily efforts are actually making a difference, and are helping to save water to the benefit of their fellow citizens, they're more likely to keep working towards this shared common good." (p. 28-29). They add: ""The concept of 'Day Zero' slipped into everyday language in October 2017 when the City released its Critical Water Shortages Disaster Plan, which spelled out clearly what the emergency rationing measures would be if the dams ran down to that critical threshold of 13.5 percent of usable water. This disaster plan turned out to be the single most effective intervention to bring about behaviour change from water users, as dam levels ran perilously low. Spelling out the urgency of the drought, and how imminent the emergency really was, seemed to send a shockwave through communities, and people were compelled to change how they used water." And "Theories from the field of economics, about what drives behaviour, supports the idea that if people have clear information about how serious a threat is, but still have a sense of agency in terms of knowing what they can do to help tackle the problem, they're more likely to act" (p. 39). Such comments emerging from the discipline of behavioural economics may be helpful from a managerial perspective. However, a civil society perspective would be "from within", not treating water users as customers to be managed, but as citizens with rights and responsibilities.

61 See, for example, Jan Jorrit Hasselaar, "The good news about climate change", in *Salvation in the World: The Crossroads of Public Theology*, edited by Stephan van Erp, Christiane Alpers, Christopher Cimorelli (London: Bloomsbury, 2017), 163-179.

### Factors that Undermine Responsibility

The role of deep divisions in society must be recognized in fostering such a sense of responsibility, not least because of slavery, imperialism, and colonialism. This manifests itself in forms of inequality in terms of class, race, gender, and culture as various demographics are able to access and use water and adequate sanitation. Alongside such access to water, vulnerability to fire and flooding also must be recognized. In some societies this is exacerbated by the role of the military, state security mechanisms, surveillance, gangsterism, caste systems, and the like.

In such situations an emphasis on responsibility will speak to those in relative positions of power and this is indeed appropriate. Everyone exercises some degree of power and has to exercise decision-making within their locus of control. However, it does not make sense to call for a sense of responsibility where something is beyond a person's locus of control. The same applies to education and awareness raising campaigns. The danger here is that some citizens are treated merely in an instrumental way by those in positions of power. When this is internalized, citizens tend to see themselves as passive victims of unequal social conditions. They then regard themselves as moral patients (on whose behalf others, including government officials, have to act) and not as moral agents in their own right. Where some political awareness is raised, such citizens tend to emphasize their rights and underplay their responsibilities. This leads to a culture of entitlement with devastating consequence for the social fabric and for a sense of contributive justice, where everyone has to contribute to the common good according to their ability.

## The Role of Worldviews and Cosmologies

Moral traditions are themselves embedded in more encompassing views of the world. Differences regarding moral judgements, not least about the use of water, are typically shaped by different worldviews. For those who inhabit the "liquid continent" viz. Oceania, water, land/is-land, moana/sea, wave, and tide create a worldview that can emphasize ideas of liquidity and mobility.
The relative influence of science and of indigenous knowledge systems play a crucial role here. Citizens who have embraced modern science are in danger of adopting a mechanistic and often reductionist view of the world. Inversely, citizens who maintain a more traditional cosmology recognize a tension between their view of the world and modern artifacts to which they may or may not have access. Likewise, economic systems shape the way we view the world. Water sources are treated in very different ways if they are regarded as sacred or as a mere utility to be used for optimal economic benefits. This shapes public engagements, educational activities, art, and sport alike.

### The Symbolic Role of Water

Attitudes towards water cannot be reduced to matters pertaining to rights and responsibilities, but the symbolic role of water needs to be recognized in civil society. Failure to do so in other sec-

tors by treating water purely as a commodity or a utility,[62] dealing in mere quantities, or putting a price on water, is imprudent because it will met with resistance in the end.[63] It can appear that what economists cannot count does not count. However, within civil society, the most important things in life cannot be captured in strictly economic terms: life itself, health, family, marriage/partnership, friendship, and time and opportunities to express one's various talents. Despite disputes over water, rich and poor drink from the same sources and is directly related to hospitality toward neighbors and strangers.[64]

The symbolism of water is expressed in multiple ways through art, culture, drama, puppetry,[65] painting, music, literature, film,[66] rituals, myths, and religion[67]. Such symbolic expressions should speak for themselves, but four aspects of the symbolic meaning of water resist any easy quantification:

### a) *Water as Gift of Life*

To say that water is a source of life is commonplace given the way rain replenishes plant growth. "It is He Who sends down water from the sky; and with it We produce vegetation of all kinds... "

62 In Sydney there is now talk of expanding desalination plants, which could result in public water becoming evermore a commodity.

63 See the following comment by Jaia Kauma Issac: "Privatization of natural resources which nourishes life is a serious crime and unforgivable sin in the cosmotheandric lenses of orthodoxy." See Issac, "Water as Divine Gift for Holistic Wellbeing", 73. See also the comment by Larry Rasmussen: "Every good ethic includes a description of what is. At present what is, in the case of water, is a resource and commodity in the service of the irrational exuberance of the post-1950 global economy ... a natural resource at the ready. That use-relationship, so 'natural' to us, frames water and its value in our way of life and erodes the mythic, poetic, and esthetic understandings of water. When water is a market commodity in a plastic bottle piled on supermarket shelves, it is no longer sacramental. This loss of sacred meaning in turn affects our moral sense: It's 'just water'." See his *Earth-honoring Faith: Religious Ethics in a New Key* (Oxford: Oxford University Press), 282.

64 There is ancient wisdom from all religious traditions in this regard, especially from arid regions where travelers needed water to drink. For example: "The Buddha encouraged his disciples to plant shade trees along roads, construct bridges, dig wells and build rest houses for the benefit of travellers, and to provide water for wayfarers." See https://www.bhantedhammika.net/like-milk-and-water-mixed/i-was-a-stranger-and-you-took-me-in (accessed 7 October 2019). Such practices continue to exist also in cities where private households have access to wells and use that for hospitality.

65 See www.cradleofcreativity.co.za. The production River and Redfin is representative here. The blurb for this performance reads: "River & Redfin is a puppet performance that uses live music, masks and visual performance. The performance is set in the Klein Huis River. This performance celebrates and reclaims the power, mythologies, and significance the river holds for the people and animals of this scenic and fertile part of the Langeberg. It brings awareness to the way water has been used to divide the community and people…".

66 See the short film "Black River" ("Agua de Río") from Argentina, which deals with the pollution of a river, the direct impacts on the surrounding communities, and how the communities respond in order to reclaim their right to access clean water. See also the documentary feature film *The Whale and the Raven* by director Mirjam Leuze, which tells the story of indigenous peoples in northwestern Canada who must face the competing interests of industrial uses for the channel through which whales migrate. The film raises questions regarding rights and access to sacred waterways and uses of the sea that disturb both humans and animals alike.

67 See the volume of biblical reflections produced by the Ecumenical Water Network, *Reflections on Water* (Geneva: WCC, 2014), with reflections entitled, "Drip, Drip, Drip", "Waters of Baptism, Water of Life", "Wells of Quarrel – Space for Peace", "Thirst for Water – Thirst for Life", "Sister Water or Blue Gold", Give me Water … The Living Water", and "We Need to Wash our Dirty Feet".

(Qur'an, 6:99).

Water should be regarded as a gift.[68] There is a deep-seated recognition, often expressed in religious terms, that water: precedes, gives, yields, and bears life. Water brings forth new life in arid conditions.[69] Our bodies are water-based; we cannot exist without it; the blue planet has life because it has water.

This gift is threatened by the absence of water. This may be the result of climate change, of water monopolization, or of the pollution of fresh water through commercial agriculture, mining, fracking, industry, or sanitation infrastructure. Wherever that is the case, resistance is to be expected on the basis of such fundamental sensitivities. The absence of rain also evokes religious sensibilities: hoping and praying for rain.[70]

**b) *Water as Threat***

That water is a threat is widely recognized by citizens in civil society. In our times such threats are associated with rising sea levels, saltification of fresh water, hurricanes, flooding, etc.
For example, in Sydney and east coast Australia people are being warned about possible floods and loss of soils/slips through landscapes denuded by fire. One disaster leads to another: too little water compounds the problem of the likelihood of too much water delivered in volume over too short period of time.

68 See Clifford Rawlins, "Water, Source of Life – Socioeconomic, Theological and Interreligious Perspectives", *Reformed World* 57:1 (2007), 17-30.

69 See the following quotations from the Qur'an: "And Allah sends down water from the skies, and gives therewith life to the earth after its death…" (Qur'an, 16:65)… And you see the earth barren and lifeless, but when We pour down water upon it, it is stirred (to life) and it swells, and it puts forth every kind of beautiful growth ( in pairs) (Qur'an, 22:5)…and He (Allah) sends down water from the sky and with it gives life to earth after it is dead…"(Qur'an, 30:24) "...And We send down pure water from the sky,- That with it, We may give life to a dead land, and slake the thirst of things We have created,- cattle and men in great numbers." (Qur'an, 25: 48-49).

70 See the poem by Christine Coates [ in McGregor Poetry Festival Anthology 2018, 41]:

**The Thirst**

I dream of rain,
Watch it fall
Through me,
No puddles form at my feet.

Only the sun
washes the earth,
stones crumble,
clouds are swallows flying north.

I am a beggar
on my knees
the moon a
communion wafer.

By its nature, this threat cannot really be removed except by its inverse, i.e. the absence of water. It is nevertheless dangerous to underplay such deep-seated fears related to water. Cities need to do what can be done in this regard but also recognize their limited power in the face of the ominous power of nature. Cities therefore need to build networks with other cities and promote international treaties that address major global challenges around nuclear weapons, ozone depletion, climate change, loss of biodiversity, ocean acidification, etc. Although humans have become a "geological force of nature," we are not able to determine the physical and chemical laws of nature (including gravity!) that both sustain and threaten us.

### c) *Water as Source of Cleansing*

The cleansing ability of water is obvious to all concerned – in terms of bathing/showering, sanitation, washing clothes, and washing dishes. Not surprisingly, such cleansing is metaphorically extended towards medical and psychological healing, toward a sense of cleanliness (as in Muslim cleansing rituals[71]), and to cleansing from various forms of guilt (as in Christian rituals around baptism).

The cleansing ability of water is obviously threatened when water is itself contaminated. The problem is not merely dirty water but toxic water. What, then would purify the impure?[72] How could water cleanse if it is not clean? And even if the water is clean, mere rain and washing cannot cleanse everything in societies riddled with injustices.[73]

71 See the following: "O you who believe! When you intend to offer *As-Salât* (the prayer), wash your faces and your hands (forearms) up to the elbows, rub (by passing wet hands over) your heads, and (wash) your feet up to ankles. If you are in a state of *Janâba* (i.e. had a sexual discharge), purify yourself (bathe your whole body). Qur'ān, (5:6)

72 For a discussion of this question, see Ernst M. Conradie, "How could Baptism cleanse us with polluted water?" (essays submitted for publication). See Addendum C for an extract from this essay.

73 See the poem by Eduard Burle [in McGregor Poetry Festival Anthology 2018, 34]:

**Man in a rainstorm**

The rain brings relief;
leaves and dirt
are swept away
into drain, unseen holes
in the earth;
roads are left, shining and wet.

But, not even
a downpour will loosen
the oil stains
and grime that remain –

and, in the man still sitting
behind the windscreen,
there are old fears,
old ways of being –
stubborn traces of the past – that have not yet relinquished
their hold
and washed away. [ in McGregor Poetry Festival Anthology 2018, 34]

### d) *Water as Source of Joy*

Water is not merely a scarce resource or a utility; it is a source of exuberance, pleasure, fun, play, and sport. This attitude towards water is expressed by rain making rituals in many indigenous cultures but also by dancing in the rain after periods of extended drought. There are of course many water-based sports – swimming, diving, canoeing, sailing, etc., but these pale to insignificance compared to children's exuberance when water is available. Grown-ups may be concerned about "wasting water" while children are rightly having fun.[74]

Strangely, water as a source of joy is not easily threatened by water scarcity. In fact, such scarcity may provoke creative responses. This may be counter-intuitive but there is evidence from around the world that making fun with water is vital in times of scarcity. One example may be the New Year festival in Myanmar where dumping anyone in the streets with a bucket of water is permissible amidst high temperatures and water scarcity. Another is the multiple jokes around "Day Zero" that abounded in Cape Town in the summer of 2018.[75]

## Best Practices

### Forms of Implementation in Civil Society

There are also more specific, tangible tasks being carried out by NGOs, CBOs, and FBOs. From case studies and anecdotal information, the following may be mentioned:

- Civil society can and has contributed to develop courageous conversation/safe spaces on topics in society that are polarized.
- Civil society can develop rituals to stimulate a certain way of dealing with water issues. See for example the Dutch "hensbeker" from the year 1717. This cup and related tradition was reinvented during the Amsterdam International Water Week and the water symposium Amsterdam (November 2019) to celebrate and seal the cooperation between business, religion, academia, NGOs with the cities of Jakarta, Cape Town, and Amsterdam.[76]

74 In Sydney at present many people are lamenting the loss of enjoyment with their gardens: decisions are being made, by private persons and public gardens, which plants to save. So many trees are stressed and dying, we lose the enjoyment of trees, and as a consequence, birds. While in the bush, in some areas koalas are now an endangered species due to fire and a lack of water. The enjoyment has been replaced by sadness and psychological trauma.

75 See also the stanza from a poem by Margaret Clough [ in McGregor Poetry Festival Anthology 2018, 38]:

**Elixir**

Delightful as the thrill of a stolen kiss
The guilty pleasure of drinking
Cape Town water
straight out of the tap.

76 See https://www.agv.nl/geschiedenis/historisch-archief/parels-uit-ons-archief/hensbeker-300-jaar/ (accessed 5 October 2019). See also pictures provided by J.J. Hasselaar.

- Civil society can and has developed specific projects and mobilization efforts to encourage development or structural work that aims at the common good—the benefit of all rather than only a handful of financial stakeholders.

## Civil Society and Advocacy

Civil society also plays a role in motivating and encouraging long-term changes to the systems and structures that have led to water crises, as well as to long-term planning that aims for conditions where such a crisis can be either avoided or anticipated and handled in the best way possible.

- Civil society can raise awareness among the populous within a given region regarding opportunities to engage with policy experts and policy makers (politicians and government leaders). Such motivation frequently arises from those values (whether religious or cultural) mentioned above.
- Civil Society can hold policy makers and institutional service providers to account on how they articulate and implement policies related to water conservation and use.
- Civil society organizations often have firsthand experience with those most affected by water crises and can raise awareness for long-term issues that need to be addressed.
- Likewise, because of their firsthand experience, civil society may be in a position to advocate for those most affected and those most likely to be on the front lines of the water crisis.
- Organizations in civil society often develop partnerships with other sectors, especially local and regional levels of government to assist with service delivery in the fields of education, health, care giving, etc. This has not often been extended to water-related concerns.
- Because they are not tied to (or by) policy or regulations, civil society organizations are often able to think more creatively and flexibly about ways to re-evaluate and reshape systems and structures for a more generative and secure future for all. There, perhaps, is always a possibility that civil society organizations become ends in themselves. To resist this tendency, one may raise questions regarding how to stimulate renewal, creativity, and flexibility for the common good as new questions arise.

## Conclusions

***Three Non-Negotiables for Cities to Consider in Addressing Escalating Water Shortages***[77]

- Access to water is a right and equitable distribution should be normalized.
- Cities will do everything they can to protect water sources (e.g. rivers, lakes, wetlands, etc.), to mobilize civil society to fight developments on these precious areas, and to educate the public on these responsibilities.
- Cities will engage in long-term planning regarding the effects of climate change on water catchments, water tables, water availability, and the effects of rising sea-levels.

77 These three non-negotiables require further discussion during the conference in order to be better aligned with the vision for 2050 and beyond as expressed above.

# Appendix I: Definitions

**Adaptation [to climate change, extreme weather events, etc.]**. Any adjustment in human systems or behaviors to moderate harmful effects or to exploit beneficial opportunities associated with actual or predicted climatic events.

**Adjudication [of water rights]**. The way courts have assigned specific water rights to specific users.

**Aqueduct**. An artificial channel or pipe that transports water.

**Artificial recharge**. The process of directing surface water to replenish groundwater.

**Aquifer**. An underground layer of water-bearing permeable rock from which groundwater can be extracted.

**Backflow**. The unwanted flow of water in the reverse direction.

**Basin.** An area of land where water meets to drain into a common outlet such as a bay.

**Biofilms**. A collective of one or more types of microorganisms (e.g. bacteria, fungi, protists) that can grow on different surfaces.

**Blackwater**. Wastewater and sewage from toilets.

**Blended finance**. Using development finance and philanthropic funds to engage private capital in sustainable development.

**Borehole**. A deep, narrow hole made in the ground, typically to access groundwater.

**Catchment**. The area from which precipitation flows through streams and rivers to the sea.

**Climate model**. A model created to simulate projected changes in climate using available data.

**Consociationalism**. A political system characterized by major internal divisions along ethnic, religious, or linguistic lines, which remains stable due to consultation among the political or ruling elites of these groups.

**Consumption model**. A model created to simulate projected changes in water demand using available data.

**Contamination**. The action or state of making water impure by polluting.

**Continuous water supply (CWS)**. A water supply system in which water is delivered continuously to every consumer of the service 24 hours a day, every day of the year, through a supply and distribution system that is continuously full and under positive pressure.

**Conurbation**. An extended urban area, typically consisting of several towns or municipalities merging with the suburbs of a central city.

**Decentralization**. The transfer of authority from central to local government or actors.

**Desalination**. The process of removing salts from sea water to provide freshwater.

**District metering area (DMA)**. A discrete area of a water distribution network.

**Drought**. Drier than usual conditions that create water related problems.

**Effluent**. Liquid waste or treated sewage that flows into a water body.

**Equitization**. The process of dividing real estate or other tangible assets among several investors and placing them into publicly traded stock.

**Evaporation**. The process of water on the Earth's surface turning from a liquid to a gas and returning to the atmosphere.

**Evapotranspiration**. The sum of evaporation and plant transpiration from the Earth's surface to the atmosphere.

**Flow regulator**. A water-saving device installed in order to maintain a defined flow independent of supply pressure.

**Flying river**. The movement of large quantities of water vapor in the atmosphere, typically used in reference to such movement from the Amazon Basin to other parts of South America.

**Greywater**. The relatively clean wastewater generated by domestic use, including use in baths, sinks, washing machines, and kitchen appliances.

**Groundwater**. Water held underground in the soil or in pores and crevices in rock.

**Headwater**. The source and upper reaches of a stream or river.

**Hydrological model**. A simplification of a real-world system (such as surface water, soil water, wetland, or groundwater) that aids in understanding, predicting, and managing water resources.

**Impervious**. Not allowing fluid to pass through.

**Informal settlement**. An unplanned settlement where housing is not in compliance with housing or building regulations, typically characterized by closely packed housing units in a situation of incomplete or deteriorated infrastructure.

**Inter-basin transfer (also known as trans-basin diversion)**. The practice of transporting water from one river basin where water is available to another basin where water is less available or could be utilized better for human development.

**Intermittent water supply (IWS)**. A piped water supply service delivering water to users for fewer than 24 hours in one day, typically used when the available supply and/or the hydraulic capacities of the water supply system are too weak to provide continuous supply.

**Junction (pipe junction node)**. A component of water supply systems that is used to transfer water from one place to another, or a pump station in a water supply system.

**Karst**. A topography formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum, typically characterized by underground drainage systems with sinkholes and caves.

**Non-point source pollution**. Pollution discharged over a large surface area that originates from land use activities and is carried by rain, snowmelt, or irrigation.

**Non-revenue water (NRW)**. Water that has been produced and is lost before it reaches the end user, typically due to leakages in the system or theft through illicit connections.

**Non-renewable (fossil) groundwater**. Groundwater bodies, or deep aquifers, that have a negligible rate of recharge and can thus be considered non-renewable.

**Pervious**. A substance which allows water to pass through; permeable.

**Poly-chlorinated biphenyl (PCB)**. Any of a class of toxic aromatic compounds whose molecules contain two benzene rings in which hydrogen atoms have been replaced by chlorine atoms, typically formed as industrial waste products.

**Pressure reducing valve (PRV)**. A device that provides steady pressure for a part of a system that operates at a pressure lower than that of the normal system.

**Privatization**. The transfer of a utility, industry, or service from public to private ownership and control.

**Public-private partnership (PPP)**. A cooperative arrangement between two or more public and private sector entities, typically of a long-term nature.

**Rainwater harvesting (RWH)**. A type of collection/harvest system in which rain is collected and stored for future use.

**Recharge**. The replenishment of an aquifer through absorption of water.

**Reclamation**. The process of converting wastewater into water that can be reused for other purposes.

**Recycled water**. Highly treated wastewater that, depending on its level of treatment, can be used for potable and non-potable uses.

**Reservoir**. A natural or artificial lake used for storage, regulation, and control of water.

**Resilience**. The capacity to withstand difficult or extreme circumstances.

**Resource**. Valued finite or replenishable materials or products.

**Scarcity**. Lack of freshwater resources to meet demand.

**Sewage**. Domestic or municipal wastewater.

**Sewerage**. The infrastructure that conveys sewage.

**Silo-based management**. A management system that is compartmentalized and characterized by lack of collaboration or communication between departments.

**Sludge**. A semi-solid slurry that can be produced from a range of industrial processes, including water and/or wastewater treatment and on-site sanitation systems.

**Stormwater**. Surface water resulting from heavy rain or snow fall.

**Subsidence**. The gradual sinking of an area of land.

**Surface water**. Water located on top of the Earth's surface in lakes, rivers, ponds, etc.

**Transpiration**. Process by which water that is absorbed by a plant, usually through the roots, is evaporated into the atmosphere from the plant surface.

**Transversal management**. A management system characterized by a high degree of collaboration and communication across departments, agencies, and levels.

**Urban metabolism**. A way to describe the flows of materials and energy within cities.

**Urban sprawl**. The unrestricted growth of residential or commercial development over large expanses of land, with limited regard for urban planning.

**Urbanization**. A population shift from rural to urban areas, resulting in the often rapid expansion of urban areas.

**Water cycle**. The cycling of water in and out of the atmosphere through evaporation, condensation, precipitation, and infiltration.

**Water security**. The reliable availability of water of sufficient quality and quantity for the flourishing of all individuals in a given area.

**Water table**. The level below which the ground is saturated with water.

**Water-sensitive**. A style of urban design characterized by an integrative approach to land

planning and engineering in which the entirety of the water cycle is considered.

**Watershed**. An area which contains bodies of water that all drain into a single larger body of water.

**Wetland**. A type of ecosystem that is flooded by water, such as a marsh or swamp.

**Some definitions were sourced from:**

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# Appendix II: Helpful Links

**Events**
Global Water Intel Events Calendar
https://www.globalwaterintel.com/events/

IRC WASH Events Calendar
https://www.ircwash.org/news/wash-events-calendar

Stockholm International Water Institute World Water Week
https://www.worldwaterweek.org/

UN Sustainable Development Goal Planning Calendar
https://www.un.org/sustainabledevelopment/sdg-planning-calendar/

USAID Global Waters Upcoming Events Calendar
https://www.globalwaters.org/UpcomingEvents

**Financing Tools**
Cities4Forests' Tools for Project Financing (for Natural Infrastructure Rehabilitation)
https://cities4forests.com/toolbox/financing-projects/

EPA's Water Finance Center
https://www.epa.gov/waterfinancecenter/effective-funding-frameworks-water-infrastructure

European Unions Funding for the Environment and Climate
https://ec.europa.eu/easme/en/life

UN Water Financing Information
https://www.un.org/waterforlifedecade/financing.shtml

**Job Boards**
Conservation Job Board
https://www.conservationjobboard.com/

The Security & Sustainability Guide Jobs Page
https://securesustain.org/job-category/water/

Global Water 2020 Jobs Page
http://globalwater2020.org/jobs.html

Josh's Water Jobs
https://www.joshswaterjobs.com/jobs

**Toolboxes and Resources**

Cities4Forests Initiative to Rebuild Natural Infrastructure
https://cities4forests.com/

Cities4Forests' Toolboxes for Maximizing Different Benefits
https://cities4forests.com/toolbox/

EPA's "Groundwater Monitoring in Karst Terranes: Recommended Protocols & Implicit Assumptions"
https://karstwaters.org/wp-content/uploads/2015/04/gw-monitoring-in-karst.pdf

FAO's Global information system on agriculture and water: AQUASTAT
http://www.fao.org/aquastat/en/

Global Water 2020 "Americans Working for Water" Briefs
http://globalwater2020.org/americans-working-for-water.html

International Water Association Resources
https://iwa-network.org/resources/

International Water Management Institute Data and Tools
https://www.iwmi.cgiar.org/resources/data-and-tools/

UN Integrated Water Resource Management
https://www.un.org/waterforlifedecade/iwrm.shtml

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