REPORT | 2023

SMART WATER CITIES

PHASE 3: FINAL REPORT ON KEY PERFORMANCE INDICATORS AND PILOT CITY EVALUATIONS

K water

AWC Asia Water Council

IWRA

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ABOUT

IWRA is an international member-based network of multidisciplinary experts on water resources management. Established in 1971, it facilitates the sharing of water knowledge and expertise across borders and sectors at the interface between science and policy. IWRA's goal is to improve and expand understanding of water issues through education, research, and the exchange of information among countries and across disciplines. Additionally, IWRA seeks to continuously improve water resource decision-making by improving our collective understanding of water's physical, ecological, chemical, institutional, social, and economic aspects. One way it does this is through the Smart Water Cities project which is dedicated to analyzing smart water technologies in urban developments, and works in partnership with K-Water.

The Korea Water Resources Corporation (K-water) is a government-owned corporation for comprehensive water resource development. Established in 1987, it provides both public and industrial water in the Republic of Korea. K-water has a large pool of practical engineering expertise regarding water resources and has championed Smart Water technologies for several years.

The Asia Water Council (AWC) is a non-profit, non-governmental organization established in 2015. It is a new and innovative, regional cooperation body that prioritizes solving water issues faced by Asia and seeks scientific and technological solutions, as well as concrete implementation plans.

ACKNOWLEDGEMENTS

This report has been written with contributions by: Monica Garcia Quesada, Lea Dasallas, Sung-Phil Jang, Suhyung Jang, and JungHwan Lee. They have benefited from the support from:

The **Smart Water Cities Steering Committee Members**: Monica Garcia Quesada, Callum Clench, Henning Bjornlund, Jin Kim, Sung-Phil Jang, Suhyung Jang, Hang Ki Kim, Kyung-soo, Jun, Jijun Xu and Yuru Lin.

The **IWRA Executive Office**: Aubrey Crosby, Awantika Pal, Callum Clench, Ignacio Deregibus, Leonore Tjikune and Nathalie Lyon-Caen.

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LIST OF ACRONYMS

ADB	Asian Development Bank
ADCP:	Acoustic Doppler Current Profiler
ADVM	Acoustic Doppler Velocity Meters
AI	Artificial Intelligence
AWC	Asia Water Council
AWS	Alliance for Water Stewardship
AWS	Automated Weather Stations
BAPPEDA	Badan Perencanaan Pembangunan Daerah (Regional Development Planning Agency)
BEDC	Busan Eco Delta City or Busan Eco Delta Smart City
BMKG	Badan Meteorologi, Klimatologi, dan Geofisika (Meteorology, Climatology and Geophysical Agency)
BOD	Biochemical Oxygen Demand
BPBD	Badan Penanggulangan Bencana Daerah (Regional Disaster Management agency)
BPKP	Badan Pengawasan Keuangan dan Pembangunan" (Supreme Audit Agency)
BPP SPAM	Badan Peningkatan Penyelenggaraan Sistem Penyediaan Air Minum (Supporting agency for the improvement of drinking water supply system)
CCTV	Closed Circuit Television
CEBR	Centre for Economics and Business Research
CICO	Cost-in, Cost-out
COD	Chemical Oxygen Demand
CSS	Combined Sewer Systems
DISPERKIM	Dinas Perumahan dan Kawasan Permukiman Kota Semarang (Department of Housing and Settlement Areas of the City of Semarang)
DISTARU	Dinas Penataan Ruang Kota Semarang (Spatial Planning Agency of Semarang City)
DLH	Dinas Lingkungan Hidup (Semarang city Environment Agency)
DPU	Dinas Pekerjaan Umum (Department of Public Works)
EIA	Environmental Impact Assessment
ESDM	Dinas Energi dan Sumber Daya Mineral (Central Java Province Department of Energy and Mineral Resources)
GBCI	Green Business Certification Inc.
GDP	Gross Domestic Product
GIS	Geographic Information System
ICTs	Information and Communication Technologies
IoT	Internet of Things
IPLT	Instalasi Pengolahan Lumpur Tinja (Fecal Sludge Treatment Plant)

ISO	International Organization for Standardization
ITU	International Telecommunication Union (),
IWRA	International Water Resources Association
IWRM	Integrated Water Resource Management
KEC	Korea Environment Corporation
KMA	Korea Meteorological Administration
KPI	Key Performance Indicator
KPK	Komisi Pemberantasan Korupsi (Commission for the Eradication of Corruption)
K-water	Korea Water Resources Corporation
LID	Low Impact Development
MAFRA	Ministry of Agriculture, Food and Rural Affairs
MOE	Ministry of Environment
MOLIT	Ministry of Land, Infrastructure, and Transport
MSWSI	Modified Surface Water Supply Index
NDVI	Normalized Differences Vegetation Index
NGO	Non-Governmental Organization
OECD	Organization for Economic Co-operation and Development
PDAM	Perusahaan Daerah Air Minum (Regional Water Supply Company)
PDSI	Palmer Drought Severity Index
RBO	River Basin Organization
R&D	Research and Development
RIA	Regulatory Impact Assessment
SDG	Sustainable Development Goal
SGI	Standard Ground Index
SIGAB	Sistem Inventarisasi Genangan Banjir, Flood Inventory System
SME	Small and Medium Enterprises
SMI	Soil Moisture Index
SPALD-T	Sistem Pengelolaan Air Limbah Domestik Terpusat (Centralized Domestic Wastewater Management System)
SPEI	Standardized Precipitation- Evapotranspiration Index
SPI	Standard Precipitation Index
U4SSC	United 4 Smart Sustainable Cities
UNECE	United Nations Economic Commission for Europe
UPTD PAL	Unit Pelaksana Teknis Dinas (Technical Implementation Unit)
USGBC	U.S. Green Building Council
WAMIS	Water Resources Management Information System

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CHAPTER 1
INTRODUCTION

The idea of a Smart Water City offers hope and potential progress in a time of fast urbanization and growing global water challenges like scarcity, pollution, and floods. Innovation and technology are crucial for reshaping urban landscapes and managing water resources effectively. A Smart Water City signifies a change in how cities handle water as a vital resource for human development, using advanced technologies and data-driven strategies.

This is the third report of the Smart Water Cities project, a three-year research collaboration between the Korean Water Resources Corporation (K-water), the Asia Water Council (AWC), and the International Water Resources Association (IWRA) that has aimed to provide an approach, both thorough and practical, to the analysis of Smart Water Cities. The report brings the main findings of the project since its inception in 2020. It includes the presentation of the Smart Water City Index, which is an instrument comprising a comprehensive set of indicators and Key Performance Indicators (KPIs) used to measure and compare urban water management and water service provision. Additionally, it covers the latest fieldwork conducted in 2023 in two cities: the Busan Eco Delta City (BEDC) in the Republic of Korea and Semarang in the Republic of Indonesia.

1. Background of the Smart Water Cities project

The Smart Water Cities project was initiated in 2020 through a collaboration among the project partners. Its primary objective is to assist cities worldwide in delivering safe and affordable urban water services while enhancing the efficiency, effectiveness, and sustainability of water management. The central focus of the project has been the development of the Smart Water City Index, a comprehensive tool for assessing and comparing water resource management and water services in cities globally. This index helps to identify key aspects of urban water resource management in existing and future cities, facilitating the recognition of successful practices and areas requiring improvement at the local level.

The Smart Water Cities project is structured into three parts, each with its own objectives and tasks. The first part, conducted from January to December 2021, involved an exploration of water-related challenges faced by cities. It aimed to define the essential features of a Smart Water City and examined existing standards and certification schemes related to urban sustainability. The findings of this phase were consolidated in the report titled “Identifying Smart Water Cities” formed the foundation for the subsequent phases of the project.

The second part of the project focused on establishing the framework and KPIs for the Smart Water City Index. This phase began by identifying core areas critical to the development of a Smart Water City, including its technological and the governance dimensions. Specific and measurable variables (KPIs) were then selected for each category and subcategory to evaluate various aspects of performance and operations. Measurement methods were determined, and values were assigned to each KPI, considering their relative importance.

In the third part of the project, conducted in 2023, the Smart Water City Index was tested in two pilot cities: BEDC in the Republic of Korea, and Semarang City, in the Republic of Indonesia. Through data collection and analysis of these diverse cases, the adequacy and feasibility of the KPIs were evaluated, areas for improvement were identified, and strategies for better supporting local authorities in utilizing the Smart Water City Index were explored. Based on this feedback, enhancements have been made to the initial Smart Water City index. During this phase, the guidelines and instructions for local authorities were also improved.

	Stage 1	Stage 2	Stage 3
Period	Jan 2021 ~ Dec 2021	Jan 2022 ~ Dec 2022	Jan 2023 ~ Dec 2023
Goal	Analysis of global standards frameworks and certification schemes	Development of Smart water city Frameworks and Key Performance indicators	Pilot cities evaluation Evaluation Guideline

With the pilot tests, the Smart Water City Index has proven to be a valuable tool for assessing the status of a city's water system It provides comprehensive information to local authorities, water professionals and experts, offering insights into the local water system's functionality. This includes identifying strengths and areas that require attention, covering aspects such as infrastructure, technology, and elements related to financial, managerial, and human resources. This initiative supports informed decision-making on local priorities, identifies potential areas for action, and contributes to building a sustainable and secure water future for cities.

2. Structure of the report

This report summarizes the main findings of the Smart Water Cities project. It is organized in four main parts, and twelve chapters:

Part I of the report introduces the concept of Smart Water Cities and their significance in addressing urban challenges. For this, **Chapter 2** opens with a discussion on the unique features of cities, the key challenges they face, and the global agenda for sustainable urban development. This discussion provides the context for **Chapter 3**, where we focus on defining Smart Water Cities, exploring the functions of water in urban contexts, policies, strategies, and technologies, leading to a clear definition of the concept.

In **Part II** the report delves into the measurements of Smart Water Cities. **Chapter 4** evaluates existing global standards, indicators, and certification schemes for such cities, providing insights into their similarities and differences. **Chapter 5** outlines the principles and processes behind developing KPIs for evaluating Smart Water Cities. **Chapter 6** introduces the framework of the Smart Water City Index and presents the KPIs selected to measure technical and governance aspects of urban water systems. It presents the Certification system and discusses its benefits.

Part III outlines the guidelines for evaluating Smart Water Cities based on the selected KPIs. **Chapter 7** introduces the methodology behind the evaluations, including their purpose, principles, collaborating organizations, and the overall evaluation process. **Chapter 8** focuses on the Technical Pillar, covering topics such as the urban water cycle, water disaster management, and water supply and treatment within smart city contexts. **Chapter 9** examines the Governance & Perspective Pillar, discussing effectiveness, efficiency, trust, and engagement in the governance of a Smart Water City.

Part IV presents practical examples of pilot evaluations for Smart Water Cities. **Chapter 10** gives details on the reasons and the procedures to select pilot cities to test the Smart Water City index. **Chapter 11** provides an in-depth evaluation of BEDC, discussing its main urban features, the results from the technical and governance assessments, and presenting its final score and recommendations. **Chapter 12** offers a similar evaluation for Semarang City, Indonesia, so it follows a similar structure to present the assessment and the results from the evaluation.

Finally, the **Conclusions** distill key insights from the pilot cities evaluations and refine lessons for future initiatives. It poses critical questions for the future development and global deployment of the Smart Water Cities Index and focuses on the Index's potential transformation into a comprehensive Certification system. This Certification would verify cities meeting specific requirements in water management, technology use, and sustainable governance. Additionally, it would recognize cities implementing innovative solutions for resource management, environmental impact reduction, and efficient urban water systems with integrity. Such a certification system provides cities with a roadmap for enhancing water management and achieving sustainability goals. Represented by a distinctive symbol or badge, it allows cities to demonstrate their commitment to sustainability to investors, businesses, and residents, thereby fostering economic development and citizens' well-being. The groundwork laid in this report establishes the foundation for a future certification scheme, propelling progress in this direction.

3. Developing organizations

The Smart Water Cities project has been guided by its partner organizations: IWRA, K-water, and AWC. IWRA is an international network of multidisciplinary water resources management experts established in 1971. It promotes knowledge sharing and expertise exchange across borders and sectors, facilitating improved water decision-making through education, research, and information exchange.

K-water, established in 1987, is a government-owned corporation for comprehensive water resource development in the Republic of Korea. It provides both public and industrial water and has expertise in Smart Water technologies.

AWC, established in 2015, is a non-profit regional cooperation body focusing on solving water issues in Asia through scientific and technological solutions and implementation plans.

The development of the project involved collaboration from various people and organizations. The project has contributed to the establishment of a solid network of researchers and cities. The first part of the project brought together a group of 37 authors that presented evidence on the use of the smart use of water technologies in nine different cities around the world: Algarrobo (Spain) Busan Eco Delta City (Republic of Korea), Ciudad Juarez (Mexico), Heredia (Costa Rica), Hong-Kong and Ningbo (China) Mumbai (India), Nakuru (Kenia) and New York City (USA).

The second part of the project included a call for pilot cities that received large interest from places around the world. The City of Semarang was selected from a pool of 24 applicants, including Abuja (Nigeria); Ado Ekiti (Nigeria); Amasya (Turkey); Baguio City (Philippines); Bahir Dar (Ethiopia); Dakar(Senegal); Gaziantep (Turkey); Gilgit (Pakistan); Islamabad (Pakistan); Jodhpur (India);Kampala (Uganda); Lagos(Nigeria); Leon (Mexico); Lusaka (Zambia); Mendoza (Argentina);Molde (Norway); Mombasa (Kenya); Ordu (Turkey); San Pedro (Colombia); Tabriz (Iran); Tekirgad (Turkey); Tervuren (Belgium); Yalova (Turkey).

The third part of the project has provided large opportunities to establish a community of practice with a committed group of civil servants and officials at the national and the local levels in Busan and in Semarang. In BEDC, a series of responses were gathered from personnel in different departments from the K-water involved in the development of the BEDC. In Semarang, the team of responsible authorities included, as well as the Mayor of Semarang, the following authorities: The Regional Secretary of Semarang City, the Head of Semarang City Regional Development Planning Agency, the Head of Semarang City Regional Financial and Asset Management Agency, the Head of Semarang City Housing and Settlement Area Agency, the Head of Semarang City Public Works Agency, and the Head of Semarang City Regional Disaster Management Agency. At the technical implementation level, we hold regular meetings with professionals responsible for the running of Semarang's water services provision and water management, including the Director of the regional water company PDAM Tirta Moedal, the Head of Infrastructure Planning and Regional Development of Semarang city, the Coordinator of Foreign Cooperation, etc.

Thus, the commitment to the project from the responsible authorities has been well established. The information that the local actors provided was verified both onsite and via triangulation with different official reports and data sources from national and international government and organizations.

Through its development the project has benefited from the support of its Steering Committee members: Henning Bjornlund, Neil Grigg, Juliette Lassman, Oriana Romano, Isam Shahrour, and Lili Yu. Their guidance and contributions for their project is greatly appreciated.

PART 1

SMART WATER CITIES

CHAPTER 2
CITIES: URBAN CHALLENGES AND GLOBAL AGENDAS

The first stage of the Smart Water Cities project has revolved around a comprehensive exploration of the fundamental characteristics of urban areas – their defining traits and inherent attributes – as well as the distinct water-related obstacles they encounter, and how they have tried to overcome them. This examination has laid the groundwork for understanding the reasons for and the use of adopting a Smart Water City Index and certification. In this chapter, we present a concise overview of the pivotal themes covered.

1. Cities and Urban Features

More than 50% of the world population is considered to live in urban areas and yet, the characteristics of these areas vary enormously. Cities differ in terms of size, density, socio-economic conditions, cultural influences, governance structures, and historical origins. They may vary in natural attributes like climate, geography, and access to resources, as well as socio-economic factors such as industrialization, urbanization, and technological advancement. The dynamic nature of cities further complicates defining them. Despite the difficulties in the definition, an understanding of urban features is essential for effective urban management. Indeed, providing essential services like water supply, drainage, and sanitation, amongst others, presents distinct challenges in densely populated or sprawling metropolises, as well as in green or heavily developed areas, which need to be thoroughly examined. Among the various important characteristics of a city, notable factors and trends include its population size, how crowded it is, how quickly it's urbanizing, its level of economic growth, and how old the city is. To grasp a city's water management and services, we must start by examining these crucial factors:

Population Size

Cities span a broad spectrum in terms of population (UN-Habitat, 2020a). This categorization includes:
- Megacities: populations exceeding 10 million;
- Large Cities: populations between 5 and 10 million;
- Medium-Sized Cities: populations ranging from 1 to 5 million;
- Small Cities: populations between 500,000 and 1 million;
- Large Towns: populations of 300,000 to 500,000;
- Urban Settlements: populations fewer than 300,000;

Over the last five decades, urban population growth has been substantial. In 1970, 63% of the global populace resided in rural regions, while 36% lived in cities. By 2018, more than half the world's population inhabited cities. This shift was marked by the growth of megacities, large cities, medium-sized cities, and other urban settlements. The urban population ballooned from 1.3 billion in 1970 to 4.3 billion in 2018. Notably, megacities saw their population swell from

55 million to 529 million within this period. This trend is poised to continue, with projections estimating that urban populations will reach 5.5 billion by 2035 (UN, 2019).

Urban Density

Urban density, gauged by the number of individuals per unit area, is categorized into four degrees (UN-Habitat, 2020a):

- Very High-Density Cities: over 8000 inhabitants/km^2;
- High Density Cities: between 6000 and 8000 inhabitants/km^2;
- Dense Cities: between 4000 and 6000 inhabitants/km^2;
- Lower-Density Cities: fewer than 4000 inhabitants/km^2;

Global data reveals that cities vary in density, with larger cities generally exhibiting higher density. There is a link between a country's income level and its city density, as cities in low-income nations tend to be much denser. The density of large cities has increased over the past four decades, significantly influencing overall population density.

Rate of Urbanization

Urbanization rate, indicating the pace of urban population growth, varies across cities. Urbanization has been particularly rapid in less developed regions, resulting in a higher concentration of larger cities within shorter time frames compared to developed nations. Some developed countries, however, are experiencing population decline due to de-industrialization and migration.

Cities with different urbanization rates face distinct challenges in providing adequate water services. Rapidly growing cities may struggle to ensure sufficient water supply, while declining cities grapple with maintaining infrastructure designed for larger populations.

New or Existing City

Urban population growth can result from densification within existing city boundaries or the creation of new urban areas. Densification has become the dominant growth pattern, with around 70% of urban growth since 1975 occurring through this process. Challenges associated with infrastructure, urban planning, and costs differ between the two strategies.

To address these challenges, the UN recommends promoting compact and contiguous urban development in existing cities' peripheries, avoiding the costly creation of entirely new cities. Such developments should prioritize lower environmental and agricultural value lands and focus on livability and sustainability.

Economic Development

Cities also vary in economic development, often categorized based on World Bank income groups. Economic development significantly impacts a country's socio-economic and technological landscape, affecting various aspects of life. High-income cities have better access to technologies and financial resources, enabling smarter water management solutions. In contrast, lower-income cities may face more challenges and require tailored strategies.

2. Key Challenges in World Cities Today

World cities, despite their diverse characteristics, confront shared and pressing challenges. The rapid pace of urbanization places immense strain on essential resources like land, energy, and water. This strain is particularly evident in the increasing difficulty of providing adequate housing, food security, and efficient transportation systems, often resulting in the proliferation of slums and exacerbating social issues such as unemployment, poverty, and inequality. The effective governance and management of these intricate urban landscapes becomes paramount.

Climate change further compounds these challenges. Urban areas are not immune to the effects of climate change, as evidenced by the escalation in weather-related disasters and hazards. These events, driven by climatic factors, not only result in loss of life but also inflict significant damage to infrastructure and property. Cities also contribute to climate change through pollution and environmental degradation, creating a complex cycle of challenges. Consequently, urban planning and development practices that incorporate principles of green infrastructure, energy efficiency, and circular economy are pivotal for achieving sustainable and resilient urban growth.

The swift growth of urban populations presents a multifaceted set of challenges. Projections indicate that by 2030, approximately 40% of the global population will require adequate housing, necessitating significant infrastructure development. Moreover, the demand for food is on the rise, compelling the agricultural sector to enhance production capacities. In this context, water resources stand out as a critical concern, as urban expansion, coupled with the impacts of climate change, amplifies the risks of water-related challenges such as floods and tropical storms.

Urban water challenges encompass a range of issues including flooding, water scarcity, compromised water quality, aging infrastructure, and inadequate urban planning. Inadequate drainage systems often contribute to devastating floods that wreak havoc on communities. Water scarcity affects millions, leading to restricted access to clean water sources and resulting in economic losses. The degradation of water quality and the aging of urban water infrastructure further strain water management systems, necessitating substantial investments. Addressing these multifaceted water challenges demands a comprehensive and integrated approach to urban planning and development.

3. The Global Agenda for Smart and Sustainable Development of Cities

In the past two decades, the global community has placed considerable emphasis on addressing the complex challenges of urban water management. Numerous international agreements and guidelines have been established to foster a coordinated response to these pressing issues. These agreements form the basis of a unified global agenda, encompassing shared visions, goals, and a collaborative action plan. Significantly, many of these international initiatives underscore the pivotal role of cities in these efforts. Consequently, effective engagement at the city level is deemed essential, where city authorities adapt international strategies to suit their local contexts. This approach often entails pursuing objectives that necessitate substantial progress within cities.

Foremost among these initiatives is the adoption of the 2030 Agenda for Sustainable Development by the United Nations in 2015. This agenda delineates the Sustainable Development Goals (SDGs), a collection of 17 interconnected global goals designed as a "blueprint to achieve a better and more sustainable future for all" (UN, 2017). Governments worldwide have endorsed the SDGs, comprising 169 targets across diverse areas such as poverty alleviation, economic growth, and environmental sustainability. Notably, two SDGs hold specific relevance to both water and cities – SDG 6 and SDG 11. SDG 6 seeks to ensure availability and sustainable management of water and sanitation for all by 2030. SDG 11 focuses on creating inclusive, safe, resilient, and sustainable cities, aiming to reduce disaster impact, minimize environmental footprint, and enhance universal access to green spaces.

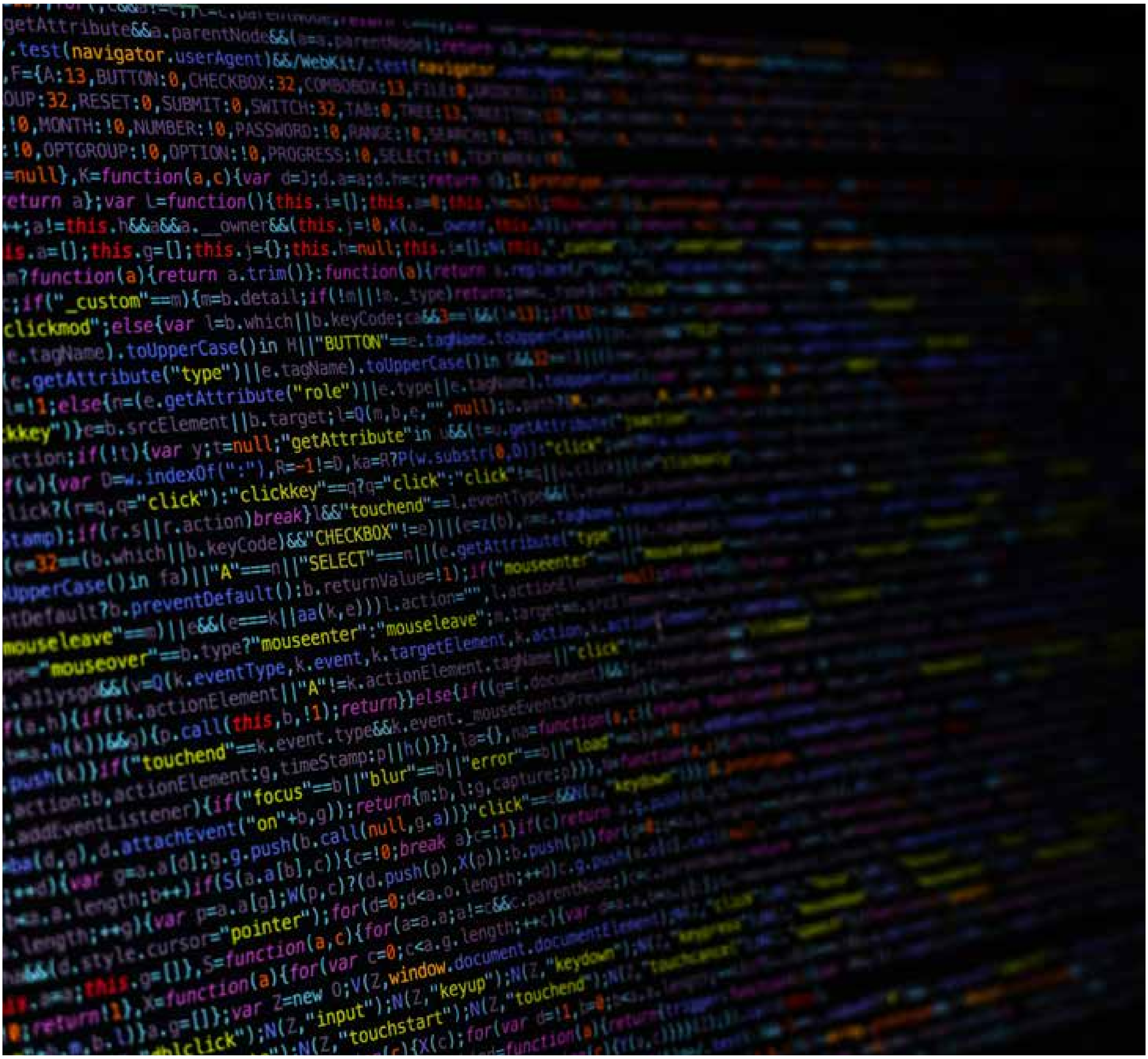
In support of the SDGs, a range of complementary measures has been enacted to expedite their realization. For instance, the United Nations declared the years 2018 to 2028 as the International Decade for Action "Water for Sustainable Development" during which various UN entities are executing a series of initiatives to advance water sustainability and accessibility. Additionally, the UN 2030 strategy and the SDG 6 global acceleration framework reflect the organization's dedication to international water action. These initiatives encompass monitoring and reporting support at global, regional, and sub-regional levels, fostering outreach through publications and campaigns, delivering technical advice, and aiding countries in prioritizing key water-related goals.

The focus on SDG 11 has similarly intensified. UN-Habitat has been instrumental in assisting national and local governments in realizing urban-related targets. With the introduction of the "Goal 11 - monitoring framework" and the UN-Habitat new urban agenda, endorsed by the United Nations General Assembly in 2016, the UN underscores the significance of well-planned urbanization for achieving sustainable development goals. UN agencies actively contribute to data collection and analysis for urban areas, supporting the formulation of country-specific reports.

Parallel to these initiatives, other pivotal agreements relating to sustainable development underscore the central role of local urban action. The Paris Agreement, a landmark accord for combatting climate change, and the Sendai Framework, offering tangible measures for safeguarding development gains from disaster risks, emphasize the vital engagement of citizens and urban authorities in mitigating climate change impacts and managing localized risks. Failing to empower local urban stakeholders could imperil up to 65% of SDG targets, highlighting the critical role of cities in achieving the global agenda (Kanuri et al, 2016).

Addressing these difficult urban challenges has spurred the rise of "smart" urban development, a paradigm that positions smart technologies as central tools in surmounting urban issues. Smart cities are able to optimize governance, minimize waste, enhance social inclusivity, and boost economic and social welfare, advocate for data-driven decision-making at the city level. The ubiquity of data and technology has fueled this global trend, leading to the expansion of information and communication technology (ICT) access and usage across diverse sectors and socioeconomic strata since the 1990s. Initiatives have emerged across various sectors, including transportation, energy, education, and natural resource management, with the goal of leveraging technology to create efficient and sustainable urban systems.

At the international level, prominent organizations have championed the cause of smart cities as a pivotal element of a united global endeavor. The "People-Centered Smart Cities Programme" stands as one of UN-Habitat's five flagship strategic action programs. This program underscores how digital technologies can contribute to achieving SDGs by enhancing livelihoods, fostering economic and gender equity, while also recognizing the potential challenges posed by ICTs. To this end, UN-Habitat has actively forged long-term partnerships with national and local governments, as well as other stakeholders, to facilitate the seamless integration of smart technologies.



CHAPTER 3
DEFINITION OF SMART WATER CITIES

To define the concept of a Smart Water City, we must first understand the functions of water in urban areas and the strategies, plans, and technology that cities use for water management and water services provision. This chapter explores these elements to provide a clear definition of a Smart Water City.

1. Functions of water in cities

Water serves a primary role in cities, as it serves to meet the needs for safe drinking water and sanitation of the population. Meeting essential water service requirements is imperative for societal well-being and economic progress, leading water planning authorities to prioritize urban water services in development plans. As a result, the provision of urban water services has been a task traditionally undertaken by local water service providers, whether public or private.

Beyond addressing the water needs of the local population, water also serves a range of equally vital functions, best comprehended through the lens of the "water cycle." The water cycle alludes to the continuous process involving water's movement through the Earth's atmosphere, in different stages such as condensation, precipitation, infiltration, runoff, and evapotranspiration. At each stage of the water cycle, water not only caters to human needs but also shapes the environment, supporting various life forms and ecosystems: it regulates temperature of the surroundings areas, it contributes to the erosion of rocks to form soil, creates geographical features, which have implications on the environment and life of other beings, etc. Importantly, any intervention at one stage can reverberate through subsequent stages, highlighting the cycle's interconnected nature.

Human activities have modified the water cycle with actions like irrigation, abstractions, storage, and deforestation. Urbanization, industrialization, and population growth have transformed key aspects of the water cycle. Processes aimed at treating and delivering water to meet human standards have changed water flow and currents, while urban landscapes have led to reduced infiltration, increased runoff, pollution, and limited groundwater replenishment. These changes have prompted the concept of an "urban water cycle" as a distinct phenomenon.

Understanding water's functions is integral to intelligent and sustainable urban planning. Recognizing water's roles at different cycle stages can inform a more cohesive, effective, and integrated city planning. Smart water technologies can enhance water services and also improve urban planning by facilitating ecosystem resilience and coexistence between humans and nature. It is therefore important to examine how technologies can facilitate efficient and sustainable water resource management, extending water's functions beyond essential drinking water and sanitation provision.

2. National and local policies and strategies for smart water city today

What strategies have been adopted by cities to address urban water challenges? In addition to having the knowledge and capacity to develop and implement technical solutions, policies and strategies need to be in place to enable the adoption of smart water solutions. Establishing a suitable regulatory structure is a fundamental requirement for embracing initiatives that promote sustainability and intelligent growth. Ensuring the availability of sufficient economic resources is also pivotal to ensure the financial viability of smart initiatives. Equally important is the development of proficient administrative capacity to navigate decisions related to water resources. The progression towards Smart Water Cities depends not solely on the availability of appropriate technology, but also on the elimination of non-technical barriers and the implementation of policy measures that encourage their adoption.

The institutional and regulatory features established for the management of urban water resources vary across cities and countries. In the report "Identifying Smart Water Cities" we examined some of the national and regional policies and strategies put in place in nine case study cities, from different countries in different regions of the world as case studies: Algarrobo (Spain), Busan Eco Delta City (Republic of Korea), Ciudad Juarez (Mexico), Heredia (Costa Rica), Hong Kong (China), Mumbai (India), Nakuru (Kenia), New York City (U.S.A.), and Ningbo (China). These cases illustrated attempts to implement smart water solutions and illustrate the regulatory measures, the national plans, the economic instruments, and the voluntary means, etc., adopted in different cities to limit the need for new water resources and to optimize the available ones in different places around the world. They showed the regulatory efforts to manage water resources in different types of cities according to population size, type of city (old or new) and economic development, and according to the different types of challenges they face water pollution, water scarcity, aging water infrastructure, and more.

The cases illustrated several factors that have impacted facilitation or adoption, be it an adequate institutional framework, economic resources, appropriate administrative capacities, etc. They showed different policy approaches to the implementation of innovative water technologies. BEDC and Ningbo, for instance, have been pilot projects supported by the national governments. Their developments have served to test innovative water technologies as well as potential solutions, and to learn from them in order to apply them in other places and circumstances. In other case studies, such as Heredia, Algarrobo, or Ciudad Juarez, technologies have had a more local outlook, and have been employed to address local policy objectives regarding the environment, water services provision, and/or urban planning.

3. Smart water technologies in the world cities today

The rapid advancement of smart technologies worldwide has led to an array of innovative solutions aimed at addressing urban challenges. This emerging landscape presents a new avenue for industrial development, offering economic incentives and growth opportunities. Projections indicate that the global smart city market could reach a valuation of around $651.7 billion by 2028,

In the context of water management, the adoption of ICTs has been slower compared to other sectors. Nevertheless, policymakers and industry stakeholders are increasingly recognizing the potential of smart technologies for water resource management and provisioning services (Leflaive et al. in 2020). A range of devices, including smart pipelines, sensor networks for monitoring water conditions, and intelligent meters for consumption measurement, have been designed to address urban water challenges comprehensively.

Thus, we can find examples worldwide where ICTs empower water service providers to confront diverse urban water challenges, spanning floods, water scarcity, water quality concerns, aging infrastructure, and deficient urban planning. The Smart Water Cities project has examined some of them in detail:

In regions prone to flooding, sophisticated monitoring equipment aids in tracking water levels and issuing timely warnings. These technologies empower both authorities and the public to prepare for potential flood events. For example, in Ningbo, China, a pioneering smart water system monitors water levels and predicts floods. In New York City, efforts to mitigate rainwater's impact on the sewer system include green infrastructure and improved drainage.

To combat water scarcity, smart metering has gained prominence in many cities. This approach, estimated to reduce consumption by about 15% in higher-income cities (McKinsey Global Institute, 2018), monitors usage and provides prompt digital feedback to users and service providers. This encourages water conservation and leak detection. Ciudad Juarez, Mumbai, and Hong Kong are cases where smart metering is used to manage water consumption and infrastructure issues. In parallel, some cities are enhancing water storage and recharge mechanisms to address scarcity. The Nakuru case study in Kenya exemplifies this approach, employing ICTs for participatory problem-solving. Smart technologies also enable the reuse of reclaimed water (wastewater/greywater) to meet local demands, lessening the pressure on existing water sources. Algarrobo, Spain, utilizes reclaimed wastewater for irrigation, benefiting the environment and local economy.

Furthermore, smart technologies play a pivotal role in improving water quality. Across various regions, automated sensors and sampling devices monitor water sources for pollutants, safeguarding public health and the environment. Heredia, Costa Rica, showcases how innovative technologies ensure safe drinking water.

A more detailed explanation of the role of technologies can be found in the first report of the project. At their core, all these different initiatives provide evidence of how smart policies and technologies have helped to deal with current urban water challenges in different cities and in different circumstances. They have shown the improvements achieved in urban water services provision and have suggested promising venues for future technological and policy developments.

4. Definition of Smart Water City

The concept of smart cities has been subject of an animated discussion in the literature (see Ahvenniemi, et al., 2017; Albino, Berardi, & Dangelico, 2015). To come up with a definition of Smart Water City, we reviewed relevant literature and drew from other resources such as the “Smart Water Management - Case Study Report” elaborated in 2019 by IWRA and K-water. This report examined different examples of the use of Smart Water Management (SWM) in diverse urban and rural settings, affecting social, economic, environmental, governance, and technological spheres. It also highlighted how SWM contributes to achieving SDGs by addressing gender equality, hunger, education, climate change, and safety. It also argued for establishing an adequate governance and regulatory framework to support the implementation of smart and sustainable water projects and initiatives.

Based on these findings, we formulated the following definition of a Smart Water City, which would be applied to urban areas making use of smart water management technologies:

“A smart water city is a sustainable city with contactless, intelligent water management for all”
A smart water city improves the quality of life of citizens by solving existing urban water problems based on various technologies and ICTs throughout the urban water cycle. It provides not only individual solutions for conventional water management, such as drainage, water treatment, and wastewater treatment. It also improves comprehensive water management through the restoration of urban water cycle, waterfront usage, and intelligent water management. (Smart Water Cities project, 2021: 32).

This definition is appropriate as it incorporates the full scope of urban water functions of the urban water cycle, surpassing the conventional focus on drinking water and sanitation. In this sense, a smart water city provides urban water services, but also revitalizes the urban water cycle, offers citizens access to water-related activities, and implements intelligent water management practices. This understanding highlights that Smart Water Cities encompass more than providing water and sanitation services; they also address urban water restoration, waterfront utilization, and integrated water management.

Moreover, a smart water city embraces ICTs in water management and their impact on citizens' quality of life, including socio-economic, cultural, and environmental aspects. This definition combines smart technology use with their outcomes, covering not only technological advancement but also economic efficiency, social equity, and environmental sustainability. It underscores the importance of sound water management for urban development, indicating that supportive institutions, regulations, and policies drive smart water city growth.

Furthermore, in a smart water city, ICT-based intelligent technologies complement and improve existing infrastructure and technologies for water management within the whole urban system. This understanding highlights that Smart Water Cities concern not only the utilization of smart technologies, but also of other infrastructure capable of meeting the demands of the city for drinking water and sanitation services for urban water users, and other urban water functions such as urban water restoration, waterfront usage, etc.

This conception of a smart water city organizes how we structured our approach to developing a Smart Water City Index, which is further examined in Parts II and III of the present report.

PART 2

Smart Water City Framework and certification schemes

Developing instruments to measure city life is of paramount importance. Measuring tools serve as the basis of informed urban policymaking and investment. By providing accurate assessments, metrics enable city stakeholders to make data-driven decisions, which ensure that resources are allocated efficiently, targeting areas in need of improvement. Such measurements also enhance transparency and accountability, offering means to communicate achievements and also to identify and point at existing deficits. They facilitate the exchange of knowledge and best practices between cities, enabling the replication of successful strategies. Overall, measuring tools can contribute to steer cities towards adopting smarter and sustainable urban policies, as they facilitate the adoption of short, medium, and long-term strategies for investment and innovation.

This part of the report explains the rationale behind creating a Smart Water City Index and examines the KPIs that constitute it. While there are global standards for assessing various aspects of smart urban sustainability, a dedicated measuring tool for evaluating Smart Water Cities is needed. This Index allows for a meticulous examination of specific cases in urban water management and service provision, enabling meaningful comparisons between them. Chapter 4 supports the need for the Smart Water City Index by presenting a thorough analysis and comparison of existing global standards and certification schemes. This includes identifying the gaps and crucial aspects related to urban smart water technologies and urban water management that existing standards do not address. Chapter 5 outlines the fundamental principles and processes for establishing KPIs in urban water management and water services provision. Finally, Chapter 6 introduces the structure of our Smart Water City Index.

CHAPTER 4
ANALYSIS OF GLOBAL STANDARDS, INDICATORS, AND CERTIFICATION SCHEMES

Many standards and certification schemes dealing with urban sustainable growth and local development have been adopted over the last 20 years. The signing of the Local Agenda 21 by the United Nations in the early 1990s inaugurated a period when monitoring urban activity became a central activity of international agencies and organizations around the world. This chapter examines the content and the structure of eight of these instruments and explains the reasons why it has been necessary to develop a Smart Water City Index.

1. Comparison of Global Standards and Certification Schemes

The Smart Water Cities project has dedicated efforts to examine existing global standards and certification schemes focusing on measuring local water management and urban sustainability. Analyzing the characteristics of some of these instruments can provide opportunities to learn from their different approaches to these topics. Eight indexes, which have been developed both by international organizations and by non-governmental organizations and the private sector, have been selected. They seek to quantify cities' ability to protect the urban environment, to facilitate the easy access of citizens to clean water, and to measure the use of digital technologies in the provision of urban services:

- The United 4 Smart Sustainable Cities (U4SSC) has been developed by the International Telecommunication Union (ITU), United Nations Economic Commission for Europe (UNECE), and UN-Habitat. This instrument focuses on three aspects: the cities' attainment of the SDGs, their degree of smartness, and their sustainability.
- The ISO 37120 Series (Sustainable Cities and Communities) is a set of three standards concerning urban sustainability, smartness, and resilience (ISO 37120, ISO 37122, and ISO 37123), is examined.
- The Organisation for Economic Co-operation and Development (OECD) Smart City Measurement Framework brings together the indicators destined to measure smart cities.
- The CITYKeys Smart City Index was developed by a consortium of European universities and research centers and focused on measuring sustainable city practices, including but not limited to water resources management.
- LEED for Cities and Communities, developed by the U.S. Green Building Council (USGBC) and the Green Business Certification, Inc. (GBCI), have focused on advocating for sustainable practices at the city level.
- The Arcadis Sustainable Cities Water Index has been developed by Arcadis and the Centre for Economics and Business Research (CEBR), which are two private consultancies operating globally from their headquarters in the Netherlands and the UK, respectively. Their index seeks to assess and rank the urban water management of cities around the world.

- KWR City Blueprint Approach has been prepared by KWR Water Research Institute, an independent research center based in the Netherlands. The City Blueprint Approach provides a methodology for diagnosing how cities around the world ensure an integrated management of their urban waters.
- AWS International Water Stewardship Standard has been adopted by the Alliance for Water Stewardship (AWS), which is a network of businesses, NGOs, and the public sector. The AWS seeks to promote local water resources sustainability through the adoption of this standard.

Four main elements are the elements for comparison:

1. Standard topic reflects what performance the standard aims to measure, such as sustainability, smartness, resilience, or other, as well as its scope of application–the city, the community, water basins, or other sites.
2. Standard categories reflect the subject of a standard, broken down into a series of elements for measuring, which may consider sectoral policies, stages of implementation, or other.
3. Standard indicators are the elements that serve to examine and measure performance. They derive from observed facts and phenomena. Examples include amount of water consumption, water stress index, water recycling rate, etc.
4. Standard metrics are concerned about the unit of measurement employed by the standards. Depending on the indicator, they may refer to an absolute number, a percentage or ratio, a measure of time or revenue, etc.

2. Key Findings from the comparison

Several aspects stand out from the comparison of these eight well-established instruments to analyze and evaluate cities from around the world (See Table 1):

Variation in the standard topic

The standards vary in their topic subject. Four of the standards analyzed make water sustainability the key topic of the standard (Arcadis Sustainable Cities Water Index, KWR City Blueprint Approach, and AWS International Water Stewardship Standard). Their objective is to measure the environmental protection of water bodies and citizens' access to water resources. The other four standards make specific references to "smartness" as a central topic (United 4 Smart Sustainable Cities, ISO 37120 series on sustainable cities and communities, OECD Smart City Measurement Framework, and CITYKeys Smart City Index). They are interested in measuring the presence of digital technologies in the provision of urban services. Smart development is, nonetheless, understood as heavily interconnected to sustainability, and so, these standards also refer to the protection of the environment and social inclusion.

In addition, quality of life–understood as citizens' wellbeing–is also an important concern, and thus smart sustainable development is also put in connection to indicators such as access to health and education, safety, food security, etc., in several cases, such as LEED for Cities and Communities, CITYKeys Smart City Index, OECD Smart City Measurement Framework, ISO 37120 Series, etc.

Cities as unit of analysis

The city–taken to be the space inhabited by many people living in proximity, and under one administration–is the preferred unit to examine urban sustainable and smart development in most of the examined standards. One standard (AWS International Water Stewardship Standard) uses the term "site" instead, which refers to areas within a river basin. In addition, two standards can be applied to cities and to "communities", understood as smaller urban units such as neighborhoods or city districts. All standards are designed to examine urban areas with different features, irrespective of their size, economic development, governance arrangements, etc.

Governance of urban water resources

Six standards except the Arcadis Sustainable Cities Water Index and the United 4 Smart Sustainable Cities do include some indicators on urban governance. Elements such as the existence of coordination between departments, citizen's participation, or mechanisms for monitoring and evaluation are measured. However, no set of the most crucial elements at the city level has been established.

Water has a key role in smart sustainable cities

Water plays a key role in all the standards dealing with smart, urban sustainability. Water is key for socio-economic development and life, and thus all standards seek to grasp the extent to which cities provide for a safe and secure access to this finite resource.

However, several of the examined standards only take a partial view of the different functions of water in cities. The United 4 Smart Sustainable Cities, ISO 37120 Series, OECD Smart City Measurement Framework, CITYKeys Smart City Index, and LEED for Cities and Communities standard have a larger scope of analysis than water and include other sectoral policies and dimensions. Thus, the functions of water as a resource and an urban service are only considered with a reduced number of indicators.

Arcadis Sustainable Cities Water Index, KWR City Blueprint Approach, and AWS International Water Stewardship Standard are much more comprehensive in the analysis of the water sector and can be of great help in the design of a future Smart Water City standard scheme. Yet, some limitations concur:

- Arcadis Sustainable Cities Water Index includes 17 indicators to measure and evaluate the functioning of urban water services provision. Some gaps are still present regarding water quality and wastewater collection. Aspects concerning urban governance are not taken into consideration.
- KWR City Blueprint Approach successfully measures characteristics of the city and also pays dedicated attention to the governance of the water sector. However, the standard is concerned with measuring the existing urban water status and not the functioning of water services provision in the city.
- AWS International Water Stewardship Standard takes the river basin and water sites as units of analysis. Therefore, the focus is not on the functions of water in the city, which have particularities that need to be specifically examined (such as, the operation of water services infrastructures, for instance).

Characteristics of the indicators: number, hierarchized, quantitative and output measures

With regards to the characteristics of the indicators of the standards examined, various elements need to be highlighted:

- The range of indicators from 19 of Arcadis Sustainable Cities Water Index to 276 of ISO 37120 Series that the standards propose is large. The other six standards have more than 40 indicators. Decisions on the number of indicators have large implications: the more data that the standard collects, the fuller their diagnosis. However, greater data requirements may also make it difficult to collect information in certain cities and lead to incomplete data gathering exercises. A trade-off between data comparability and exhaustiveness exists.
- Some standards have established a hierarchy of indicators. This means that the collection of certain information is deemed essential, whereas other indicators may help to complement the data gathering exercise.
- Most standards indicators collect quantitative data, gathered in percentages and rates. Doing so facilitates comparisons across city and country cases. In some cases, such as KWR City Blueprint Approach and the CITYKeys Smart City Index, the information requested is of a qualitative nature and requires an evaluation. In these cases, the information is collected with a Linkert scale where the evaluator grades the circumstances and the status of water in the city. The LEED for Cites and Communities standard employs a scoreboard. In these cases, it is necessary to establish a set of guidelines to ensure the information collected by different researchers/evaluators is reliable and comparable.
- Most of the standards have preferred indicators that account for city outputs, that is, the measure of sustainability or smartness that the city displays. Indicators on the resources employed to achieve such smart and sustainable results (input indicators) are employed less. Process indicators are heavily employed only in the AWS International Water Stewardship Standard, as it accounts in detail the mechanisms and the measures put in place, irrespective of their results or the resources employed.

Table 1. Comparison Eight Global Standards on Smart and Sustainable Water Urban Management

Standard	Subject	Structure	Water-related indicator
United 4 Smart Sustainable Cities	Smart Sustainable Cities	3 dimensions (Economy; Environment; Society and Culture) 7 sub-dimensions (ICT; Productivity; Infrastructure; Environment; Energy; Education, Health and Culture; Safety, Housing and Social Inclusion) 28 categories 91 indicators (quantitative)	11 indicators 2 in water distribution (supply) 1 measuring smart technology 1 in water distribution (loss) 2 in consumption 1 in drinking water (supply) 1 in drinking water (quality) 1 in wastewater (collection) 1 in wastewater (treatment) 1 in sanitation 1 in water source (quantity)

Standard	Subject	Structure	Water-related indicator
ISO 37120 Series (Sustainable Cities and Communities) *	Smart and sustainable cities and communities	19 themes 104 indicators (ISO 37120 standard); 80 indicators (ISO 37122 standard); 68 indicators (ISO 37123 standard), all quantitative	11 indicators (ISO 37120 standard) 1 in water distribution (supply) 1 in water distribution (loss) 2 in consumption 1 in drinking water (supply) 1 in drinking water (quality) 1 in wastewater (collection) 2 in wastewater (treatment) 1 in sanitation 1 in water source (quantity)
			9 indicators (ISO 37122 standard) 1 in water distribution (supply), measuring smart technology 1 in consumption, measuring smart technology 1 in drinking water (quality), measuring smart technology 1 in wastewater (collection), measuring smart technology 1 in wastewater (reuse) 3 in wastewater (resource recovery) 1 in water source (quality), measuring smart technology
			2 indicators (ISO 37123 standard) 1 in drinking water (supply) 1 in water source (quantity)
OECD Smart City Measurement Framework	Smart cities	3 pillars (Digitalization; Engagement; Smart City Performance) 32 sub-categories 93 indicators (quantitative)	2 indicators 1 in consumption, measuring smart technology 1 in drinking water (quality), measuring smart technology

Standard	Subject	Structure	Water-related indicator
CITYKeys Smart City Index	Smart cities	4 categories (People; Planet; Prosperity; Governance) 19 sub-categories 76 indicators (quantitative – with Likert scale)	5 indicators 1 in water distribution (loss) 1 in consumption 2 in water source (quantity) 1 in ecosystem
LEED for Cities and Communities*	Cities and communities' sustainability	9 categories (Energy; Water; Waste; Transportation; Quality of Life) 40 indicators (quantitative and qualitative – scoreboard)	8 indicators 1 Access to water and sanitation 1 Quality of drinking water 1 Quality of treated wastewater 1 Quality of stormwater infrastructure 1 on Water consumption per capita (water performance) 1 on water balance 1 on flooding 1 on Water audit
Arcadis Sustainable Cities Water Index	Sustainable water cities	3 categories (Resilience; Efficiency; Quality) 18 indicators (quantitative)	All 1 in water distribution (supply) 1 in water distribution (loss) 2 in consumption 1 in drinking water (supply) 1 in wastewater (treatment) 1 in wastewater (reuse) 2 in sanitation 3 in water source (quantity) 1 in water source (quality) 2 in ecosystem 2 in disaster risk

Standard	Subject	Structure	Water-related indicator
KWR City Blueprint Approach	Cities' Integrated water resources management	3 frameworks (Trends and Pressures; City Blueprint; Governance Capacity) 64 indicators (quantitative – with Likert scale)	All 1 in water distribution (loss) 3 in consumption 2 in drinking water (supply) 1 in drinking water (quality) 2 in wastewater (collection) 4 in wastewater (resource recovery) 1 in sanitation 1 in water source (quantity) 2 in water source (quality) 1 in ecosystem 3 in climate change 3 in social factor 12 in trends and pressures 27 in governance capacity
AWS International Water Stewardship Standard*	Water resources sustainability in sites and river catchments	5 categories (Gather and Understand; Commit and Plan; Implement; Evaluate; Communicate and Disclose) 30 sub-categories 98 indicators	All 34 indicators in gather and understand 10 in commit and plan 36 in implement 8 in evaluate 10 in communicate and disclose

* Certification schemes present

3. Lessons learned from comparing standards and certification schemes

The analysis of standards and certification schemes has brought valuable insights into the large number of instruments available for assessing Smart Water Cities. Furthermore, it has shed light on the requisite information for a comprehensive evaluation of intelligent water management within urban contexts. This examination has also brought three critical gaps in the methodology employed to evaluate urban water smartness:

1. Conventional vs. Comprehensive Focus: Primarily, it has come to light that existing standards are predominantly centered around conventional urban water management practices. While some data collection refers to fundamental urban services like drinking water and sanitation, there remains a lack of measurements concerning functions such as reuse and resource recovery, disaster risk mitigation, and water ecosystem functions. These aspects, crucial for the overall sustainability of urban water systems, are often overlooked.

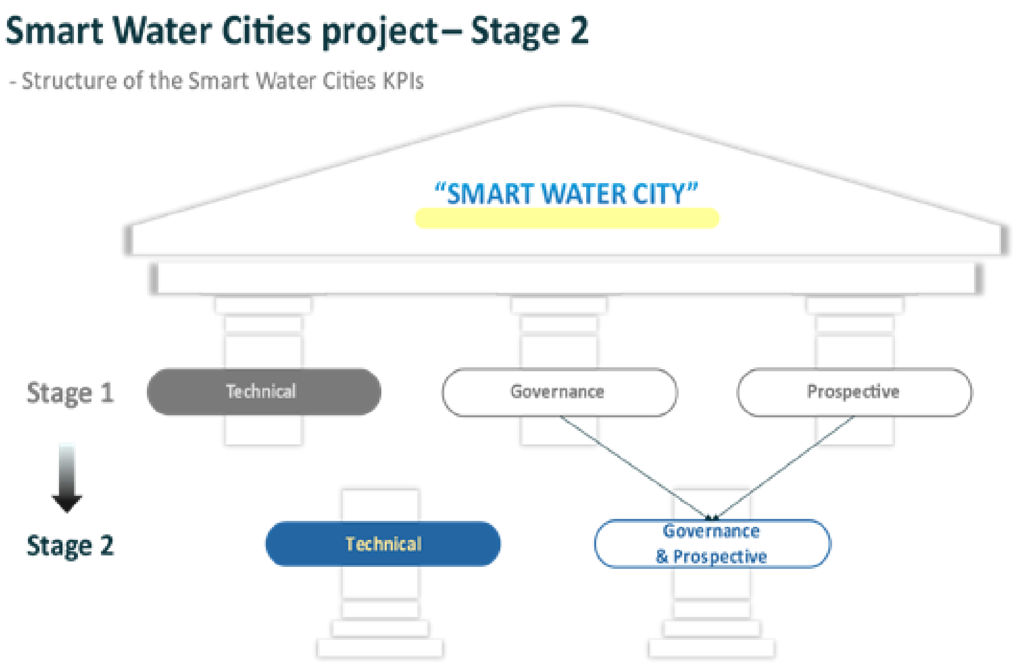
2. Smart Technologies Integration: A second observation is that while certain standards do touch upon smart development as a thematic focus, the attention given to the use of smart water technologies remains limited. The lack of attention given to the presence of water smart technologies in many standards and certifications raises questions about their comprehensive integration. As a result, we have limited information as to the extent of their use at the city level.
3. Role of Governance: Additionally, the significance of effective governance in urban water resource management emerges as a key factor for Smart Water Cities. The adoption and successful implementation of smart water solutions depends not only on technological competence but also on the encompassing institutional frameworks and strategic policy decisions. While some standards do incorporate indicators to evaluate water governance, a considerable number either lack these metrics or only cover them partially.

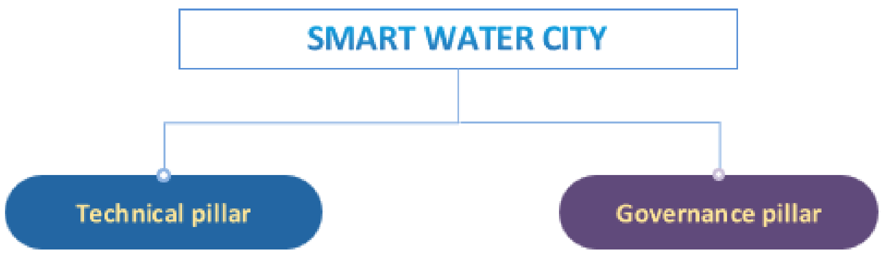
As the water sector increasingly embraces smart technologies, a pressing need arises to develop a methodology for analyzing and comparing the efficacy of water system management across diverse cities. Such a methodology can provide an initial diagnostic assessment of individual cities, serving as a foundational reference for subsequent development. Furthermore, it can highlight areas in need of enhancement—including technology implementation and management reforms—offering policymakers and water authorities guidance on how to prioritize strategic actions in urban water management. This approach can also facilitate the progress tracking within a city and support cross-city strategy comparison to optimal practices according to different contexts.

Drawing from these insights, the Smart Water Cities project formulated a framework for examining urban water management and urban water services provision organized along two dimensions: Technical and Governance. Under the Technical dimension, this framework encompasses indicators measuring not only the use of traditional water technologies but also the integration of ICTs at various stages of the urban water cycle. The objective is to assess interventions in water service provision and urban ecological systems while gauging the extent to which water technologies contribute to enhancing local urban water resource management. This encompassing examination is designed to offer a comprehensive diagnosis of the city's status.

For its part, the Governance dimension looks at the institutional and regulatory measures that a city has enacted to govern urban water. It analyses elements like the distribution of responsibilities among local actors, the existing coordination mechanisms, the participatory frameworks for stakeholders' involvement in local decision making, and the effectiveness of monitoring and oversight practices. By comprehensively evaluating the Technical and the Governance dimensions, the framework assesses a city's capacity to address evolving circumstances such as demographic, industrial, and environmental changes. The indicators also help to assess the city's preparedness to address alterations in its existing conditions, deriving from aspects such as technical and human capacities, financial independence and infrastructures, users' involvement in policy water-related investments, etc.[1]

Figure 1. Main structure of the Smart Water City Index





1. Note that the research originally identified three areas, not two, corresponding to technical aspects, a governance aspects and prospective aspects, which would be concerned with the capabilities of the cities to plan and prepare for future aspects. As the research unfolded, it became evident that there was considerable overlap between the Governance and Prospective pillars. This realization prompted the research team to make a decision to consolidate these two pillars. This adjustment was primarily driven by the goals of achieving greater consistency and simplicity in the overall framework.

CHAPTER 5
DEVELOPING PRINCIPLES AND PROCESSES OF KPIS

Once the basic structure of the Smart Water City Index is established, the indicators for each dimension – technical and governance- need to be defined and developed. This chapter examines the principles employed to define the KPIs of the Smart Water City Index, as well as the process to select them.

1. Principles for the development of KPIs

The selection of indicators has been guided by the SMART principles (Doran, 1981). These principles define the key characteristics that indicators should encompass:

1. Specificity: Indicators must be narrowly focused on a particular area where performance enhancement is concentrated. This necessitates the establishment of clear and well-defined standards.
2. Measurability: Indicators should be quantifiable and evaluable, whether through quantitative or qualitative analysis. This facilitates the assessment and recording of performance.
3. Attainability: Indicators ought to gauge performance that can be reasonably achieved within typical operational conditions.
4. Realism: Indicators need to reflect feasible outcomes based on the resources at hand.
5. Time Relativity: Indicators should be adaptable for deployment across various evaluation timeframes, suitable for both short-term progress tracking and long-term impact assessment.

In addition to these five principles, we've introduced two more to elevate the quality of the Index:

6. Relevance: Indicators must pertain to pertinent issues under resolution, ensuring alignment with the overall goals.
7. Revisability: Indicators should remain open to continuous refinement, allowing for ongoing adjustments to accommodate evolving environments, technologies, and other relevant factors.

2. Process to select KPIs

To identify and define the constitutive indicators of the Smart Water City Index and Certification scheme, the project has taken five successive steps (see Figure 2):

Figure 2. Steps of the development of the Smart Water City Index

Firstly, the research process involved categorizing and subcategorizing each facet of the Smart Water City Index, resulting in a comprehensive breakdown of the areas and concepts that the index evaluates. This foundation led to the formulation of two distinct pillars: The Technical pillar and the Governance and Prospective pillar. The Technical pillar focuses on the various technical interventions that can be implemented at different stages of the urban water cycle. On the other hand, the Governance and Prospective pillar delves into the examination of the institutional and regulatory frameworks established at the local level to manage urban water resources, deliver water services, and proactively address potential risks.

Secondly, within each of these categories and subcategories, the research has meticulously identified indicators capable of measuring the specific aspects in question. This process involved drawing from existing literature, using established standards as points of reference, and employing an inductive approach that draws on our understanding of the roles water plays within urban settings.

Thirdly, as we explore these indicators, careful consideration has been given to the measurement units and the manner in which scores are assigned. In the Technical pillar, the categories predominantly employ numerical measurements, which allow for an assessment of technical equipment performance. In contrast, the Governance and Prospective pillar employs qualitative categories that encompass varying levels of attainment, such as 'fully achieved,' 'partly achieved,' or 'not achieved.' This evaluation mechanism enables a nuanced analysis of city performance across individual indicators within each pillar.

Fourthly, the process has extended to the weighting of indicators. This is a crucial step that involves assigning weights between the two pillars and within the categories and subcategories of each pillar. Such a step is decided in consideration of the objectives and the purpose of the Smart Water City index and certification scheme; indeed, a higher weight assigns more importance to indicators that are more relevant.

The Smart Water City Index has attributed equal significance to both the technical and governance pillars. This reflects the understanding that in the context of a Smart Water city, the contributions of technical solutions and effective managerial and governance structures hold similar importance. Within the Technical pillar, certain indicators hold greater prominence, particularly those that gauge the presence and utilization of smart water technologies. By assigning this emphasis, the Smart Water City Index rewards cities that prioritize the implementation of innovative solutions. Within the Governance and Prospective pillar, all indicators weigh the same.

Fifthly, the culmination of these efforts results in the computation of city scores, where values are combined in accordance with their designated weights. The Smart Water City Index incorporates a visually informative radar chart to effectively communicate the outcomes across both the technical and governance pillars. These graphs show the individual scores that cities obtain in each category and subcategory, which allows for identifying their strengths across different steps of the urban water cycle, as well as areas where improvements need to be made.
The cities are then ranked and conferred with certifications that distinguish them as Gold, Silver, or Bronze. Gold-rated Smart Water Cities demonstrate exceptional proficiency in both technical and governance practices, with avenues for selective advancements. Silver-rated cities exhibit commendable performance, yet they possess identifiable areas where enhancements can be undertaken. Meanwhile, Bronze-rated cities display moderate to good performance, and there is potential for further progress.

The next chapters will delve deeper into the characteristics of the Smart Water City Index KPIs, their weights and their representation.

CHAPTER 6
SMART WATER CITY FRAMEWORK AND CERTIFICATION SCHEMES

This chapter offers a comprehensive and in-depth exploration of the Smart Water Cities framework, examining its key components: the Technical and Governance pillars. These pillars have been established to provide a comprehensive analytical framework for assessing and evaluating the urban water environment. Within each pillar, a detailed examination of categories and subcategories is provided. Furthermore, the chapter examines individual indicators, discussing their respective measurement methodologies and assigned weights. Through this analysis, the chapter facilitates a robust comprehension of its constituents' parts while providing valuable insights into the significance of adopting such an approach.

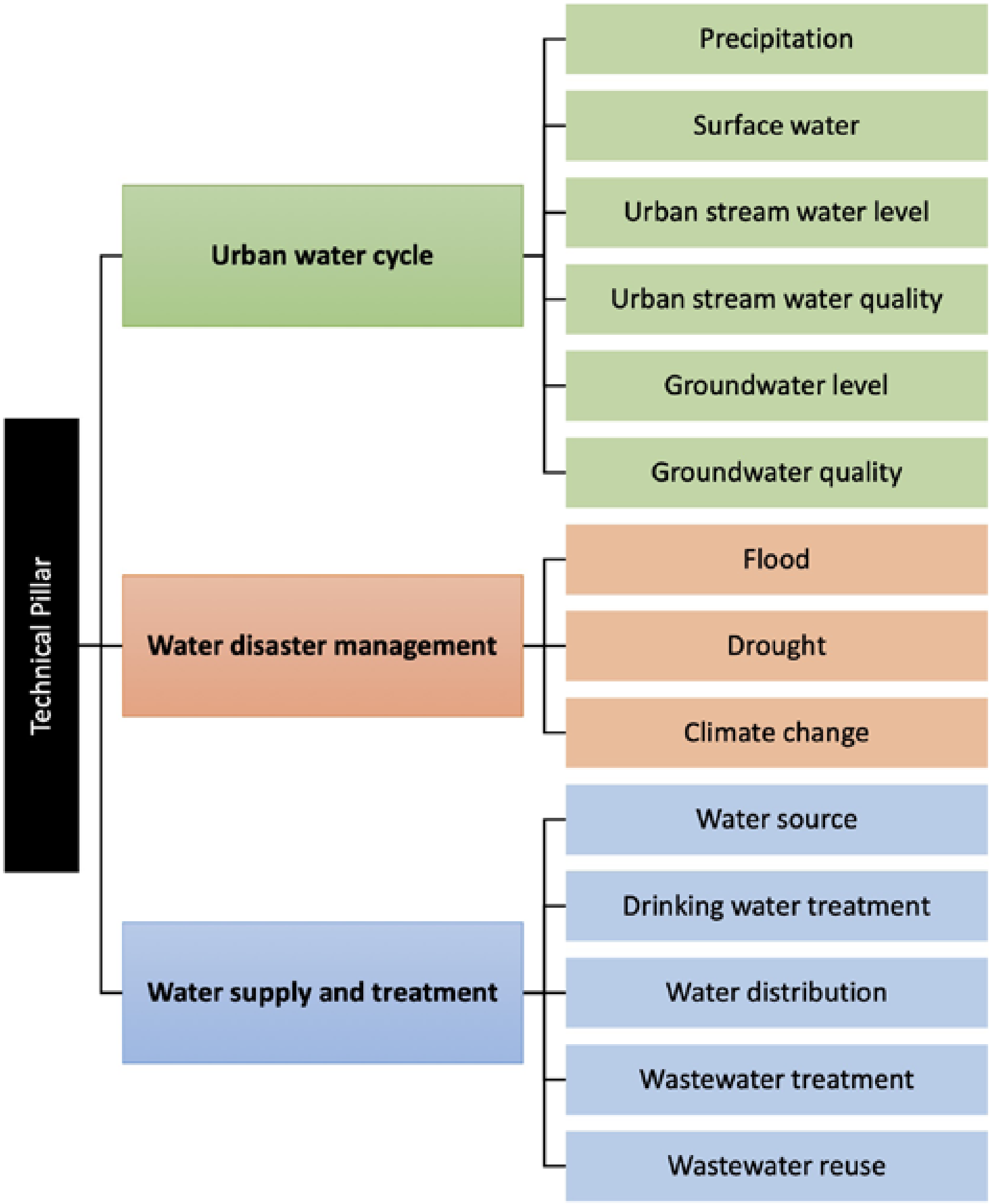
This chapter also explains the procedure for calculating and representing the Smart Water Cities scores deriving from analysis of the cities' performance, as measured by the Smart Water City Index. It describes how to compute the scores of the Technical and the Governance and Prospective pillars, and how to combine the two to obtain the city's overall score, which constitutes the basis for awarding the Smart Water Cities certification to applicant cities.

1. Technical Pillar

The first set of indicators of the Smart Water City index concerns the technical aspects of providing water services and managing water resources in the city. The Technical pillar evaluates how cities use technologies, including, but not limited to, Information and Communication Technologies, to strength disaster resilience, minimize vulnerability, ensure the sufficiency of water supply, monitor, and maintain water quality, and balance the urban ecosystem. In doing this, the Technical pillar assesses the existing applications of these technologies in cities all over the world.

The technical pillar consists of three main categories: urban water cycle, water disaster management and water supply and treatment. Along with these three main categories, the technical pillar breaks down into 14 subcategories as listed in Figure 3, which further classify the indicators according to the particular function that the different water technologies fulfill at the city level.

Figure 3. Classification of Smart water city technical pillar KPIs.



Urban water cycle

Urban water cycle category will examine how cities facilitate water data and information through precipitation, soil surface, infiltration, and river flow, and how the natural hydrological cycle is being preserved and maintained in spite of the persistent development of artificial construction due to urbanization. With fast-paced urban development, associated with smart cities, alterations might occur, resulting in a series of negative impacts to the hydrological environment, which can cause long-term and detrimental effects. It is important to conduct continuous and detailed monitoring of the urban water cycle parameters and to look out for sudden shifts in the hydrological processes. Such efforts can be made by the local government to preserve the naturalness of the urban water cycle.

The Urban water cycle category is divided into sub-categories, namely: Precipitation, Surface water, Urban water level and quality, and Groundwater level and quality. These classifications are arranged based on the different stages of water source and usage in the city hydrological cycle. The following discusses the importance of the assessment of each sub-category for smart water city:

- Precipitation, as the primary determinant of freshwater resource availability, flood prediction and drought mitigation, plays a key role in the smart water city evaluation. Indicators under this category assesses the city's performance in terms of rainfall monitoring distribution, frequency, data availability, rain gauge recording automation, instrument calibration, application of ICT-based instruments and public access to rainfall data.
- Surface water category pertains to the efforts conducted by the city to preserve the natural cycle of the urban hydrology, as well as ways in which the urban water bodies are used for additional purposes, including recreational and commercial designs. Indicators under this category include ground surface impermeability, natural conserved areas, waterfront usages and application of LID (low impact development), NBS (nature-based solutions) and green infrastructures.
- **Urban stream water level** category examines the city's capability to adequately monitor the urban water bodies' level (river, lake, sea, etc.), that directly affects the city's water resource, the sustainability of the aquatic ecosystem, as well as flood and drought monitoring and mitigation. These indicators include water level monitoring distribution, frequency, data availability, automation and calibration of stream gauge instruments, application of ICT in water level monitoring, as well as public access to water level data.
- **Urban stream water quality** indicators ensure the safety of public water supply and urban water ecosystem, enabling early responses to potential water-related health disasters and keeping track on long-term trends and environmental impacts. This assessment covers the stream water quality monitoring distribution, frequency, data availability, city stream water compliance standards, stream water quality instruments automation and calibration, application of ICTs in water quality monitoring, and public access to stream water quality data.
- **Groundwater level** category underpins the sustainable use of groundwater vital for freshwater resource, preventing over-extraction, mitigating water supply deficiencies and protect the health of the environment. Groundwater level monitoring distribution, frequency, data availability, automation and calibration of ground water level monitoring wells, application of ICTs in groundwater level observation, and access of public to groundwater level information.
- **Groundwater quality** indicators warrant the safety of groundwater for consumption, agriculture, and industrial use. Groundwater quality monitoring indicators include groundwater quality monitoring distribution, frequency, data availability, groundwater quality compliance, groundwater quality data automation and instrument calibration, application of ICTs in groundwater quality observation, and public access to groundwater quality data.

For this report, the Urban water cycle indicators assess the capability of the smart water city to (1) monitor the processes of water circulation within the city by constant observation of spatial and temporal characteristics of the hydro-meteorological and urban surface data; (2) guarantee the quality of observation data through high-frequency and monitoring, (3) ensure the accuracy of the observations through consistent data quality assurance, limiting missing and error data, and instrument calibrations; (4) implement development and infrastructure that assists the natural flow of the water circulation, [including, but not limited to, low impact developments (LID), green infrastructures (GI) and nature-based solutions (NBS)]; (5) secure the health of the urban water bodies and aquatic ecosystem; (6) apply modern technological developments in the collection, storage, and transmission of water cycle data; (7) implement real-time measurements, automations, and easy access to data; and (8) build infrastructures that enhance urban amenity water for ecological health and aesthetic purposes.

Water disaster management

Natural disasters occur in cities alike. However, the measures by which cities handle the impacts of water disasters and how they adapt to the anticipated effects make a city a disaster-resilient one. Enhancing water disaster resiliency allows for better preparation and planning, reduces potential losses, and works to implement a proactive approach rather than a reactive one. Difficulties can be encountered when building a progressive city that is at high risk of natural disasters, such as flooding and droughts. These events can result in damage to infrastructures, negatively impacting the economy and more often than not, resulting in the loss of lives. Addressing vulnerability through building and strengthening resilience is proven to be more cost effective compared to replenishing loss and sustenance. To start, it is important to assess the vulnerability a city has to disasters, and what kinds of disasters are experienced, based on climate conditions and geographical location. The measures set in place to minimize damage during such events shall be assessed as indicators for excellent capability of the city-scale water disaster management system.

- **Flood** indicators are crucial in smart water management systems due to their role in the prediction and mitigation of the effects of urban floods. These indicators assess the capability to the city to offer early warnings, enabling timely evacuation and emergency responses. These examine the city's capability for flood disaster management, through indices relating to number of flood-related casualties annually, flood-related damages to properties, flood prevention structures and the range of flood-prone areas. This category also assesses the technologies used by the city to perform flood hazard analysis, urban flood prediction and early warning.
- **Drought** plays an essential role in assessing and addressing water scarcity related to climate variability. The indicators under this category evaluate the vulnerability of the city to drought events through damage index and occurrence of drought events. Included in this category as well are the drought hazard mapping application, drought information availability, existence of emergency water supply facilities, and application of drought prediction system.
- **Climate change** information provides critical insights into the shifting patterns of precipitation, temperature and extreme weather events that can hugely affect the city's water resource and vulnerability to water-related disasters. This category assesses the initiatives the city takes for climate change actions and adaptation measures and decreasing energy usage through application of alterative renewable energy source.

As a whole, the Water disaster management indicators evaluate the city's (1) exposure and vulnerability to water-related disasters, specifically urban flooding and drought events; (2) capability to provide accurate weather-related predictions and adequate early warning to residents; (3) capability to identify and fortify urban risk areas; (4) utilize state-of-the art real-time measuring devices for monitoring and prevention; (5) application of ICT in flood and drought management; (6) capability to store excess water and provide alternative water supply sources in case of water deficit (7) develop city-scale action plans for climate change adaptation, and (8) efforts conducted to save and reduce municipal-level energy usage through application of renewable energy, usage of eco-friendly facilities, zero-emission devices, and more.

Water supply and treatment

Finally, Smart Water Cities must be evaluated based on their capability to provide sufficient, up-to-standard quality water to urban residents and their proper handling of sanitation and wastewater treatment at a municipal-scale level. Water supply is one of the most important key resources for sustainable urban development since water is indispensable in all human activities. It plays a crucial role in the functioning of urban ecosystems and in the environment. However, traditional sources of water supply, such as fresh water and rainwater, are not enough to sustain the needs of a city in operation. Non-revenue water caused by pipe leakages also contribute to huge volumes of water loss that can be optimized. Due to its limited capability, action must be taken to govern the supply and demand, as well as facilitate treatment, manage the reuse of water. To maintain the balance on city sustenance, modern technologies should be used.

- **Water source** serves as the foundation basis for the assessment, protection, and optimization of the usage of water source through continuous and start-of-the-art monitoring. This category examines the ability of the city to effectively monitor the city's primary water source through indicators related to monitoring frequency, water source reliability, automation and calibration of water source monitoring devices, application of ICTs in monitoring, and public access to water source data.
- **Drinking water treatment** ensures the safety and quality of drinking water to the public. This process needed to be continuously overseen to identify issues, enabling quick actions to ensure water quality standards and meet the public health requirements. This category examines the city's ability to govern the drinking water treatment facilities, which includes compliance to drinking water quality, drinking water quality instruments monitoring frequency, automation and calibration of water quality instruments, application of ICTs in water quality observations, public access to drinking water treatment data, and implementation of advanced drinking water treatment technologies.
- **Water distribution** evaluates the efficient and reliable supply of consumable water to the city household end users. Through the monitoring of the water supply networks, early detection of leaks, fluctuations on pipe pressure and water quality issues can be immediately addressed, preventing water supply interruptions. The indicators under water distribution category include the water supply network distribution, amount of deteriorated water supply pipelines, percentage of revenue water, water facilities effective storage capacity, water distribution instruments automation and calibration, pipe network maintenance, application of smart water meters, and public access to water supply distribution data.
- **Wastewater treatment** plays an important role in smart water assessment, ensuring the responsible management of urban water waste for the purpose of environmental and public health protection. The wastewater indicators include the distribution of sewage pipe networks, amount of deteriorated sewage pipelines, monitoring frequency of wastewater quality, automation

and calibration of sewage water monitoring instruments, city implementation of separated centralized storm and sewage water networks, application of sewage pipe maintenance system, and advanced sewage water treatment technologies.
- **Wastewater reuse** promotes sustainable water management through harnessing of wastewater products for various purposes. These indicators examine the amount of wastewater output being reused into the city, and the quantity of solid waste being recycled into agriculture, construction, etc.

To summarize, the indicators for water supply and treatment are used to evaluate the capability of the city to (1) monitor and maintain the quality standards for water supply and sewage water constantly; (2) provide an alternative source of water supply; (3) cater sufficient distribution of water supply and wastewater services to the urban population; (4) detect the status of deteriorating supply and sewage pipe networks, as well as provide adequate maintenance; (5) manage and operate city-scale water purification and wastewater treatment plants; (6) implement real-time water supply and quality monitoring or smart meter reading; (7) utilize ICTs in remote control and monitoring; (8) apply advanced water treatment technologies in the treatment facilities; (9) ensure quality of tap water; (10) maintain proper treatment regulations for sewage solid-waste discharges; and (11) efficiently reuse and monitor the quality of treated wastewater.

For each of the categories and subcategories, the Smart Water City Index has selected indicators that can be categorized into two types: Sustainability and Smartness, depending on the kind of technologies that they measure:
- **Sustainability** refers to the capability of the city to provide basic necessities for the sustainable management of the urban water system. As a technical aspect, sustainability provides a fundamental framework for preserving and improving the quality of life of citizens, and aids in the stability of the urban water system. This further emphasizes the enhancement in the soundness of the urban water environment, focusing not only on covering the present needs but also preparing for future problems. Sustainability indicators seek to measure the performance of these functional purposes at different stages of urban water management.
- **Smartness**, as a solution tool to resolve the urban water problems, defines the city's capacity to utilize a more sophisticated form of technologies in achieving and improving the sustainability of the urban water management system. Smartness indicators are comprised of advancements in the provision and operation of modern technology in terms of data, infrastructure, and services. Data indicators provide an evaluation for managing and securing the fundamental hydro-meteorological data for optimal urban smart water management, indicators under infrastructure assesses the ICT-based infrastructure solutions tools for urban water system functional awareness and solving urban water-related problems, while service indicators analyzes the capability of the smart city to provide decision support services and increasing the efficiency and competitiveness of water services in improving the quality of life of the citizens.

Together, the Technical pillar has 78 indicators, divided amongst the 3 categories and 14 subcategories; it includes indicators measuring both sustainability and smartness of technical solutions adopted by cities. The list of technical KPIs from each category is summarized in Table 2.

Table 2. Indicators of Technical pillar by categories and subcategory

Sub-category	Sustainability		Smartness	
Urban water cycle				
Precipitation	1.1a	Precipitation station coverage extent	1.1d	Precipitation data automation and instrument calibration
	1.1b	Precipitation monitoring frequency	1.1e	ICT-based precipitation data collection
	1.1c	Precipitation missing and error data	1.1f	Precipitation data accessibility
Surface water	1.2a	Impervious surface percentage	1.2d	LID and green infrastructures
	1.2b	Urban stream biodiversity		
	1.2c	Stream waterfront facilities		
Urban stream water level	1.3a	Stream water level station coverage extent	1.3d	Stream water level data automation and instrument calibration
	1.3b	Stream water level observation frequency	1.3e	ICT-based stream water level data collection
	1.3c	Stream water level missing and error data	1.3f	Stream water level data accessibility
Urban stream water quality	1.4a	Stream water quality station coverage extent	1.4e	Stream water quality data automation and instrument calibration
	1.4b	Stream water quality observation frequency	1.4f	ICT-based stream water quality data collection
	1.4c	Stream water quality missing and error data	1.4g	Stream water quality data accessibility
	1.4d	Stream water quality pollution level		
Groundwater level	1.5a	Groundwater level station coverage extent	1.5d	Groundwater level data automation and instrument calibration
	1.5b	Groundwater level observation frequency	1.5e	ICT-based groundwater level data collection
	1.5c	Groundwater level missing and error data	1.5f	Groundwater level data accessibility
Ground water quality	1.6a	Groundwater quality station coverage extent	1.6e	Groundwater quality data automation and instrument calibration
	1.6b	Groundwater quality observation frequency	1.6f	ICT-based groundwater quality data collection
	1.6c	Groundwater quality missing and error data	1.6g	Groundwater quality data accessibility
	1.6d	Groundwater quality pollution level		

Sub-category	Sustainability		Smartness	
Water disaster management				
Flood	2.1a	Flood casualty index	2.1e	Flood hazard map analysis
	2.1b	Flood property damage index	2.1f	Integrated disaster information system
	2.1c	Flood risk area index	2.1g	Urban flood prediction and early warning
	2.1d	Levee structure maintenance percentage		
Drought	2.2a	Drought damage index	2.2c	Drought hazard mapping
	2.2b	Recent drought occurrences	2.2d	Drought information and emergency water supply facilities
			2.2e	Drought prediction information
Climate change	2.3a	City-scale climate adaptation planning	2.3b	Renewable energy application

Sub-category	Sustainability		Smartness	
Water supply and treatment				
Water source	3.1a	Water source monitoring frequency	3.1c	Water source data automation and instrument calibration
	3.1b	Water source availability	3.1d	Water source data collection process
			3.1e	Water source data accessibility
Drinking water treatment	3.2a	Drinking water quality compliance	3.2c	Drinking water treatment data automation and instrument calibration
	3.2b	Drinking water quality monitoring frequency	3.2d	Drinking water treatment data collection process
			3.2e	Drinking water data accessibility
			3.2f	Advanced water treatment process
Water distribution	3.3a	Water supply network distribution	3.3e	Water distribution data automation and instrument calibration
	3.3b	Aging water supply pipelines	3.3f	Smart metering
	3.3c	Revenue water percentage	3.3g	Pipe maintenance system
	3.3d	Water storage capacity	3.3h	Water distribution data accessibility

Wastewater treatment	3.4a	Sewage network distribution	3.4d	Wastewater treatment data automation and instrument calibration
	3.4b	Aging sewage pipelines	3.4e	Separated sewage network system
	3.4c	Wastewater treatment monitoring frequency	3.4f	Sewage pipe maintenance system
			3.4g	Advanced wastewater treatment process
Wastewater reuse	3.5a	Reused and recycled wastewater	3.5b	Sewage solid waste recovery percentage

2. Governance Pillar

The second pillar of the Smart Water City Index refers to governance, a subject that has garnered significant scholarly and institutional attention over the past two decades. This attention derives from the realization that water-related crises frequently emanate not solely from resource scarcity, but from inadequate resource management.

While varying interpretations of water governance exist, the Smart Water Cities project defines it as "the political, social, economic and administrative systems that are in place to develop and manage water resources and deliver water services to different levels of the society" (Roger & Hall, 2003). This definition pays attention to the regulations and operational practices governing water management and puts the focus on the decision-making practices and the effective implementation of policies.

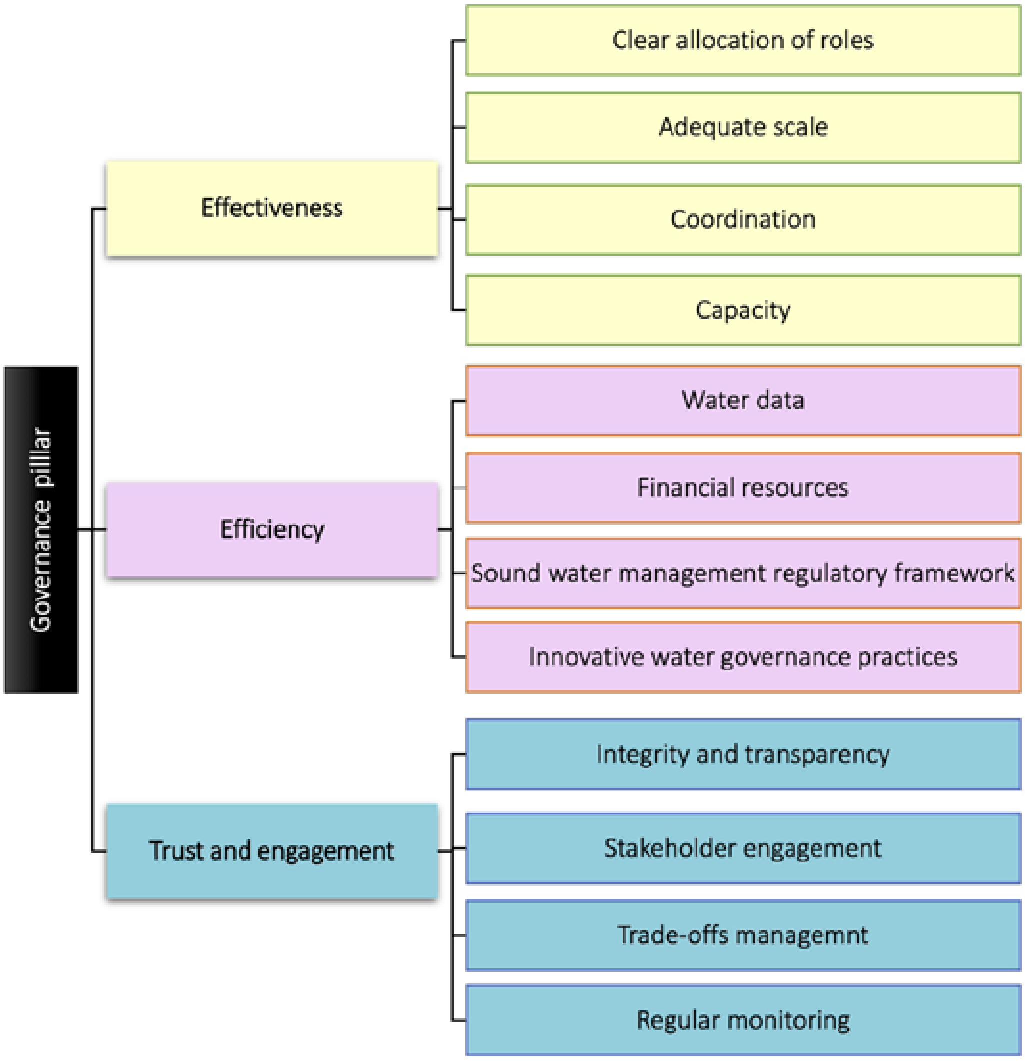
Within the urban milieu, water governance warrants specific analysis. Cities are progressively assuming influential roles in the governance of natural resources, and in doing so, they are developing their capacities to serve as intermediaries between overarching global trends, challenges, and localized idiosyncrasies. Cities can facilitate solutions tailored to their unique contexts (Raco, 2020). Consequently, assessing water governance at the local level needs an examination of cities' abilities and capacities to formulate, structure, and orchestrate urban water management. This analysis involves the examination of the role of local institutions, policy initiatives, and interactions with supralocal and national agencies dedicated to urban water concerns.

Selection and categorization of governance indicators

One of the most complete approaches to the topic of water governance has been offered by the OECD, with the adoption, in 2015, of the OECD Water governance principles. These principles, formulated collaboratively with various water stakeholders like governments, public and private providers, and civil society, encompass areas such as administrative capacity, funding, involving stakeholders, policy oversight, management scales, data, and information. Endorsed by 38 OECD member countries, 7 non-member countries and 140 stakeholder groups, the OECD principles acknowledge that governance is contextual and there is no one-size-fits-all solution. Thus, evaluating local water management must consider its distinctive attributes.

The Smart Water City project has drawn from the OECD's Water Governance principles and customized them to examine local water governance. Following the OECD structure, the Governance and Prospective pillar is categorized into three principal groups: Effectiveness, Efficiency, and Engagement and Trust. Each of these is further subdivided into four measurement areas that assess different facets of the primary categories (See Figure 4).

Figure 4. Categories and subcategories of the Governance and Prospective pillar



Effectiveness is concerned with the degree of attainment of policy objectives. Effectiveness indicators measure if policy goals and targets are well established, if policies are implemented in time, and if they meet their expected objectives. Effectiveness is closely linked to the organization of a policy. For this reason, the indicators in this category examine the distribution of the roles and responsibilities, as well as the use of policy instruments and the existence of appropriate financial and human capacities. In the Governance and Prospective pillar of the Smart Water City index, the focus is the authorities in charge of water resources management and water services provision at the local level.

The Effectiveness category breaks down into four subcategories: Clear allocation of roles, Adequate scale, Coordination, and Capacity. Looking at each of these, we specify what indicators will help to measure them

- **Clear allocation of roles** is concerned with the distribution and distinction of roles and responsibilities for water policymaking, policy implementation, operational management, and regulation. It examines whether there is a clear division of responsibilities and clear authority in charge.
- **Adequate scale.** This subcategory is concerned with the existence of integrated basin governance systems that take account of urban conditions. It examines the extent to which the city is involved with other authorities from different levels in the design and implementation of integrated river basin management policies, and to what degree the city level is taken into account in such policies.
- **Coordination.** The subcategory of coordination deals with the degree of policy coherence between different local cross-sectoral policies, including water and the environment, health, energy, agriculture, industry, spatial planning, and land use.
- **Capacity deals with** the local authorities' capacity to adjust to the complexity of water challenges to be met and the competencies required to carry out duties. The subcategory examines the existence and use of transparent and merit-based procedures for recruiting water professionals, the capacity to identifying capacity gaps in local government through mechanisms, and the adoption of educational and professional training programs for water professionals.

The second category is Efficiency. Efficiency relates to the contribution of local governance to maximizing the benefits of water management and welfare at the least cost to society. The Efficiency category examines whether the existing resources for water services provision and water resources management at the city level operate sustainably and productively. The category contains four subcategories focusing on the resources employed, including the water data, financial resources, regulatory frameworks, and innovative management practices that the city has set up and uses.

- **Water data** points at the production, updating, and sharing of timely, consistent, comparable and policy-relevant water and water-related data and information at the city level, as well as its use to guide, assess, and improve local water policy. The indicators examine the existence of such data, the existence and functioning of institutions responsible for producing and managing the data, and the mechanisms used to evaluate and improve the water data as necessary.
- **Financial resources** regards the governance arrangements that help raise local water resources and allocate them in an efficient, transparent, and timely manner. It ultimately seeks to evaluate the financial viability of the urban water sector. The subcategory examines whether the local level has the institutions necessary for collecting revenues to run the local water system, the powers, and responsibilities to do so, and the adequate mechanisms to assess short-, medium-, and long-term investment and operational needs.
- **Sound water management regulatory frameworks** regards the measures that ensure that sound local water management regulatory frameworks are effectively implemented and enforced in pursuit of the public interest. These could include, for instance, rules and regulations defining adequate water

service standards and pricing mechanisms, procedures for avoiding and dealing with the misuse of water resources, the means to address failures to pay service charges and bills, etc.
- **Innovative water governance practices** looks at the existing mechanisms to promote the adoption and implementation of innovative water governance at the local level. The three indicators to measure this subcategory consider whether the city has a supportive policy framework to incentive innovation in the management of local water policy, institutions dedicated to innovative initiatives, and mechanisms to incentive the use of innovative technologies, information sharing, co-design, etc.

Finally, the third category on Trust and engagement brings together indicators measuring the contribution of governance to the ethical functioning of the system, building public confidence, and ensuring inclusiveness of stakeholders. Together, they examine aspects related to both the democratic legitimacy and the fairness of urban water governance. The subcategories relate to the following aspects:
- **Integrity and transparency** examines the degree of integrity and transparency practices across water policies, water institutions and water governance frameworks for greater accountability and trust in decision-making. This subcategory measures whether there is a legal and institutional framework for integrity and transparency, if courts and audit institutions operate with independence, and if mechanisms exist to identify corruption risks.
- **Stakeholder engagement** concerns the promotion of stakeholders' engagement in local water policy design and implementation. It examines whether stakeholders are formally invited and represented to participate in decision making, what organization looks after the protection of stakeholders' participation, and whether instruments exist to identify and review stakeholders' engagement, making necessary adjustment if unsatisfactory.
- **Trade-offs management** regards the existence of water governance frameworks that help manage trade-offs across water users and the needs of present and future generations at the local level. It examines to what degree is water allocated when there are different economic water uses and environmental water flows requirements, and how are the interests of all people protected, particularly vulnerable groups (economic migrants, refugees, and the homeless
- **Regular monitoring** deals with the monitoring and evaluation of local water policy and governance. It examines to what extent the city has put in place regulatory frameworks, agencies, and mechanisms to monitor, report, and evaluate progress on water policies and practices. Review and feedback provided on the functioning of the water service management and policies for water services provision is considered one of the central elements of water governance in Smart Water Cities.

These 12 subcategories are then broken down into three indicators, responding to the questions of "what," "who," and "how":
- **The "what"** indicator concentrates on the specific actions necessary for the successful implementation of the principle. It identifies essential components and requirements for effective execution, highlighting any potential implementation hurdles.

- **The "who"** indicator pinpoints the pertinent stakeholders and institutions responsible for executing actions related to each subdivision. It clarifies the existence of dedicated agencies or departments within the city.
- Lastly, **the "how"** indicator delineates the methodologies, approaches, and strategies for putting the principle into practice. This encompasses processes, tools, and techniques necessary for achieving desired outcomes and integrating the principle effectively into water governance protocols.

As a result, the Smart Water City's Governance and Prospective pillar encompasses a total of 36 indicators: 12 for Effectiveness, 12 for Efficiency, and 12 for Trust and Stakeholder Engagement. Together, these indicators yield a more granular comprehension of each principle and guide the assessment of their application. Breaking down the principles into these three indicators streamlines assessment, facilitates progress monitoring, identifies gaps, and informs decision-making for sustainable and efficient water governance. This framework offers an essential foundation for evaluating and comparing water governance on a municipal scale, furnishing crucial insights for decision-making and policy enhancement. The breakdown of the 36 KPIs of the Governance and Prospective pillar is presented in Table 3.

Table 3. Indicators of Governance and Prospective pillar by categories and subcategory

Category	Subcategory	KPI	
Effectiveness	Allocation of roles	1.1a	Local regulatory powers for smart water services provision and water resources management
		1.2b	Department at the local level with core water-related responsibilities for water policy making
		1.1c	Mechanisms to review roles and responsibilities, to diagnose gaps and adjust when need be
	Adequate Scale	1.2a	integrated water resources management policies and strategies that include the urban level and cities' features and water status
		1.2b	Institutions managing urban water (not necessarily exclusively) at the hydrographic scale
		1.2c	Co-operation mechanisms for the management of water resources across water-related users and levels of government, including the local level.
	Coordination	1.3a	Cross-sectoral local policies and strategies promoting policy coherence between water and key related areas
		1.3b	Inter-departmental body or institutions at the local level for horizontal co-ordination across water-related policies
		1.3c	Mechanisms to review barriers to policy coherence and/or areas where water and related local practices, policies or regulations are misaligned.
	Capacity	1.4a	Hiring policies based on a merit-based and transparent professional and recruitment process of water professionals independent from political cycles
		1.4b	Mechanisms to identify and address capacity gaps in local water institutions
		1.4c	Educational and training programs for local water professionals

Category	Subcategory	KPI	
Efficiency	Water data	2.1a	Updated, timely shared, consistent and comparable water information systems at the local level.
		2.1b	Public institutions, organizations, or agencies in charge of producing, coordinating and disclosing standardized, harmonized and official local water-related statistics.
		2.1c	Mechanisms to identify and review local water data gaps, overlaps and unnecessary overload.
	Financial resources	2.2a	Governance arrangements that help local water institutions collect the necessary revenues to meet their mandates and drive water-sustainable and efficient behaviors
		2.2b	Dedicated institution in charge of collecting water revenues and allocating them to the right level
		2.2c	Mechanisms to assess short -, medium- and long-term investment and operational needs and ensure the availability and sustainability of such finance
	Sound water management regulatory frameworks	2.3a	Sound water management regulatory framework to foster enforcement and compliance, achieve regulatory objectives in a cost-effective way, and protect the public interest
		2.3b	Dedicated public institutions responsible for ensuring key regulatory functions for water services and resources management at the city level
		2.3c	Regulatory tools to foster the quality of regulatory processes for water management at city level
	Innovative water governance practices	2.4a	Policy frameworks and incentives fostering innovation in water management practices and processes at the local level
		2.4b	Institutions encouraging bottom-up initiatives, dialogue and social learning as well as experimentation in water management at the local level
		2.4c	Knowledge and experience-sharing mechanisms to bridge the divide between science, policy and practice at the local level

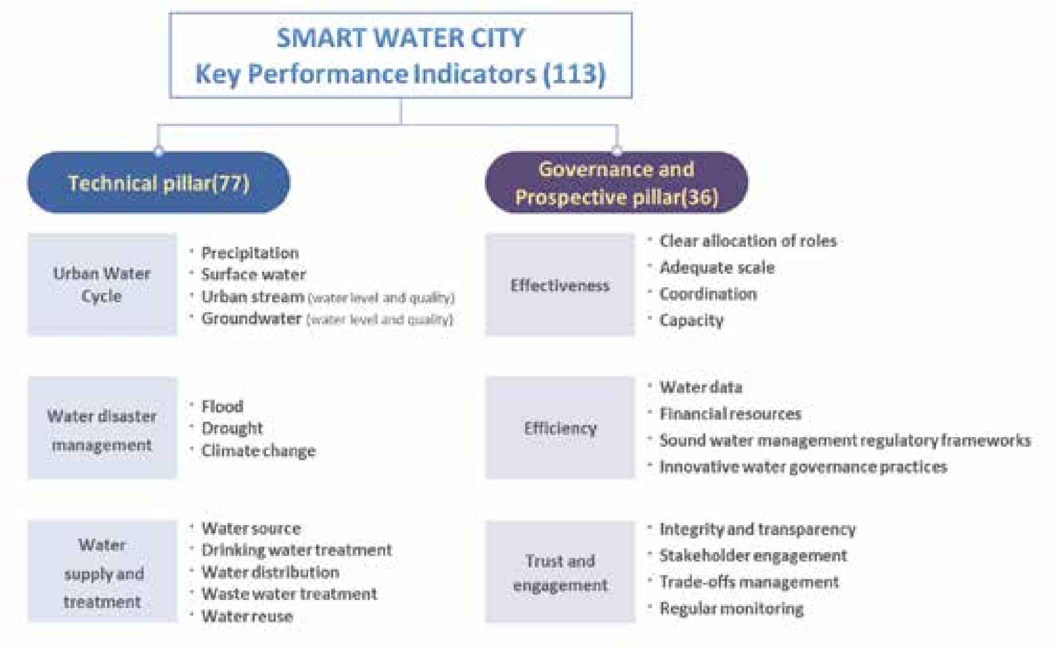
Category	Subcategory	KPI	
Trust and stakeholder engagement	Integrity and transparency	3.1a	Legal and institutional frameworks (not necessarily water-specific) on integrity and transparency
		3.1b	Independent courts (not necessarily water-specific) and supreme audit institutions that can investigate water-related infringements and safeguard the public interest
		3.1c	Mechanisms (not necessarily water-specific) to identify potential drivers of corruption and risks in all water-related institutions at different levels, as well as other water integrity and transparency gaps
	Stakeholder engagement	3.2a	Legal frameworks to engage stakeholders in the design and implementation of local water-related decisions, policies and projects
		3.2b	Organizational structures and responsible authorities to engage stakeholders in local water-related policies and decisions
		3.2c	Mechanisms to diagnose and review stakeholder engagement challenges, processes, and outcomes
	Trade-offs management	3.3a	Formal provisions or legal frameworks fostering equity across water users and generations at the local level
		3.3b	Ombudsman or institution(s) to protect water users, including vulnerable groups
		3;3c	Mechanisms to manage trade-offs across users, and/or over time in a non-discriminatory, transparent and evidence-based manner at the local level
	Regular monitoring:	3.4a	Policy frameworks promoting regular monitoring and evaluation of water policy and governance
		3.4b	Institutions in charge of monitoring and evaluation of water policies and practices and help adjust where need be
		3.4c	Monitoring and evaluation mechanisms to measure to what extent water policy fulfils the intended outcomes and water governance frameworks are fit-for-purpose

3. Smart Water City Rating System

Together, the Smart Water City Index, combines a total of 113 KPIs, represented in Figure 5.

Once the KPIs have been established, the Smart Water City project has developed an approach to rate urban water system: a scoring mechanism to evaluate a city's performance, as measured by the Smart Water Index. By assigning scores based on cities' performance, the rating system offers a structured and objective means of benchmarking and comparing urban water management practices, which indicates to what extent the existing urban water management enhances sustainability and quality of life (Oberascher, Rauch, & Sitzenfrei, 2022).

Figure 5. Pillars and categories of the Smart Water City Index



The adopted scoring system operates on a scale from 0 to 4 for all indicators in both the Technical and Governance and Prospective pillars. This scale represents a spectrum from poor to excellent performance. A score of 4 indicates outstanding performance, 3 denotes good performance, 2 signifies moderate performance, 1 represents poor performance, and 0 reflects inadequate performance. In cases where a specific indicator is irrelevant to a given city (e.g., data collection involving a city river or stream in areas not part of a watershed with an active river or stream), it is designated as 'Not applicable' (See Table 4). This scoring system allows for a more nuanced evaluation compared to a binary response, while still being straightforward. More details of the scoring system of the technical and the governance pillars follow.

Table 4. Scoring the Smart Water Cities indicators

n/a	0	1	2	3	4
Not Applicable	Bad	Poor	Moderate	Good	Excellent

Assessing and rating water management requires an in-depth understanding of local systems and their implementation. The complexity of water management necessitates inputs from various urban water sector stakeholders and diverse sets of evidence to accurately score each KPI. A central challenge when evaluating urban water management lies in the need for comprehensive comprehension of the local water system and its functioning. For the technical pillar, this involves expertise from various city departments and access to different data sources. For the governance pillar, the categories encompass a broad spectrum of concepts and scenarios that demand not only expertise in local water regulation but also firsthand experience of implementation. This ensures that the evaluation genuinely mirrors the existing reality of water management in the city.

Scoring in the Technical pillar

Following the general approach to the Smart Water Cities rating system, each of the technical KPIs needs to be scored. Various strategies can be adopted to determine the values for each indicator (Ranta, et al., 2021):

1. Ratio calculations: Indicators are assessed as a ratio calculation of a certain established reference value. Depending on the attainment of the reference value by the city, a score of 1 to 4 is given.
2.. Reference ranges: Indicators are assessed based on a specific range from an established reference (journal articles, technical reports, website data, established guidelines, etc.). The reference ranges also provide information on the values to each indicator.
3.. Presence or absence of standards: Indicators are assessed as present (full score) or absent (zero score) of a certain standard. In these cases, evidence of existence shall be required (documentations, reports, photo, etc.)
4.. Survey questionnaires: indicators are assessed as a survey questionnaire confirming the present establishment of certain standards.
5.. Comparisons with other cities: indicators are assessed as a comparison with the average performance of cities/mega cities from progressive countries.
6.. Expert opinions: certain criteria without established standards from literature shall be evaluated based on experts' opinion.

Once each indicator is examined and rated from 1 to 4, a total score of the Technical pillar needs to be calculated. For this, we have established that the maximum score that a city can obtain in the technical pillar equals 100 points. That number results when the city gains 4 points for its performance in every single technical indicator. This score includes the application of a weight correction to the indicators, which has been established according to two criteria:

- . (a) the **category of the indicator** within the pillar. The applicable weight has been set for 0.4 for indicators in the Urban water cycle category, 0.2 for indicators in the Water disaster management category, and 0.4 for indicators in the Water supply and treatment category.
- . (b) the **type of technologies that the indicator measures**. A different weighing value is given to indicators that examine conventional technologies (Sustainability) and those that look at ICTs (Smartness). The values assigned are 0.4 and 0.6, respectively. This different weight reflects that the emphasis is put in the utilization of modern technologies for maintaining and improving the urban water system over covering basic necessities implemented for the urban water regulation.

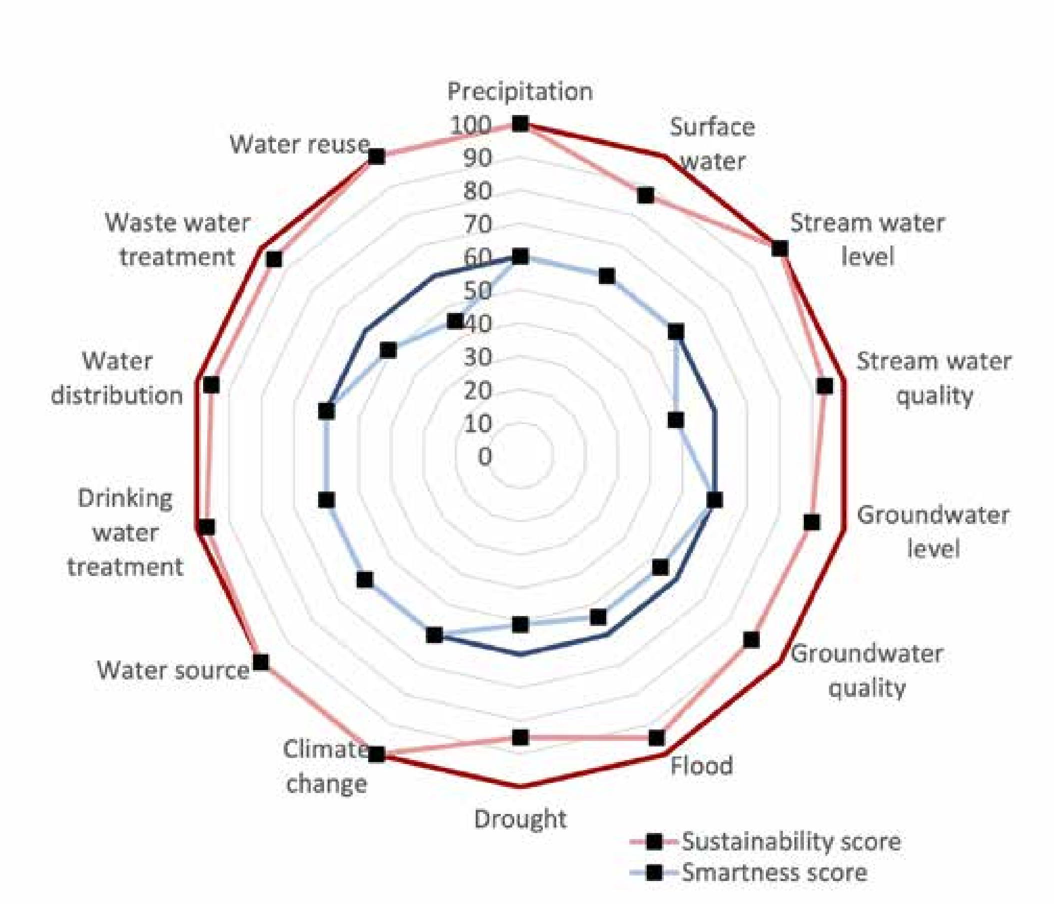
The summarized weighing values for each technical pillar sub-categories are shown in Table 5.

Finally, with the final scores a radar graph represents the technical scores of the applicant city, per subcategory. An ideal Smart Water City must have a balanced and satisfactory evaluation score to be awarded certification. Figure 6 presents the results of a fictional city, for both the sustainability score and the smartness score

Table 5. Combined weighing values of each sub-category in Technical Pillar

Category	Sub-category	Sustainability	Smartness
Urban water cycle	Precipitation	4.8	7.2
	Surface water	1.6	2.4
	Urban stream water level	2.4	3.6
	Urban stream water quality	2.4	3.6
	Groundwater level	2.4	3.6
	Groundwater quality	2.4	3.6
Water disaster management	Flood	4.0	6.0
	Drought	2.4	3.6
	Climate change	1.6	2.4
Water supply and treatment	Water source	3.2	4.8
	Drinking water treatment	4.0	6.0
	Water distribution	3.2	4.8
	Wastewater treatment	4.0	6.0
	Wastewater reuse	1.6	2.4
Total by type of indicator		**40**	**60**
Total		**100.00**	

Figure 6. Example of Representation of over-all technical pillar scores based on sub-categories



More information for data collection is available in Chapter 8 which provides more details about required information and assessment strategies for each indicator, along with corresponding performance scores.

Scoring in the Governance and Prospective pillar

As for the scores for the Governance Pillar, these are established according to the information given by local experts and professionals via a questionnaire and interviews referring to the city's performance. This information needs to be verified and contrasted with reference to existing evidence: legislation, adopted policies, and other existing sources.

The information gathered seeks to assess whether governance measures, as described by the indicators, have been, first, formally adopted and, secondly, fully implemented by the city. The distinction between formal adoption and actual implementation is a distinguishing feature of the Smart Water City Index. By doing so, the evaluation accounts not only for the presence or absence of a particular standard but also offers a flexible scale to accurately reflect the specific context under review. The highest value on the scale (4, or excellent) is awarded when a measure is both formally adopted and fully implemented. This evaluates both the introduction of a water governance provision by the water authority and the extent of its practical application. Conversely, the lowest value (0, or bad) is assigned when a governance measure is absent, signifying no adoption or development. This nuanced approach within the Likert scale allows differentiation between non-adoption and ongoing development of measures, highlighting the procedural aspects from initial inclusion in local agendas to eventual full implementation (See Table 6).

Table 6. Likert values for the Governance and Prospective pillar indicators

Values	Score
In place, fully operational. When a measure, as defined in the indicator, is both adopted and fully implemented by the city, the value of the indicator is the highest	4
In place, partly operational. The measure is adopted, but it is only partially implemented	3
In place, but not operational. The decision to adopt a particular measure is taken, but the implementation is inexistent	2
Under development. Only preliminary measures have been adopted (the topic is on the agenda)	1
Not in place. No points are given when a measure is neither adopted nor under development	0
Not applicable. The indicator is not considered.	N/A

As with the Technical pillar, the total Governance and Prospective pillar score needs to be calculated once the performance of the cities has been examined according to the Governance and Prospective pillar indicators. For this, the Governance and Prospective pillar score will be a number between 0 and 100, resulting from adding the values for all 36 indicators of the pillar. To calculate this number, we need to transform its Likert values of the pillar indicators into individual scores: 4 points in the Likert scale (the highest Likert value a city can get in an individual variable) equals 100 points; 3 points equals 75; 2 points equals 50; 1 equals 25; and finally, 0 points in the Likert scale equals 0 points. The sum of these values, divided by 36, gives a number between 0 and 100 which corresponds to the score that the city receives in this pillar. In the Governance and Prospective pillar, all indicators have equal weights; thus, all variables measured in the pillar have the same importance. Table 7 presents the scores by subcategory, which represents 1/12 of the total city score.

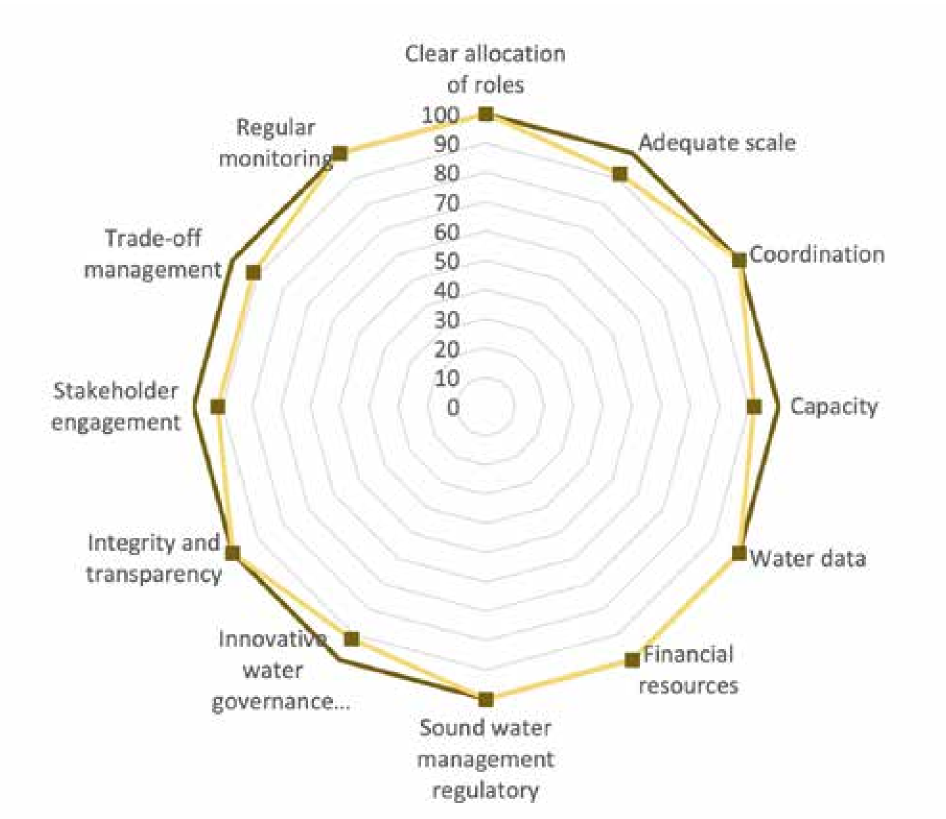
Table 7. Combined weighing values for Governance Pillar

Category	Sub-category	City score
Effectiveness	Clear allocation of roles	100
	Adequate scale	100
	Coordination	100
	Capacity	100
Efficiency	Water data	100
	Financial resources	100
	Sound water management regulatory	100
	Innovative water governance practices	100
Trust and engagement	Integrity and transparency	100
	Stakeholder engagement	100
	Trade-off management	100
	Regular monitoring	100
Total:		**100.00**

Chapter 7 provides more information on the guidelines for the experts' evaluation.

As with the previous pillar, the scores of the Governance and Prospective pillar are presented in a radar figure. Figure 7 illustrate the values corresponding to the 12 subcategories in a fictional city. Each subcategory groups together the values of their three indicators.

Figure 7. Representation of governance and technical sub-categories



Calculating the Total score for a Smart Water City Certification

After a comprehensive evaluation of a city's performance using the Technical and Governance and Prospective pillars, the Smart Water City Index calculates the overall score. Both pillars carry equal weight, contributing 50% each to the final score. The combined total score is determined by adding the Technical Pillar Score and Governance and Prospective Pillar Score, then dividing by two:

Combined total score= Technical pillar score + Governance and Prospective pillar score / 2

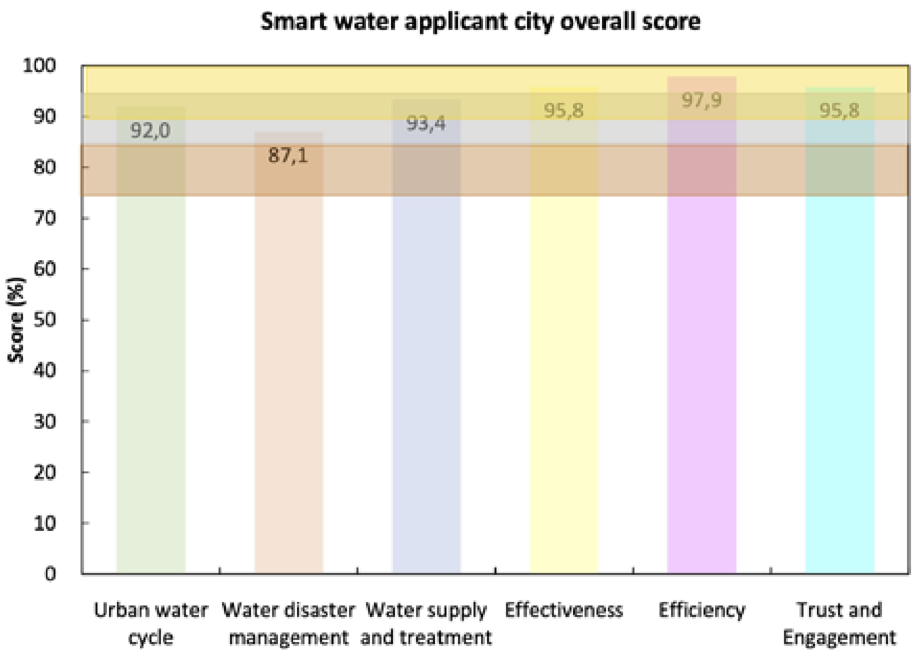
This computation results in a final score on a scale of 0 to 100. A higher score signifies the city's adept management of water resources and services, reflecting a more effective technical and governance approach to address urban needs. For a deeper understanding, a detailed breakdown into pillars and categories provides a more granular perspective.

The Smart Water Cities project proposes a Certification for cities. According to the initial scoring system proposal, cities would be awarded when they score over 75 combined points, with different grades for various score ranges:

- Bronze: 75 to 85 combined points
- Silver: 85 to 95 combined points
- Gold: 95 to 100 combined points

Figure 8 provides an illustrative example, displaying scores across six subcategories for a fictional city. The depicted overall score of 93.7 would, in this case, qualify the city for a gold certification. It's important to note that this represents an initial approach to certification and scoring, and further refinement is necessary to finalize and enhance this methodology.

Figure 8. Example of overall score of an applicant city



Technical score:	91.0
Governance and Prospective Score:	96.5
City overall score:	93.7

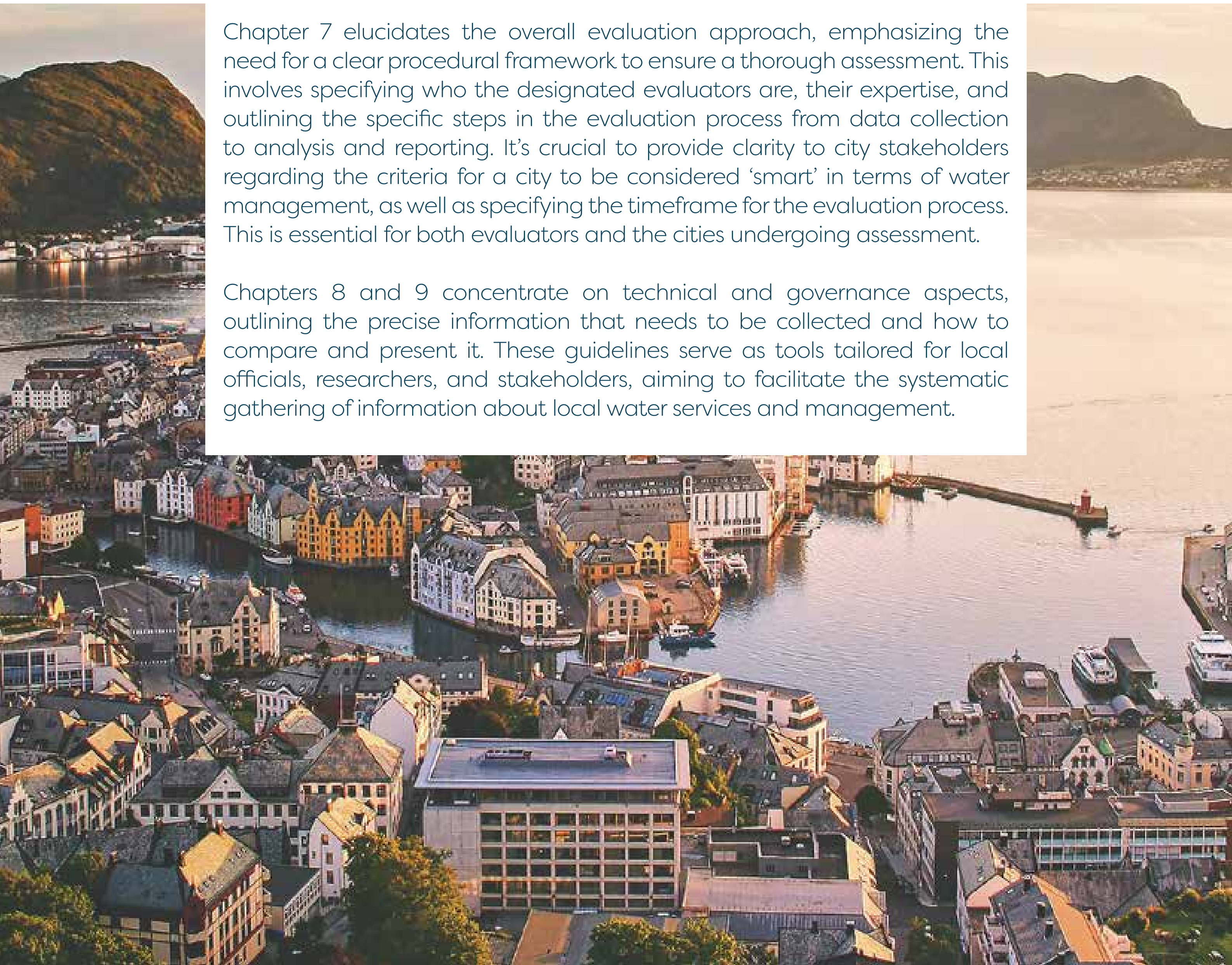
PART 3

Evaluation Guidelines

Part III of this report outlines the steps for evaluating Smart Water Cities. After establishing Key Performance Indicators (KPIs) and defining city scores, it's important to establish a procedure for conducting city evaluations. Chapters 7, 8, and 9 cover various aspects of this process.

Chapter 7 elucidates the overall evaluation approach, emphasizing the need for a clear procedural framework to ensure a thorough assessment. This involves specifying who the designated evaluators are, their expertise, and outlining the specific steps in the evaluation process from data collection to analysis and reporting. It's crucial to provide clarity to city stakeholders regarding the criteria for a city to be considered 'smart' in terms of water management, as well as specifying the timeframe for the evaluation process. This is essential for both evaluators and the cities undergoing assessment.

Chapters 8 and 9 concentrate on technical and governance aspects, outlining the precise information that needs to be collected and how to compare and present it. These guidelines serve as tools tailored for local officials, researchers, and stakeholders, aiming to facilitate the systematic gathering of information about local water services and management.



CHAPTER 7
METHODOLOGY FOR EVALUATING SMART WATER CITIES

This chapter provides an overview of the methodology for evaluating cities' water systems. It begins by clarifying the purpose, objectives, and guiding principles of the evaluation process. Following this, it addresses the pivotal stakeholders and organizations involved in this effort. Additionally, the chapter explores the assessment process, highlighting its phases, key characteristics, and the essential requirements for its successful execution.

1. Principles of the Smart Water City evaluation

Establishing the main principles guiding the Smart Water City evaluation is crucial for providing the framework of the evaluation and to establish clear expectations on the process and the expected outcomes for both participant cities and any future prospective candidate cities. The Smart water city evaluation is guided by the following main principles:

Integrity: the evaluation is carried out with integrity, that is, with honesty and respect to all participant organizations and stakeholders.
Objectivity: the evaluation is undertaken in a rigorous, pertinent manner, without bias, according to the information and data gathered
Competence/skill. The evaluation is an exercise carried out by competent, skilled, and conscientious professionals, capable of undertaking all responsibilities associated with the analysis.
Independence. The evaluation is undertaken by independent professionals that have no conflict of interests limiting their objective and professional practice and judgement.
Confidentiality. The evaluation is carried out in a confidential manner. The evaluation team are committed to not to disseminate information about the cities, the organizations, or the staff all rapports and diagnostic resulting from the evaluation cannot be shared with third parties without explicit consent from the city authorities. The pilot cities were offered full confidentiality; results would be presented to the city representatives, but not made public without the explicit consent from the cities' authorities.
Collaboration. The city authorities and the evaluation team must be able to collaborate with adequate time and resources.
Transparency. The evaluation is undertaken with transparency. The evaluators communicate all their activities and tasks with the cities and participant organizations, and cities assure co-operation and access to all relevant information in the city with the evaluators.

Actionable recommendations. The evaluation is to provide actionable and realistic recommendations that can help the city improve its performance and achieve its goals.

2. Collaborating Organizations

The evaluation process of cities involves a team of water experts from IWRA and K-water. They are responsible for scrutinizing urban water management structures, data, and information systems in the selected cities. With active participation and contributions from local water stakeholders, the evaluation team assesses the cities' water sector performance using a comprehensive set of indicators from the Index. This provides an overview of the cities' strengths and weaknesses in urban water resources management and water service provision.

The Smart Water Cities evaluation procedure engages the following organizations and bodies:

Applicant Organization: This is the entity that has submitted its candidacy for the city's water system evaluation. In cases where a consortium of local organizations is involved, the applicant organization serves as the primary point of contact.
Data Analysis Team: This group comprises technical experts tasked with reviewing and evaluating the data and information supplied by the city. They possess in-depth knowledge and expertise regarding the city, including its challenges and characteristics.
Expert Panel: This panel consists of professionals who provide support to the Data Analysis Team on various aspects, throughout the pilot evaluation. This may include potential adjustments and modifications of the index and process, communication and outreach activities, and the dissemination and promotion of the Smart Water City index, among others.

3. Phases of the pilot city evaluation

The Smart Water City evaluation unfolds in three distinct phases, each with its defined objectives and tasks (See Figure 9):

1. Preparatory Phase:

- City authorities and the Data analysis team establish initial contact, sharing information on city characteristics and challenges.
- Goals and objectives are set, and the evaluation methodology is explained.
- Memorandum of Agreement is signed to formalize the Smart Water City evaluation.

2. Analysis Phase:

- Self-Evaluation Stage:
- Local authorities conduct a self-assessment using a questionnaire, reflecting on their actions, policies, and outcomes.
- Assessment is led by local policymakers, civil service personnel, or local water professionals.
- Verification Stage with Data Analysis Team:
- Team reviews self-evaluation reports, comparing them with available data and evidence.

- Comprehensive analysis of water governance system performance, including on-site visits to address data gaps or unreliable information.
- The dual-stage approach enhances the evaluation's comprehensiveness and reliability.

3. Conclusion Phase:

- Results of the analysis are presented in a city consultation organized for the evaluation team.
- City authorities can provide additional information or challenge conclusions.
- After considering any new input, the evaluation report is finalized and sent to the applicant organization.

This structured approach ensures a thorough and reliable assessment, combining internal insights with external analysis for a comprehensive Smart Water City evaluation.

Figure 9. Phases of the Pilot city evaluation

4. The City evaluation report

The main output of the pilot city evaluation is the city evaluation report. This report summarizes the findings, results, and assessment of the pilot city. It is structured in three main parts:

- A preliminary part of the report provides the background information about the pilot city, including the contextual indicators of the city, its general characteristics, and the institutional mapping of the responsible authorities and the key stakeholders involved.
- The central part of the report presents the results of the city's evaluation, including both quantitative and qualitative data, according to the KPIs in both the technical and governance pillars. This part of the city's report provides a discussion of the results, including any challenges or limitations encountered during the pilot project, as well as any lessons learned, or best practices identified.
- Finally, the report also includes specific, actionable, and feasible recommendations to improve the city's performance that take into account the city's resources and capabilities. The evaluation report also proposes a plan to monitor and evaluate the progress of the city's performance over time.

CHAPTER 8
TECHNICAL PILLAR

This chapter discusses the methodology of the assessment of urban water management technologies under the technical pillar. The discussion highlights the developed guidelines for the evaluation of technical indicators. This pillar covers three major categories: Urban water cycle, water disaster management, and water supply and treatment, and has 14 subcategories and a total of 78 key performance indicators.

1. Technical pillar Evaluation guidelines
The following provides details of the technical indicators, data needed for the assessment, computation method and evaluation. Please follow the following guidelines in providing the assessment for each indicator:

1. Data collection. Collect the necessary data from the corresponding water government agencies. For quantitative data assessment, information such as excel files, documents, GIS shapefiles, website screenshots are collected. For qualitative assessment, technical reports, photo evidence, screenshots are stored. These collected data are saved to their corresponding folders.

For certain indicators where data are not available, please tag as "Not available" and detail the reason in the Comment column.

2. Data source. Include the reference source of the data in the evaluation form. For internal provision, write the name of the providing agency. For web sources, write the website name and corresponding location.
3. Computation method. Given the data, calculate the indicator value based on the corresponding computation method. Be mindful of the units of the parameters so that the correct results are calculated.
4. Evaluation. Select the corresponding score based on the value computed. The score values range from 0 as the lowest score and 4 as the highest score.

n/a	0	1	2	3	4
Not Applicable	Bad	Poor	Moderate	Good	Excellent

5. Supporting evidence. For qualitative analysis that does not have computational methods, supporting evidence is required.

2. Technical pillar KPIs
The following contains detailed guidelines for the evaluation of each indicator in urban water cycle, water disaster management and water supply and treatment.

Urban Water Cycle

Precipitation

Indicator 1.1a	Coverage extent of precipitation observation stations
Definition	Total coverage extent (area per station) of precipitation monitoring stations within the city (Sustainability)
Function	
Precipitation greatly affects the social and economic activities within the city; ranging from traffic occurrences to potential long-term ecological problems characterized by over and under-supply of rainfall and/or snow. Weather stations built within the city measure the parameters of atmospheric conditions, such as rainfall, that are used to provide information for urban weather forecasts and analysis. Reliable observations are necessary to understand and evaluate the past and present weather conditions of the area.	
Data type	Number of rainfall observation stations/rain gauge instruments within the city (table, excel file, GIS data); city total surface area (km2) (Quantitative analysis)
Calculation Method	
The spatial distribution of short-term precipitation is the main input for estimating runoff. Observation network must be composed of a certain number of stations, which was collectively agreed upon by meteorological agencies, indicating the necessity to initiate monitoring and planning for the development of the water resources. The calculation of the coverage density of precipitation stations within the city is as follows: Precipitation station area density (km2/station) = Total urban area (km2) / Number of precipitation stations within the city The WMO (2020) recommended densities of hydro-meteorological stations based on topographical characteristics are as follows: Topographical characteristics Precipitation monitoring station coverage (km2/station) Non-recording* Recording** Urban area - 10-20 *Precipitation gauges that only show the amount of rainfall per event, manned **Precipitation gauges that automatically record the amount of rainfall collected as a function of time, can be unmanned. Higher rainfall observation station density corresponds to a more favorable smart water indicator.	
References	World Meteorological Organization (2020). Guide to Hydrological Practices, Volume 1. WMO-No. 168, Switzerland.
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Value (km2/station) Description Score 4 <5 Operation of at least one rain gauge per 5 km2 3 5 - 10 Operation within 5 – 10 km2 2 10 – 20 Operation within 10 – 20 km2 1 > 20 Rain gauge coverage is more than 20 km2 0 No data City has no data on rainfall station coverage density, or no rainfall measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.1b	Precipitation monitoring frequency
Definition	Monitoring and recording frequency of rain gauges/ precipitation stations within the city (Sustainability)
Function	
The information on the temporal distribution of rainfall is equally important in assessing the effect of short-term rainfall intensity within the city. The small-scale characteristic processes, such as storm drainage, infiltration, etc. can vary greatly, from seconds to hours, and from centimeters to hundreds of meters.	
Data type	Precipitation station rainfall data timeseries (excel, txt file) (Quantitative Analysis)
Calculation Method	
Based on the hydrological processes critical for the analysis of urban water dynamics, the temporal variability based on the urban dynamics is shown in Table (Cristiano et al., 2017). Table. Rainfall monitoring frequency of observation stations based on urban hydrologic process. Urban dynamics Time scale (seconds) Sewers and leakages 500-50,000 Urban drainage 100-1000 Sewers and storm drains 10-800 Channel flows 20-500 These research results shall be the basis for the evaluation for this indicator.	
References	Cristiano, E., Velfhuis, M. and van de Giesen, N. (2017). Spatial and temporal variability of rainfall and their effects on hydrological response in urban areas-a review. Hydrol Earth Syst Sci. 3859-3878.
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Value Description Score 4 1 min Precipitation is recorded at 1-minute interval 3 10 min Recorded at least 10-minute interval 2 30 min Recorded at least 30 min interval 1 ≥ hourly Recorded at hourly or more than hourly interval 0 No data City has no data on rainfall monitoring frequency, or no rainfall measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.1c	Precipitation error and missing data
Definition	Number of missing and error rainfall data compared to the overall observation data (Sustainability)
Function	
Missing observation data imposes various problems for the rainfall analysis, particularly causing biases in the estimation of the parameters critical for evaluating urban processes. Harnessing these data effectively is essential in the context of alleviating risk from flood and other hazards. However, accurate estimation of daily precipitation data remains a difficult task, due to a wide variety of causes for missing data, such as malfunctioning or deteriorating instrument, human-related incorrect data readings due to manual data collection, relocation of stations, and more. Observed rainfall records are often subject to errors, which may affect the analysis if not corrected or removed. The accuracy of the urban rainfall observations is highly dependent on the density and distribution of rain gauge stations over the city.	
Data type	Precipitation station rainfall data timeseries (excel, txt file) (Quantitative Analysis)
Calculation Method	
Ocampo-Marulanda et al., (2021) states that, to limit the effect of missing data in the estimation of parameters, such as climate indices, a minimum value of 0.5-5.4% missing data must be implemented. The percentage of missing data for precipitation can be calculated as: Percentage of missing data (precipitation) (%) = (Number of missing values / Total number of precipitation observations) * 100 The fulfillment of the appropriate percentage of missing data would be the basis for the scoring for this indicator.	
References	Ocampo-Marulanda, C., Ceron, W., Avila-Diaz, A., Canchala, T., Alfonso-Morales, W., Kayano, M. and Torres, R. (2021). Missing data estimation in extreme rainfall indices for the Metropolitan area of Cali-Colombia: An approach based on artificial neural networks. Data in Brief. 107592
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description Score 4 < 6 Percentage of missing and error precipitation data is less than 6 % 3 6 – 10 Percentage is within 6 to 10 % 2 10 – 20 Percentage is within 10 to 20 % 1 > 20 Percentage is more than 20 % 0 No data City has no information on rainfall observation error and missing data, or no rainfall measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.1d	Precipitation measurement method and quality assurance
Definition	Quantity of observed precipitation data that is recorded electronically and precipitation observation instruments calibration status (Smartness) (Data)
Function	
The digitalization of rainfall data preserves the historical observations and provides an understanding on the evaluation of climate variability, climate extremes and designing climate adaptation strategies. Automation of precipitation data also improved access to observation records, the network becomes more available to traditional users and the public. Presently, monitoring networks transmits real-time precipitation measurements to the main data center through the use of wireless communication protocols, limiting the window of errors during transfer. These kinds of connections operate with efficient radio communications through the optimization of packet forwarding transmission speed and consumption power of the connected devices. The evaluation for this indicator shall be scored whether the precipitation data are recorded fully or partially automated, in real-time, and whether instrument calibrations are performed in the instruments.	
Data type	Status of automation of rainfall recording instruments, and the application of quality assurance and instrument calibrations (Qualitative analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in precipitation monitoring: Rainfall observation method and quality assurance Real-time and automated recording of rainfall Existence of auto-calibration function within the rainfall instrument or system Regular calibration of the rainfall instrument Recorded rainfall data quality assurance	
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 The city implements the automation and quality assurance methods criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the automation and calibration of precipitation monitoring instruments n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.1e	ICT-based precipitation data collection process
Definition	Process of precipitation data collection using radar, satellite, and other ICT-based technologies (Smartness) (Infrastructure)
Function	
Rainfall data are traditionally logged using the rainfall volume recorded from rain gauges such as tipping-bucket or collection well rain gauges. However, damage and obstructions in rain gauges may introduce errors, which may create observational problems for some cases where intense precipitation is occurring in areas without a reliable gauging station. Therefore, scopes of using calibrated remote sensing observations are used to represent rain gauge data with poor rain gauge spatial distribution density. This would ensure the quality of the rainfall data being observed, and secure data recording even when instrument failure occurs. Some of the available ICT-based rainfall observation remote sensing data are the application of the following (Maswanganye, 2018): Ground-based weather radar (radio detection and ranging), regional scale rainfall estimation satellites (visible, infrared and microwave sensors), TRMM (Tropical Rainfall Measurement Mission), GPM (Global Precipitation Measurement) and blended rainfall estimation techniques, etc. The application of these ICT-based rainfall data collection systems and techniques in the urban domain shall be the basis for scoring for this indicator.	
Data type	Information on the remote sensing instruments utilized (national and/or regional-scale), specifically recording precipitation, that covers the scope of the city area (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of the following ICT-based technologies in rainfall observation. Rainfall observation ICT-based technologies Automated weather stations (AWS), Automated synoptic observation system (ASOS), IoT rainfall instruments, Sensor rain gauges Ground-based doppler radar, Microwave radiometers, Rawinsonde Regional-scale satellite data, GIS Numerical weather prediction, AI-based rainfall prediction systems, Machine learning	
References	Maswanganye, S. (2018). A comparison of remotely-sensed precipitation estimates with observed data from rain gauges in the Western Cape, South Africa. Univ of Wester Cape.
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 The city utilizes all of the ICT-based rainfall monitoring instruments criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the application of ICT in rainfall monitoring, or city does not apply ICT in rainfall monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.1f	Precipitation data accessibility
Definition	Status of public ease of access to precipitation data records (Smartness) (Services)
Function	
Easy access to meteorological data, specifically rainfall, can improve overall understanding of weather information that can have a direct effect on the society. However, a significant challenge on building the capacity of non-specialists to use climate information includes the complexities in the access of relevant and timely data, that can be easily incorporated into non-research related analysis and reporting. Mabon (2020) emphasized the importance of more appropriate climate information to the public. The ease of access to climate information can: (a) Help citizens in identifying the appropriate institutions to seek for information on local weather and climate, (b) acknowledge the capability of the public to engage with complex information on the risks in urban climate, and (c) consider how the data-driven information services can fit in informal ways in which people can experience the changes in environment.	
Data type	Information on the accessibility of precipitation data (Qualitative Analysis)
References	Mabon, L. (2020). Making climate information service accessible to communities: What can we learn from environmental risk communication research? Urban Climate. 31, 100537.
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 Open online access of complete observed precipitation data 3 Open online access of partial or incomplete precipitation data 2 Manual retrieval of precipitation data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to precipitation data (i.e. data only available within intergovernmental agencies) 0 City has no information on precipitation data accessibility, or data is not available to public access n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Surface water

Indicator 1.2a	Percentage of urban impervious surfaces
Definition	Comparison of percentage of impervious and total city surface area (Sustainability)
Function	
The surface permeability is an important factor in the urban water balance, and is an indicator determining the ecological performance of the urban environment. Impervious surfaces that take up most of the urban areas composed of concrete, metal, glass, tarmac and plastic, results to disruption in natural water balance and in turn reduces water purification, groundwater recharge, stream water quality, overwhelms retention basins, strains the pipe network, and increases the risk of flooding. In addition, the material of the surface is known to have the capability to contribute to urban heat island effect, indicated by the increase in land surface temperature. Research shows that increased impervious surfaces in the environment have major effect on air and soil temperature, relative humidity, and soil moisture content. Therefore, higher percentage of impervious surface can have a negative effect to urban flooding and drought indicators.	
Data type	Urban land use data (excel file, GIS) (Quantitative Analysis)
Calculation Method	
The percentage of impermeable surface in the urban area can be calculated as: Percentage of urban impervious surface = (Total impervious surface area (km2) / Total urban area (km2)) * 100 Liu et al., (2014) compiled the comparison and global ratio of urban area to impervious surface area, listed as follows: Region Ratio of urban area to impervious surface area Impervious surface area percentage (%) North America 6.08 16.5 Europe 5.53 18.1 Asia 6.47 15.5 Africa 8.40 11.9 Latin America and the Caribbean 7.97 12.6 Oceana 11.80 8.5 China 7.90 12.7 Global average 6.67 15.0 However, for progressive cities, impervious surfaces are expected to be greater due to the necessity for industrialization. Therefore, the indicator shall be adjusted to compensate the current status of surface area percentage of cities all over the world.	
References	Liu, Z., He, C., Zhou, Y. and Wu, J. (2014). How much of the world's land has been urbanized, really? Hierarchical framework for avoiding confusion. Landscape Ecol. 29, 5.
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description Score 4 <70 The percentage coverage of impervious surface area compared to the city total area is less than 70% 3 70 – 75 Percentage is within 70 to 75% 2 75 – 80 Percentage is within 75 to 80% 1 > 80 Percentage coverage is more than 80% 0 No data City has no data on impervious surface information n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.2b	Green space ecosystem protection
Definition	The percentage of conserved green space in comparison to the total percentage area of the city (Sustainability)

Function

The land transformation brought about by urbanization has a consistent and pervasive effect on the ecosystem of the urban stream. The runoff discharges from urbanized surfaces results to increased reception of nutrients, metals, pesticides, and other contaminants to the streams, which results to decline in the richness of algae, invertebrate and fish communities Any artificial alterations regulated by the city government to reinstate the natural water chemistry, protects the diverse biological aquatic communities in the urban stream is an indicator of a smart water city.

Data type	Nature conserved area (Excel file, GIS), city total surface area (km2) (Quantitative Analysis)

Calculation Method

The percentage of nature conserved area can be evaluated as:
Percentage of natural conserved area (%) =
(Total surface area dedicated for nature conservation (km2) / Total urban area (km2)) * 100

Evaluation Method

This indicator shall be scored depending on whether the above recommendations are satisfied.

Rating	Value (percentage)	Description	Score
4	> 20	The percentage of the natural conserved area within the city is more than 20%	
3	15 – 20	Percentage is from 15 to 20%	
2	10 – 15	Percentage is from 10 to 15%	
1	< 10	Percentage is less than 10%	
0	No data	City has no data on nature conserved area information	
n/a	-	Not applicable	

Sources of information

Please indicate the source of this information

Indicator 1.2c	Urban waterfront facilities
Definition	Existence and establishment of waterfront or water space areas in the city (Sustainability)
Function	
Water spaces in cities provide an interface between the land and water, which plays a vital role in transportation, commerce and recreation. The presence of manmade waterfront areas in the city creates both habitats for aquatic species and improves the city aesthetics. The waterfront facilities and structures can be harbors and ports, piers, dry docks, quay walls, marinas, breakwaters or jetties, auxiliary structures etc. The management of the urban waterfront areas can also facilitate the preservation of urban water bodies preventing the reckless development and construction surrounding the waterfront.	
Data type	Information on the existence of waterfront or water spaces within the city (Qualitative Analysis)
Calculation Method	
This indicator is based on the usage of the city waterfronts based on the following criteria. Waterfront purposes Recreation, leisure, parks and green spaces, cycling and walking trails, cultural entertainment Environmental conservation ad protection, ecological habitat, wetland restoration, storm water management Commercial, industry Transportation, ferry terminal, water-based public transits	
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city waterfront and water spaces satisfy all the waterfront purpose criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 None of the criteria is satisfied, or the city has no information on waterfront management, or no waterfront /water space areas within the city n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.2d	LID and Green Infrastructure percentage
Definition	Percentage of developed LID and green infrastructure in the city (Smartness) (Infrastructure)
Function	
Low Impact Development (LID) refers to practices that are created to mimic the natural processes involving infiltration, evapotranspiration, or stormwater usage with the aim of preserving the quality of urban water and the associated ecologic habitat. LID employs techniques that are designed to reintroduce the hydrologic and natural functions modified with conventional storm water management procedures. Some examples of LID technologies are (Whole Building Design Guide, 2016): LID technologies Examples Engineered systems filtering storm water from impervious surfaces Bio-retention cells, filter strips, tree box filters Engineered systems retaining and slowly infiltrating water Sub-surface collection facilities, infiltration trenches Infrastructures to reduce impervious surfaces Curbless and gutterless streets, reduced-width streets Low-tech storm water retaining vegetated areas Rain gardens, bio-swales Innovative recycles materials in disconnecting impervious surfaces Porous concrete, permeable pavers, recycled waste-made site furnishings Water collecting systems Sub-surface collection facilities, cisterns, rain barrels	
Data type	Urban land use data, LID and green infrastructures (table, excel file, GIS) (Qualitative Analysis)
Calculation Method	
The assessment for the application of LID facilities and green infrastructures can be assessed as the percentage of application of LID and green infrastructures, given as: Percentage of application of LID and green infrastructures (%) = Total area of LID and green infrastructures (km2) / Total urban area (km2) * 100 According to the percentage green infrastructure data gathered by European Environmental Agency (2022), the average percentage of application of green infrastructure in European cities is 41%, with Oslo leading at 77%.	
References	Whole Building Design Guide (2016). Low Impact Development Technologies. Accessed in wbdg.org/resources/low-impact-development-technologies 16 Aug 2022. European Environmental Agency (2022). Percentage of total green infrastructure, urban green space, and urban tree cover in the area of EEA-38 capital cities. Accessed in eea.europa.eu/data-and-maps/daviz/percentage-of-total-green-infrastructure 05 Sep 2022.
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description Score 4 > 15 The percentage of urban surfaces with LID and green infrastructures is more than 15 % 3 10 – 15 Percentage is between 10 to 15 % 2 5 – 10 Percentage is between 5 to 10 % 1 < 5 Percentage is less than 5 % 0 No data City has no data on LID and green infrastructures, or city has no application of LID and green infrastructures n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Urban stream water level

Indicator 1.3a	Extension extent of urban stream water level observation stations
Definition	The total extent of coverage of the water level monitoring stream gauge stations within the city (Sustainability)
Function	
Water level monitoring in urban streams is important in various applications such as flood control, water flow measurements and managing water resources. Monitoring urban river water level and discharge helps in detecting changes in the environment, as a function of climatic, biological, geological and topographical variables within the basin. During rainfall events, it is important to keep a close attention to the water level situation of the rivers within the city. These techniques are usually based on floats or pressure sensors, ultrasonic water meters, satellite-based and image-based systems.	
Data type	Quantity of installed stream gauge observation stations within the city (table, excel file, GIS), total urban surface area (km2) (Quantitative Analysis)
Calculation Method	
The stream flow monitoring station coverage based on the recommended densities of hydro-meteorological stations by WMO (2020) (area in km2 per station) is as follows: Topographical characteristics Stream flow monitoring station coverage (km2/station) Coastal 2700 Mountainous 1000 Inner plains 1875 Hilly 1875 Small islands 300 Polar arid 20000 Urban area - However, for urban areas that are prone to urban flooding due to river overflow, it is important to have an operating stream gauge stations at every few kilometers extension. The calculation of the coverage of water level stations inside the city can be calculated as: Stream gauge water level monitoring station coverage (km/station) = Total urban river extension (km) / Total number of stream gauge monitoring stations	
References	World Meteorological Organization (2020). Guide to Hydrological Practices, Volume 1. WMO-No. 168, Switzerland.
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Value (km) Description Score 4 > 5 Operation of more than 5 stream gauges per 10 km river extent 3 > 3 More than 3 stream gauges per 10 km extent 2 > 1 More than 1 stream gauge per 10 km extent 1 ≤ 1 Equal to or less than 1 stream gauge per 10 km extent 0 No data City has no data on stream water level extent coverage, or no stream water level measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.3b	**Urban stream water level monitoring frequency**
Definition	Frequency of recording of the water level stations within the city (Sustainability)
Function	
Continuous and frequent monitoring of urban river water levels is critical in providing prior warning for flood risk to the urban population during storm events. In addition, consistent river level observations are important in assessing the health of the river since aquatic plants and animal species are dependent on the quantity of river water to survive. Due to the small water storage capacity and high flow velocity, the response of urban area downstream water level to upstream rainfall is rapid and intense, the effect to flooding can be instantaneous. To properly provide an accurate short-term forecast for the increase in urban water level, high-resolution temporal variability of water level is necessary.	
Data type	Station water level timeseries data (Quantitative Analysis)
Calculation Method	
Liu et al., (2021) utilized different temporal scales of water level observation for river water level forecasting. The results show that simulation errors increase with the increase in recording interval time. A minimum temporal resolution of 10 min water level records is recommended for accurate prediction of flooding.	
References	Liu, Y., Wang, H., Feng, W. and Huang, H. (2021). Short term real-time rolling forecast of urban river water levels on LSTM: A case study in Fuzhou City, China. Int Journal of Environ Resear and Public Health. 18, 9287.
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Value Description Score 4 ≤ 10 min Water level measurements are performed at interval of equal to or less than 10-minute 3 30 min Water level is measured at least 30-minute interval 2 hourly Water level is measured at least hourly interval 1 > hourly Water level is measured at more than hourly interval 0 No data City has no data on stream water level monitoring frequency, or no stream water level measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.3c	Urban stream water level missing and error data
Definition	Number/quantity of missing and error water level data (Sustainability)
Function	
Operational management of water resources, including stream flow analysis and forecasting, requires reliable time series data. For efficient estimation of stream flow data, little to no missing values are necessary. This missing data may be attributed to various reasons such as bad weather, equipment failure, maintenance problems, machine storage malfunction or human errors. The missing intervals on the streamflow timeseries represents loss of information that can result to erroneous data interpretation and analysis. Stream gauge calibrations require records of water level and flow discharge from strategic points within the river stream, which are conventionally determined from the measurements of river cross-section profiles during repeated field campaigns. The streamflow data are critical to management of water supply, irrigation, energy generation, industrial water, surface, and ground water interaction, and most importantly, flood monitoring.	
Data type	Station water level timeseries data (Quantitative Analysis)
Calculation Method	
The percentage of missing data for water level can be calculated by: Percentage of missing data (water level) = (Number of missing values / Total number of water level observations) * 100 According to the research done by Tencaliec et al. (2015), a 5% significance level is classified as "useful" and may therefore be categorized as homogeneous data. For developing countries, missing data percentage may range up to 25 % (Tencaliec et al., 2015) or 33% (Mfwango et al., 2018).	
References	Tencaliec, P., Favre, A., Prieur, C. and Mathevet, T. (2015). Reconstruction of missing daily streamflow data using dynamic regression models. Water Resour Res. Mfwango, L., Salim, C. and Kazumba, S. (2018). Estimation of missing river flow data for hydrologic analysis: The case of Great Ruaha river catchment. Hydrol: Current Res. 9, 2.
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description Score 4 ≤ 5 Percentage of missing and error water level data is equal to or less than 5 % 3 5 – 10 Percentage is within 5 to 10 % 2 10 – 20 Percentage is within 10 to 20 % 1 > 20 Percentage is more than 20 % 0 No data City has no information on stream water level observation error and missing data, or no stream water level measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.3d	Urban stream water level measurement and calibration method
Definition	Quantity of observed water level data that is recorded electronically and observation instruments calibration status (Smartness) (Data)
Function	
Urban stream water level monitoring is important in early detection of river overflow and assessment of urban river quantity necessary for maintaining water ecosystem. Automated and real-time monitoring allows for efficient water management, disaster preparedness, more in depth research and overall stream sustainability. The evaluation for this indicator shall be scored whether the stream water level data are recorded fully or partially automated, in real-time, and whether instrument calibrations are performed in the instruments.	
Data type	Status of automation of stream water level recording instruments, and the application of quality assurance and instrument calibrations (Qualitative analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in stream water level monitoring: Stream water level observation method and quality assurance Real-time and automated recording of stream water level Existence of auto-calibration function within the water level instrument or system Regular calibration of the water level instrument Recorded water level data quality assurance	
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 The city implements all of the stream water level automation and calibration criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the implementation of automation and calibration, or the city does not implement automation and calibration in stream water level monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.3e	ICT-based water level data collection process
Definition	Process of water level data collection and storage using stream gauge, automatic flow meters and other ICT-based technologies (Smartness) (Data)
Function	
The accumulation of accurate water level variations in reservoirs and urban streams is crucial to urban flood preparation and water management. Stream gauge instruments are developed to monitor urban stream measures variables such as water level, depth and velocity. The data are traditionally recorded using water level stream gauges, automatic flow meters and water velocity measuring instruments such as the acoustic Doppler current profiler (ADCP), etc. Modern stream gauging stations oftentimes feature measuring functions and data loggers containing internal radio and cellular modern for transmitting data to database (YSI Inc., 2022). In addition to on-site stream measuring instruments, remote sensing is also often used to measure water levels and estimate storage.	
Data type	Information on the process of ICT-based urban stream data collection and storage within the city (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of the following ICT-based technologies in stream water level observation. Stream water level observation ICT-based technologies Water level sensors (ultrasonic, radar, acoustic doppler, pressure transducers etc.)-based stream gauges Solar panel generation, system controller, etc., data transmission and monitoring instrument Numerical analysis, Water level prediction, machine learning, etc., water level analysis Remote sensing-based instruments, IoT sensors, Image recognition, cctv etc.	
References	YSI Incorporated (2022). YSI Parameter Series: Water level measurement. Accessed in ysi.com/parameters/level 19 Sept 2022.
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city utilizes all of the ICT-based stream water level monitoring instruments criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the application of ICT in stream water level monitoring, or city does not apply ICT in stream water level monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.3f	Urban stream water level accessibility
Definition	Status of public ease of access to stream water level data records (Smartness) (Services)
Function	
Open access to water level data promotes transparency in urban water management, allowing the public community to understand the data used for decision making that is relevant to the society. Timely access to river water level information enables the population to take necessary precautions during flooding events and water-related emergencies.	
Data type	Information on the accessibility of water level data (Qualitative Analysis)
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 Open online access of complete observed stream water level data 3 Open online access of partial or incomplete stream water level data 2 Manual retrieval of stream water level data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to stream water level data (i.e. data only available within intergovernmental agencies) 0 City has no information on stream water level data accessibility, or data is not available to public access n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Urban stream water quality

Indicator 1.4a	Coverage extent of stream water quality observation points
Definition	The total extent of coverage of water quality monitoring points performed within the city (Sustainability)
Function	
Urban stream water quality monitoring stations are important for keeping track of urban stream health, monitoring its impact to public health and the capacity of the urban stream to support ecosystem. To determine the status of water quality throughout the river network, the number of water quality observation sites need to be optimized to balance sufficient data source quantity, and the cost for instrument installations and operations. According to the US Environmental Protection Agency, monitoring can be conducted as: fixed sites on a continuous basis, at selected sites on an as-needed basis (i.e., watershed characterization), on seasonal basis (i.e., bathing beaches at summer), at random sites, on emergency basis (i.e., oil spill), etc.	
Data type	Quantity of installed stream water quality observation stations within the city (table, excel file, GIS), total city surface area (km2) (Quantitative Analysis)
Calculation Method	
The number of urban stream water quality monitoring stations based on the recommended densities of hydro-meteorological stations (WMO, 2020) (area in km2 per station) are as follows: Topographical characteristics Stream water quality stations (km2/station) Coastal 55000 Mountainous 20000 Interior plains 37500 Hilly 47500 Small islands 6000 Polar-arid 200000 Urban area - However, for this indicator, stream water quality inspection shall be calculated based on the urban river extent: Stream water quality inspection coverage (km/station) = Total rive extent (km) / Number of stream water quality stations However, more dense stream water quality observation stations are necessary for urban areas, where more monitoring stations are expected.	
References	Environmental Protection Agency (2017). An introduction to water quality monitoring. Accessed in archive.epa.gov/water/archive/web/html/monitor 17 Aug 2022. World Meteorological Organization (2020). Guide to Hydrological Practices, Volume 1. WMO-No. 168, Switzerland.
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Value (km) Description Score 4 10 At least one stream water quality inspection within 10 km river extent 3 20 At least one inspection within 20 km extent 2 30 At least one inspection within 30 km extent 1 > 30 At least one inspection within more than 30 km extent 0 No data City has no data on stream water quality monitoring coverage, or no stream water quality measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.4b	Urban stream water quality monitoring frequency
Definition	The frequency at which the water quality of the urban stream is collected and analyzed (Sustainability)
Function	
The urban stream water quality needed to be tested frequently, to identify prospective problems that might affect the health of the urban stream ecosystem. Monitoring of water quality is essential to understand the complex dynamics of water ecosystems and the impact of construction of urban infrastructure, ensuring the water safety for drinking, recreation and transport. Frequent monitoring reduces data uncertainties and allows the capture of transient events. Therefore, the frequency of water quality sampling is implemented is an important aspect for water quality monitoring management.	
Data type	Urban stream water quality monitoring timeseries data (Quantitative Analysis)
Calculation Method	
Corragio et al. (2022) summarized the optimum sampling frequencies for different purpose of stream water quality monitoring, listed below: Purpose of water quality monitoring Optimum sampling frequency Author/s Water framework directive implementation Monthly Naddeo et al (2007) River water quality modeling 15 min Anvari et al (2009) Routine river water quality monitoring Monthly Liu et al. (2013) Long-term environmental monitoring 3 months Guigues et al. (2013) Ambient water quality assessment Monthly Khalil et al. (2014) Surface water quality monitoring 5 min Chen and Han (2018) Long term river water quality monitoring Hourly da Silva et al. (2019) The evaluation for the frequency of urban stream water quality monitoring indicator shall be scored whether the above optimum sampling frequencies are satisfied.	
References	Corragio, E., Han, D., Gronow, C. and Tryfonas, T. (2022). Water quality sampling frequency analysis of surface freshwater: A case study on Briston. Naddeo. V., Zarra, T. and Belgiorno, V. (2007). Optimization of sampling frequency for river water quality assessment according to Italian implementation of the EU Water Framework Directive. Environ. Sci and Policy. 243-249. Anvari, A. et al. (2009). Designing an automated water quality monitoring system for West and Rhode rivers. Syst Info Eng Design Symposium. Charlottetown, VA. Liu, Y., Zheng, B., Wang, M., Xu, Y. and Qin, Y. (2013). Optimization of sampling frequency for routine river water quality monitoring. Sci China Chem. 57, 772-778. Guigues, N., Desenfant, M. and Hance, E. (2013). Combining multivariate statistics and analysis of variance to redesign a water quality monitoring network. Environ. Sci, 15, 1692-1705. Khalil, B., Ou, C., Proulx-McInnis, S., St-Hilaire, A. and Zanacic, E. (2014). Statistical assessment of the surface water quality monitoring network in Saskatchewan. Water, Air and Soil Pollution. 225, 1-22. Chen, Y. and Han, D. (2018). Water quality monitoring is smart city: A pilot project. Automation Const. 89, 307-316. da Silva, R., da Silviera, A. and da Silviera, G. (2019). Spectral analysis in determining water quality sampling intervals. Rev. Brasil Recursos Hidricos, 24, 80077.

Evaluation Method

This indicator shall be scored based on the following recommendations for smart water city.

Rating	Value (frequency)	Description	Score
4	At least hourly	Stream water quality monitoring is conducted at least hourly interval	
3	Semi-daily	Monitoring is conducted at semi-daily interval (3-, 6-, 12-hourly)	
2	Daily	Monitoring is conducted at least once a day	
1	> Daily	Monitoring is conducted more than once a day	
0	No data	City has no data on stream water quality monitoring frequency, or no stream water quality measurements are performed	
n/a	-	Not applicable	

Sources of information

Please indicate the source of this information

Indicator 1.4c	**Urban stream water quality missing and error data**
Definition	Number of missing and error urban stream water quality data compared to the overall observation data (Sustainability)
Function	
Monitoring the real-time water quality is valuable to water quality prediction, assessment and urban environmental management. Missing values in stream water quality data can be prevalent due to network miscommunication, device corruption, as well as sensor failures (Zhang and Thorburn, 2022). Application of datasets with missing or error data can create biases in the results when performing water quality statistical analysis or hydrologic modeling.	
Data type	Urban stream water quality monitoring timeseries data (Quantitative Analysis)
Calculation Method	
The percentage of missing data for urban stream water quality can be calculated using: Percentage of missing data (urban stream water quality) = (Number of missing (error) stream quality data / Total number of observations) * 100	
References	Zhang, Y. and Thorburn, P. (2022). Handling missing data in near real-time environmental monitoring: A system and a review of selected methods. Future Gener Syst. 63-72.

Evaluation Method

This indicator shall be scored depending on whether the above recommendations are satisfied.

Rating	Value (percentage)	Description	Score
4	< 5	Percentage of missing urban stream water quality data is less than 5 %	
3	5 – 10	Percentage is within 5 to 10 %	
2	10 – 15	Percentage is within 10 to 15 %	
1	> 20	Percentage is more than 20 %	
0	No data	City has no information on stream water quality missing and error data, or no stream water quality measurements are performed	
n/a	-	Not applicable	

Sources of information

Please indicate the source of this information

Indicator 1.4d	Urban stream water quality standard
Definition	Standard quality of the urban stream water (Sustainability)

Function

The water bodies surrounding the urban area are often adversely affected by the quality of urban water coming from storm runoffs, ensuing pollution and degradation of ecological health of the urban stream. Urban runoff is found to be the leading source of pollutants creating negative impact in the water quality, aquatic habitat and biological resources, public health and aesthetic appearance of the urban water body. The impact of storm water discharges to urban stream can be categorized into three classes (EPA, 1999): Temporary increase in the concentration of pollutants, toxins and bacteria during and after storm events, cumulative effect on long term water quality associated with repeated storm discharge from sources, and physical impact that alters the aquatic habitats such as soil erosion, scour and deposition.

Data type	Urban stream water quality data test results (Quantitative Analysis)

Calculation Method

To ensure that the Smart water city is securing the health and quality of its urban streams, water quality monitoring should be set in place. The advancement in the degree of development of the city is oftentimes proportional to the number of pollutants received by the water bodies. Based on EPA National Urban Water Runoff Program, the constituents that needed to be monitored are listed below.

Pollutant	Residential		Commercial		Combined	
	Average	Recommended	Average	Recommended	Average	Recommended
BOD (mg/l)	10	≤5	9.3	≤5	7.8	≤5
COD (mg/l)	73	≤20	57	≤20	65	≤20
TSS (mg/l)	42-101	73	70-170	93	47-188	76
TP (µg/l)	260-380	325	200-340	200	160-840	290

The evaluation score for stream water quality indicator shall be assessed based on the measurement of the actual pollutant taken real-time in the city stream as compared to the recommended and averaged measurements established by EPA (1999).

References	Environmental Protection Agency (1999). Preliminary data summary of urban storm water best management practices. Washington, DC. 4303.

Evaluation Method

This indicator shall be scored depending on whether the above recommendations are satisfied.

Rating	Value	Description	Score
4	All within recommended	Measurements of BOD, COD and TP are within the recommended values established by EPA (1999) or measurements are satisfied based on city standards	
3	Majority within recommended	Majority of measurements are within the recommended values	
2	min. average ≤ value < recommended	Measurements between average and recommended values	
1	< minimum average	Measurements are below average values	
0	No data	City has no data on stream water quality measurements, or no stream water quality measurements are performed	
n/a	-	Not applicable	

Sources of information

Please indicate the source of this information

Indicator 1.4e	Urban stream water quality data automation and quality assurance
Definition	Quantity of observed water quality data that is recorded electronically and observation instruments calibration status (Smartness) (Data)
Function	
Automation and consistent quality assurance of stream water quality instrument are necessary for the accuracy and reliability of the urban river water quality data. The automatic recording of water quality devices reduces potential human errors derived from manual data gathering. The regular interval in monitoring ensures consistency and reliability of data gathering. In addition, regular calibration of stream water quality instruments and quality control procedures are essential in validating the accuracy and precision of the collected data. The evaluation for this indicator shall be scored whether the stream water quality data are recorded fully or partially automated, in real-time, and whether instrument calibrations are performed in the instruments.	
Data type	Status of automation of rainfall recording instruments, and the application of quality assurance and instrument calibrations (Qualitative analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in stream water quality monitoring: Stream water quality observation method and quality assurance Real-time and automated recording of stream water quality Existence of auto-calibration function within the water quality instrument or system Regular calibration of the water quality instrument Recorded water quality data quality assurance	
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 The city utilizes all of the ICT-based stream water quality monitoring instruments criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the application of ICT in stream water quality monitoring, or city does not apply ICT in stream water quality monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.4f	**ICT-based water quality data collection process**
Definition	Process of water quality data collection and storage using ICT-based technologies (Smartness) (Data)

Function

To monitor and assess the quality of river water for water management purposes, technologies are used in the context of real-time observation, increasing the accuracy of data, maintaining cost effectiveness, large-scale coverage and data integration and analysis.
This indicator shall be assessed based on the usage of the following instruments in river water quality monitoring: Water quality sensors, automatic water samplers, spectrophotometers, GPS, data loggers, communication systems. AI-based water quality prediction instruments, etc.

Data type	Information on the process of ICT-based urban stream data collection and storage within the city (Qualitative Analysis)

Calculation Method

This indicator is based on the application of the following ICT-based technologies in stream water level observation.
Stream water quality observation ICT-based technologies
Stream water quality sensors (multi-, single parameter sensors, etc.)
Automatic water samplers
Spectrophotometers, microbial detection equipment
Data loggers and telemetry system, Communication systems, environmental monitoring software, system controller, etc., data transmission and monitoring instrument

Evaluation Method

This indicator shall be scored depending on whether the above recommendations are satisfied.

Rating	Description	Score
4	The city utilizes all of the ICT-based stream water quality monitoring instruments criteria mentioned above	
3	At least three of the criteria are satisfied	
2	At least two of the criteria are satisfied	
1	At least one of the criteria is satisfied	
0	City has no information on the application of ICT in stream water quality monitoring, or city does not apply ICT in stream water quality monitoring	
n/a	Not applicable	

Sources of information

Please indicate the source of this information

Indicator 1.4g	Urban stream water quality accessibility
Definition	Status of public ease of access to stream water quality data records (Smartness) (Services)
Function	
The accessibility of city stream water quality data is vital in the safety and health protection of the urban residents as river water quality directly affects the community as they rely on these bodies of water for consumption. In addition, rivers are critical to the environmental ecosystem supporting a wide range of animal and plant life. Constant monitoring of the quality of urban rivers enables the community to be vigilant of potential pollution threats and can therefore take appropriate actions in time.	
Data type	Information on the accessibility of urban stream water quality data (Qualitative Analysis)
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 Open online access of complete observed stream water quality data 3 Open online access of partial or incomplete stream water quality data 2 Manual retrieval of stream water quality data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to stream water quality data (i.e. data only available within intergovernmental agencies) 0 City has no information on stream water quality data accessibility, or data is not available to public access n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Groundwater level

Indicator 1.5a	Coverage extent of groundwater level observation stations
Definition	The total extent of coverage of ground water level monitoring observation stations/ground water observation instruments installed within the city (Sustainability)
Function	
The increased water demand due to urban growth leads to over exploitation of ground water sources and consequently produces large volumes of water waste. The establishment of network of groundwater monitoring stations in the city is an important process towards understanding and providing solutions for the challenges associated with depleting groundwater resources. These data gathered from these observations enable urban planners, groundwater resource managers, and policy makers to make informed decisions about allocation of groundwater. It is therefore important that there is an existing ground water monitoring system within the urban area.	
Data type	Quantity of installed ground water level observation stations within the city (table, excel file, GIS), total city surface area (km2) (Quantitative Analysis)
Calculation Method	
The station density for ground water can be calculated using (Kwater, 2017): Groundwater level station density (km2/station) = Urban area (km2) / Number of groundwater observation stations and storage networks The indicator shall be scored based on the established ground water station density guidelines by the Korea Water Resource Corporation (2017).	
References	Kwater (2017). Development of KPIs for level evaluation of water resource management. KIWE-WSO-16-32 Final Report. Korea Water Resource Corporation (Kwater), Korea.
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (km2/station) Description Score 4 ≤10 The ratio of groundwater level monitoring station coverage within the city is one station per 10 km2 3 10 – 40 Operation of at least one station per 10 to 40 km2 2 40 – 100 Operation of at least one station per 40 to 100 km2 1 > 200 Operation of at least one station per more than 200 km2 0 No data City has no information on groundwater level monitoring coverage, or no groundwater level measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.5b	Groundwater level monitoring frequency
Definition	The frequency at which the ground water level data in the urban area is collected and analyzed (Sustainability)
Function	
Measuring the frequency of ground water level is one of the most important considerations in the design of ground water monitoring programs, depending on the objectives and intended use of the data. The frequency should be adequate to detect short-term and seasonal fluctuations of ground water level in discriminating between the effects of short- and long-term hydrological stresses. Advanced monitoring stations offer high precision and detailed observations on groundwater level in a much shorter interval. These high frequency monitoring are essential in identifying rapidly changing groundwater contents influenced by human activities or climate variation.	
Data type	Groundwater level observed timeseries data (Quantitative Analysis)
Calculation Method	
The ground water observation frequency determines whether the records reflect the status of the ground water and develop a response of the system to the natural and human influences. These observations show variation that can be classified as trends or fluctuations (IGRAC, 2008): (1) long-term fluctuation – long period of relatively dry or wet years, (2) Seasonal fluctuation – wet and dry seasons and (3) short-term fluctuation – day by day rainfall or human influences. Though there is not a standard frequency of observation for ground water, general considerations are given depending on the area's climate conditions listed as follows: Conditions Groundwater observation frequencies Dry climates (arid zones) 1 - 2 per year Humid climates 4 per year Semi-arid zones 4 per year During recharge studies 12 – 24 per year However, for urban areas, the frequency of groundwater level monitoring needed to be more frequent, in order to necessitate immediate action in case of sudden changes in water availability that might result to groundwater depletion.	
References	International Ground Water Resource Assessment Centre (2008). Guidelines on: Groundwater monitoring for general reference purposes. International Working Group 1. Report nr. GP 2008-1.
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (frequency) Description Score 4 > Hourly Groundwater level observations are performed at more than hourly interval 3 Daily Observations at daily interval 2 Monthly Observations at monthly interval 1 < Monthly Observations are performed more than monthly interval 0 No data City has no information on groundwater level monitoring frequency, or no groundwater level measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.5c	**Groundwater level missing and error data**
Definition	Number/quantity of missing and error groundwater level data (Sustainability)
Function	
Groundwater level monitoring, like other automatic monitoring instruments, can often produce errors of missing data due to power outage or errors in the digital sensors. The percentage of acceptable missing data can depend on the objective of the measurement and the resource available for the data management and analysis. In general, a lower percentage of missing groundwater data is preferable to maintain data accuracy and reliability of the datasets.	
Data type	Groundwater level observed timeseries data (Quantitative Analysis)
Calculation Method	
The percentage of missing data for groundwater level can be calculated by: Percentage of missing data (groundwater level) = (Number of missing values / Total number of groundwater level observations) * 100	
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description Score 4 < 5 Percentage of missing and error groundwater level data is less than 5 % 3 5 – 10 Percentage is within 5 to 10 % 2 10 – 20 Percentage is within 10 to 20 % 1 > 20 Percentage is more than 20 % 0 No data City has no information on groundwater level missing and error data, or no groundwater level measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.5d	Ground water level data automation and quality assurance
Definition	Quantity of observed groundwater level data that is recorded electronically and observation instruments calibration status (Smartness) (Data)
Function	
The automation and consistent calibration of groundwater level monitoring instruments play a critical role in managing urban ecosystem, agriculture, drinking water supply and various industrial processes. The groundwater level monitoring automation and quality control assures accuracy and reliability of data, continuous monitoring, timely detection of anomalies and cost-effectiveness in reducing the need to perform manual visits, and more. The evaluation for this indicator shall be scored whether the groundwater level data are recorded fully or partially automated, in real-time, and whether instrument calibrations are performed in the instruments.	
Data type	Status of automation of ground water level monitoring instruments, and the application of quality assurance and instrument calibrations (Qualitative analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in groundwater level monitoring: Groundwater level observation method and quality assurance Real-time and automated monitoring of groundwater level Existence of auto-calibration function within the groundwater monitoring instrument or system Regular calibration of the groundwater instrument Recorded groundwater level data quality assurance	
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 The city implements groundwater level monitoring automation and calibration criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the implementation of automation and calibration, or the city does not implement automation and calibration in groundwater level monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.5e	**ICT-based observed groundwater level data collection process**
Definition	Process of groundwater level data collection and storage using ICT-based technologies (Smartness) (Data)
Function	
The application of ICTs in monitoring of groundwater water level makes it possible to manage various groundwater wells at the same time, allowing to find out the status of the wells and the groundwater distribution at certain time for real time intervention. This indicator shall be assessed based on the usage of ICT-based technologies in groundwater level monitoring such as remote sensing-based instruments, groundwater sensors, IoT devices, transducers, data loggers, telemetry systems, AI-based groundwater prediction, etc.	
Data type	Information on the process of ICT-based groundwater level data collection and storage within the city (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of the following ICT-based technologies in groundwater level observation. Groundwater level observation ICT-based technologies Groundwater level sensors (acoustic, optical), pressure transducers, piezometer, etc., based groundwater gauges Automated data loggers, Real-time wireless communication, Telemetry, system controller, etc., data transmission and monitoring instrument Numerical analysis, Groundwater prediction, machine learning, etc., groundwater level analysis Remote sensing-based instruments, IoT devices	
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city utilizes all of the ICT-based groundwater level monitoring instruments criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the application of ICT in groundwater level monitoring, or city does not apply ICT in groundwater level monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.5f	Ground water level accessibility
Definition	Status of public ease of access to groundwater level data records (Smartness) (Services)
Function	
For effective groundwater management, research and decision-making, open access to groundwater level data is crucial. Easy access allows water managers and the public to foster trust and accountability in the groundwater resource management. Allowing open access to groundwater level data empowers the public to be aware of their groundwater conditions for public health and sustainability.	
Data type	Information on the accessibility of ground water level data (Qualitative Analysis)
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 Open online access of complete observed groundwater level data 3 Open online access of partial or incomplete groundwater level data 2 Manual retrieval of groundwater level data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to groundwater level data (i.e. data only available within intergovernmental agencies) 0 City has no information groundwater level data accessibility, or data is not available to public access n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Groundwater quality

Indicator 1.6a	**Coverage extent of groundwater quality observation stations**
Definition	The total extent of coverage of groundwater quality monitoring stations installed within the city (Sustainability)
Function	
The spatial density of groundwater quality monitoring stations installed within the city is crucial in gaining comprehensive understanding on the current and past status of groundwater quality within the city. The spacing of observation wells should depend on the differentiation between diffuse and point pollution stations, which is important in the evaluation and comparison of data. The density of the observation wells is dependent on some parameters such as the hydrogeological complexity of the area, setting and sizes of the main aquifers, land use, existing monitoring systems, observation objectives and financial limitations.	
Data type	Quantity of installed groundwater quality observation stations within the city (table, excel file, GIS), city total surface area (km2) (Quantitative Analysis)
Calculation Method	
The calculation of the density of groundwater quality stations inside the city can be calculated as: Groundwater quality station density (km2/station) = Total urban area (km2) / Number of ground water quality stations within the city	
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Value (km2) Description Score 4 < 10 Ground water quality inspection with area coverage less than 10 km2 3 10 – 40 Inspections within 10 to 40 km2 2 40 – 100 Inspections within 40 to 100 km2 1 > 100 Inspections within more than 100 km2 0 No data City has no data on groundwater quality monitoring coverage, or no groundwater quality measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.6b	**Groundwater quality monitoring frequency**
Definition	Frequency of recording of the ground water quality stations within the city (Sustainability)

Function

To constantly monitor the groundwater quality necessary for water resource management, high-frequency water quality observations are necessary; these high-resolution timeseries data improve the understanding of the changes in subsurface water quality. These data are used for monitoring surface-water-groundwater interaction, measuring the transport rate of contaminants, and analyze the variability of water quality in relation to precipitation and groundwater extraction. According to Barcelona et al. (2002), quarterly sampling of groundwater quality can be a good initial start for monitoring network design but stated that a bimonthly frequency is more appropriate in monitoring chemical constituents.

Data type	Groundwater quality observation timeseries data (Quantitative Analysis)
References	Barcelona, M., Wehrmann, H., Schock, M., Sievers, M., and Karny, J. (2002). Sampling frequency for groundwater quality monitoring. US EPA. DC. EPA/4-89/032.

Evaluation Method

This indicator shall be scored based on the following recommendations for smart water city.
Rating Value (Frequency) Description Score
4 ≥ Weekly Groundwater quality monitoring is performed at least weekly interval
3 Monthly Monitoring is performed at least monthly interval
2 Quarterly Monitoring is performed at least quarterly interval
1 > Quarterly Monitoring is performed at more than quarterly interval
0 No data City has no data on groundwater quality monitoring frequency, or no groundwater quality measurements are performed
n/a - Not applicable

Sources of information

Please indicate the source of this information

Indicator 1.6c	Groundwater quality missing and error data
Definition	Number of missing and error groundwater quality data compared to the overall observation data (Sustainability)

Function

Generally, groundwater management should strive to minimize the quantity of missing and error data to ensure the accuracy and reliability of the water quality measurements. The significance of minimizing missing and error data cannot be overlooked, as even a small gap or inaccuracies in the measurements undermine the integrity of the assessment and compromises the effectiveness of the mitigation strategies. Reliability in the results is essential in identifying trends and understanding the groundwater contaminant source and assessing the long-term health of the observation wells and aquifers. The percentage of acceptable missing data for analysis can vary based on the regions, methods used, monitoring infrastructure and criteria used.

Data type	Groundwater quality observation timeseries data (Quantitative Analysis)

Calculation Method

The percentage of missing data for groundwater quality can be calculated using:
Percentage of missing data (groundwater quality) =
(Number of missing (error) groundwater quality data / Total number of observations) * 100

Evaluation Method

This indicator shall be scored depending on whether the above recommendations are satisfied.

Rating	Value (percentage)	Description	Score
4	< 5	Percentage of missing groundwater quality data is less than or equal to 5 %	
3	5 – 10	Percentage is within 5 to 10 %	
2	10 – 20	Percentage is within 10 to 15 %	
1	> 20	Percentage is more than 20 %	
0	No data	City has no information on groundwater quality missing and error data, or no groundwater quality measurements are performed	
n/a	-	Not applicable	

Sources of information

Please indicate the source of this information

Indicator 1.6d	Groundwater quality compliance
Definition	Standard quality of the groundwater (Sustainability)
Function	
The standards for groundwater quality indicate the amount of maximum allowable contaminant concentration that can be acceptable for consumption without risking the health and safety of the population. Different regions have different groundwater quality compliance procedures depending on their respective requirements. These regulations are applied for the purpose of the protection of water resources including water supply, agriculture, aquatic life and ecosystem. For example, US EPA (2016) monitors allowable limit for parameters in groundwater wells such as general chemicals (i.e., pH level, Alkalinity, Bicarbonate), metals (Aluminum, Arsenic, Mercury), organic (Benzene, Xylenes) and radiochemicals (total Uranium, Radium).	
Data type	Groundwater quality data test results (Quantitative Analysis)
References	Environmental Protection Agency (2016). Appendix 1 Groundwater Quality Alert Levels and Compliance Monitoring. Clear Creek Associate, AZ USA. 373002.
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 Groundwater quality compliance based on regional/city-scale regulatory law and standards for groundwater quality 3 Groundwater quality compliance based on national regulatory law and standards for groundwater quality 2 Groundwater quality measured is not fully complied with the regulatory standards 1 City does not follow any groundwater regulatory standards 0 City does not have information on groundwater quality standards, groundwater quality monitoring is not performed n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.6e	Groundwater quality data automation and quality assurance
Definition	Quantity of observed groundwater quality data that is recorded electronically and observation instruments calibration status (Smartness) (Data)
Function	
Automation in groundwater quality monitoring ensures the consistency and precision of data collection, reducing the chance for human error in measurement and data transmission. Automated systems also allow remote monitoring for groundwater quality measurements in challenging site locations, and can serve as early warning systems for potential groundwater quality contamination events. The evaluation for this indicator shall be scored whether the ground water quality data are recorded fully or partially automated, in real-time, and whether instrument calibrations are performed in the instruments.	
Data type	Status of automation of groundwater quality monitoring instruments, and the application of quality assurance and instrument calibrations (Qualitative analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in groundwater quality monitoring: Groundwater quality observation method and quality assurance Real-time and automated monitoring of groundwater quality Existence of auto-calibration function within the groundwater monitoring instrument or system Regular calibration of the groundwater instrument Recorded groundwater quality data quality assurance	
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 The city implements groundwater quality monitoring automation and calibration criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the implementation of automation and calibration, or the city does not implement automation and calibration in groundwater quality monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 1.6f	ICT-based groundwater quality data collection process
Definition	Process of groundwater quality data collection and storage using ICT-based technologies (Smartness) (Data)

Function

The usage of ICT in urban groundwater quality monitoring and data collection has numerous benefits that significantly enhances the data collection efficiency, data accuracy, and overall effectiveness of the process. The leverage of these advanced sensors enables remote and continuous monitoring, reducing the reliance on periodic sampling, enhancing the ability to detect sudden changes or contamination events in a prompt manner. This indicator shall be assessed based in the usage of the following instruments in groundwater quality monitoring: Groundwater quality sensors, water quality meters, data loggers, telemetry, groundwater samplers, spectrophotometers, biosensors, AI-based groundwater quality prediction systems, etc.

Data type	Information on the process of ICT-based groundwater quality data collection and storage within the city (Qualitative Analysis)

Calculation Method

This indicator is based on the application of the following ICT-based technologies in groundwater quality observation.
Groundwater quality observation ICT-based technologies
Groundwater quality sensors (Multi- and single-parameter groundwater quality sensors, water quality meters, biosensors, etc.)
Automatic groundwater samplers
Automated data loggers, Real-time wireless communication, environmental monitoring software, system controller, etc., data transmission and monitoring instrument
Remote-sensing based instruments, GIS

Evaluation Method

This indicator shall be scored depending on whether the above recommendations are satisfied.

Rating Description Score
4 The city utilizes all of the ICT-based groundwater quality monitoring instruments criteria mentioned above
3 At least three of the criteria are satisfied
2 At least two of the criteria are satisfied
1 At least one of the criteria is satisfied
0 City has no information on the application of ICT in groundwater quality monitoring, or city does not apply ICT in groundwater quality monitoring
n/a Not applicable

Sources of information

Please indicate the source of this information

Indicator 1.6g	**Groundwater quality data accessibility**
Definition	Status of public ease of access to groundwater quality data records (Smartness) (Services
Function	
Limited public accessibility to groundwater quality data can present several problems in water resource management such as hindering effective communication necessary for water management and environmental protection. This would impose difficulties in the overall assessment of health and conditions of aquifers, hampering efforts for addressing potential contamination sources. It is essential to establish a comprehensive groundwater monitoring networks and enhance the data sharing mechanisms and promote transparency.	
Data type	Information on the accessibility of groundwater quality data (Qualitative Analysis)
Evaluation Method	
This indicator shall be scored based on the following recommendations for smart water city. Rating Description Score 4 Open online access of complete observed groundwater quality data 3 Open online access of partial or incomplete groundwater quality data 2 Manual retrieval of groundwater quality data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to groundwater quality data (i.e. data only available within intergovernmental agencies) 0 City has no information groundwater quality data accessibility, or data is not available to public access n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Water Disaster Management

Flood

Indicator 2.1a	Flood casualty index
Definition	Flood casualty index as an indicator of the city population's vulnerability to life-threatening flood events (Sustainability)
Function	
Though rainfall is an integral part of the urban water cycle, prolonged and intense rainfall episodes can often result to flooding that causes city inconveniences, such as traffic occurrences, among others, which can contribute to the slowing down of economy. Prolonged torrential rainfall, in addition, generates floods that causes damages to properties, agriculture and loss of lives. Reducing flood casualties is an essential aspect of efficient disaster preparedness and mitigation, by leveraging technologies and data to enhance flood preparedness and response. For this indicator, the Flood casualty index can be determined by the number of deaths caused by urban flood events in the last 10 years.	
Data type	Flood casualty data (Number of flood-related casualties in recent years) (table, excel file) (Quantitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 No casualties related to urban flood events occurred in the past 10 years 3 No casualties related to urban flood events occurred in the past 5 years 2 No casualties related to urban flood events occurred in the past 3 years 1 No casualties related to urban flood events occurred in the past year 0 Casualties relating to urban flooding have occurred n/a City is not prone to urban flooding	
Sources of information	
Please indicate the source of this information	

Indicator 2.1b	Flood property damage index
Definition	Flood damage index as an indicator of city's vulnerability to property damages resulting from urban flood occurrences (recent 10 years) (Sustainability)
Function	
The flood damage index is used to estimate the localized potential risk caused by flood damages, that is essential in establishing regional flood countermeasures and implementing flood restoration measures and emergency action plans. The index reflects the integration of advanced technologies, data-driven decision-making, and strategies aimed to minimize the impact of floods on urban infrastructure, economy, and well-being of the citizens.	
Data type	Flood damage data (amount of damages in properties) (table, excel file), city gross domestic product (latest year) (Quantitative Analysis)
Calculation method	
The relationship between the flood property damage and the gross domestic product (GDP) of the city is used to assess the impact of flood events in the city's economic state, which is directly correlated to the city's level of preparedness and infrastructures in place, and the response measures taken by the city. The Flood damage index can be calculated using (Kwater, 2017): Flood damage index = Total flood property damage amount (residential, commercial, industrial, agricultural) (recent ten years) / Total city gross regional domestic product (GRDP)	
References	Kwater (2017). Development of KPIs for level evaluation of water resources management. Korean Water Resource Corporation.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value Description Score 4 < 0. 1 Calculated Flood Property Damage Index is less than 0.1 3 0. 1 – 0. 3 Index is within 0. 1 to 0.3 2 0. 3 – 0.5 Index is within 0.3 to 0.5 1 > 0.5 Index is more than 0.5 0 No data City has no data on flood-related property damage n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.1c	Flood risk area index
Definition	Percentage of areas prone to flooding compared to the total urban surface area (Sustainability)

Function

Urban flooding takes place when intense rainfall occurs in the city, and the runoff accumulates from higher elevation to lower elevation areas. Lower elevated regions, particularly those nearby rivers, are prone to flooding from river overflows. Urban flood mapping plays an important role in urban planning and management, specifically aimed to reduce the risk of damage due to flooding. Predicting the location of recurrent flood prone areas using hazard maps can mitigate the effect of flooding and can be used for urban planning. Types of flood maps can range from usage (i.e. inundation maps, hazard maps, risk maps, etc.) to the technique used (statistical, physical model-based). Depending on the objective of the application.

Data type	Low lying area/flood prone areas (km2) (GIS data), total urban surface area (km2) (Quantitative Analysis)

Calculation method

Due to the concentration of population living in a smaller surface area, more severe urban flood disasters can have a more substantial impact on the urban population. For example, a study performed for Lishui City, China (Zhu et al., 2020) shows that about 13.48% of population can be affected by a 5-year return period flooding, and about 45.6% population affected for a 100-year return period flooding.
The of urban area vulnerable to flooding can be assessed from the following:
Flood risk area index =
(Total surface area that are vulnerable to flooding based on historical events (km2) / Total urban area (km2)

According to a disaster report in 2017, as much as 56% of smart cities are still prone to urban flooding (Business standard, 2018). Big cities on developed countries, such as in Chicago, USA, is found to have 13% of the city vulnerable to 100-year flood risk (New York Times, 2020). To evaluate the urban flood prone area status indicator of the smart city, threshold value of 10% will be used to compare with the percentage of city flood prone areas based on 100-year return period rainfall.

References	Zhu, S., Dai, Q., Zhao, B. and Shao, J. (2020). Assessment of population exposure to urban flood at building scale. Water. 12, 3253. Business standard (2018). 56% of smart cities prone to floods: Report. Accessed in business-standards.com/article/news-ians/56-smart-cities-prone-to-floods-report 07 Sept 2022. The New York Times (2020). New data reveals hidden flood risk across America. Accessed in nytimes.com/interactive/2020/06/29/climate/hidden-flood-risk-maps 07 Sept 2022.

Evaluation method

This indicator shall be scored depending on whether the above recommendations are satisfied.

Rating	Value	Description	Score
4	< 0.01	Calculated flood risk area index is less than 0.01	
3	0.01 – 0.05	Index is within 0.01 to 0.05	
2	0.05 – 0.1	Index is within 0.05 to 0.1	
1	> 0.1	Index is more than 0.1	
0	No data	City has no data on flood risk area, or no flood risk assessments are performed	
n/a	-	Not applicable	

Sources of information

Please indicate the source of this information

Indicator 2.1d	Levee structure maintenance
Definition	Percentage improvement of stream levee structures along the urban river (Sustainability)
Function	
Restoration of urban streams greatly contributes to preventing riverine flooding by reducing the likelihood of high-water levels and supporting the natural capability of the river to retain the water. River restoration greatly improves the resilience of the river network and provides sustainable multifunctional framework for the use of estuaries, rivers, and streams. Some examples of flood risk management through river restoration includes: (1) Building dikes, reservoirs, artificial retention areas, (2) straightening rivers to increase discharge capacity, (3) deepening channels by dredging, (4) Reconnecting streams and rivers to floodplains, and (5) enhancing quality and capacity of wetlands.	
Data type	Urban stream improved section data (km), total city river extension (km) (GIS, table data) (Quantitative Analysis)
Calculation method	
The percentage of river stream improvement is computed as (Kwater, 2017): Levee structure percentage (%) = (Total extent of constructed levee for flood prevention (km) / Total urban river extension) * 100	
References	European Center for River Restoration (2019). How does river restoration reduce flood risk? Accessed in ecrr.org/River-Restoration/Flood-risk-management 01 Aug 2022. Kwater (2017). Development of KPIs for level evaluation of water resources management. Korean Water Resource Corporation.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 > 80 The percentage of constructed and maintained levee structures for flood protection is more than 80 % 3 60 – 80 Percentage is between 60 to 80 % 2 40 – 60 Percentage is between 40 to 60 % 1 < 40 Percentage is less than 40 % 0 No data City has no data on levee structure or flood prevention measures n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.1e	Urban flood hazard mapping
Definition	Application of city-scale flood hazard maps (Smartness) (Data)
Function	
For flood-prone cities, it is important to construct a flood management council that handles all the flood-hazard related assessment and mitigation. These involves evaluation of flood events (real-time and probabilistic), structural flood control measures, flood forecasting and early warning, storm water plan, etc. Early warning on sudden increase of river water level needed to be set in place for proper action from residents living near the river. Cities have different methods on issuing water level early warning during rainfall events.	
Data type	Information on the city application of flood hazard mapping (Qualitative Analysis)
Calculation Method	
This indicator is based on the application different types and techniques in flood hazard mapping. Criteria for smart water city flood hazard mapping Application of advanced numerical techniques on city-scale flood hazard mapping (i.e., numerical modeling, hydro-dynamic, rainfall-runoff, physical-based, AI-based, Machine learning) Application of integrated flood hazard mapping that includes urban flood, storm surge/coastal flood, riverine flood, climate change projected flood risk etc. Application of city-scale flood hazard mapping using conventional approach, based on historical return-period flood data, field survey, etc. Application of high-resolution flood hazard maps (< 10 m)	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city satisfied all of the criteria for flood hazard mapping mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the city-scale flood hazard mapping, or the city does not apply urban flood hazard mapping n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.1f	Integrated disaster information center
Definition	Implementation of city-scale integrated disaster information system and application of ICT in for flood management (Smartness) (Infrastructures)
Function	
An integrated approach to flood disaster management involves collaboration and coordination with multiple stake holders, facilitated by the city local government, together with emergency services, urban planners, infrastructure developers and communities at large, to foster cooperation in response and preparation for flood events. This approach does not only minimize the immediate damage and casualties resulting from flood events but also promotes the city's sustainability, resilience and adaptability to extreme weather events. The implementation of ICTs in disaster risk reduction and management allows the real-time dissemination of information in the form and manner that facilitates the process of decision making, creating resilience, and reducing risk. The advancement of ICTs in the form of geographic information system, remote sensing, satellite, wireless sensors, mobile technology, and social media, plays an increasing role in different stages of flood disaster management such as in flood forecasting and prediction, mitigation, early warning, response, rescue including rehabilitation.	
Data type	Information on the application of ICTs in urban flood data management (Qualitative Analysis)
Calculation Method	
This indicator is based on the application and implementation of the following establishments in disaster information strategies: Criteria for smart water city disaster information strategies Establishment of city-scale information system Utilization of ICT-based technologies in disaster information transmission. Existence of integrated disaster information management (flood, drought) Interdepartmental communication between monitoring agencies and disaster mitigation agencies	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city satisfied all of the criteria for integrated disaster management mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the integrated disaster management, or the city does not apply integrated disaster management n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.1g	Urban flood prediction and early warning
Definition	Operation of urban flood prediction and advanced real-time alarm services (Smartness) (Services)
Function	
Early warning systems, specifically for urban flooding, are the key elements for disaster risk reduction, whose objective is to minimize the potential damages resulting from flood hazards. The active involvement of the community at risk, facilitating education and awareness, disseminating information and warning efficiently, and ensuring that preparedness and early action are enabled, are needed for the system to be effective. Standards must exist for the effectivity of the flood warning system, capacities are needed to facilitate and effectively disseminate timely warning information, that allows individuals and communities threatened by hazard to prepare and perform appropriate actions to reduce the possibility of harm or death.	
Data type	Information of the urban flood prediction and warning system (Qualitative Analysis)
Calculation Method	
This indicator is based on the application and implementation of the following strategies in flood prediction and early warning: Criteria for smart water city flood prediction and early warning Establishment of city-scale urban flood prediction Establishment of flood early warning center Application of ICT-based technologies in city flood prediction and early warning system Application of ICT-based technologies in flood information communication	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city satisfied all of the criteria for the urban flood prediction and early warning system mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the flood prediction and early warning, or the city does not apply flood prediction and early earning n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Drought

Indicator 2.2a	Drought damage index
Definition	Calculation of drought damage index in identifying the city's vulnerability to drought events (Sustainability)
Function	
Frequent occurrences of drought events can greatly affect the urban sustainable development. These occurrences disrupt the balance between urban water demand and supply which increases the vulnerability of the urban water cycle. Continuous drought events can cause significant depletion of ground water and reservoir storage, resulting in a wide range of socio-economic and environmental impacts. As the city's water demand increases, pressures in limited water supply makes drought problems more serious in the future. Understanding the severity of this effect on the urban population is important to implement further actions needed to supplement lacking water supply during drought season. Because of these periodic shortages of water supply due to lack of precipitation, institutional bodies implement drought adaptive response and strategies to manage the distribution of water supply.	
Data type	Total number of people affected by drought-based limited water supply, total number of population (Quantitative Analysis)
Calculation method	
The urban drought damage index can be determined by the number of people affected by the control measures during drought periods, given by: Drought damage index = Number of people affected by the water service interruption, limited supply, etc. / Total number of populations A low score for this indicator, corresponding to the city's preparedness on the limitation of water supply during drought events, is indicative of a smart water city.	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value Description Score 4 < 0.01 Calculated Drought damage index is less than 0.01 3 0.01 – 0.05 Index is within 0.01 to 0.05 2 0.05 – 0.1 Index is within 0.05 to 0.1 1 > 0.1 Index is more than 0.1 0 No data City has no data on drought-related limited water supply population n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.2b	Recent drought occurrences
Definition	Occurrences of recent drought events in the city, affecting water supply and distribution (Sustainability)
Function	
Drought has severe impact on the environment and society, including shortages on water supply, deterioration of quality, decrease in ground water levels and more. Severe drought events can seriously deplete water storage in the reservoirs, imposing challenges in the current water usage of the population. This indicator shall be assessed based on the frequency of occurrence of drought events in the city for the past couple of years.	
Data type	Information on occurrence of recent drought events based on drought standards (table) (Qualitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 Occurrence of drought event within the last 10 years 3 Occurrence of drought event within the last 5 years 2 Occurrence of drought event within the last 1 years 1 Occurrence of drought event within the last year 0 City is susceptible to drought events n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.2c	Drought hazard mapping
Definition	Application of ICT-based mapping of drought-prone areas (Smartness) (Data)
Function	
Drought risk assessment and mapping is an important element in city-scale drought management since it assists in identifying drought risk areas, allowing for planning, preparation and mitigation of possible drought impacts. These hazard maps area implemented based on hydro-meteorological indicators such as the Normalized Differences Vegetation Index (NDVI) and Standardized Precipitation- Evapotranspiration Index (SPEI) through the application of remote-sensing data to determine potential drought hazards.	
Data type	Information on application of city-scale drought hazard mapping (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of different types and techniques in drought hazard mapping. Criteria for smart water city drought hazard mapping Application of drought hazard mapping based on calculation of Standard Precipitation Index (SPI), Hydrological drought indices, Normalized Vegetation or Soil moisture Index, etc. Application of drought forecasting models, or climate projected drought models Application of drought impact assessment Application of drought hazard mapping using historical drought data	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city satisfied all of the criteria for drought hazard mapping mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the city-scale drought hazard mapping, or the city does not apply drought hazard mapping n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.2d	Drought information and emergency water supply facilities
Definition	Operation of city-scale emergency water supply facilities and drought information and preparedness system (Smartness) (Infrastructure)
Function	
The negative effect of drought can also be prepared for through municipal infrastructure services. Drought conditions have the potential to affect critical infrastructure sectors including water supply and water waste, energy, agriculture, and food, as well as public health. These infrastructures are especially vulnerable due to their interdependence with each other; where strains on one system can disrupt the services on others as well.	
Data type	Information on city-scale drought information and management infrastructures for emergency water storage (Quantitative Analysis)
Calculation Method	
This indicator is based on the implementation of drought management and availability of emergency water supply facilities. Criteria for smart water city drought information Application of city-scale drought monitoring and information Availability of drought information (hazard map, forecasts) to public (website, television, etc.) Availability of emergency water supply facilities in the event of water supply shortage due to drought Application of ICT in drought data collection and monitoring	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city satisfied all of the criteria for drought information and emergency water supply mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the city-scale drought information, or the city does not apply drought information n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.2e	Drought prediction system
Definition	Operation of drought advanced warning system and advanced information services (Smartness) (Services)
Function	
The establishment of a drought warning system is necessary in warning local communities regarding drought risk, strengthening preparedness and decreasing potential risks associated with agriculture and water resource management, and subsequent effect in food production. An efficient early warning system can provide appropriate lead time for local decision makers to address drought threat mitigation, such as facilitating emergency food supply, designing water harvesting programs and introduction of dry-land farming initiatives, etc.	
Data type	Information on city-scale drought advanced warning systems (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of ICT-based technologies in drought prediction system. Criteria for smart water city drought prediction system Application of drought model for drought forecasting Application of ICT in drought early warning systems Application of remote-sensing instruments for drought monitoring Application of ICT in drought forecast information dissipation	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city satisfied all of the criteria for drought prediction system mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the city-scale drought prediction system, or the city does not apply drought prediction system n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Climate change

Indicator 2.3a	Climate adaptation planning
Definition	City-scale climate change adaptation planning (Sustainability)
Function	
Cities are particularly vulnerable to the negative impacts of climate change. These impacts come in a lot of forms such as urban flooding, heatwave, and more. Planning is crucial in identifying and addressing these vulnerabilities effectively. Such climate change adaptation and planning program can include strategies for promoting low emission developments, climate extreme adaptation plans, city resilience profiling, robust urban planning and design, etc.	
Data type	Information city-scale climate adaptation planning (Qualitative Analysis)
Calculation Method	
This indicator is based on the implementation of climate adaptation planning of the city. Criteria for smart water city climate adaptation planning Establishment of climate change adaptation measures and planning guidelines for the city Use of climate models and climate-projected hazard maps Assessment and analysis of climate risk areas Establishment of capacity building and community climate education	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city satisfied all of the criteria for climate change adaptation planning mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the city-scale climate change adaptation, or the city does not apply climate change adaptation planning n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 2.3b	**Application of renewable energy**
Definition	Information on application of renewable energy in the city (Smartness) (Services)

Function

Cities account for the majority of the world's energy usage consequently producing the predominant amount of greenhouse gas emissions. Therefore, efforts in the implementation and application of renewable energy sources are excellent indicators of smart water cities. Some of these applications include carbon footprint reduction, energy saving strategies, zero emission devices, eco-friendly transportation, etc. The usage of solar panels in wind turbines to power public devices such as smart streetlights, weather sensors, smart charging stations, heating and cooling systems, electric or biogas-based public transportations is helpful in effectively utilizing renewable energy.

Data type	Information on city-scale application of renewable energy (Qualitative Analysis)

Calculation Method

This indicator is based on the application of renewable energy strategies of the city.
Criteria for smart water city renewable energy application
Carbon footprint reduction, zero emission devices, e-transportations
Energy saving strategies
Eco-friendly facilities, green infrastructures, rainwater harvesting
Alternative power source (hydropower, solar, wind, geothermal etc.)

Evaluation method

This indicator shall be scored depending on whether the above recommendations are satisfied.
Rating Description Score
4 The city satisfied all of the criteria for renewable energy application mentioned above

3 At least three of the criteria are satisfied
2 At least two of the criteria are satisfied
1 At least one of the criteria is satisfied
0 City has no information on the city-scale renewable energy application, or the city does not apply renewable energy application
n/a Not applicable

Sources of information

Please indicate the source of this information

Water Supply and Treatment

Water source

Indicator 3.1a	Water source quality monitoring frequency
Definition	Frequency at which the water source is being monitored (Sustainability)
Function	
Water quality monitoring system detects the level of pollution in urban water and ensures the safety of drinking water supply to the population. High-frequency remote monitoring systems are more preferable due to a much finer temporal measurement scales possible and reduced cost as compared to traditional water quality sampling. Modeling water quality in finer frequency also reduces the possibility of uncertainty and allows capture of transient events. The detailed water source monitoring facilitates timely compliance with regulations, enhancing understanding of hydrological cycles and empowers managers with accurate water data information.	
Data type	Water quality sampling inspection data timeseries in city water source (dam, groundwater, etc.) (Quantitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Interval Description Score 4 ≤ hourly Raw water quality observations are performed at hourly or less than hourly interval 3 Daily Observations performed at daily interval 2 Weekly Observations performed at weekly interval 1 > Weekly Observations performed at more than weekly interval 0 No data City has no data on raw water quality monitoring frequency, or no water source quality measurements are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.1b	Water resource availability
Definition	Available water source as compared to city water consumption (Sustainability)
Function	
The assurance of availability of adequate water supply is increasingly important as population continuously concentrates in urban areas. Rapidly growing urban demands are straining local and regional water sources, water shortages reflect deeper concerns about the impact of climate change, urban population growth and environmental regulations on water supplies. Understanding and managing the balance between the water availability and consumption ensures efficient water allocation, prevention of over-extraction and depletion of limited resources.	
Data type	City available water supply (m3) and water use (m3) (Quantitative Analysis)
Calculation method	
The water availability / use index (WI) is computed based on Thompson (1999), defining the level of water shortage through water supply-demand situation, expressed as: Water reliability index = (Volume of available water (m3) / total volume of water consumption (m3)) * 100	
References	Thompson, S.A. (1999). Hydrology for Water Management. VT. USA.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value Description Score 4 > 100 Calculated water reliability index is more than 100 % 3 90 – 100 Index is between 90 to 100 % 2 80 – 90 Index is between 80 to 90 % 1 < 80 Index is less than 80 % 0 No data City has no data on water availability and water consumption n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.1c	Water source data automation and quality assurance
Definition	Application of automated and real-time water source monitoring instruments and instrument calibration quality assurance (Smartness) (Data)
Function	
The application of continuous real-time information on water quality is necessary for decision-making specifically for drinking water treatment, regulatory programs, recreation and for public safety. The improvement in the frequency of data collection provides a better understanding of factors that can affect the quality of urban drinking water. The recent advances in water quality monitoring provides an increased awareness in the issues in the status of drinkability of the water supply. Some of these technologies include innovative water quality sensors, multiple-sensor monitors, data recorders and transmission equipment. The advantages of installation of real-time and continuous water quality monitoring instruments are as follows: (1) Data can be available readily to end-users online, (2) dense and continuous data can improve the knowledge and understanding in the relationship between water quality and changes in environment, (3) can improve the understanding on factors that affect the water quality, (4) can provide richer data sets for tool and model development, (5) real-time notifications from water resource managers, (6) can decrease time and cost associated with manually sampling data, etc.	
Data type	Information on application and quality assurance for real-time water source monitoring devices within the city (Qualitative Analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in water source monitoring: Water source observation method and quality assurance Real-time and automated recording of water source Existence of auto-calibration function within the water source monitoring instrument or system Regular calibration of the water source monitoring instrument Recorded water source data quality assurance	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city utilizes all of the water source monitoring automation and calibration criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the water source monitoring automation and calibration, or city does not apply automation and calibration in water source quality monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.1d	ICT-based water source data collection process
Definition	Utilization of ICT-based technologies in water source data collection (Smartness) (Infrastructure)
Function	
The establishment of a managing entity specifically for water source data collection, processing and analysis is an important aspect in managing water supply source. Efficient management of water resources needs timely access and dissemination of comprehensive and reliable data for effective decision making. This information must be easily accessed by the population, providing them with information and understanding, which might provide guidance for them to have an active participation in the water supply management. This indicator shall be evaluated bases on the application of ICT-based water source monitoring instruments such as (Park, et al., 2020): basic sensor monitoring systems (i.e., colorimetry, membrane electrode, optical sensor, thermistor), organic compound monitoring (electrochemical sensor), nutrient monitoring, harmful algal blooms monitoring (satellite images, fluorometric sensors) and water physical status (acoustic sensors, etc.).	
Data type	Information of the usage of water source monitoring instruments for the city (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of the following ICT-based technologies in water source quality observation. Water source quality observation ICT-based technologies Stream water quality sensors (multi-, single parameter sensors, etc.) Automatic water samplers Spectrophotometers, microbial detection equipment Data loggers and telemetry system, Communication systems, environmental monitoring software, system controller, etc., data transmission and monitoring instrument	
References	Park, J., Kim, K. and Lee, W. (2020). Recent advances in information and communications technology (ICT) and sensor technology for monitoring water quality. Water, 12, 2.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city utilizes all of the ICT-based water source quality monitoring instruments criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the application of ICT in water source quality monitoring, or city does not apply ICT in water source quality monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.1e	Water source data accessibility
Definition	Urban population access to water source data (Smartness) (Services)
Function	
The public's access to important water resource information such as the status of water source quality can be used to identify potential water contaminations that can affect the health of the consumers. Easy access to these kinds of information also promotes transparency from water monitoring agencies that can help the relation between the public and water managers. This indicator shall be evaluated based on the availability and convenience of access of water source data to the general public.	
Data type	Information on the ease of public access to water source data (Qualitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 Open online access of complete observed water source data 3 Open online access of partial or incomplete water source data 2 Manual retrieval of water source data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to water source data (i.e. data only available within intergovernmental agencies) 0 City has no information water source data accessibility, or data is not available to public access n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Drinking water treatment

Indicator 3.2a	Drinking water quality compliance
Definition	Drinking water quality compliance with water quality standards (Sustainability)

Function

The quality of readily available water is important to be consistently monitored and improved, whether it is used for drinking, domestic use, food production or even recreation purposes. Contaminated tap water can transmit diseases such as diarrhea, cholera, typhoid, etc. which are estimated to cause more than 400,000 deaths per year. Possible sources of tap water contaminations include Accidental mixing with sewage fluids, reaction from natural occurring chemicals and minerals, land use practices (ie., fertilizers, pesticides), manufacturing processes and malfunctions from wastewater treatment sites. Constant monitoring of tap water quality is therefore essential for public health through effective water supply management.

Data type	Tap water quality inspections, City drinking water standards (Quantitative Analysis)

Calculation method

The evaluation for the urban tap water quality is assessed based on established health standards from the World Health Organization. For example, the Seoul Metropolitan Government (2022) established guidelines for analysis and management of urban tap water quality are listed as:
Substances Unit Water quality standard Guidelines Description
Minerals mg/L - 20-100 Human body essential elements
Total organic carbons mg/L 5.0 1.0 or less Health benefits
Turbidity NTU 0.5 0.3 or less Health benefits
Residual chlorine mg/L 4.0 0.1~1.3 Odor disinfection
2-MIB ng/L 20 8.0 or less Eliminate odor-causing substances
Geosmin ng/L 20 8.0 or less Eliminate odor-causing substances
Copper mg/L 1.0 0.05 or less Pure water producing substance
Iron mg/L 0.3 0.05 or less Red water producing
Temperature °C - 4~15 Refreshing sensation for drinking

The percentage for drinking water standard compliance is defined as:
Water standard compliance percentage (%) =
(Number of compliance water quality standards / Total number of inspections) * 100

References	Seoul Metropolitan Government (2022). Seoul tap water Arisu. Accessed in seoulsolutions.kr/sites/default/files 24 Aug 2022.

Evaluation method

This indicator shall be scored depending on whether the above recommendations are satisfied.
Rating Value (Percentage) Description Score
4 100 Percentage compliance of city water quality inspection for drinking water quality standards is 100 %
3 97 – 99 Compliance percentage is between 97 to 99 %
2 95 – 97 Compliance percentage is between 95 to 97 %
1 < 95 Compliance percentage is less than 95 %
0 No data City has no data on water quality compliance inspections, or no water quality inspections are performed
n/a - Not applicable

Sources of information

Please indicate the source of this information

Indicator 3.2b	**Drinking water quality monitoring frequency**
Definition	Frequency at which water quality output from the city drinking water treatment plants are being monitored (Sustainability)
Function	
It is necessary to have continuous and real-time information on the quality of water discharged from the drinking water treatment plants to ensure the safety of water production. A proper and frequent monitoring program applied in the treatment plants can reduce the associated risk with the chemical balance, compliance with environmental regulations, improved operation quality and increased water and energy savings. Higher degree of precision of water treatment control and monitoring is required to improved reliability and quality, this high precision is achieved by continuous online monitoring using automatic measuring instruments.	
Data type	City drinking water treatment plant water quality timeseries data (Quantitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 ≤hourly The quality of drinking water from water purification plants are being monitored at an hourly or less than hourly interval 3 Daily Monitoring at daily interval 2 Weekly Monitoring at weekly interval 1 > weekly Monitoring at more than weekly interval 0 No data City has no data on drinking water quality data frequency, or no drinking water quality inspections are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.2c	Drinking water data automation and quality assurance
Definition	Status of data automation and quality assurance in the city drinking water purification plants (Smartness) (Data)
Function	
The application of smart water technologies holds promising solutions for problems in water pollution in treatment plants. Another quality of the application of smart technologies in water purification management is process automation, which improves operation, performance, assist supervision, operational safety and reduces potential for human error. The application of these instruments can greatly help in preventing unexpected occurrences in multi-regional water supply, such as leakages and instrument malfunctions. This indicator shall be assessed based on the status of applicated of automatic monitoring devices and implementation of instrument calibrations within the city drinking water facilities.	
Data type	Information on application of automated system and smart technologies in the water purification system (Qualitative Analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in drinking water quality monitoring: Drinking water observation method and quality assurance Real-time and automated observation of drinking water quality Existence of auto-calibration function within the water quality monitoring instrument or system Regular calibration of the drinking water quality monitoring instrument Recorded drinking water quality data quality assurance	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city implements drinking water quality monitoring automation and calibration criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria are satisfied 0 The city has no information on the drinking water quality monitoring automation and calibration, or the city does not implement automation and calibration in drinking water quality monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.2d	ICT-based drinking water data collection process
Definition	Operation and management of ICT-based technologies in data monitoring for the city drinking water facilities (Smartness) (Infrastructures)
Function	
Efficient and reliable ICTs in centralized facilities, such as drinking water purification and wastewater treatment plants, are key factors in the development of Smart Water Cities. Real-time water quality monitoring system is applied in processes for drinking water supply, which requires real-time monitoring to maintain water quality standard, preventing unexpected accidents, such as water treatment machine malfunction and contamination of raw water. Reduction of the duration and costs of water quality monitoring and inventory activities, improvement of the efficient gains of water service providers, improves water service collection rates through ICT-based payment systems, ensure better services to the poor, and strengthens citizen voices and framework accountabilities. The indicator shall be assessed based on the application of ICT-based technologies such as automatic water samplers, smart meters (pH, turbidity, conductivity, DO), test kits (chlorine, coliform and E. coli), spectrometers, cytometers etc. in the city drinking water treatment plant.	
Data type	Information on application of ICT-based technologies in the city drinking water treatment facilities (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of the following ICT-based technologies in drinking water quality observation. Drinking water quality observation ICT-based technologies water quality sensors (multi-, single parameter sensors, etc.) Automatic water samplers Spectrophotometers, microbial detection equipment Data loggers and telemetry system, Communication systems, environmental monitoring software, system controller, etc., data transmission and monitoring instrument	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city utilizes all of the ICT-based drinking water quality monitoring instruments criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the application of ICT in drinking water quality monitoring, or city does not apply ICT in drinking water quality monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.2e	Drinking water data accessibility
Definition	Status of public ease of access to drinking water data records (Smartness) (Services)
Function	
Accessibility to the water data from Drinking water purification facilities embodies transparency, accountability, and informed decision making from the public. The availability of these data to the community provides information on the quality and safety of their drinking water. Individuals can make informed decisions about their water consumption and can take necessary precautions by understanding the purification process and potential presence of contaminants on the drinking water supply.	
Data type	Information on the accessibility of drinking water treatment data (Qualitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 Open online access of complete observed drinking water data 3 Open online access of partial or incomplete drinking water data 2 Manual retrieval of drinking water data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to drinking water data (i.e. data only available within intergovernmental agencies) 0 City has no information on drinking water data accessibility, or data is not available to public access	
Sources of information	
Please indicate the source of this information	

Indicator 3.2f	Advanced water purification treatment
Definition	Operation of advanced water purification treatment and disinfection process in the drinking water treatment plant (Smartness) (Service)
Function	
The water purification process needed to meet the standards for medical, pharmacological, chemical and industrial qualifications for safe potable water. The procedure reduces or eliminates the risk for contaminants such as suspended particles, parasites, bacteria, etc. Disinfection method is also necessary to remove harmful pathogenic microbes responsible for water-borne diseases, improving odor and taste of the treated drinking water.	
Data type	Information on the application of advanced technologies in water treatment and disinfection process (Qualitative Analysis)
Calculation method	
The process of advance technology in water purification plants includes the following procedures (US EPA, 2022; University of California, 2022): Advanced water purification treatment process criteria Granular or activated carbon, Ozonation Packed tower aeration Reverse osmosis, water oxidation, Chemical precipitation and coagulation Membrane filtration, Biofiltration, Desalination, UV Disinfection	
References	University of California (2022). What are the advanced water treatment processes? Accessed in engineeringonline.ucr.edu 08 Aug 2022.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city utilizes all of the advanced water purification treatment criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the application of water purification advanced water treatment, or city does not apply advanced water treatment n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Water distribution

Indicator 3.3a	Water supply network distribution
Definition	Percentage of extent and distribution of water supply network (Sustainability)
Function	
The city water pipe distribution system is the network of delivering treated water supply to the consumers in the city. The system is constantly analyzed to identify the optimize the design, operation and maintenance. The requirements for appropriate water pipe distribution for a city-level area are as follows: The quality of water should not be contaminated during the distribution in the pipe system, should have the capability to supply water at all intended areas with enough pressure, should have the capability to supply the required water for fire hydrants, no consumer should be without water supply during pipe repair, should be fairly water tight to prevent losses from leakages, and should be laid one meter away / above the sewer line.	
Data type	Information on extent of water supply pipe network within the city (Quantitative Analysis)
Calculation method	
The extent at which the water distribution reaches as far as possible means that the majority of the urban population receives adequate water supply services. The percentage of pipe distribution system can be computed as: Percentage extent of water pipe distribution (%) = (Number of population with access to water supply / Total number of population) * 100	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description Score 4 100 Percentage of with access to water supply distribution network is 100 % 3 95 – 100 Percentage is within 95 – 100 % 2 90 – 95 Percentage is within 90 – 95 % 1 85 – 90 Percentage is within 85 – 90 % 0 < 85 Percentage of urban population with access to water supply distribution network is less than 85 % n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.3b	Aging water supply pipe status
Definition	Percentage of water supply network aging pipelines (more than 30 years old) (Sustainability)
Function	
Due to frequent contact with water, water distribution pipes are susceptible to degradation as they age. The accumulation of corrosion and suspended particles within the inside wall of the pipes increases the pipe roughness and consequently reduces the pipe diameter. The increase in pressure due to smaller pipe diameters causes water breaks and leakages, which accounts for huge water loss and maintenance expenses.	
Data type	Quantity of water supply pipelines installed more than 30 years ago (Quantitative Analysis)
Calculation method	
Water breaks also lead to water contamination. As pipe ages, a collection of organic materials begins to form around the walls, which might cause health problems when consumed by the population. According to Seoul Metropolitan Government (2017), the quality of transmission pipes deteriorates within 30 years, while water supply pipes are only good for 20 years. It is therefore of utmost importance to maintain the condition of the water pipes by constant maintenance and replacement. The percentage of aging water distribution pipelines can be calculated as: Percentage of aging pipelines (%) = (Extension of pipes lines installed more than 30 years ago (km) / total extension of urban pipelines (km)) *100 Lower percentage to non-existence of deteriorated pipelines is a good indicator of well-functioning water supply for a smart water city.	
References	Seoul Metropolitan Government (2017). Water Distribution: Old pipe network maintenance project. Accessed in seoulsolution.kr/content/water-distribution-old-pipe-network-maintenance-project 21 Sept 2022.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 0 – 5 The percentage of water supply pipelines that are installed more than 30 years ago is less than 5 % 3 5 – 10 Percentage is from 5 to 10 % 2 10 – 15 Percentage is from 10 to 15 % 1 > 15 Percentage is greater than 15 % 0 No data City has no data on aging water supply pipelines n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.3c	Revenue water percentage
Definition	Percentage of revenue and non-revenue water (Sustainability)
Function	
Urban water supply pipelines are used as a means to transport water to the consumers across the city. However, these networks are vulnerable to challenges such as water loss due to pipe leaking, which is recognized as a costly problem, strongly linked to waste of natural resources, environmental pollution, and financial loss. Pipe leakages occur when water fills out from the pipe network other than controlled actions. The factors that cause the pipe leaks are: pipe material poor quality, aging and deteriorating pipes, insufficient pipe diameter, water pressure, ground movement around the pipe, accidental hitting, use of unsuitable materials for the pipe basis and coverage, incorrect installation, pressure from overhead, corrosive waters, climate conditions, temperature changes, etc.	
Data type	Total water supply volume and total city water consumption (Quantitative Analysis)
Calculation method	
The percentage amount of revenue water can be computed as: Percentage of revenue water (%) = (Amount of total water consumption (m3) / Total amount of water supplied from the treatment plant (m3)) * 100 According to Klepka et al. (2015), the estimated average water loss in water network is about 5% in well-maintained and up to 30% in older pipe networks.	
References	Klepka, A. et al (2015). Leakage detection in pipelines – The concept of smart water supply system. 7th ECCOMAS Thematic conference on Smart Structure and materials.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 > 95 The percentage of revenue water is more than 95 % 3 85 – 90 Percentage is between 85 to 90 % 2 80 – 85 Percentage is between 80 to 85 % 1 < 80 Percentage is less than 80 % 0 No data City has no data on water consumption and water revenue n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.3d	Water storage effective capacity
Definition	Status of management of urban water distribution effective storage capacity and water supply stability (Sustainability)
Function	
Water supply distribution management is necessary in the development and implementation of management designs for rules and regulations to provide adequate supply of water for human consumption, agricultural irrigation, industrial usage, hydropower generation, etc. (Freshwater Inflows, 2022).	
Data type	Daily maximum water supply volume and water distribution storage capacity (Quantitative Analysis)
Calculation method	
The evaluation for the water supply distribution effective capacity and stability of water supply can be assessed as: Reservoir effective storage capacity = ((Maximum water supply per day (m3) / maximum water storage capacity per day)) * 100	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 < 70 The effective reservoir storage capacity percentage is less than 70 % 3 70 – 75 Percentage is between 70 to 75 % 2 75 – 80 Percentage is between 75 to 80 % 1 > 80 Percentage is greater than 80 % 0 No data City has no data on daily and maximum storage capacity n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.3e	Water supply data automation and quality assurance
Definition	Status of water supply data automation and instruments quality assurance (Sustainability)
Function	
Incorporating automation and quality assurance measures for water distribution data management enhances efficiency of operation of water supply and distribution, can reduce the likelihood of human error in data collection, minimizing risk of incorrect information necessary for decision-making. Real-time monitoring allows water supply operators to immediately respond to anomalies leading to leak detection, pressure variations and other issues. Consistent instrument calibration of monitoring equipment promotes data accuracy and integrity, this ensures that water data complies with standards and regulatory requirements.	
Data type	Information on automation and instrument calibration procedures for water supply monitoring (Quantitative Analysis)
Calculation method	
This indicator is based on the implementation of the following criteria in water supply monitoring: Water supply observation method and quality assurance Real-time and automated monitoring of water supply Existence of auto-calibration function within the water supply monitoring instrument or system Regular calibration of the water supply monitoring instrument Recorded water supply data quality assurance	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city implements the water supply monitoring automation and calibration criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 The city does not have information on the water supply automation and calibration, or the city does not apply automation and calibration in water supply monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.3f	Water supply pipe network maintenance
Definition	Implementation of water supply pipe maintenance system (Smartness) (Infrastructure)

Function

Pipe maintenance and operation ensures the continuous sustainable service provision, preventing decline leading to greater water losses, financial losses, and health risk to urban consumers. The main purpose of the water distribution system is to provide reliable and adequate supply of safe drinking water to the population. The water supply operation involves the procedures required to deliver the service, and maintenance involves activities to keep the system in good operational condition. Consistent maintenance of water pipelines ensures uninterrupted water supply, preventing pipe bursts that can be costly to repair and. Some of the benefits of having an established pipe maintenance system are the ability to detect early pipe leakages, prevent water-borne diseases, allows reduction of water consumption, and hence saves time and money.

Data type	Information on implementation of pipe maintenance system (such as custom washing, automatic drain equipment, rust prevention, damage, and leak detection) (Quantitative Analysis) (Infrastructure)

Calculation Method

This indicator is based on the application of the following ICT-based technologies in water supply pipe maintenance systems.
Water supply pipe maintenance system ICT-based technologies criteria
Real-time pipe sensors for leak detection, pressure and valve gauges
Remote sensing-based technologies, GIS, Drones, Robotics, CCTV
Machine learning predictive analysis, IoT.
AI-based maintenance systems, Early warning leakage devices

Evaluation method

This indicator shall be scored depending on whether the above recommendations are satisfied.
Rating Description Score
4 The city utilizes all of the ICT-based technologies in water pipe maintenance system criteria mentioned above
3 At least three of the criteria are satisfied
2 At least two of the criteria are satisfied
1 At least one of the criteria is satisfied
0 City has no information on the ICT-based technologies in water pipe maintenance system, or city does not apply ICT-based technologies in water pipe maintenance system
n/a Not applicable

Sources of information

Please indicate the source of this information

Indicator 3.3g	Smart water meter reading
Definition	Real-time monitoring, measuring and application of remote-control system for water supply network (Smartness) (Infrastructure)
Function	
Water reading equipment was originally set in place for the purpose of customer water billing, and consequently water conservation. With smart water reading however, water consumers can access the amount of water used and usage pattern in real time, allowing them to limit the water usage when. In addition, information from real-time smart water meters constitutes a key component in water management system, enabling users to be mindful of their water consumption, alerting them to abnormal water usage and help conserve water. Some of the smart water meter functions are as follows. (1) To capture water readings, (2) to limit water remotely, (3) to act as a water leakage detector, (4) to monitor water pressure, and (5) to share water reading data to consumers. The use of these advanced technologies is necessary to better meet the demand of consumers and optimize the availability of water supply.	
Data type	Information on application of smart flow metering instruments (Qualitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 > 30 The percentage of smart water meter installations in the city is greater than 30 % 3 20 – 30 Percentage is within 20 to 30 % 2 10 – 20 Percentage is within 10 to 20 % 1 < 10 Percentage is less than 10 % 0 No data City has no information on smart water meter installations, or no application of smart water reading in the city n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.3h	Water supply data accessibility
Definition	Publics access to water supply data (Smartness) (Services)
Function	
The ease of public access to municipal water supply and distribution data aids transparency and accountability between the residents and water authorities. This also enables consumers to monitor their usage of water, which can instigate water conservation efforts, identify potential water leakages, and adapt water saving strategies.	
Data type	Information on accessibility city water supply and distribution data (Qualitative Analysis)
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 Open online access of complete observed water supply data 3 Open online access of partial water supply data 2 Manual retrieval of water supply data (i.e. official letter request, direct request to the office in charge) 1 Restricted access to water supply data (i.e. data only available within intergovernmental agencies) 0 City has no information water supply data accessibility, or data is not available to public access n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Wastewater treatment

Indicator 3.4a	Sewage pipe network distribution
Definition	Percentage of distribution of sewage network in the city (Sustainability)
Function	
According to the World Bank (2020), as of 2017, only about 45% of global population have access to centralized sanitation services. In prospective, the likeliness of suffering from water-borne illnesses such as diarrhea, is aligned with not having access to well-managed sanitation system. The benefits of having a centralized sanitary facility include higher capacity, reduction in the risk of septic system back up, reduction in the occurrence of septic odor and more marketability resulting in increased property values. This problem is gradually being resolved as more and more sewage network connections have been established in cities over the years.	
Data type	Number of populations with access to wastewater treatment and sewage network, total number of population (Quantitative Analysis)
Calculation method	
The evaluation for the percentage of urban population with access to sewage network can be expressed as: Percentage of urban population with access to sewage network (%) = (Number of population with access to sewage network / Total number of populations) * 100 For OECD (Organization for Economic Cooperation and Development) countries, the average percentage of population with households connected to wastewater treatment plants is about 83.4% (OECD, 2022). Hence, a threshold value of 90% shall be used to assess the performance for smart water cities in terms of sewage network distribution.	
References	The World Bank (2020). Connecting the unconnected: what it takes to get households to connect to sewerage networks. Accessed in worldbank.org/en/news/feature 24 Aug 2022. OECD (2022). Wastewater treatment (% population connected). Accessed in stats.oecd.org/ 25 Aug 2022.
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 100 Percentage of urban population with household connected to city sewage network system is 100 % 3 95 – 100 Percentage is between 95 to 100 % 2 90 – 95 Percentage is between 90 to 95 % 1 < 90 Percentage is less than 90 % 0 No data City has no data on population with access to sewage network n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.4b	Aging sewage pipe status
Definition	Percentage of aged sewage water pipelines (Sustainability)
Function	
The deterioration of sewage pipelines in the city can cause disturbance in the function of the pipes, which is transporting water wastes, but might also cause the city activities such as traffic obstructions caused be road cave ins, further resulting to social, environmental, and economic impacts. The pipe infrastructures deteriorate over time due to factors such as aging, environmental, and chemical factors, which may cause water quality issues when the wastewater contaminates the water supply pipes. Some of the additional causes of sewage pipe damage are as follows: Pipe structure fatigue such as traffic loading, thaw cycle, soil movement and erosion, pipe corrosion, broken or damaged pipe due to installation error, adjacent construction, root intrusion etc. and material decay, organic and inorganic deposits. When a sewage pipe is given away due to one of these reasons, people might be exposed to toxic gas that had built up over the sewer lines, which can impose hazard in public health. Therefore, the aging status of the sewage pipe is an important aspect to be accounted for.	
Data type	Extension of deteriorated sewage pipelines (More than 30-year-old), total pipe extension (Quantitative Analysis)
Calculation method	
The percentage of aging sewage pipelines are calculated as: Percentage of aging sewage pipes (%) = (Extension of aging sewage pipes (m) / total extension of the urban sewage pipes (m)) * 100	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (Percentage) Description Score 4 < 5 The percentage of sewage pipes lines that are more than 30 years old is less than 5 % 3 5 – 10 Percentage is from 5 to 10 % 2 10 – 15 Percentage is from 11 to 15 % 1 > 15 Percentage is greater than 15 % 0 No data City has no data on aging sewage pipelines n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.4c	Sewage treatment monitoring frequency
Definition	Frequency at which the water from sewage treatment plants are being monitored (Sustainability)
Function	
Municipal wastewater discharges for harmful chemical substances must be analyzed on a regular basis. The probability of failure event detection depends on the sensitivity of the processing parameters and the monitoring frequency of the instruments. The evaluation of treatment efficiency requires dynamic monitoring of influent and effluent water quality. The high sampling frequency for automatic monitoring and low sampling frequency for manual laboratory sampling can range from 15 min to monthly interval (Song et al., 2022).	
Data type	Wastewater treatment output observation timeseries data (Quantitative Analysis)
Reference	Song, S., Sheng, S., Xu, J. and Zhao, D. (2022). What is the suitable frequency for water quality monitoring in full-scale constructed wetland treating tail water? Water. 14 (15).
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Frequency Description Score 4 ≥ Daily Sewage treatment monitoring is performed on a daily basis 3 Weekly Monitoring is performed at least weekly interval 2 Monthly Monitoring is performed at least monthly interval 1 < Monthly Monitoring is performed less than monthly interval 0 No data City has no data on sewage water treatment monitoring frequency, or no sewage water treatment monitoring are performed n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.4d	Sewage water treatment data automation and quality assurance
Definition	Status of automation of wastewater treatment data and information on instrument calibration (Smartness) (Data)
Function	
A real-time wastewater monitoring system measures the quality of wastewater using measuring sensors, control panels, and communication units, to store and analyze the wastewater data in real-time. The access of sewage water data in various at various points during the treatment process is necessary for the management to address and handle potential problems that might occur during the operation.	
Data type	Information of wastewater data automation collection and quality assurance procedure (Qualitative Analysis)
Calculation Method	
This indicator is based on the implementation of the following criteria in wastewater monitoring: Wastewater observation method and quality assurance Real-time and automated monitoring of wastewater Existence of auto-calibration function within the wastewater monitoring instrument or system Regular calibration of the wastewater monitoring instrument Recorded wastewater data quality assurance	
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city implements wastewater monitoring automation and calibration mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 The city has no information on the wastewater automation and calibration, or the city does not implement automation and calibration in wastewater monitoring n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.4e	Separated sewage network status
Definition	Application of separated sewage network (Sustainability)
Function	
The combined sewer systems (CSS) referred to the sewer systems that convey both sanitary sewage and storm water network through a single pile line. CSS has the capability to convey flows to the wastewater treatment facilities during normal conditions. However, the capacity of CSS may be exceeded during heavy rainfall events, often causing the combined waste and storm water to overflow from pipes to the surface. These overflows can also cause problems to the receiving water bodies, since their flows have high concentrations of suspended solids, BOD, oils and greases, toxins, pathogenic microorganisms, and other contaminants. In addition, the odors, and solid deposits from the overflows to the receiving bodies can also compromise the city aesthetics during these events. One of the strategies to effectively reduce the impact of CSS application and its ecological risks is the implementation of sewer separation, or the practice of separating the combined pipe system for sanitary and storm water discharges. The positive effects of sewer separation include Reduction in basement and street flooding, elimination of sanitary discharges to urban water bodies, decrease in the effect on the aquatic species and habitats, decrease in pathogen contact and bacteria from domestic sewages and relief from regulations for the combined sewer systems. The application of sewer separation has been implemented and put into practice in most of the modern cities in the world.	
Data type	Separated and combined sewage and storm pipe network extension (km), total pipe extension (km) (Quantitative Analysis)
Calculation method	
The percentage of sewer pipelines the utilizes separate sewer system can be computed as: Percentage of separated sewer system (%) = Extension of separated sewer system (m) / total extension of urban pipelines (m) * 100	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied.	
Sources of information	
Please indicate the source of this information	

Rating	Value (Percentage)	Description	Score
4	> 70	The percentage of separated sewage and storm pipe system is more than 70 %	
3	65 – 70	Percentage is between 65 to 70 %	
2	60 – 65	Percentage is from 60 to 65 %	
1	< 60	Percentage is less than 60 %	
0	No data	City has no data on separated sewage system	
n/a	-	Not applicable	

Indicator 3.4f	Sewage pipe maintenance system
Definition	Status of maintenance of sewage pipe network (Smartness) (Infrastructure)
Function	
Sewage pipeline maintenance procedures are necessary to identify existing problems in the wastewater collection and transportation and examine structural integrity of the pipes. Pipe maintenance is crucial due to the cost and associated impact of pipe failures, understanding these issues allows better management of risk and can save extensive reactive repair expenses. This indicator shall be assessed whether the city's sewage network is being maintained through the use of technologies such as remote sensing and control system, sensors and telemetry, metal detectors, gas detection devices, sonars, machine learning, GIS, closed circuit television, mobile applications etc.	
Data type	Information the process of maintenance for city sewage pipe network (Qualitative Analysis)
Calculation Method	
This indicator is based on the application of the following ICT-based technologies in sewage pipe maintenance system. Sewage pipe maintenance system ICT-based technologies criteria Real-time sewage pipe sensors for leak detection, pressure and valve gauges Remote sensing-based technologies, GIS, Drones, Robotics, CCTV Machine learning predictive analysis, IoT (Internet of Things) AI-based maintenance systems, Early warning leakage devices	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city utilizes all of the ICT-based technologies in wastewater pipe maintenance system criteria mentioned above 3 At least three of the criteria are satisfied 2 At least two of the criteria are satisfied 1 At least one of the criteria is satisfied 0 City has no information on the ICT-based technologies in wastewater pipe maintenance system, or city does not apply ICT-based technologies in wastewater pipe maintenance system n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.4g	Advanced sewage water treatment process
Definition	Application of advanced sewage treatment process (Smartness) (Infrastructure)
Function	
The water waste from households and industrial establishments imposes significant pressure on the urban aquatic environment due to the organic matters and contaminants being disposed to the water bodies. The levels of wastewater treatments can be broken down into (Water Corporation, 2023). Wastewater treatment levels Description Pre-treatment Physical removal of large objects in the water to prevent damage in the equipment Primary treatment Removal of fine particles through separation of settling and floating materials Secondary treatment Biological treatment that removes remaining organic matters, suspended solids, bacteria, viruses, and parasites Tertiary treatment Removal of remaining stubborn nutrients missed in secondary treatment.	
Data type	Information on the application of advanced treatment process for wastewater (Qualitative Analysis)
References	Water Corporation (2023). How wastewater is treated. Accessed in watercorporation.au 20 Dec 2023.
Calculation Method	
This indicator is based on the application of the following advanced sewage treatment process in the wastewater treatment facilities. Advanced water purification treatment process criteria Preliminary treatment (screening, grit removal, comminution, equalization) Primary treatment (solid waste removal, sedimentation, separation) Secondary treatment (bacterial decomposition, ozonation, oxidation processes) Tertiary treatment (membrane, ultra and nano-filtration, disinfection, activated carbon-absorption)	
Evaluation method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Description Score 4 The city wastewater facilities process until tertiary level of wastewater treatment 3 Process until secondary level of wastewater treatment 2 Process until primary level of wastewater treatment 1 Process only until preliminary wastewater treatment 0 City has no information on the process of advanced wastewater treatment, or city does not implement advanced wastewater treatment n/a Not applicable	
Sources of information	
Please indicate the source of this information	

Wastewater reuse

Indicator 3.5a	Application of recycled and reused wastewater
Definition	Percentage of reused and recycled rainwater and wastewater resource services (Sustainability)
Function	
While excessive stormwater can cause flooding, with proper management, rainwater can also be an excellent source of alternative water supply. Rainwater harvesting is an environmental-friendly practice of collecting and storing rainwater impermeable surfaces, such as building rooftops, traffic areas, and recycling the harvested water for various usages, most commonly irrigation, sanitary sewer flushing, water features, street cleaning and dust control, vehicle washing etc. Harvesting storm and rainwater can add to the maintenance and improvisation of the urban watershed hydrology, participate in the reduction of pollutants, reduction on the stress on infrastructures, reduction on the energy consumption and increase water conservation. For city-scale implementation of storm water reuse, the best management sustainable management systems are the tools and technologies that are not only aimed in preventing urban flooding but are also aimed to protect the urban aquatic integrity through removal of pollutants and treating the floodwater before its discharge back to the environment.	
Data type	Recycled and reused wastewater volume (m3), total city water usage (m3) (Quantitative Analysis)
Calculation Method	
The application of rainwater reuse and recycle for the city can be assessed as: Percentage of recycled/reused rainwater and wastewater (%) = (Volume of urban water undergoing recycling and reuse (m3) annually / Total volume of municipal used water annually (m3)) * 100	
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description Score 4 > 60 The percentage of reuse of recycled water for the city is more than 60 % 3 55 – 60 Percentage is from 55 to 60 % 2 50 – 55 Percentage is from 50 to 55 % 1 < 50 Percentage is less than 50 % 0 No data City has no data on recycled and reused wastewater, or no wastewater recycling are implemented n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

Indicator 3.5b	**Percentage recovery of sewage solid waste**
Definition	Percentage of recycled sludge materials (Smartness) (Services)
Function	
City sewage sludges or biosolids are wastewater treatment byproducts, normally a mixture of organic matters from human waste, food waste, microorganisms, chemical traces and inorganic solids from products and medicines. The main objective in treating sewage sludges is to reduce the harmful organism byproducts, reducing the risk for the environment and the population, to stabilize the sludge organic matters that had the potential to turn into harmful gases in the atmosphere, and decrease the final volume and consequently handling costs. The utilization of biosolid materials, such as in brick making, ceramic making, and inclusion in cement materials, as well as recycled into agricultural uses such as landscaping, could provide advantageous recycling process.	
Data type	Recycled sludge material volume (m3), total sludge material byproduct volume (m3) (Quantitative Analysis)
Calculation Method	
The application of recycled sludge material for the city can be assessed as: Percentage of recycled sludge materials (%) = (Volume of wastewater sludge materials being recycled (agriculture, construction, etc.) / Total sludge material byproducts) * 100	
Evaluation Method	
This indicator shall be scored depending on whether the above recommendations are satisfied. Rating Value (percentage) Description 4 > 90 The percentage of recycled sludge materials is more than 90 % 3 80 – 90 Percentage is from 80 to 90 % 2 70 – 80 Percentage is from 70 to 80 % 1 < 70 Percentage is less than 70 % 0 No data City has no data on sludge material recycling, or no solid waste recycling are implemented n/a - Not applicable	
Sources of information	
Please indicate the source of this information	

CHAPTER 9
GOVERNANCE AND PROSPECTIVE PILLAR

In Chapter 6, we examined the Governance and Prospective pillar of the Smart Water City Index, examining its 36 KPIs spread across twelve main categories and categorized into three primary domains: effectiveness, efficiency, and trust in Governance. This comprehensive set of KPIs collectively provides valuable insights into the local-level management of water resources.

Building upon this work, Chapter 9 takes a closer look at the evaluation procedures for urban water governance within the cities participating in the Smart Water Cities project. Here, we provide detailed guidance on gathering the necessary information for each KPI and we present the instructions on how to assign values to reflect the cities' performance. These guidelines cater to both local stakeholders and the evaluation team, ensuring a consistent approach to data collection and facilitating the interpretation of performance. In essence, this chapter serves as a practical manual for navigating the assessment of urban water governance, fostering a more coherent evaluation process.

1. General Guidelines for the Governance and prospective KPIs

To facilitate the measurement of each KPI within the Governance and Prospective pillar, we have developed guidelines containing specific information for each KPI. These guidelines comprise 36 tables providing clarification, examples, and targeted questions for each KPI. They also specify the type of evidence evaluators should collect from the cities. These documents serve as a roadmap for the data gathering process.

For each KPI, we provide five key aspects:

1. KPI Name: A concise label describing the measured aspect.
2. Function: Background information explaining what the KPI measures and its significance. This contextual information helps highlight the KPI's relevance, its correlation with other indicators, and its contribution to governance in the city.
3. Question: A focused query tailored to each KPI, honing in on the specific variable being measured. This precision allows for a detailed examination of the indicator, excluding unrelated aspects.
4. Response: the responses to these questions are of a qualitative nature. This means that they involve subjective judgments, observations, interpretations, or explanations by the local stakeholders themselves at the time of the self-evaluation, or by the evaluation team, when the verification or validation of the information provided is in place. In the context of water governance, a qualitative response describes, for instance, the level of community engagement in decision-making processes, the effectiveness of communication between stakeholders, or the degree of transparency in governance practices. These aspects cannot be easily expressed in numerical terms, but they provide valuable insights into the overall quality of water governance at the local level. Conscious of the difficulties of streamlining analysis and also with the purpose to enhance the comparability of the different assessments, we offer suggested answers in various instances. These serve as helpful references, but respondents are also encouraged to provide their own responses beyond the proposed options. Responses can be binary (Yes or No) or on a scale, with five statements for each indicator, allowing selection of the statement that best aligns with local circumstances. The options vary based on formal adoption and actual implementation of measures:
   - Excellent: Both adopted and fully implemented.
   - Good: Adopted but only partially implemented, resulting in operational gaps.
   - Moderate: Adopted but not yet operational.
   - Poor: Under development (preliminary measures adopted).
   - Bad: No measures adopted.

   Depending of the response provided, a value is given, according to the scoring system explained in Chapter 6.
5. Supporting Evidence: It is crucial to provide justifications for the selected response. When a measure is formally adopted, respondents are asked to specify the specific provisions, legislation, or policy document governing it. Conversely, if there are implementation gaps, respondents should substantiate them by identifying encountered problems. Supporting evidence may originate from various stakeholders, including local authorities,

customers, local associations, companies, and other relevant parties. The tables provided invite both local stakeholders and evaluators to indicate the sources of information comprehensively.

2. Analyzing performance in Governance in Smart Water cities

The following 36 tables are designed to streamline the evaluation process of the governance pillar by providing structured guidance on how to assess specific aspects of urban water governance, dividing it into categories. A formatted version of these tables, tailored to the local authorities and accompanied with instructions, are provided at the beginning of the analysis phase to the local stakeholders.

Effectiveness

Indicator 1.1.a. Existence of a clear allocation of responsibilities in water resources management and water services provision	
Function	This indicator examines if the distribution of responsibilities is comprehensive and detailed enough so every stakeholder knows their roles and duties. A clear allocation of responsibilities is important in water resources management, urban water safety and all water services provision because it helps to ensure that stakeholders understand their roles and responsibilities, promotes efficient use of water resources, and ensures sustainable provision of water services. In water resources management, various stakeholders such as national and local governments have different roles and responsibilities in managing water resources. If these roles and responsibilities are not clearly defined, there may be conflicts and duplication of efforts, which can lead to inefficient use of water resources and even water scarcity. Clear allocation of responsibilities helps to avoid such conflicts, ensure coordination among stakeholders, and promote efficient use of water resources. In water services provision, different entities such as different water utilities and regulatory bodies have different roles and responsibilities. Clear allocation of responsibilities helps to ensure that each entity performs its role effectively, and that water services are provided efficiently and sustainably. A clear allocation of responsibilities is usually established by legal texts and policy documents.
Q1.1.a	Is there a clear allocation of responsibilities among relevant stakeholders in water resources management and water services provision in your city?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but underdevelopment No For Urban water resources management Urban water safety Wastewater Water quality and treatment
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.1.b. Existence of department(s) at the city level in charge of local water-related responsibilities	
Functions	The existence of a department or departments at the city level in charge of local water-related responsibilities is important for several reasons. In particular, a department dedicated to managing water-related issues at the city level is equipped to understand the local context, including the availability of water resources, the needs of the city, and the status of the existing infrastructure. This circumstance can inform policy decisions and ensure that they meet the needs of the city. Also, a department can respond more quickly to emerging issues and changing circumstances related to water management at the city level. This can help ensure that policies remain relevant and effective over time.
Q1.1.b	Does a department or departments in charge of local water-related responsibilities exits?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of the information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.1.c	Existence and implementation of mechanisms to review roles and responsibilities of the cities, to diagnose gaps, and to adjust when need be
Function	An effective allocation of roles requires developing mechanisms to review the roles and responsibilities of water stakeholders in the city to diagnose gaps and introduce adjustments. Some examples of these mechanisms are, for instance: Performance audits, which examine how different water actors perform in water resources management and water services provision; Reviews of regulatory frameworks, which may involve changes in how responsibilities are allocated amongst departments; city assessments reviews, etc. Benchmarking, which involves comparing the performance of a city in water resources management and water services provision with other cities or industry standards. This can help identify gaps in the allocation of responsibilities and areas for improvement. Other mechanisms may exist. Respondents are invited to indicate what these mechanisms are in the city.
Q1.1.c	Do mechanisms to review roles and responsibilities in water resources management and water services provision exist? Have they been used within the last two years?
Response	Please tick the option that better describe the existing situation Yes, and they are regularly employed Yes, but only employed occasionally Yes, but never employed Under development No Performance audits Reviews of regulatory frameworks Benchmarking If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information

Indicator 1.2.a	Existence and level of implementation of integrated water resources management policies and strategies that include the urban level and cities' features and water status
Function	An integrated water resources management policies and strategies that include the urban level contributes to water effectiveness. Integrated water resources management consider the entire water cycle, from water supply to wastewater treatment, and the interactions between different water sources, such as surface water and groundwater. This approach Includes the water needs of the urban population within the broader context of water management. Objectives such as addressing water scarcity, reducing pollution, considering the long-term impacts of urban planning, promoting water reuse, etc. can be better addressed by with an Integrated water resources management policies and strategies.
Q1.2.a	Do integrated water resources management policies and strategies that include the urban level and cities features and water status exist? How are they implemented?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.2.b	Existence and functioning of institutions managing urban water (not necessarily exclusively) at the hydrographic scale
Function	The existence and functioning of institutions managing urban water at the hydrographic scale is crucial to ensure a comprehensive approach to water management, promoting collaboration and coordination among stakeholders, encouraging measures for sustainable development and resilience, and supporting an efficient and effective management of urban water resources.
Q.1.2.b	Do institutions managing urban water at the hydrographic scale exist?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.2.c	**Existence and level of implementation of co-operation mechanisms for the management of water resources across water-related users and levels of government, including the local level.**
Function	The existence of particular cooperation mechanisms for the management of water resources across water-related users and levels of government is necessary for an effective integrated water resources management. Amongst them are the following: river basin management plans, shared approaches for financial or human resources, joint investments, common water allocation plans, shared information platforms at the river scale, etc.
Q.1.2.c	Do the mechanisms for cooperation for water resources management and water services provision exist? Are they employed regularly?
Response	Please tick the option that better describe the existing situation Yes, and they are regularly employed Yes, but only employed occasionally Yes, but never employed Under development No River basin management plans Shared approaches for financial or human resources Joint project investments Common water allocation plans Shared information platforms If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.3.a	Existence and implementation of cross-sectoral local policies and strategies promoting policy coherence between water and key related areas, in particular local environment, health, energy, agriculture, land use, and spatial planning
Function	The existence and implementation of cross-sectoral local policies and strategies promoting policy coherence between water and key related areas is necessary to ensure an integrated approach to local development, efficient use of resources, synergies and co-benefits, improved outcomes, and resilience to climate change. Coordination entails that water management is not viewed in isolation but as part of a broader system that encompasses other sectors. For instance, the following policies need to be coordinated with local water policies to ensure water policy effectiveness. Environmental policies play a critical role in ensuring water policy effectiveness by protecting and preserving the quality of water resources. For instance, policies aimed at reducing pollution and managing land use can help prevent contamination of water sources and maintain water quality. Energy production and consumption have a significant impact on water resources, and policies related to energy production and efficiency can help reduce water use and protect water quality. For example, policies aimed at promoting renewable energy sources such as wind and solar power can reduce the need for water-intensive power generation. Urbanization and population growth are major drivers of water demand, and policies related to urban planning and development can help manage the demand for water resources. Policies aimed at promoting water-efficient building designs, landscaping, and infrastructure can help reduce water demand in urban areas. Access to safe and clean water is essential for human health, and policies related to health and sanitation can help ensure access to safe water resources. Policies aimed at promoting safe drinking water, wastewater treatment, and hygiene practices can help reduce waterborne illnesses and improve public health.
Q.1.3.a	Do cross-sectoral policies and strategies promoting policy coherence at the local level exist?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Water and environment Water and energy Water and urban planning Water and health
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.3.b	Existence and functioning of an inter-departmental body or institutions at the local level for horizontal co-ordination across water-related policies
Sources of information	The existence and functioning of an inter-departmental body or institution at the local level for horizontal coordination across water-related policies is necessary as the agency responsible for promoting policy coherence across different departments or sectors involved. It ensures that policies and strategies are aligned and that there is consistency and coherence in their implementation. Such department promotes policy effectiveness as it is responsible for ensuring that water policies are developed and implemented at the city level.

Q.1.3.b	Do interdepartmental bodies or institutions for horizontal coordination across water-related policies exist at the local level?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.3.c	**Existence and implementation of mechanisms at the local level to review barriers to policy coherence and/or areas where water and related local practices, policies, or regulations are misaligned.**
Function	It is essential to have mechanisms at the local level to review barriers to policy coherence and/or areas where water and related local practices, policies, or regulations. Examples of such mechanisms are the following, amongst others: Communication channels such as email, messaging apps, or virtual meetings to facilitate communication between departments. Regular meetings provide opportunities for departments to share updates, challenges, and feedback. Shared Goals and Objectives can help to align the priorities of different departments towards a common goal. Cross-department working teams can help promote collaboration. Conflict Resolution Mechanisms: can help to resolve any disputes between departments can help promote cooperation and reduce tension.
Q.1.3.c	Do mechanisms for facilitating policy coherence reviewing barriers and misalignment exist at the local level?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Communication channels Regular meetings Shared goals and objectives Cross department working teams Conflict resolution mechanisms If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.4.a	Existence and level of implementation of hiring policies with merit-based approach and transparent professional process of water professionals independent from political cycles
Function	The existence and level of implementation of hiring policies based on a merit-based and transparent professional and recruitment process of water professionals independent from political cycles is crucial for to reduce effective water management as it ensures competence and expertise, reduces political interference, increases accountability, improves continuity and stability, and enhances public trust.
Q.1.4.a	Do policies based on merit and transparent processes for recruiting water professional exist?
Response	Please tick the option that better describe the existing situation Yes, they exist Yes, with some deficiencies Yes, they exist, but no operational No, but under development No
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.4.b	Existence and functioning of mechanisms to identify and address capacity gaps in local water institutions
Function	This indicator examines the existence and functioning of mechanisms to identify and address capacity gaps in water institutions There are many different mechanisms and instrument that can help to identify and address capacity gaps in local water institutions, improving effectiveness in the local water system. Amongst them, for instance, are the following: Assessments of needs, which can help identify the areas where local water institutions lack the necessary skills and expertise. Capacity Building Workshops and Training Technical Assistance activities to provide to local water institutions with the guidance and support to address capacity gaps. Mentoring programs can be established to provide guidance and support to staff in local water institutions. Knowledge management systems can be established to ensure that best practices are documented and shared within local water institutions. Partnerships with other organizations and institutions can help address capacity gaps by providing access to expertise, knowledge, and resources. Performance monitoring and evaluation can help identify capacity gaps and measure progress in addressing them.
Q.1.4.b	Do mechanism to identify and address capacity gaps in local water institutions exist?

Response	Yes Yes, with some deficiencies Yes, but no operational No, but under development No Assessments of needs Capacity Building Workshops and Training Mentoring programs Knowledge management systems Performance monitoring and evaluation Please tick the option that better describe the existing situation If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 1.4.c	**Existence and level of implementation of educational and training programmes for local water professionals**
Functions	Educational and training programs for local water professionals are crucial instruments to favour the development of capacities for water resources management. Educational and training programs can help local water professionals improve their skills and knowledge. This can lead to more effective and efficient water management practices, better decision-making, and improved service delivery. They can also promote collaboration, networking, and innovation between local water professionals. This can facilitate the exchange of knowledge, ideas, and experiences and promote cooperation develop new solutions to water management challenges and improve existing practices between institutions and stakeholders in the water sector.
Q.1.4.c	Do educational and training programs for local water professionals exist at the local level?
Response	Please tick the option that better describe the existing situation Yes, they exist Yes, with some deficiencies Yes, they exist, but no operational No, but under development No
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Efficiency

Indicator 2.1.a	Existence and functioning of water information systems at the local level that are updated, timely shared, consistent, and comparable.
Function	The existence and functioning of water information systems at the local level is crucial for an efficient management of water resources. Water data facilitates an effective and informed planning and water allocation, water treatment, and water conservation measures, and ensures an adequate monitoring, preparedness and response to events such as floods and drought. The data may concern: Water quantity, including amount of water available in a given area, such as water levels in rivers, lakes, and reservoirs, as well as groundwater levels and aquifer recharge rates. Water quality, such as the chemical, physical, and biological characteristics of water. Water use, such as information irrigation, industrial use, domestic use, livestock watering, etc. Water infrastructure, including the number and characteristics of dams, reservoirs, water treatment plants, distribution networks, and wastewater treatment facilities... Hydrological information on the hydrological cycle, such as precipitation, evapotranspiration, and streamflow.
Q.2.1.a	Is there a functioning water information system at the local level that are updated, timely shared, consistent, and comparable?
Response	Yes, water information systems at the local level exist for all relevant data Yes, with some deficiencies (There are some water information systems at the local level, but not all of them – not all data or no regular data) Yes, but with large deficiencies, or no operational No, but under development No, there are no water information systems at the local level Please tick the option that better describe the existing situation
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.1.b	**Existence and functioning of public institutions, organizations, or agencies in charge of producing, coordinating, and disclosing standardized, harmonized, and official water-related statistics.**
Functions	The purpose of this indicator is to examine if there is an agency or organization that collects water data. Different public organizations may be responsible for collecting and managing water data, such as government agencies at the national, provincial, and local level, and agencies responsible for water resources, environment, health, or agriculture. The existence and functioning of such agencies is an element with impact on the efficiency of the water governance sector.
Q.2.1.b	Is there a functioning public institution or agency in charge of producing, coordinating, and disclosing standardized, harmonized, and official local water-related statistics?

Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.1.c	**Existence and level of implementation of mechanisms to identify and review local water data gaps, overlaps, and unnecessary overload.**
Functions	Certain mechanisms and instruments can help to identify and review water data gaps, overlaps, and unnecessary overload. Some of these include: Data audits, which serve to review the existing data to assess its quality, completeness, and relevance; Stakeholder consultations, which can help identify data needs and gaps in existing data; Data standards, which can help reduce data overlaps and ensure interoperability between different data sources, or Data management plans, which indicate the procedures on how data will be collected, stored, and shared.
Q.2.1.c	Do mechanisms to identify and review local water data gaps, overlaps, and unnecessary overload exist? How are they implemented?
Response	Yes Yes, with some deficiencies Yes, but no operational No, but under development No Data audits Stakeholder consultations Data standards Data management plans Please tick the option that better describe the existing situation If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.2.a	Existence and level of implementation of governance arrangements that help local water institutions collect the necessary revenues to meet their mandates and drive water-sustainable and efficient behaviors
Functions	Developing governance arrangements that help local water institutions to collect the necessary revenues has an impact on the efficiency of the water governance system in several ways. First, this revenue is essential to maintaining and upgrading water infrastructure, ensuring the continuity of water services, and supporting long-term planning. In particular, these revenues can enable the investment in new technologies. Also, charging users based on the amount of water they consume might encourage more efficient use of water, reducing water waste, promoting conservation, and supporting sustainable water management practices. Finally, these governance arrangement that require water institutions to report on their financial performance and use of funds can promote accountability and transparency, and local decision-making:
Q.2.2.a	Do governance arrangements that help local water institutions collect the necessary revenues to meet their mandates and drive water-sustainable and efficient behaviors exist at the local level?
Response	Yes, water information systems at the local level exist for all relevant data Yes, with some deficiencies(There are some water information systems at the local level, but not all of them – not all data or no regular data) Yes, but with large deficiencies, or no operational No, but under development No, there are no water information systems at the local level Please tick the option that better describe the existing situation
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.2.b	Existence and functioning of a dedicated institution in charge of collecting water revenues and allocating them to the right level
Functions	A dedicated institution in charge of collecting water revenues and allocating them contributes to increase efficiency in water governance by different means. First, it is more able to ensure that sufficient funds are available to meet the needs, as it specializes in collecting water revenues and aligning them with policy objectives. A dedicated institution is more likely to employ staff with expertise in water management, revenue collection, and financial management. By establishing a dedicated institution, it is easier to trace revenue streams and expenditure, thereby promoting transparency and accountability
Q.2.2.b	Does a functioning dedicated institution in charge of collecting water revenues and allocating them to the right level exist at the local level?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.2.c	Existence and level of implementation of mechanisms to assess short -, medium-, and long-term investments and operational needs and to ensure the availability and sustainability of such finances
Functions	Several mechanisms can assess short, medium, and long-term investments and operational needs and to ensure the availability and sustainability of such finances. Here are some examples: Financial planning and budgeting involves setting financial goals, estimating revenue and expenses, and creating budgets for each fiscal period. Risk management involves identifying and assessing potential risks to an organization's financial stability and developing strategies to mitigate them. Capital expenditure planning identifies and prioritizes long-term investments in infrastructure, technology, and other assets. Asset management involves assessing the condition and performance of an organization's physical assets, such as water treatment plants, pipelines, and reservoirs. This can help to identify areas for improvement and inform capital expenditure planning. Performance management involves setting performance targets, monitoring progress, and making adjustments as necessary to achieve financial goals.
Q.2.2.c	Do mechanisms to assess short -, medium-, and long-term investments and operational needs and to ensure the availability and sustainability of such finances exist at the local level?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Financial planning and budgeting Risk management Capital expenditure planning Asset management Performance management If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.3.a	Existence and level of implementation of a sound water management regulatory framework to foster enforcement and compliance, achieve regulatory objectives in a cost-effective way, and protect the public interest
Functions	The existence of a working sound water management regulatory framework is important for an efficient water governance as it provides the legal basis for enforcing water management regulations and ensuring. Doing so provides clear guidance to water users and minimises the need for costly enforcement actions. A sound regulatory framework provides certainty and predictability for water users, which can help to promote investment and innovation in water management, and facilitates the protection of public interests.

Q.2.3.a	Does a sound water management regulatory framework to foster enforcement and compliance, achieve regulatory objectives in a cost-effective way, and protect the public interest exist at the local level?
Response	Yes, a sound water management regulatory framework exist at the local level Yes, with some deficiencies(Yes, but with large deficiencies, or no operational No, but under development No, there are no water management regulatory framework at the local level Please tick the option that better describe the existing situation
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.3.b	**Existence and function of dedicated public institutions responsible for ensuring key regulatory functions for water services and resources management at the city level**
Functions	A dedicated public institution responsible for ensuring key regulatory functions for water services and resources management can help water governance, first, by ensuring that water services and resources management are effectively and efficiently regulated. This can help to ensure that water services are reliable, safe, and affordable for all residents. Also, such institution can help to develop strategic plans for water services and resources management and brings technical expertise to the regulation of water services and resources management, so they more likely to ensure that regulatory decisions are based on sound science and engineering principles. A dedicated institution is also more likely to be able to help to manage crises related to water services and resources management, such as droughts, floods, or waterborne disease outbreaks, and also more capable of coordinating efforts of utilities, regulators, and local governments.
Q.2.3.b	Do dedicated public institutions responsible for ensuring key regulatory functions for water services and resources management exist at the city level?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.3.c	Existence and level of implementation of regulatory tools to foster the quality of regulatory processes for water management at the city level
Functions	Various instruments can be employed to foster the quality of regulatory processes at the city level. Amongst the more salient and more widely employed are: performance standards which can establish minimum levels of performance that water management organizations must meet; permits and licenses, destined to ensure that water management organizations comply with environmental and public health regulations; enforcement mechanisms, such as penalties, fines, and legal action, that can deter non-compliance and ensure that regulatory processes are effective; compliance assistance programs, aiming at providing guidance, technical assistance, and training to water stakeholders to ensure that they comply with regulations; regulatory impact analysis, destined to facilitating water management regulatory processes are designed in a way that maximizes their benefits and minimizes their costs, etc.
Q.2.3.c	Do regulatory tools to foster the quality of regulatory processes for water management exist at the city level?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Performance standards Permits and licenses Enforcement mechanisms Compliance assistance programs Regulatory impact analysis If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.4.a	Existence and level of implementation of policy frameworks and incentives fostering innovation in water management practices and processes at the local level
Functions	The existence of policy frameworks and incentives that foster innovation in water management practices and processes at the local level facilitate efficiency in water governance in various ways. Such measures encourage experimentation, which can help to identify innovative solutions to problems. They facilitate that all stakeholders are involved in water management decision-making, which contribute to developing skills, knowledge, and expertise needed to tackle complex water management challenges. Innovative water governance practices ensure that water management strategies are revised and updated based on feedback from stakeholders and from monitoring and enforcement actions. This can help to ensure that water resources are managed in a way that is adaptable and able to withstand changes and challenges.

Q.2.4.a	Have policy frameworks and incentives fostering innovation in water management practices and processes been developed at the local level?
Response	Yes, policy frameworks and incentives fostering innovation in water management practices and processes Yes, with some deficiencies Yes, but with large deficiencies No, but under development No, there are no water information systems at the local level
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.4.b	**Existence and functioning of institutions encouraging bottom-up initiatives, dialogue, and social learning as well as experimentation in water management at the local level**
Functions	The existence of institutions encouraging bottom-up initiatives can play an important role in promoting sustainable and effective water management practices that meet the needs of local communities and the environment. These organizations can be local water user associations or Community-Based Organizations that, along with other topics, help to establish discussion and organization of local stakeholders through community-led projects and initiatives. Also, local government institutions can support bottom-up initiatives and social learning in water management by involving community members in decision-making processes and by providing support for community-led projects and initiatives. Local Universities and research institutions can also play a key role in promoting social learning and experimentation in water management, as well as local NGOs and Civil Society Organizations.
Q.2.4.b.	Do institutions encouraging bottom-up initiatives, dialogue, and social learning as well as experimentation in water management exist at the local level?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 2.4.c	Existence and level of implementation of knowledge and experience-sharing mechanisms to bridge the divide between science, policy, and practice at the local level
Functions	Various instruments can help to bring the divide between science, policy and practice at the local level, including the following: Conferences and workshops can bring together scientists, policymakers, and practitioners to share knowledge and experiences on specific topics related to water management. Research partnerships can involve scientists, policymakers, and practitioners working together on specific research projects related to water management. Online resources, such as webinars, online courses, and knowledge-sharing platforms, can provide access to information, best practices, and case studies related to water management Technical assistance programs can provide hands-on support and guidance to local policymakers and practitioners on specific water management issues.
Q.2.4.c	What knowledge and experience-sharing mechanisms to bridge the divide between science, policy, and practice exist at the local level?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Conferences and workshops Research partnerships Online resources Technical assistance programs If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Trust and Engagement

Indicator 3.1.a	Existence and level of implementation of legal and institutional frameworks on integrity and transparency (not necessarily water-specific)
Function	The existence and level of implementation of legal and institutional frameworks on integrity and transparency are important for several reasons: they promote accountability reducing the likelihood of corrupt behavior, such as bribery or embezzlement; by doing so, they enhance public trust, which is essential stability and economic growth. Also, by establishing clear rules and standards, these institutions improve efficiency: they help reduce ambiguity and uncertainty, and ensure that resources are allocated based on merit and need and not on spurious reasons.
Q.3.1.a	Do legal and institutional frameworks on integrity and transparency (not necessarily water-specific) exist at the local level?
Response	Yes, legal and institutional frameworks on integrity and transparency exists at the local level (for instance, legislation to publish decisions, mechanisms to protect whistleblowing, freedom of information acts?) Yes, with some deficiencies Yes, but with large deficiencies, or no operational No, but under development No, there are no legal and institutional frameworks on integrity and transparency exist at local level Please tick the option that better describe the existing situation
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.1.b	Existence and functioning of independent courts (not necessarily water-specific) and supreme audit institutions that can investigate water-related infringements and safeguard the public interest
Function	The existence of independent courts and supreme audit institutions that can investigate water-related infringements and safeguard the public interest is essential for ensuring accountability, upholding the rule of law, protecting the public interest, and promoting transparency in water-related matters. Without these institutions, water-related issues could be handled in an arbitrary or unethical manner, which could have negative consequences for the environment, public health, and social stability.
Q.3.1.b	Do independent courts (not necessarily water-specific) and supreme audit institutions that can investigate water-related infringements and safeguard the public interest exist at the local level?
Response	Please tick the option that better describe the existing situation YES NO
Data type	Qualitative
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.1.c	**Existence and level of implementation of mechanisms (not necessarily water-specific) to identify potential drivers of corruption and risks in all water-related institutions at different levels, as well as other water integrity and transparency gaps**
Function	Different instruments can be employed to identify potential drivers and risks in water-related institutions at different levels, including the following: Corruption risk assessments to identify corruption risks in water-related institutions. This involves analyzing the various processes and activities in the institution and assessing the likelihood and impact of corruption. Whistleblowing mechanisms to report corruption can help identify potential drivers of corruption and risks. Transparency and accountability mechanisms such as public disclosure of information, financial audits, and public participation in decision-making processes. Capacity building and training for staff in water-related institutions can help to identify potential drivers of corruption and risks Independent oversight, such as anti-corruption commissions or ombudsmen, can help to investigate complaints, monitor compliance with laws and regulations, and promote transparency and accountability.
Q.3.1.c	Do mechanisms (not necessarily water-specific) exist to identify potential drivers of corruption and risks in all water-related institutions at different levels, as well as other water integrity and transparency gaps?
Response	Yes Yes, with some deficiencies Yes, but no operational No, but under development No Corruption risks assessments Whistleblowing mechanisms Transparency and accountability Capacity building and training Independent oversight Please tick the option that better describe the existing situation If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.2.a	**Existence and level of implementation of legal frameworks to engage stakeholders in the design and implementation of local water-related decisions, policies, and projects**
Function	Engaging diverse stakeholders (local communities, government agencies, businesses, non-governmental organizations, etc.), ensures that diverse perspectives are considered. This can lead to more informed, balanced, and equitable decision-making processes, taking into account the needs and concerns of all involved parties. Collaboration amongst stakeholders can foster for negotiation, dispute resolution, and consensus-building, which can result in economic benefits for communities, businesses, and governments. Additionally, engaging stakeholders can lead to increased social cohesion, improved quality of life, and greater overall well-being for communities.

Q.3.2.a	Do legal frameworks to engage stakeholders in the design and implementation of local water-related decisions, policies, and projects exist at the local level?
Response	Yes, legal frameworks to engage stakeholders exist at the local level exist Yes, with some deficiencies (i.e. engagement of stakeholders only in limited areas of decision making) Yes, but with large deficiencies, or no operational (i.e. the legal framework exist, but not implemented) No, but under development No, there are no legal framework for stakeholder engagement Please tick the option that better describe the existing situation
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.2.b	**Existence and functioning of organizational structures and responsible authorities to engage stakeholders in local water-related policies and decisions**
Function	The existence of organizational structures and responsible authorities provide a defined framework for decision-making, outlining the roles and responsibilities of different stakeholders. The existence of such institution ensures representation of different stakeholders, fosters collaboration, and promotes effective resource management. Moreover, it enhances accountability, transparency, and long-term stability, leading to better outcomes for both people and the environment.
Q.3.2.b	Do organizational structures and responsible authorities to engage stakeholders in local water-related policies and decisions exist at the local level?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.2.c	Existence and level of implementation of mechanisms to diagnose and review stakeholder engagement challenges, processes, and outcomes
Function	Various mechanisms exist to diagnose and review stakeholder engagement challenges, processes, and outcomes in water-related decision-making. Amongst them are the following: Public consultations and hearings provide forums for stakeholders to voice their concerns, opinions, and suggestions, as well as for decision-makers to gather input and feedback. Stakeholder analysis, which consist in identifying stakeholders based on their areas of interests and their influence. This analysis can help to identify gaps and challenges, and inform engagement strategies. Monitoring and evaluation can help to assess the impact of engagement practices. They involve setting objectives, indicators, and targets for the engagement actions, and examining results. Surveys and feedback mechanisms (interviews, focus groups) can provide information to help identify gaps, dissatisfaction with the current mechanism or areas for improvement, as well as inform future engagement efforts. Independent assessments or audits conducted by external experts can help review stakeholder engagement processes and outcomes.
Q.3.2.c	Have mechanisms to diagnose and review stakeholder engagement challenges, processes, and outcomes been developed at the local level?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Public consultations Stakeholder analysis Monitoring and evaluation Surveys and feedback mechanisms Independent assessments or audits If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.3.a	Existence and level of implementation of formal provisions or legal frameworks fostering equity across water users and generations at the local level
Function	Formal provisions or legal frameworks fostering equity across water users and generations at the local level are important for several reasons. They ensure that water resources are distributed fairly among all users, preventing the monopolization or over-exploitation of water by certain groups or sectors. This helps to balance competing demands and promote the sustainable use of water resources. They also facilitate that marginalized or vulnerable communities have access to clean and safe water. This is essential for promoting social justice and reducing disparities in health, well-being, and economic opportunity. In addition, legal frameworks that consider the needs of both current and future generations can help promote long-term sustainability and responsible resource management, ensuring that water resources are preserved. Thus, these legal provision can help promoting the sustainable use and management of water resources, protecting the environment and preserving vital ecosystem services, and thus facilitating climate change adaptation.
Q.3.3.a	Do formal provisions or legal frameworks exist for fostering equity across water users and generations at the local level?

Response	Yes, formal provisions or legal frameworks fostering equity across water users and generations exist Yes, formal provisions or legal frameworks fostering equity across water users and generations exist, with some deficiencies (i.e. not for all decisions, not for all users) Yes, but with large deficiencies, or no operational No, but under development No, there are no water information systems at the local level Please tick the option that better describe the existing situation
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.3.b	**Existence and functioning of a local Ombudsman or institution(s) to protect water users, including vulnerable groups**
Function	The existence of a local Ombudsman or institution(s) to protect water users, including vulnerable groups, is important as they provide an accessible and cost-effective avenue for water users, especially vulnerable groups, to voice their concerns, seek redress, and ensure their rights are protected. In addition, these institutions can represent the interests of water users, particularly vulnerable groups, and advocate for their needs and rights in decision-making processes. They also can act as mediators, addressing disputes between water users and other stakeholders. They can provide mediation services, facilitate dialogue, and help find mutually acceptable solutions to conflicts, fostering a more harmonious and collaborative environment for water management, which can subsequently raise awareness about water-related rights, regulations, and best practices among water users and stakeholders.
Q.3.3.b	Does a Ombudsman or institution(s) to protect water users, including vulnerable groups exist for the local level?
Response	Please tick the option that better describe the existing situation YES NO
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.3.c	**Existence and implementation of mechanisms to manage trade-offs across users, and/or over time in a non-discriminatory, transparent, and evidence-based manner at the local level**
Function	Several mechanisms exist to manage trade-offs across users and/or over time in a non-discriminatory, transparent, and evidence-based manner at the local level.: Integrated Water Resource Management (IWRM) facilitates coordination, communication, and collaboration among stakeholders, helping to identify and manage trade-offs more effectively. Consultations and other participatory decision-making, which can promote transparency, inclusiveness, and equity. Environmental impact assessments and social impact assessments, which can help identify potential trade-offs between water use, environmental protection, and social considerations. Scenario planning and modelling, which can help identify potential trade-offs and evaluate the implications of different management options, and support a more informed decision-making.
Q.3.3.c	Have mechanisms to manage trade-offs across users, and/or over time in a non-discriminatory, transparent, and evidence-based manner been developed at the local level?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Integrated Water Resource Management Consultations and other participatory decision-making Environmental impact assessments Social impact assessments Scenario planning and modelling If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.4.a	**Existence and level of implementation of policy frameworks promoting regular monitoring and evaluation of water policy and governance**
Function	The existence and level of implementation of policy frameworks promoting regular monitoring and evaluation of water policy and governance is of great importance for several reasons; First, regular monitoring and enforcement enables decision-makers to track progress, assess the effectiveness of policies and governance structures, and gather evidence to inform future decisions. This helps ensure that water management strategies are grounded in data and evidence, leading to more effective outcomes. Indeed, monitoring and enforcement processes generate valuable knowledge and lessons learned that can be shared among stakeholders, including policymakers, practitioners, and communities. This can help to identify where resources may be underutilised, adapt policies and governance structures to evolving circumstances, build capacity, promote the adoption of best practices, and contribute to continuous improvement in water governance

Q.3.4.a	Do policy frameworks promoting regular monitoring and evaluation of water policy and governance exist at the local level?
Response	Yes, water information systems at the local level exist for all relevant data Yes, with some deficiencies(There are some water information systems at the local level, but not all of them – not all data or no regular data) Yes, but with large deficiencies, or no operational No, but under development No, there are no water information systems at the local level Please tick the option that better describe the existing situation
Data type	Qualitative
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.4.b	**Existence and functioning of institutions in charge of monitoring and evaluating water policies and practices, adjusting where/when needed**
Function	The existence and functioning of institutions in charge of monitoring and evaluating water policies and practices facilitate and make more effective policy evaluation and monitoring: the specialized knowledge of this agency can lead to more accurate assessments and effective recommendations for improvement. In addition, a dedicated agency can ensure consistency and continuity in monitoring and evaluation efforts, providing a stable foundation for tracking progress, identifying trends, and making comparisons over time... Such an institution is commonly associated with the provision of objective and unbiased assessments of water policies and practices. Finally, a dedicated institution can serve as a hub for knowledge-sharing, capacity-building, and learning among stakeholders involved in water governance.
Q.3.4.b	Do institutions in charge of monitoring and evaluating water policies and practices, adjusting where/when needed exist at the local level?
Response	Please tick the option that better describe the existing situation YES NO
Data type	Qualitative
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

Indicator 3.4c	Existence and level of implementation of mechanisms that monitor and evaluate the extent to which water policies fulfil intended outcomes and water governance frameworks and are fit-for-purpose
Function	There are several mechanisms that can be used to monitor and evaluate the extent to which water policies fulfill intended outcomes and whether water governance frameworks are fit-for-purpose. Some of these mechanisms include: performance indicators, based on specific outcomes or targets (water quality or quantity) that can be used to monitor progress over time; Evaluation frameworks, which can be developed to assess the effectiveness of water policies and governance frameworks. Stakeholder engagement, which can be used to gather feedback on the effectiveness of water policies and governance frameworks.
Q.3.4.c	Have mechanisms that monitor and evaluate the extent to which water policies fulfil intended outcomes and water governance frameworks and are fit-for-purpose been developed at the local level?
Response	Please tick the option that better describe the existing situation Yes Yes, with some deficiencies Yes, but no operational No, but under development No Performance indicators Evaluation frameworks Stakeholder engagement If any other mechanism exists, please indicate its name and characteristics, and how often it is employed
Sources of information	Please indicate the source of this information (national or local laws, regulations, policies, guidelines etc.)

PART 4

Smart Water Cities Pilot Evaluation

Testing the Smart Water City Index has been a fundamental phase of the Smart Water Cities project. In February 2023, the project issued a call for pilot cities, inviting submissions from municipalities eager to assess and enhance the sustainability of their local water services provision and urban water resources management. Following a selection process, the chosen cities were announced in June 2023, and the pilot evaluation started shortly afterwards.

Part IV of this report explains the details of how the pilot evaluations were carried out. Chapter 10 outlines the general approach employed for these evaluations, focusing on the objectives and principles guiding the selection of participating cities. Chapters 9 and 10 furnish a comprehensive analysis of two pilot cities: the Busan Eco Delta Smart City (BEDSC) in the Republic of Korea and Semarang in the Republic of Indonesia. Each chapter explores the unique characteristics of these cities, evaluates their performance against identified KPIs, and offers an overarching analysis of their respective strengths and weaknesses."

CHAPTER 10
SMART WATER CITY INDEX: PILOT EVALUATION AND CITY SELECTION

This chapter serves a dual purpose: firstly, to elucidate the fundamental objectives behind conducting a pilot evaluation test within the Smart Water Cities project, and secondly, to outline the key principles that directed the selection of cities for this critical phase. The chapter also explains the steps followed in selecting two cases, BEDC in the Republic of Korea and Semarang in the Republic of Indonesia. By providing a transparent account of the selection methodology, this chapter aims to offer a clear understanding of how these two cases emerged as the focal points for the pilot evaluation within the broader Smart Water Cities initiative.

1. Purpose and Steps of the pilot evaluation

A pilot evaluation is a process destined to test the feasibility and impact of a new initiative or policy on a smaller scale, in order to identify potential issues and make any necessary adjustments before it is rolled out more broadly. In the case of the Smart Water City Index, the pilot city test has sought to determine the Index's effectiveness, assess its potential impacts, and identify any challenges or barriers to its implementation. The information collected during the pilot city evaluation can help us make informed decisions about whether to make any necessary modifications to improve the indicators' effectiveness and on whether it is possible to expand the initiative to other cities or regions.

By participating in the pilot test for the Smart Water Cities project, the selected cities would get a complimentary assessment report, which would include a full diagnosis of the functioning of their urban water systems and a comprehensive proposal on how to improve them, both in terms of the technologies to employ and the measures needed to enhance their local financial, human, and regulatory capacities.

Figure 10. Milestones of Smart Water Cities evaluation.

The call invited applications from organizations involved in the management and/or regulation of water resources and water services at the local level. This included entities directly responsible for these tasks, such as local and metropolitan authorities, public bodies, water regulators, water operators, etc. Also, research centers, university and non-profit organizations with knowledge and experience in the functioning of water services provision and water resources management in cities were welcome to submit a proposal. As a necessary condition to apply, all participant organizations needed to ensure that they have access to, and are entitled to share, data and information concerning the urban water system.

2. Principles for selecting pilot cities

The selection of the pilot cities was made according to the principles of City relevance, Local commitment, and Feasibility of the case study:

1. City relevance refers to the suitability of the city for a particular initiative or project. This involves considering factors such as the city's size, population density, demographics, economic activity, and relevance of water in the local agenda. The project should be relevant to the needs and challenges of the city, and there should be a clear connection between the pilot city initiative and the city's goals and priorities.
2. Local commitment emphasizes the importance of engaging with local stakeholders and ensuring their active participation in the project. This includes building partnerships with local government, community organizations, businesses, and residents. By involving these stakeholders from the beginning, the pilot city test is more likely to gather the relevant information and be successful.
3. Feasibility of the case study refers to the practicality of implementing the project in the selected city, and particularly assessing whether the city has relevant data and information that can be shared with the plot city evaluators.

Together, these principles sought to ensure that the city selected for the pilot evaluation was relevant to the Smart Water Cities project's objectives, had the support of local stakeholders, and the evaluation could be conducted practically.

3. Pilot cities selection

A total of 25 applications were submitted by the deadline of 16 April. Figure 11 presents the wide geographical spread of the cities that submitted proposals, while Table 8 presents the breakdown of the candidacies submitted according to geographical provenance:

Figure 11. Origin of candidate cities

Table 8. Number of submitted candidacies for the Smart Water Cities by region.

Region	Number of submitted candidacies
Africa	8
Asia and the Pacific	10
Europe	4
Latin America and the Caribbean	2
North America	1

While numerous city candidatures presented an excellent alignment with the selection principles, the final decision saw the inclusion of only two cities: BEDC in the Republic of Korea, and Semarang in the Republic of Indonesia.

BEDC is a novel urban development situated to the west of the old Busan center, to the southeast on the Republic of Korea. Designed to host around 76 thousand residents, BEDC is characterized by the effort to create a new city able to provide access to green and blue spaces, integrating nature into various facets of city life. Notably, BEDC has also been designed to serve as a Living Lab, a unique space comprising diverse housing units where different water sector technologies are actively tested. This innovative approach provides valuable insights into the real-world applications and adaptability of water technologies.

For these reasons, the BEDC evaluation serves as a unique exploration of the Smart Water City Index, examining its capacity to measure both technical and governance aspects within a highly advanced urban project. The insights from this case can serve as a valuable benchmark and point of comparison for other cities and urban developments aspiring to integrate cutting-edge technologies and ICTs into their local water sector, extending both to the provision of water services and the management of water resources.

Semarang, a historic city in Central Java with over 1.7 million residents, confronts severe water challenges, including land subsidence, floods, pollution, and infrastructure gaps. The city's authorities are resolutely committed to addressing these issues, ensuring solutions meet the diverse needs of all citizens. The nation as a whole is actively modernizing its water sector to foster overall development while prioritizing vulnerable segments of society. Semarang's historical and socioeconomic context adds a unique dimension to the challenges and solutions that cities face around the world, contributing to the varied conditions under examination.

Together, BEDC and Semarang are cases offering very contrasting urban landscapes and present an excellent opportunity to scrutinize and evaluate the Smart Water City Index under diverse and challenging conditions. Chapters 11 and 12 of this report delve into the outcomes of this comprehensive evaluation, highlighting key features of each city, assessing their performance in technical and governance aspects, and providing valuable recommendations for policymakers and managers engaged in advancing sustainable water management practices.

CHAPTER 11
PILOT CITY EVALUATION: BUSAN ECO DELTA SMART CITY

Busan is a coastal city located in the Republic of Korea. It is a metropolis with a population of over 3.5 million people, which makes it the country's second-largest city and serves as a significant economic and cultural center in the region. With a population density of approximately 4,500 people per square kilometer, Busan has experienced rapid growth and development. The city enjoys a temperate climate, with distinct seasons throughout the year. Summers are warm and humid, with temperatures averaging around 25-30 degrees Celsius. Winters are generally mild, but temperatures can drop to around 0 degrees Celsius.

BOX 1. KEY FEATURES OF BUSAN

City Population: 3.3 million (2020)
Population density 527 per km^2
City population growth (0.06% (2021))
Gross Domestic product: 34,500 USD (2020)
Geography (Coastal, mountain-sea border
Climate: Humid sub-tropical climate
Water consumption: 18 million m^3/year (2020)

1. General features of BEDC

BEDC is a joint development project initiated in 2012 situated to the west of the city of Busan. The planning and development of BEDC is being carried out under MOLIT's waterfront development project, in accordance with the Special Act on the Utilization of Waterfronts.

The BEDC project's primary goal is to drive economic growth in the Busan metropolitan area, home to nearly eight million people, while also enriching cultural and recreational experiences along the riverside. With a substantial capital investment of 660 trillion Korean won (approximately 660 billion US dollars), the initiative encompasses the creation of fresh urban districts dedicated to housing, commerce, research, and development, as well as logistics within the expansive 11.8 km^2 BEDC zone. This innovative town is poised to host 76,000 residents, facilitated by the addition of 30,000 new housing units. The development aims to pioneer innovation across various aspects of city life, leveraging intelligent infrastructure and robotics in education, health, transportation, clean energy, water management, and more. Notably, in the realm of water, the project aspires to transform the waterfront into a city landmark that elevates residents' quality of life and addresses critical water challenges through cutting-edge management and data-driven solutions (See Report Smart Water Cities: Identifying Smart Water Cities).

Examining the BEDC according to the Smart Water City Index is helpful to take stock of this large ongoing and complex new urban development project. The analysis of the technical pillar of the Smart Water City Index provides information on the progress and improvements that have been taken place against the objectives when the initiative started. The indicators for the governance pillar gather information on governance aspects for both BEDC and the city of Busan as a whole, as at times insufficient information exists exclusively concerning the new development area.

Main water challenges of Busan

The Republic of Korea faces significant water challenges, influenced by various factors including environmental concerns and population dynamics. Despite having annual precipitation 1.6 times the global average, Korea's high population density results in a per capita annual precipitation rate of only 1/6 of the global average. This contributes to water scarcity issues in cities like Busan. Moreover, industrial activities and urbanization can lead to water pollution, with contamination from waste, sewage, and runoff. Aging water infrastructure is also a concern, potentially causing inefficiencies and water loss. (for an overview of water challenges and historical evolution in Korea, see Choi et al, 2017; Ministry of Environment 2017, Kim et al 2018).

Much of the Korean coast, including cities such as Busan, is vulnerable to flooding and stormwater management due to heavy rainfall and occasional typhoons. Climate change-related shifts in rainfall patterns have increased the frequency of localized heavy rain events. Additionally, Busan's coastal location makes it susceptible to saltwater intrusion into freshwater sources, aggravated by overextraction of groundwater.

Droughts in the Republic of Korea have become more severe, with a historic drought in 2015 causing water reserves to drop to alarming levels. Korea's water stress is high at 58%, far surpassing the global average of 13%. Water consumption is projected to rise, particularly with an aging population entitled to water tariff reductions. Korea's reliance on supply-oriented, expensive options like reservoirs and desalination poses economic and energy challenges.

Nonetheless these challenges, the progress made by the Republic of Korea in water services provision and water management in the last 50 years is remarkable. Korea has invested heavily in water infrastructure, including dams, reservoirs, and water treatment facilities, which has helped in regulating water supply, managing floods, and ensuring access to clean water. The country has also implemented stringent water quality standards and monitoring systems. Efforts have been made to reduce water pollution from industrial, agricultural, and urban sources. In terms of water management, the government has adopted an integrated approach to favor river basin management to balance water use for agriculture, industry, and domestic purposes and environmental protection. The analysis of the BEDC case shows evidence of the progress made.

Main water actors

With regards to the organization and management of water resources, the following are the most important institutions in Korea. At the national level:

- The Ministry of Land, Infrastructure and Transport (MOLIT) is involved in the planning and development of water-related infrastructure, such as dams and reservoirs.
- The Ministry of Environment (MOE) is responsible for overall environmental policies, including water resource management and pollution control.
- The Ministry of Agriculture, Food and Rural Affairs (MAFRA) is concerned with water use in agriculture and rural areas.

Other ministries may also be involved at times in the management of water issues, such as maintenance of small-sized stream and disaster management for the Ministry of the Interior and Safety, or the management and operation of hydroelectric dams for the case of the Ministry of Trade, Industry and Energy.

Also at the national level, K-water has key functions. As the public, government-owned corporation responsible for the development and management of water resources in the country, K-water manages water resources development facilities such as dams and estuaries in order to supply domestic and industrial water to local governments or industries. For its part, the National Groundwater Information Management and Service Center is also a public body in charge of collecting, managing, analyzing, and servicing groundwater data to other Korean authorities, including local authorities. Finally, Korea Meteorological Administration (KMA) is the national meteorological and atmospheric service of Korea. As such it is responsible for providing weather forecasts, warnings, and information related to meteorology, climatology, and atmospheric sciences. KMA issues warnings for severe weather events (typhoons, heavy rain, snowstorms, and other natural disasters) to all administrations and the public in the country.

For their part, local authorities are responsible for the local water supply system, including managing water resources at the local level, including water supply and sanitation services responsibilities. Although some local governments build and operate their own water supply system, in some cases, local authorities have delegated this task to K-water. K-water has the knowledge and resources required to undertake this task, and thus its water provision is more stable.

In these cases, K-water supply water services in multi-regional water supply system on behalf of the government. As of December 2013, the Republic of Korea has 162 local waterworks operators (7 metropolitan cities, 1 metropolitan autonomous city, 1 special self-governing province, 75 cities, and 78 districts) and 1 multiregional water supply system business operator, by K-water.

In the case of Busan, the Busan Metropolitan City Government is the local authority responsible for overseeing urban planning, public services, infrastructure, transportation, education, and healthcare. The Busan Metropolitan Council, composed of elected representatives, plays a crucial role in decision-making, policy formulation, and approving budgets for the municipality. The Mayor of Busan, elected by residents, serves as the chief executive, setting policies and representing the city's interests.

The Busan Water Authority is the public water company responsible for delivering drinking water, managing water treatment and wastewater treatment plants in the city, ensuring appropriate standards for water quality, overseeing the local water network and distribution systems, and determining and collecting consumers' water tariffs.

2. Results of the pilot evaluation in BEDC

The assessment of the water system in the Busan Eco Delta Smart City occurred between March and June 2023, encompassing two key phases: a self-assessment and result verification for both technical and governance components. The collected data aimed to provide specific insights into BEDC. However, due to BEDC being part of the larger Busan municipality, at times the available information pertains to the municipality in its entirety, and not exclusively to BEDC. The report acknowledges and addresses this aspect by making references to the broader municipal context within the text.

For Technical pillar, various data sources have been utilized to gather the data needed for the smart water city evaluation. The urban water data for BEDC was obtained from the information presented on the K-water website. The rest of the information was gathered from either the surrounding districts of BEDC (Gangseo, Sasang and Buk districts), or from Busan Metropolitan city data. In the Republic of Korea, the majority of the data necessary for the smart water city evaluation can be accessed online. The national agencies that facilitate the collection of these data include the Korea Water Resources Corporation (K-water), Korea Meteorological Administration (KMA), National Institute of Environmental Research (NIER), National Groundwater Information Management and Service Center (GIMS), Korea Statistics Ministry, Ministry of Environment (MOE) and the Korea Environment Corporation (KECO). City-scale data was also collected from the Busan Metropolitan City government, Busan Water Authority, and Busan Environmental Corporation (BECO). Data information sources were also utilized, such as the Water Resources Management Information System (WAMIS), Water Environment Information Center, Integrated Groundwater Information Services, Busan Open Data Portal, Korea Public Data Portal, Busan Metropolitan City Urban Flood Integrated Information, National Drought Information Portal, National Water Supply Information System, Korea Water Resources Water Information Portal, Water

Information Portal, National Water Supply Information System and the Korea Statistical Information Services (KOSIS).

For the Governance and Prospective pillar, K-water personnel actively contributed by providing information and data, drawing on their expertise gained through K-water's pivotal role in advancing water-related initiatives in BEDC. Various K-water professionals submitted assessments of BEDC's governance, shedding light on water management in Busan as a whole. To ensure a robust evaluation, their input was cross-referenced with official documents, water governance data from studies by institutions like the OECD and the Asian Development Bank (ADB), as well as national organizations and researchers.

This assessment offered a chance to scrutinize the Smart Water City Index's effectiveness in a technologically advanced urban development committed to addressing water challenges like pollution, scarcity, and floods. The pilot evaluation allowed an examination of how even advanced cases fared under this comprehensive test, revealing room for improvement despite a steadfast commitment to sustainable and smart water planning. Identified challenges emphasize the ongoing need for improved coordination and information gathering.

Looking ahead, the evaluation demonstrated that, even in cases with a strong dedication to sustainable water development, there is still potential for enhancement. The recognized challenges underscore the importance of continuous efforts in coordination and information management.

Regarding lessons learned about the Index, the assessment highlighted the necessity for clearer guidelines, particularly for local actors, emphasizing a comprehensive examination of the urban water system beyond just water services provision. This lesson aligns with findings from the Semarang case study (See Chapter 12. Pilot city evaluation of Semarang City, Indonesia), emphasizing the importance of providing clear guidance for a thorough examination of water aspects in urban water systems.

Evaluation Results on Technical Pillar

Indicator 1.1a Coverage extent of precipitation monitoring stations

For Busan Metropolitan City, which includes the Busan Eco Delta City (BEDC), the agency that is responsible for rainfall monitoring is the Korea Meteorological Administration (KMA). BEDC is located within the scope of Gangseo, Sasang and Buk districts. Within these boundaries, a total of 13 rainfall stations are in operation (2 from the Ministry of Environment [MOE] and 11 from KMA). Considering the total surface area of the districts at 253.19 km2, the rainfall station coverage for BEDC is therefore 19.5 km2 per station. The BEDC rainfall station coverage density satisfies WMO recommended densities for meteorological stations for urban areas, which is 10-20 km2 per station.

Score assigned	**2**

Indicator 1.1b Monitoring and recording frequency of precipitation instruments

The KMA rainfall stations located within the vicinity of Busan Eco Delta City (Gangseo, Sasang and Buk districts) records rainfall intensity (mm) at a 1-minute interval. The recommended temporal variability for rainfall observations, in order to properly analyze the small-scale hydrological processes such as the channel flows in sewer and storm drains, should be less than 10-minute interval.

Score assigned	4

Indicator 1.1c Percentage comparison of missing and error of observed precipitation data to the total observed data

The nearest rainfall station in the Busan Eco Delta City is Gupo station. Based on the data gathered from the Water Resources Management Information System (WAMIS), the station records rainfall since 2006, logging a total of 6,225 rainfall observations. The computed missing and error rainfall data for this station is 0.78%. According to literature, a minimum value of 0.5-5.4% of missing and error rainfall data must be implemented in order to limit the effect of missing data in climate parameter estimations.

Score assigned	4

Indicator 1.1d Quantity of observed precipitation data that is recorded electronically and the calibration status of precipitation recording instruments

The KMA rainfall stations within close proximity of Busan Eco Delta City, namely the Synoptic and Automated Weather Stations (ASOS and AWS) are all recording automatically and in real-time. In addition, according to the "Meteorological Instrument Regulations" under Meteorological Order No. 734, rainfall observation devices are subject to inspections and routine calibrations at least 10 times annually. This is to determine the suitability by comparing the performance, structure, condition, etc. of meteorological observation.

Score assigned	3

Indicator 1.1e Process of precipitation data collection using ICT-based technologies

The Korea Meteorological Administration utilizes radar and satellite data to perform rainfall observations for the city of Busan, which includes the BEDC. Included in the ICT-based instruments used by the Agency for rainfall monitoring are automated weather stations (AWS), sensor rain gauges, ground-based doppler radars, regional-scale satellite data and numerical weather predictions.

Score assigned	4

Indicator 1.1f Status of public accessibility to precipitation data records

The rainfall data for Korea are accessible to the public through the Korea Meteorological Administration website (data.kma.go.kr), including the observed data for the stations located in Gangseo, Sasang and Gu districts, around the vicinity of BEDC. The observed data are complete and open access by registering using an active email address.

Score assigned	4

Indicator 1.2a Percentage comparison of impervious surface to the total surface area

Based on the land use data provided by the Korea Water Resource Corporation (K-water), the total surface area and total pervious surface area (Parks and Grasslands) of the Busan Eco Delta City are 11.89 km2 and 3.02 km2, respectively. The total impervious surface area for BEDC is therefore 8.87 km2, amounting to about 74.6% of the total surface area. The percentage of impermeability is an important factor in the natural water balance, higher percentage can have a negative effect to urban flooding and groundwater recharge.

Score assigned	3

Indicator 1.2b Percentage comparison of the nature conservation area to the total surface area as related to the status of urban stream biodiversity

The Busan Eco Delta city land use data gathered from K-water (kwater.or.kr/website/ecodeltacity) indicates that 2.36 km2 of the area is dedicated to nature conservation green spaces, which equates to 19.8% of the total surface area. Artificial alterations initiated by the city management to conserve the natural state of the surface is an indicator of smart water city.

Score assigned	3

Indicator 1.2c Establishment of urban waterfront or water space facilities

The Busan Metropolitan city, which includes the Busan Eco Delta city, constructed the Busan North port to serve as international marine tourism, gateway for the Eurasian continent, as a leisure water park and revitalize the local economy. The establishment of man-made waterfront facilities and structures can serve in various purposes, including transportation, commerce, recreation, environmental protection, storm water management and city aesthetics.

Score assigned	4

Indicator 1.2d Percentage comparison of applied Low Impact Development (LID) and green infrastructure area and total surface area

Based on the "Study on enhancing response to climate change using spatial analysis of green infrastructure" by the Busan Development Institute, the LID and green infrastructures with the residential, commercial, industrial, greenbelt and unassigned area within the city is 23.0 km2, 2.0 km2, 6.7 km2, 421.9 km2 and 0.4 km2, respectively. The total percentage of LID and green infrastructures in the city is 58.4%. LID and green infrastructures are practices that mimic the natural process of the urban hydrological cycle with the purpose of preserving the quality of urban water and the associated ecological habitat.

Score assigned	4

Indicator 1.3a Coverage extent of urban stream and coastal water level monitoring stations

Busan Metropolitan city has a total of 62.73 km river extent of the major rivers within the city (Oncheon stream, Suyeong River, Dong stream, Daecheon stream, Jisa stream, Kamjeon stream, Hakjang stream and Choryang stream). According to the Busan Metropolitan City Major River Water Level Information, there are a total of 18 stream gauge stations along the river pathways. Therefore, the coverage extent of water level stations within the city is 3.49 km extent per station. These water level stations are important for flood control and early warning, water flow measurements and proper water resource management.

Score assigned	4

Indicator 1.3b Monitoring and recording frequency of water level instruments

According to the official data portal of the Busan Metropolitan city, the regional water level stations record real-time water level data at 10-min intervals. Continuous and frequent water level monitoring is critical in providing prior early warning in case of flood events.

Score assigned	4

Indicator 1.3c Percentage comparison of missing and error of observed water level data to the total observed data

The nearest water level station within the vicinity of Busan Eco Delta city is the Gupo Bridge water level station. This station has been recording water levels since 1987, having a total number of 12,836 recorded data over 13,060 observation period. The total percentage of missing data for this station is therefore 1.72%. Research suggests that a missing value of <5.0% is considered acceptable and can be categorized as homogeneous data.

Score assigned	4

Indicator 1.3d Quantity of observed water level data that is recorded electronically and the calibration status of water level recording instruments

Based on the data gathered from the Water Resources Management Information System (WAMIS), all stream gauge monitoring stations within the vicinity of Busan Metropolitan City are recording automatically and in real-time. Automated and real-time monitoring allows for efficient water management, disaster preparedness and over all stream sustainability.

Score assigned	3

Indicator 1.3e Process of water level data collection using ICT-based technologies

The stream flows within the Busan Metropolitan city are measured using ICT-based real-time and automatic data collection methods, such as Telemetry, ADCP (Acoustic Doppler Current Profiler), ADVM (Acoustic Doppler Velocity Meters), Propeller flow meter, etc. The usage of modern ICT-based technologies in water level monitoring is an indicator of a smart water city.

Score assigned	4

Indicator 1.3f Status of public accessibility to water level data records

The complete river and stream water level data for Busan Metropolitan city can be accessed from WAMIS website (wamis.go.kr) and the Busan Open Data website (data.busan.go.kr). The ease of access to water level data promotes transparency in urban water management, allowing the public to have access to important information that is crucial in decision making during flood events.

Score assigned	4

Indicator 1.4a Coverage extent of urban stream water quality monitoring stations

Busan Eco Delta city is located within the areas of Gangseo, Sasang and Buk Districts, having a total surface area of 253.19 km2. According to the Korea Water Resources Corporation, there are a total of 8 water quality monitoring stations along the urban stream and rivers located within the districts. Therefore, the calculated stream water quality station coverage density is about 31.6 km2 per station. These water quality stations are important in keeping track of the health of the water bodies, monitoring its impact on public health and aquatic ecosystem.

Score assigned	3

Indicator 1.4b Monitoring and recording frequency of stream water quality sampling instruments

The water quality of urban streams needed to be frequently tested in order to identify prospective issues that might affect the health of the urban stream ecosystem. According to the Busan Open data, the stream water quality parameters such as temperature, electric conductivity, dissolved oxygen, pH, salinity, turbidity, etc. are measured at an hourly interval.

Score assigned	4

Indicator 1.4c Percentage comparison of missing and error of observed water quality data to the total observed data

According to the data gathered from Water Resources Management Information Sy, the 8 water quality monitoring stations within the city are Eulsukdo, Geumgok, Gupo, Nakdong Estuary 1 and 2, Seobusan, Seonakdong 1,2,3,4 and 5 water quality stations. The percentage of missing water quality data for each station are 0.0%, 41.7%, 25.2%, 52.4%, 52.4%, 0.0%, 27.8%, 27.8%, 27.8%, 48.9% and 48.9%, respectively. The average water quality percentage of missing data is 32.1%. A large percentage of missing data can lead to biases in performing water quality trends or modeling.

Score assigned	1

Indicator 1.4d Standard quality of urban stream water

According to data from the Korea Water Resource Corporation, the Busan Metropolitan city stream water measured pollutant levels for BOD (biochemical oxygen demand), COD (chemical oxygen demand) and TP (total phosphorus) are 3.2 mg/l, 5.62 mg/l and 0.26 µg, respectively. These measurements satisfy the Environmental Protection Agency (EPA) recommendations for BOD, COD and TP pollutant levels, which are ≤5 mg, ≤ 20 mg, and 0.29 µg, respectively.

Score assigned	4

Indicator 1.4e Quantity of observed water quality data that is recorded electronically and the calibration status of water quality recording instruments

For Busan Metropolitan City, the river water quality measurements are performed through manual measuring networks by the Busan Health and Environment Research Institute (22 stations), the Nakdong River Basin Environmental Office (2 stations), the Nakdong River Water Environment Research Institute (3 stations), while automated monitoring is performed by the Busan Institute of Health and Environment (37 manual and 13 automated monitoring). No information on instruments calibrations is gathered.

Score assigned	**3**

Indicator 1.4f Process of water quality data collection using ICT-based technologies

According to the Water Environment Information Center, the city utilizes real-time water quality indices through ICT-based instruments or methods such as thermistor, glass and reference electrode, non-dispersive infrared detection, ultraviolet absorbance spectrophotometry and turbidimeter. The usage of these technologies in water quality monitoring increase data quality, maintains cost effectiveness, larger scale coverage, and more.

Score assigned	**4**

Indicator 1.4g Status of public accessibility to water quality data records

According to the Busan open data (data.busan.go.kr), stream water quality parameters such as temperature, electric conductivity, dissolved oxygen, pH, salinity, turbidity, etc. are provided in real-time through the website. The accessibility of this information allows the public to constantly monitor the quality of the urban river, enabling the community to be vigilant of potential threats.

Score assigned	**4**

Indicator 1.5a Coverage extent of groundwater level monitoring stations

The groundwater data for the Republic of Korea is being managed by the National Groundwater Information Center. Busan Eco Delta City is located within the Gangseo District. According to the Center, the total number of groundwater monitoring wells within the District of Gangseo (total surface area of (179.05 km2) is 8 stations. The groundwater level monitoring coverage density is about 22.4 km2 per station.

Score assigned	**3**

Indicator 1.5b Monitoring and recording frequency of groundwater level instruments

The groundwater monitoring frequency should be enough to detect the short-term and seasonal fluctuations of groundwater level in the effect of hydrological stresses. According to the National Water Information Center, the groundwater level monitoring for the city of Busan is being conducted at an hourly interval.

Score assigned	**4**

Indicator 1.5c Percentage comparison of missing and error of observed groundwater level data to the total observed data

According to the data gathered from the National Groundwater Information Center, the missing data percentage among 6 groundwater level stations within the city are 1.1%, 84.3%, 94.5%, 90.8%, 90.8% and 5.14%. The average missing data percentage is 61.1%. A higher missing data percentage is not recommended in maintaining the accuracy and reliability of groundwater level datasets.

Score assigned	**1**

Indicator 1.5d Quantity of observed groundwater level data that is recorded electronically and the calibration status of ground water level recording instruments

According to the Integrated Groundwater Information Services, the groundwater level, temperature and electric conductivity are measured automatically at hourly intervals in the installed aquifer and alluvial wells. The automation and calibration of groundwater level monitoring instruments play an important role in managing groundwater source for public water supply.

Score assigned	3

Indicator 1.5e Process of groundwater level data collection using ICT-based technologies

The groundwater monitoring networks for the republic of Korea are composed of automatic and manual observations, conducted by the Ministry of Land, Infrastructure and Transport, Korea Water Resource Corporation, Ministry of Environment, Korea Environment Corporation, and the regional municipalities. The ICT-based groundwater level monitoring instruments located within the districts of Gangseo, Sasang and Buk includes data transceiver device, monitoring and control system, real-time data management and ethernet database.

Score assigned	4

Indicator 1.5f Status of public accessibility to groundwater level data records

Open access to groundwater level data is crucial in effective groundwater management, research, and decision-making. The National Groundwater Information Center provides open access to the groundwater monitoring wells all over Korea, including the city of Busan.

Score assigned	4

Indicator 1.6a Coverage extent of groundwater quality monitoring stations

The district of Gangseo, where the Busan Eco Delta City is located, has a total of 9 groundwater quality observation wells covering a total of 179.05 km2 of surface area. Therefore, the groundwater quality station coverage density is 19.9 km2 per station. The spatial density of groundwater quality monitoring stations is important in understanding the current and past status of the quality of groundwater within the city.

Score assigned	4

Indicator 1.6b Monitoring and recording frequency of groundwater quality sampling instruments

High-resolution groundwater quality timeseries data is necessary for water resource management and understanding the changes in subsurface water quality. According to the National Groundwater Information Center, the average total number of groundwater quality observation per year for the city of Busan (1996-2022) is 2004, while the total number of groundwater observation wells within the city is 158. The groundwater quality monitoring frequency for Busan Metropolitan city is therefore 12.7 groundwater quality inspections per year.

Score assigned	3

Indicator 1.6c Percentage comparison of missing and error of observed groundwater quality data to the total observed data

Based on the groundwater quality data gathered from the National Groundwater Information Center, the total number of inspections from 1996 to 2022 is 54097, resulting to roughly 342.4 groundwater quality inspections annually. Since the target inspection 12.7 inspections per year, the total groundwater quality inspections should be 342.9. Therefore, the percentage of missing data for groundwater quality monitoring is 0.15%.

Score assigned	4

Indicator 1.6d Standard quality of urban groundwater water

The groundwater quality standards indicate the maximum permitted contaminant concentration amount that can be acceptable for water supply. According to the Groundwater Annual report by the National Groundwater Information Center, the average passing percentage of the groundwater quality compliance for Busan Metropolitan City from 1996 to 2022 is 89%. The groundwater monitoring for the city follows the compliance standard for the city of Busan.

Score assigned	4

Indicator 1.6e Quantity of observed groundwater quality data that is recorded electronically and the calibration status of groundwater quality recording instruments

According to the National Groundwater Information Center, the groundwater quality for the city performed by the Korea Water Resources Corporation, K-eco Regional Environment Office and the municipality of Busan conduct a combination of manual and automatic monitoring. Automation in groundwater quality observations ensures the consistency and accuracy of data collection, reducing opportunities for error in recording.

Score assigned	3

Indicator 1.6f Process of groundwater quality data collection using ICT-based technologies

Monitoring of groundwater quality in Korea are composed of automatic and manual observation wells conducted by the Ministry of Land, Infrastructure and Transport, the Korea Water Resources Corporation, Ministry of Environment, the Kore Environment Corporation, and the regional municipalities. For Busan Metropolitan City, the observation wells utilize ICT-based technologies such as online data transceiver devices, real-time data management, and monitoring and control system.

Score assigned	4

Indicator 1.6g Status of public accessibility to groundwater quality data records

Limitations in the public's access to groundwater data can present issues in water resource management hindering effective public communication. For the city of Busan, the National Groundwater Information Center provides open access information to groundwater quality monitoring. Some of the groundwater quality parameters that can be accessed are electric conductivity, pH levels, total chloroform and nitric acid nitrogen, chlorine ion, cadmium, arsenic, mercury, lead and more.

Score assigned	**4**

Indicator 2.1a Flood casualty index as an indicator of the city population's vulnerability to life-threatening flood events

Reducing flood-related casualties is an essential aspect in city disaster preparedness and mitigation. According to the Water Resource Management Information Service, flood-related casualties have occurred in Busan Metropolitan city in 2016.

Score assigned	**3**

Indicator 2.1b Flood damage index as an indicator of the city's vulnerability to property damages caused by urban flood events

Flood damage index refers to the potential risk of flood damage of the city as referred to the relationship between the cost of damage resulted from flood events and the city's gross domestic product (GDP). According to the Korea Statistics Ministry and the Water Management Information System, Busan Metropolitan City's most recent GDP and the 10-year averaged flood damage amount (2011-2020) are 91,698,334,000,000 KRW and 2,882,926,460,000 KRW, respectively. The computed flood damage index for Busan Metropolitan city is therefore 0.0003.

Score assigned	**4**

Indicator 2.1c Percentage comparison of the flood-prone areas to the total surface area

Flood risk area index pertains to the portion of the urban area susceptible to recurrent flooding. For Gangseo district in Busan Metropolitan city, the maximum recorded flooded area for the recent 10-year data is 0.07 km2 (Water Resource Management Information Service). Given the district's total surface area of 181.5 km2, the flood risk area index is therefore 0.0004. An index of less than 0.1 is considered a good indicator for reduced risk of the city relating to flood events.

Score assigned	**4**

Indicator 2.1d Percentage comparison of completed stream levee structures to the total stream extent

There are a hundred rivers and streams within the Busan Metropolitan city, the largest ones being the Suyeong River, Nakdong river, West Nakdong river and Oncheon stream. Based on the data gathered from the Busan Metropolitan city current river status from the public data portal, the total river extension and the total repaired river extension are 499.2 km and 327.4 km, respectively. The computed levee maintenance percentage is 65.8%. Levee maintenance refers to the restoration of rivers and urban streams to prevent riverine flooding through construction of dikes, levees, artificial retentions, etc.

Score assigned	**3**

Indicator 2.1e Application of city-scale flood hazard maps

This indicator refers to the city's application of city-scale flood hazard mapping for the municipal flood mitigation strategies. According to the Busan Metropolitan city Integrated Urban Flood Information, the city implements flood hazard maps based on historical return period flooding. These high-resolution flood hazards include rainfall-induced flooding (50- and 100-year return period rainfall), coastal flooding (tsunami) and river flooding.

Score assigned	**4**

Indicator 2.1f Implementation of city-scale integrated disaster information system and application of ICT-based technologies in flood management

The Gangseo district flood disaster information can be accessed to safecity.busan.go.kr. The website provides real-time weather and traffic information, in addition to dissipation of disaster text messages, etc. The Busan Metropolitan city integrated disaster information system utilized ICT-based information for monitoring, safety protocols and disaster recovery.

Score assigned	**4**

Indicator 2.1g Operation of urban flood prediction system and advanced real-time alarm services

The Busan Metropolitan city integrated flood disaster information center also provides real-time information on river water level and heavy rainfall alert, and other ICT-based technologies such as disaster surveillance CCTVs, necessary for flood forecast and mitigation. These early warning systems are key elements for flood disaster risk reduction, minimizing potential casualties and damage due to flooding.

Score assigned	**4**

Indicator 2.2a Drought damage index as an indicator in identifying the city's vulnerability to drought events based on the percentage of population affected by drought-related limited water supply

The urban drought damage index refers to number of people affected by the control measures during drought periods, including water service interruptions, limited water supply, etc. in relation to the total number of city's population. According to the National Drought Information Portal, there is zero drought-affected population within the Gangseo district for 2010 to 2020. This score can be attributed to the preparedness of the city on the limitations in the city's water supply during drought events.

Score assigned	**4**

Indicator 2.2b Recent drought occurrences affecting water supply and distribution

This indicator pertains to the occurrences of drought events in recent years that had affected the water supply and distribution in the city. According to the National Drought Information Portal, drought frequency analysis shows occurrence of drought events in Busan for 2017 (200-year return period) and 2020 (50-year return period).

Score assigned	**2**

Indicator 2.2c Application of ICT-based drought mapping

Drought risk assessment and mapping is critical in city-scale drought management in identifying drought risk areas allowing for planning, preparation, and mitigation strategies for the impact of drought in the city. The National Drought Information portal provides district-scale information and drought forecasting for Gangseo district based on standard ground index

(SGI), standard precipitation index (SPI), Palmer drought severity index (PDSI), modified surface water supply index (MSWSI) and soil moisture index (SMI). These indices are mapped for the cities and districts through geographic information system using observed hydro-meteorological data.

Score assigned	**3**

Indicator 2.2d Operation of city-scale emergency water supply facilities and drought information system

The National Drought Information portal provides drought information and emergency water supply related information for Gangseo district, and other districts in Korea, accessible to drought.go.kr. The information provided by the drought portal includes current and past status of drought in the city and districts, showing drought normal status, states of interest, warning, precaution and severe warning.

Score assigned	**4**

Indicator 2.2e Operation of drought advanced warning system and advanced information services

The application of advanced drought warning and information services are important in decreasing potential risk. The drought information for Gangseo district can be accessed in the National Drought information portal drought.go.kr, including neighborhood drought information, emergency water supply facilities, meteorological and hydrological data, and drought damage status. In addition, drought forecasts and warnings are provided in the website, identifying potential drought risks within 1-month, 2-month and 3-month outlook.

Score assigned	**4**

Indicator 2.3a Application of city-scale climate change adaptation planning

City-scale climate change planning and adaptation is crucial in addressing climate-induced vulnerabilities. According to the South Kore Metropolitan Cities urban climate adaptation strategies, climate adaptation programs and budgets for planned climate change adaptation measures for Busan Metropolitan city is established. Highlighted in the planning is climate change monitoring and projection, industry and energy adaptation, agriculture, and fisheries.

Score assigned	**4**

Indicator 2.3b Application of renewable energy and energy-saving strategies

According to the Optimal Renewable Power Generation systems for Busan Metropolitan city in South Korea 2016, about 1.68% of the city's electricity consumption is derived from renewable energy. Among the renewable power strategies include power saving streetlights, LED traffic lights, PV generation supply for Drinking water treatment and Wastewater treatment facilities, ocean thermal generation plant and green home supply businesses.

Score assigned	**4**

Indicator 3.1a Monitoring and recording frequency of water source monitoring instruments

The water source quality monitoring system aims to detect level of pollution in the water source, enabling adequate actions to prevent the effect to public consumption. According to the Busan Water Authority, the water source quality monitoring at reservoir dam for Gangseo district, Busan is conducted on a 5-min interval, with averaged value computed at hourly interval. Finer temporal measurement scales are preferable to reduce the possibility of uncertainty and allows capture of transient events.

Score assigned	4

Indicator 3.1b Water source availability based on the total volume of available water and consumed water

According to the National Water Supply Information Center, the Busan Metropolitan city water source availability data obtained from the data from annual water intake volume and annual water supply consumption from 2006 to 2011 is 100.5%. A water source reliability value of more than 100% assures the sufficiency of water supply to the city's consumers.

Score assigned	4

Indicator 3.1c Quantity of observed water source data that is recorded electronically and the calibration status of water source recording instruments

Gangseo district, Busan Metropolitan city receives the majority of their water source from Nakdong river. According to Korea Water Resource Corporation water information portal, all of the stream water source monitoring stations (Estuary bank pier 8, 10, Upstream gate, Eulsukdo bridge P3, 20, Nakdong river estuary, Nakdong bridge, etc.) along this river records in real-time. The application of real-time information in water source monitoring is necessary for prompt and adequate actions for prevention in water pollution.

Score assigned	3

Indicator 3.1d Process of water source data collection using ICT-based technologies

This indicator assesses the application of ICT-based technologies in water source monitoring. According to the Busan Metropolitan city Water Purification Results Report 2016, the city utilizes real-time ICT-based measuring instruments in water source monitoring in Maeri water reservoir, Busan. The types of water parameters measured include water depth, salinity, temperature, and electric conductivity.

Score assigned	4

Indicator 3.1e Status of public accessibility to water source data records

The water source quality data for Busan Metropolitan city is accessible to various government open-source websites such as the Water Information Portal (water.or.kr), Water Environment Information System (water.nier.go.kr) and the Busan Open Data Portal (data.busan.go.kr). These water quality data include water temperature, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and more.

Score assigned	4

Indicator 3.2a Drinking water quality compliance with the established drinking water quality standards

The standard for drinking water quality compliance is important in preventing the consumption of contaminated tap water. Based on the Busan Metropolitan city compliance status of Drinking water purification plants (2023 data), the drinking water facilities that supply drinking water to Gangseo, Sasang and Buk districts (Daeoksan and Hyangyeong plants) all complied to the standard requirements for pH, ammonium nitrogen (NH3), residual chlorine, turbidity, trihalomethane (THMs) and potassium permanganate (KMnO4).

Score assigned	4

Indicator 3.2b Monitoring and recording frequency of water quality monitoring instruments in Water purification treatment plants

According to the Busan Water Authority, the drinking water purification plants operating within the city perform quality performance observations at least once a day. High frequency of drinking water monitoring can reduce the associated risk in the chemical balance, compliance with the environmental regulation, improving reliability and public safety.

Score assigned	3

Indicator 3.2c Quantity of observed drinking water treatment data that is recorded electronically and the calibration status of drinking water recording instruments

Automation and quality assurance application in Drinking water quality monitoring can assist in the early prevention of unexpected occurrences. According to the Busan Metropolitan City Water Purification Results Report 2016, the energy management, intelligent alarm, and mobile process management has been fully automatized through intelligent integrated management system.

Score assigned	3

Indicator 3.2d Process of drinking water treatment data collection using ICT-based technologies

According to Korea Water Resources Corporation, drinking water treatment facilities provides clean water using innovative water management technologies, digitalized management system using artificial intelligence (AI) and big data. These integrated solutions provide real time information in water plant management and smart water treatment plants, especially applied to Busan Eco Delta City drinking water management.

Score assigned	4

Indicator 3.2e Status of public accessibility to drinking water treatment data records

The availability of drinking water quality data to the public embodies transparency, accountability and informed decision making. For Busan Metropolitan city, drinking water data information can be easily accessed through the Busan Water Authority website (busan.go.kr/water). On the website, information such as the standard and the measured values of purified water parameters such as pH, turbidity, ammonium nitrogen, etc. can be accessed.

Score assigned	4

Indicator 3.2f Application of advanced water purification treatment process in the Drinking water treatment facilities

According to the Busan Water Authority, the city's drinking water treatment plants utilize treatment methods such as deposition, filtration, ozonation, and active carbon to eliminate germs, foul taste, and odors. These water treatment facilities, namely Deoksan, Myeongjang, Beomeosa and Hwamyeong apply slow and rapid filtration methods and advanced treatment methods to purify the drinking water for the city.

Score assigned	**4**

Indicator 3.3a Percentage extent of water supply distribution based on the number of populations with access to water supply

The extent to which the water supply distribution that benefits majority of the urban population, receiving adequate water supply services is an indicator of a smart water city. According to the National Water Supply Information System, there is no district in Busan that does not have access to centralized water supply network since 2009. Therefore, 100% of the city's population have access to drinking water services.

Score assigned	**4**

Indicator 3.3b Percentage of aging and deteriorating water supply pipelines

According to the 2006-2011 data of Waterworks Supply Status data from the Ministry of Environment, the total water supply pipe extension for Busan Metropolitan city is 4,253,477 m, while the total extension of pipelines installed more than 30 years ago is 409,626 m. Therefore, the percentage of aging pipelines for Busan Metropolitan city is 9.6%. Aging pipelines introduce potential for water breaks and leakages, which can result in huge water loss and expensive maintenance.

Score assigned	**3**

Indicator 3.3c Percentage of revenue and non-revenue water

For the annual water supply leakage percentage for 2006 to 2021, the average non-revenue water for Busan Metropolitan city is 5.4%. Therefore, the city's average percentage of revenue water is 94.6%. According to literature, an estimated average water loss in water network is about 5% for well-maintained pipes. Small percentage loss indicates good maintenance of water supply network.

Score assigned	**3**

Indicator 3.3d Water storage effective capacity of water treatment facilities

The water storage effective capacity pertains to the stability of water supply, can be calculated based on the water treatment facility's maximum daily water supply and the maximum daily storage capacity. Based on the National Water Supply Information System data (2006-2020), the average daily storage capacity and maximum daily water supply performance for Busan purification plants are 2,913,933 m3 and 1,363,023 m3, respectively. Therefore, the city's computer effective storage capacity percentage is 46.8%.

Score assigned	**4**

Indicator 3.3e Quantity of observed drinking water quality data that is recorded electronically and the calibration status of water quality recording instruments

Real-time monitoring and automation in water supply network monitoring allows immediate actions in times of leak detection, pressure variations and other issues. Based on the data gathered from the Busan Water Authority, automated remote water meter monitoring is utilized for all of Busan city districts, where Gangseo district has the highest percentage (96.8%) of automated remote reading.

Score assigned	3

Indicator 3.3f Implementation of water supply pipe maintenance system

According to the Busan Water Authority, the city coordinates with pipe leak specialists and maintenance companies to address issues in water supply pipeline leakages and damages. These companies facilitate maintenance issues including high-tech pipe leak detection equipment, waterproof construction, piping maintenance, repair, plumbing etc. Pipe maintenance ensures continuous and sustainable water service provision, preventing decline of pipe quality leading to greater water loss and contamination.

Score assigned	4

Indicator 3.3g Application of smart water meter reading

Busan Metropolitan city utilizes remote smart meter system that is operated by IoT (Internet of Things) technology. These smart meters provide status information on an hourly basis. According to Busan Water Authority, about 96.8% of meter reading in Gangseo district, Busan is automated and run remotely. The application of smart water reading in water consumption constituent key component in water management, allowing more mindful water consumption and efficient usage.

Score assigned	4

Indicator 3.3h Status of public accessibility to drinking water treatment data records

For the drinking water treatment facilities in Busan Metropolitan city, including Deoksan, Hwamyeong, Beomeosa and Myeongjang, the daily water supply volume can be accessed in the Busan Water Authority website (busan.go.kr). Public access to water supply data enables consumers to monitor their water consumption which can initiate water saving strategies.

Score assigned	4

Indicator 3.4a Percentage extent of sewage service distribution based on the number of populations with access to sewage system

Sewage network population access percentage refers to the coverage of sewage pipe network distribution, wherein a larger percentage shows a well-managed sanitation system. According to the Busan Metropolitan city total population and the population with access to centralized wastewater facilities (1998-2021) are 3,398,000 and 3,385,645. Aside from the 0.12% of the population using individual septic tanks, 99.88% of the city's population benefits from wastewater services.

Score assigned	3

Indicator 3.4b Percentage of aging and deteriorating sewage pipelines

According to the 2021 Sewage network statistics facilitated by the Ministry of Environment, the total sewage pipe network for Busan Metropolitan city is 10,149.8 km. On a 2020 Final report by the Ministry of Environment, the total extension of aging sewage pipes in the city is about 420 km. Therefore, for Busan Metropolitan city, the percentage of aging sewage pipe network is 4.1%.

Score assigned	4

Indicator 3.4c Monitoring and recording frequency of wastewater monitoring instruments in the Wastewater Treatment facilities

For the Gangseo, Sasang and Buk districts in Busan Metropolitan city, the quality of wastewater in the sewage treatment facilities is being monitored on a daily basis, according to the data obtained from the Busan Environmental Corporation. High frequency monitoring would allow higher probability of early detection of failure events within the treatment facilities.

Score assigned	4

Indicator 3.4d Quantity of observed sewage data that is recorded electronically and the calibration status of wastewater recording instruments

The Busan Environment Corporation developed an automatic system that measures and controls dissolved oxygen and microbial concentration, installed in Subyeon sewage treatment plant (Saha district) and Nam sewage treatment plant (Nam district). Real-time and automated monitoring during the wastewater treatment process is necessary in addressing and handling potential problems that might occur during the operation.

Score assigned	4

Indicator 3.4e Application of separated wastewater and storm water network

Separated sewer system operates individual pipe networks for wastewater and storm water flow. Based on the 2021 Korea sewer statistics data, the total combined sewage, storm water, and wastewater network total extent for Busan Metropolitan city are 132,975.0 km, 21,928.0 km, and 61,308.0 km, respectively. The separated sewage network percentage for the city is therefore 38.5%.

Score assigned	1

Indicator 3.4f Implementation of sewage network maintenance system

The application of maintenance procedures in sewage networks are needed in order to identify problems in wastewater collection and transportation. Busan Metropolitan city utilizes modern equipment such as high-pressure washing machines, dredging vehicles and pipe endoscope cameras to monitor and provide maintenance for the sewage network.

Score assigned	4

Indicator 3.4g Application of advanced sewage treatment process in the Wastewater treatment facilities

According to the Korea Statistics Information Service, Busan Metropolitan city wastewater facilities perform physical (primary), biological (secondary) and advanced (tertiary) treatment processes for sewage wastewater. About 91.4% of the city's population benefits from advanced level wastewater treatment results. Advanced wastewater treatment offers advantages in more effectively removing pollutants and contaminants, producing high-quality treated water, and minimizing negative impacts to the environment.

Score assigned	4

Indicator 3.5a Percentage of reused and recycled wastewater

Based on the Sewage water treatment status summary (1991-2021) published by the Korea Statistical Information Service, the total amount of daily water inflow and discharge for Busan Metropolitan city are 1,423,906.3 m3 and 1,338,228.7 m3, respectively. The percentage of recycled treated wastewater for the city is 94.0%. Reusing treated wastewater promotes conservation of water resources, reducing demand for fresh water supplies and promotes sustainability.

Score assigned	4

Indicator 3.5b Percentage of recycled sewage solid waste materials

Reuse of sewage treatment facilities' solid byproducts foster a more sustainable and environmentally friendly approach to wastewater management. For Busan Metropolitan city, the amount of total and recycled sludge materials according to a 2001-2014 data by the Korea Statistical Information Service, are 131,719.8 ton (91.3% for biomass energy, 1.05% for fertilizers and the remaining to cement or plastic production) and 215,236.5 ton, respectively. The percentage of recycled sludge materials for the city is computed as 61.1%.

Score assigned	1

Evaluation Results on Governance & Perspective Pillar

Indicator 1.1.a. Existence of a clear allocation of responsibilities in water resources management and water services provision

Water resources management responsibilities are clearly defined in Korea. The Water Management Basic Act, enacted on May 28, 2018, is a pivotal document that outlines the distribution of water resource responsibilities. The Ministry of Environment bears significant responsibilities in water resources management and pollution control, with MOLIT and the Ministry of Agriculture also having distinct competencies for water-related infrastructure, such as dams and reservoirs, and use of water resources for agriculture and rural areas. Local governments are responsible for providing water services within their jurisdiction. In certain instances, local governments establish and manage their water supply systems, although many in metropolitan areas receive water from multi-regional systems operated by K-water.

Score assigned	4

Indicator 1.1.b. Existence of department(s) at the city level in charge of local water-related responsibilities

In Busan, the local government has established the Environment and Water Policy office, tasked with managing and providing water services for the city. This includes formulating environmental policies, enhancing the living environment, overseeing water quality, diversifying water sources, managing rivers, restoring river systems, and administering sewers and environmental facilities. The Civil Safety Office, also under the local government, is responsible for urban water management, covering general safety oversight, disaster prevention, civil defense, disaster response and recovery, on-site safety inspections, and disaster situation management. Additionally, the Busan Water Corporation holds the responsibility for providing water services to the citizens of Busan. Their duties encompass constructing medium and small-scale dams, developing water resources, managing water intake, purification, transmission, distribution, leak detection, and infrastructure replacement. They also conduct research and implement improvements for water quality, as well as handle the imposition and collection of fees and charges.

Score assigned	4

Indicator 1.1.c. Existence and implementation of mechanisms to review roles and responsibilities of the cities, to diagnose gaps, and to adjust when need be

In Korea, instruments such as performance audits, regulatory framework reviews, and benchmarking are employed at various administrative levels, including the local level, to assess the suitability of the distribution of responsibilities. According to the received questionnaires, these instruments function satisfactorily. In Busan they are notably prevalent during the revision of the 'Integrated Water Management Master Plan' for Busan Metropolitan City. This master plan, outlining the roles and responsibilities of the city, undergoes a review every five years, requiring approval from local stakeholders

Score assigned	4

Indicator 1.2.a. Existence and level of implementation of integrated water resources management policies and strategies that include the urban level and cities' features and water status

Since the adoption of the Water Management Basic Act in 2018, Korea has implemented policies and strategies that designate the river basin as the primary management unit. This legislation has facilitated the decentralization of the water-based governance system for water resources management, transitioning from a previously more centralized approach.

Score assigned	4

Indicator 1.2.b. Existence and functioning of institutions managing urban water (not necessarily exclusively) at the hydrographic scale

The Republic of Korea features four major river basins: Nakdong, Han, Geum, and Yeongsan, along with up to 117 Mid-level basins mid-scale rivers such as Anseongcheon, Sapgyochun, Mangyeong, Dongjin, and Hyeongsan, and 840-unit basins, affecting small-scale areas1. The Nakdong River, stretching 506.17 km with a basin area of 23,384 km2, holds the distinction of being the country's longest and encompasses the city of Busan. For integrated water resource management, the Republic of Korea has established River Basin agencies, which are tasked with coordinating policies at the river basin level, including the urban areas. In the case of Busan, the Nakdong River Basin

1. J. Korean Soc. Hazard Mitig. Vol. 20, No. 2 (Apr. 2020), pp.251~263 https://doi.org/10.9798/KOSHAM.2020.20.2.251 www.kosham.or.kr Assessment of Nakdong River Basin Management: Target Water Quality Achievement and Future Challenges Kang, Kyeong Hwan, Kim, Junghyeon, Jeon, Hyeonjin; Kim, Kyoungwoo; and Byun, Imgyu

Authority implements projects for water quality improvement for the Nakdong river, issuing permits for river water usage, maintenance and management, as well as ecosystem restoration and flood prevention efforts.

At the city level, the Environment and Water Policy office of the Busan local authority has established the River Management Division, which participates directly in the management of the Nakdong river and other Small River Management Committees, in collaboration with the Ministry of Environment.

Score assigned	4

Indicator 1.2.c. Existence and level of implementation of co-operation mechanisms for the management of water resources across water-related users and levels of government, including the local level.

The Ministry of Environment in the Republic of Korea is actively involved in the development and implementation of river basin management plans. These plans guide the activities of the river basin authorities and include strategies for sustainable water resource management, pollution control, and the protection of aquatic ecosystems. As such, they serve as the tool to organize the activities of different actors at the river basin scale, including local authorities, that impact water resources. For large river basins, the plans need to be updated every 10 years, while medium and small river plans need to be reviewed every 5 years.

Score assigned	4

Indicator 1.3.a. Existence and implementation of cross-sectoral local policies and strategies promoting policy coherence between water and key related areas, in particular local environment, health, energy, agriculture, land use and spatial planning

Efforts to improve horizontal (between departments) and vertical (between different tiers of government) coordination have been made in the last few years with the purpose of improving the mitigated performance highlighted in the past (OECD 2017). The Water Management Basic Act, enacted in 2018, has significantly enhanced coordination across various water-related domains. This legislation establishes the ground for a unified water resources plan and budget, along with shared mechanisms for regulating conflicts or divergent interests among the various ministries overseeing water quantity, water quality, agricultural water, and water-related disasters. Furthermore, the Act mandates local authorities to formulate water plans for cities, aiming to consolidate all water-related sectors under a cohesive framework, thus facilitating coordination among the diverse sectors.

Score assigned	3

Indicator 1.3.b. Existence and functioning of an inter-departmental body or institutions at the local level for horizontal co-ordination across water-related policies

At the national level, the National Water Management Committee, comprising representatives from ministries with water-related policies, chairpersons from the four river basin committees, members of civil society, and other officials, serves a three-year term. Similarly, at the basin level, Watershed Management

Committees have been established, bringing together national government officials from various ministries, representatives from local governments, and members of civil society.

This committee model has been replicated at the local level. Recently, Busan established the Busan Metropolitan City Water Management Committee, responsible for matters related to the establishment and amendment local water plans. The committee is composed of the Directors of the Environment and Water Policy Department, the Water Management Department, other council members, water experts, and local water stakeholders.

Score assigned	3

Indicator 1.3.c. Existence and implementation of mechanisms at the local level to review barriers to policy coherence and/or areas where water and related local practices, policies or regulations are misaligned.

We find very different answers from the respondents – from those that consider that Communication channels, regular meetings and conflict resolutions mechanisms exists – albeit with deficiencies, to those that consider that these mechanisms are being considered but are not implemented. In any case, the responses seem to indicate deficiencies in the actual operation of mechanisms to review barriers, which needs to be taken into account. This indicator requires additional scrutiny to fully understand the nuances and implications

Score assigned	3

Indicator 1.4.a. Existence and level of implementation of hiring policies based on a merit-based and transparent professional and recruitment process of water professionals independent from political cycles

In Korea, the selection of staff working at both national and local levels in water-related departments follows transparent procedures with clearly defined criteria and processes. Typically, the hiring process for public staff begins with government agencies announcing job openings, specifying qualifications, and outlining application details. Applicants are then required to submit necessary documents, such as resumes and transcripts, and may undergo written exams and interviews. Successful candidates undergo document verification and, in some cases, a medical examination. The final selection is based on overall performance, and appointed individuals undergo orientation before assuming their roles. For example, K-water posts its job vacancies online, and a similar practice is encouraged for local authorities.

Score assigned	3

Indicator 1.4.b. Existence and functioning of mechanisms to identify and address capacity gaps in local water institutions

Various mechanisms and instruments can assist in identifying and addressing capacity gaps in local water institutions. Examples include assessments of needs, capacity-building workshops and training, technical assistance activities, mentoring, partnerships with other organizations, and performance monitoring and evaluation activities. These tools play a crucial role in recognizing capacity gaps and assessing progress in mitigating them.

In the context of Busan, the issue of existing mechanisms and their functionality sparks division among respondents, with no consensus reached. Responses range from affirming the existence and full functionality of all these mechanisms to considering them non-existent (but under development).

A comparison of these responses with analyses from international institutions, such as the OECD and the ADB, reveals identified gaps in the training of local authorities' staff due to their subsidiary role to the national government. National entities, like K-water, have implemented well-defined approaches to identify knowledge gaps in their hiring processes, yet it appears these practices are not mirrored at the local level in Busan.

Further examination is necessary in this aspect, given the evident contention. This indicator requires additional scrutiny to fully understand the nuances and implications

Score assigned	3

Indicator 1.4.c. Existence and level of implementation of educational and training programs for local water professionals

Greater consensus exists here compared to the previous Indicator 1.4.b. The responses emphasize shortcomings in educational programs and training for local water professionals, deemed insufficient to varying degrees by the respondents. This aligns with assessments conducted by international organizations on the same issue.

Score assigned	3

Indicator 2.1.a. Existence and functioning of updates, timely shared, consistent and comparable water information systems at the local level.

Extensive data and information on water resources and services are consistently generated across the country. The nation's strategy for an Integrated Water Management System heavily depends on the establishment of large-scale automated data systems. At the urban level, there exists a well-established, timely, shared, consistent, and comparable information system, collaboratively produced by both national and local agencies. This discovery aligns seamlessly with the data obtained through the technical pillar, which extensively utilizes information collected and supplied by public authorities and companies.

Score assigned	4

Indicator 2.1.b. Existence and functioning of public institutions, organizations, or agencies in charge of producing, coordinating and disclosing standardized, harmonized and official local water-related statistics.

At the local level, several entities are responsible for providing water-related statistics in Busan. The Health and Environment Research Institute of Busan Metropolitan City operates the 'Health and Environment Information Disclosure System,' producing data on water quality, availability, and reporting water incidents at monthly, quarterly, and hourly intervals through automated equipment. This information is shared with national authorities. Additionally, the Nakdong River Flood Control Office, under the Ministry of Environment, manages the 'Nakdong River Flood Control Office Website,' which compiles automatic data on river water levels, precipitation, dam and weir inflow/outflow. K-water has established the Water Information Portal (MyWater), disseminating information on dam and weir water levels, precipitation, dam and weir inflow/outflow, and domestic and public water intake. At the national level, the Korean Statistical Information Service portal, accessible through the website kosis.kr, collects and provides water-related statistics for the Republic of Korea

Score assigned	4

Indicator 2.1.c. Existence and level or implementation of mechanisms to identify and review local water data gaps, overlaps and unnecessary overload.

All institutions tasked with collecting water data employ distinct methods to identify the necessary information. According to responses from the received questionnaires, there are established mechanisms to review data gaps, overlaps, and overload. Continuous efforts are made for the adoption of improvements and modifications based on these assessments, with improvements to be made at the local level.

Score assigned	3

Indicator 2.2.a. Existence and level of implementation of governance arrangements that help local water institutions collect the necessary revenues to meet their mandates and drive water-sustainable and efficient behaviors

In the Republic of Korea, various water tariffs and user charges are in place. At the city level, local authorities collect fees such as water tariffs, wastewater tariffs, income from local rivers, groundwater utilization charges, as well as local resource and facility taxes.

Score assigned	4

Indicator 2.2.b. Existence and functioning of a dedicated institution in charge of collecting water revenues and allocating them to the right level

Yes, the Busan Water Authority is directly responsible for the imposition and collection of water fees and charges for all uses and services provided in the city.

Score assigned	4

Indicator 2.2.c. Existence and level of implementation of mechanisms to assess short -, medium- and long-term investment and operational needs and ensure the availability and sustainability of such finance

The mechanism for setting water tariffs in the Republic of Korea involves a multi-step process. Initially, local governors propose tariff changes, which are then submitted for deliberation to the local price committee. Upon approval, the proposed tariff undergoes a vote by the local council, and only after this process is it implemented. Consequently, water tariffs exhibit variation across the 161 local governments, reflecting local decisions and priorities.

In cases where K-water provides water services in cities, any tariff changes must be submitted to the central government for approval. The request then undergoes deliberation by the Water Tariff Committee. Before final approval, the Ministry of Land, Infrastructure, and Transport consults with the Ministry of Strategy and Finance, responsible for overseeing inflation on the national level. The approved decision is subsequently applied in areas where K-water provides water services.

Existing research indicates that the average water charge covers only a portion (77.8% in 2013) of the production costs. Notably, water is priced without adhering to a full cost recovery principle, and environmental externalities are not considered. This aspect of water pricing and its impact on the use and management of water in the Republic of Korea has emerged as a significant social and political issue.

Score assigned	**3**

Indicator 2.3.a. Existence and level of implementation of a sound water management regulatory framework to foster enforcement and compliance, achieve regulatory objectives in a cost-effective way, and protect the public interest

Korea has implemented measures to ensure a robust water regulatory framework. With a history of auditing public government activities, the country has, over the past 25 years, successfully established institutions, processes, and tools supporting good regulatory practices2. Key tools in fostering a strong water management regulatory framework include Regulatory Impact Assessments, as well as permits and licenses, which are elaborated upon below.

Score assigned	**4**

Indicator 2.3.b. Existence and function of dedicated public institutions responsible for ensuring key regulatory functions for water services and resources management at the city level

At the national level, the Ministry of Government Legislation plays a crucial role in overseeing regulatory reform initiative. It has the task of improving the regulatory environment and enhancing transparency. Additionally, the Regulatory Reform Commission, established as a presidential committee, coordinates and discusses the fundamental aspects of Korea's regulatory policy. This includes research and development of regulatory systems, examination of new and enhanced regulations, review of existing regulations, and the formulation and execution of a comprehensive plan for regulatory reform. The commission evaluates initiatives from all ministries and, if deemed insufficient, may return assessments to the respective ministries for refinement.

Legislation adopted by local authorities is subject to scrutiny by these national actors. At the city level, the local authorities are responsible for upholding and implementing the national legislation that delegates tasks. As such, they are responsible for issuing permits and licenses regulating how water resources are employed. In Busan, the Clean Water Policy Division and the River Management

2. Framework Act on Administrative Regulation as per the 2021 OECD Indicators of Regulatory Policy and Governance - iREG

Division, both part of the Environment and Water Policy Office, have these tasks.

Score assigned	4

Indicator 2.3.c. Existence and level of implementation of regulatory tools to foster the quality of regulatory processes for water management at city level

The national level has established mechanisms to enhance the quality of regulatory processes and prevent undesirable outcomes while ensuring compliance. Tools such as Regulatory Impact Assessment (RIA), Environmental Impact Assessments (EIA), and controls, including water quality and effluent standards, are implemented to ensure that water management aligns with defined policy objectives.

RIAs involve the national government evaluating the potential economic, social, and environmental impacts of proposed regulations—a prerequisite for adopting regulations, as outlined in the Basic Act on Administrative Regulations (1998). A significant mechanism within this framework is the “Cost-in, Cost-out” (CICO) principle, which limits cost increases associated with new or reinforced regulations by offsetting them through the abolition or relaxation of regulations incurring equal or greater costs.

EIAs mandate both national and local authorities to evaluate the environmental implications and risks of adopting policy measures. They are also required to explore alternative options, and the findings undergo review by a council comprising representatives of the approving authority (local government or ministry), relevant public officials, experts, and residents’ representatives.

In addition to these ex-ante mechanisms, various tools such as pollution permits, water quality standards, abstraction limits, etc., are in place to ensure comprehensive and effective water management. Pollution permits establish permissible levels of pollutants that entities are allowed to discharge into water bodies, ensuring compliance with environmental regulations. Water quality standards define the desired water quality parameters, providing benchmarks for assessing and maintaining the health of water resources. Abstraction limits set restrictions on the amount of water that can be withdrawn from water sources, preventing over-extraction and safeguarding the sustainability of water ecosystems.

The application of these instruments has at times been insufficient, which explains the lesser score.

Score assigned	3

Indicator 2.4.a. Existence and level of implementation of policy frameworks and incentives fostering innovation in water management practices and processes at the local level

Since 2017, Korea has implemented the Korean Regulatory Sandbox program, an initiative designed to facilitate the introduction of innovative products and services to the market. This program allows companies to operate under specific conditions, including a limited time frame, designated location, and defined scale. Participating firms benefit from exemptions from regulations that would typically apply outside the sandbox. The data collected during this period is used to inform amendments and improvements to relevant regulations, fostering a more conducive regulatory environment.

Initially targeting four sectors—information and communication technology (ICT) convergence, industrial convergence, innovative finance, and regional innovation—the program has since expanded to include the Smart City and Research and Development (R&D) Innovation Cluster sectors. This expansion aims to enhance social safety and encourage innovation across diverse areas.

As part of this program, the Busan Eco Delta City has granted K-water the opportunity to test its technology and assess its functionality within a living-lab environment.

Score assigned	4

Indicator 2.4.b. Existence and functioning of institutions encouraging bottom-up initiatives, dialogue and social learning as well as experimentation in water management at the local level

The Korean Regulatory Sandbox program initiative has received endorsement from the national government, extending its influence to cities such as Busan. Although it did not originate as a bottom-up initiative, its success relies on collaboration with the private sector and civil society. This collaborative approach actively involves the government and addresses potential regulatory issues that may arise in emerging markets (Malyshev, 2021).

Moreover, the Republic of Korea has established nationally-funded research institutes that bring together industry, government, and academia. In Busan, the Busan Research Institute has played a crucial role in fostering partnerships to enhance innovation capacity. These partnerships involve other public agencies, not-for-profit organizations, and city residents/resident associations. The collective efforts of these entities contribute to the overall development and success of innovation initiatives within the region.

Score assigned	4

Indicator 2.4.c. Existence and level of implementation of knowledge and experience-sharing mechanisms to bridge the divide between science, policy and practice at the local level

The Sandbox program and the initiatives of the Busan Research Institute have created opportunities for the establishment of collaborative mechanisms among private entities, research centers, and public organizations. These platforms facilitate partnerships that promote innovation, knowledge-sharing, and collective efforts in addressing various challenges and opportunities within the region.

Score assigned	4

Indicator 3.1.a. Existence and level of implementation of legal and institutional frameworks (not necessarily water-specific) on integrity and transparency

The Republic of Korea has a highly functioning judiciary and audit institutions that adhere to the principles of democracy and independence. The Constitution of the Republic of Korea establishes the framework for the independence of the judiciary from executive and legislative branches, in accordance with the principle of separation of powers.

Korea has undergone various legal reforms over the years to enhance the efficiency and transparency of its judiciary. These reforms have aimed to improve access to justice and strengthen the rule of law, and are applicable to all cases of mismanagement and corruption in the water services provision. Today, the Criminal act of the Republic of Korea regulates antibribery measures, and imposes sanctions to these corruption acts. In addition, there are laws that prevent public officials from taking bribes. Also, the act on the Prohibition of Improper Solicitation and Graft, enacted in 2015, criminalizes bribery and corruption involving public officials. Furthermore, the Act on Public Officials' Ethics, applicable to all public function, regulates the ethical conduct of public officials and aims to prevent corruption within the public sector.

Score assigned	**4**

Indicator 3.1.b. Existence and functioning of independent courts (not necessarily water-specific) and supreme audit institutions that can investigate water-related infringements and safeguard the public interest

Korea has a three-tiered court system, consisting of the Supreme Court, which serves as the highest court in the country, responsible for interpreting the constitution and reviewing the constitutionality of laws. The High Courts operate as appellate courts, hearing appeals from lower courts within their respective jurisdictions. District Courts handle both civil and criminal cases at the first instance, and can issue penalties against individuals found guilty of corruption offenses according to anticorruption laws. Additionally, there is a Constitutional Court responsible for reviewing the constitutionality of laws and government actions.

In addition to courts, Korea has established the Anti-Corruption and Civil Rights Commission, which operates as an independent anticorruption body. The ACRC is responsible for investigating corruption allegations and promoting anticorruption policies.

It is important to point out that the responses in the questionnaires of the BEDC evaluation have revealed a contradiction, with some answers affirming the existence and full functionality of the courts and audits, while others deny their existence. This discrepancy underscores the indicator as a potentially contentious issue, necessitating further analysis and potential clarification.

Score assigned	**4**

Indicator 3.1.c. Existence and level of implementation of mechanisms (not necessarily water-specific) to identify potential drivers of corruption and risks in all water-related institutions at different levels, as well as other water integrity and transparency gaps

Korea has laws in place to protect whistleblowers who report corruption or other illegal activities. The protection measures are designed to encourage individuals to come forward with information without fear of retaliation. Enforcement efforts involve both preventive measures and legal action against those who violate anticorruption laws

However, similar to Indicators 3.1.a and 3.1.b, this indicator has proven to be contentious. Some respondents assert that instruments such as independent oversight, corruption assessments, and whistleblowing mechanisms are only under consideration and not fully implemented. This topic demands further attention, as there is a perception among some respondents that these mechanisms are not fully operational.

Score assigned	3

Indicator 3.2.a. Existence and level of implementation of legal frameworks to engage stakeholders in the design and implementation of local water-related decisions, policies and projects

Korea has implemented measures to enhance public participation and access to information regarding environmental matters, including water policy, especially since 2006. These efforts have aimed to overcome a previously restrictive system that offered limited opportunities for involvement to water stakeholders. Indeed, previous reports on the country have highlighted areas for improvement in implementing stakeholder participation. This has particularly impacted consumer associations and other NGOs, which, unlike in other OECD countries, generally do not receive financial support from the government.

Amongst the recent initiatives on the water sector are have been introduced to actively engage water stakeholders in policy-making and water-related decisions is the 2018 Framework Act on Water Management, which establishes that decisions on water management policies shall be made through broad participation by interested parties, such as public officials of the State and local governments, water users, local residents, and relevant experts, as well as through consensus among such interested parties (art 19).

Score assigned	3

Indicator 3.2.b. Existence and functioning of organizational structures and responsible authorities to engage stakeholders in local water-related policies and decisions

The Central Environmental Policy Committee serves as the primary national stakeholder consultation body on environmental matters. With nearly 200 members hailing from academia, research institutions, private companies, and more, this committee plays a pivotal role in shaping environmental policies. Its contributions extend to the development of the Comprehensive National Environmental Plan, conservation master plans, and other significant initiatives. Alongside the Central Environmental Policy Committee, there are river basin management committees that feature representatives from local organizations and water users, operating at the river basin level.

In Busan, the city has recently established the Water Management Committee3. This committee includes the Director of the Environment and Water Policy Department and the Head of the Water Management Department as ex officio members. The Mayor appoints additional members, considering expertise in water quality preservation, ecological environments, and knowledge in the water industry.

Score assigned	**3**

Indicator 3.2.c. Existence and level of implementation of mechanisms to diagnose and review stakeholder engagement challenges, processes, and outcomes

The analysis has not identified particular mechanisms to diagnose and review stakeholder engagement challenges, processes and outcomes – perhaps due to the recent nature of the measures establishing participation from interested parties. Some respondents to the questionnaires have highlighted that these topic is under discussion, so that there is an awareness of the limitations of the governance model.

Score assigned	**3**

Indicator 3.3.a. Existence and level of implementation of formal provisions or legal frameworks fostering equity across water users and generations at the local level

The questionnaires distributed to K-water experts reveal that Korea lacks a developed regulatory or policy framework directly addressing the necessity to promote equity among users and/or between generations at both the local and national levels. Notably, no provision takes into account arguments related to fairness within the same generation concerning environmental issues. Likewise, although the judiciary could potentially contribute to considering inter-generational equity in enforcing and implementing environmental law, Korea lacks an authoritative judicial precedent explicitly incorporating inter-generational equity considerations.

Score assigned	**3**

Indicator 3.3.b. Existence and functioning of a local Ombudsman or institution(s) to protect water users, including vulnerable groups

No specific institutions are identified in this case. While there is an Ombudsman Office, it is primarily focused on Small and Medium Enterprises (SMEs) with the goal of safeguarding the interests of SMEs. However, it does not directly address water users, urban water resources management, or urban water services provision.

Score assigned	**2**

Indicator 3.3.c. Existence and implementation of mechanisms to manage trade-offs across users, and/or over time in a non-discriminatory, transparent and evidence-based manner at the local level

Measures accounting for prospective environmental risks, such as environmental risk assessments, play a crucial role in incorporating potential future environmental costs and benefits into current analyses. This, in turn, provides a mechanism for managing trade-offs among users. However, addressing these trade-offs is not explicitly on the agenda, as emphasized in some of

3. By means of the'Water Management Basic Ordinance' in December 2022

the questionnaires collected for the BEDC analysis, where the absence of such tools is empathized.

Score assigned	2

Indicator 3.4.a. Existence and level of implementation of policy frameworks promoting regular monitoring and evaluation of water policy and governance

Korea has established a robust legal and policy framework to enhance the monitoring and evaluation of water policy and governance, demonstrating a commitment to continual improvement. The Board of Audit and Inspection Act Law (No. 17560, October 20, 2020) outlines the scope, responsible organizations, and subjects subject to audit and inspection. Simultaneously, the Act on Public Sector Audits empowers central administrative agencies, local governments, and public institutions to establish self-audit organizations. Both the central and local governments have intensified their efforts to prevent non-compliance with environmental and water resource policies, resulting in enhancements to environmental policing. Moreover, the national government has endorsed and encouraged voluntary compliance plans to promote the adoption of environmentally friendly practices.

In Busan, the Enforcement Rules of the Busan Metropolitan City Administrative Organization, adopted in September 2023, formally allocate responsibilities to the local government. These strengthened measures are relatively recent, highlighting the recent focus on environmental laws, particularly those related to water resources.

Score assigned	4

Indicator 3.4.b. Existence and functioning of institutions in charge of monitoring and evaluation of water policies and practices and help adjust where need be

At the national level, the Board of Audit and Inspection (BAI) scrutinizes the final revenue and expenditure accounts of the State, primarily for financial compliance but also for performance evaluation. Additionally, Korea has implemented mechanisms to monitor and evaluate national policies, including the application of a "sunset clause." This clause, which establishes an expiration date for legislation, contracts, or policies, ensures periodic reviews to assess their effectiveness. It allows for adjustments, amendments, or the possibility of allowing the law to expire if no longer deemed necessary.

At the local level, the Busan Metropolitan City Audit Committee possesses the authority to audit local authorities. This committee is empowered to take disciplinary actions and request punitive measures, including ordering compensation for accounting-related personnel. It has the authority to issue demands for correction, warnings, improvements, recommendations, and reporting demands. Furthermore, it can request the reconsideration and exoneration of active administration and address other related matters (Article 63, Busan Metropolitan City Administrative Organization Establishment Ordinance, Busan City Ordinance No. 6972, July 5, 2023)

Score assigned	4

Indicator 3.4.c. Existence and level of implementation of monitoring and evaluation mechanisms to measure to what extent water policy fulfils the intended outcomes and water governance frameworks are fit-for-purpose
In addition to the actions undertaken by the Board of Audit and Inspection, which includes conducting audits of government agencies and public institutions to ensure transparency, accountability, and efficiency in the use of public resources, Korea has established mechanisms at the national level to monitor and evaluate national policies. One notable approach is the application of a "sunset clause," a provision that stipulates an expiration date for the application of legislation, contracts, or policies. This proactive measure ensures that the legislation undergoes periodic review and assessment to gauge its effectiveness. The clause allows for necessary adjustments, amendments, or the possibility of letting the law expire if it is no longer deemed necessary, promoting a dynamic and adaptive approach to governance.

At the local level, the Busan Metropolitan city audit committee can audit local authorities, has actions related to disciplinary actions and requests for punitive measures; can order for compensation for accounting-related personnel, etc.; issue demands for correction, warnings, improvements, recommendations, and reporting demands; asks for the reconsideration and exoneration of active administration and other matters4.

Score assigned	4

3. Smart Water City Certification Rating and Recommendations

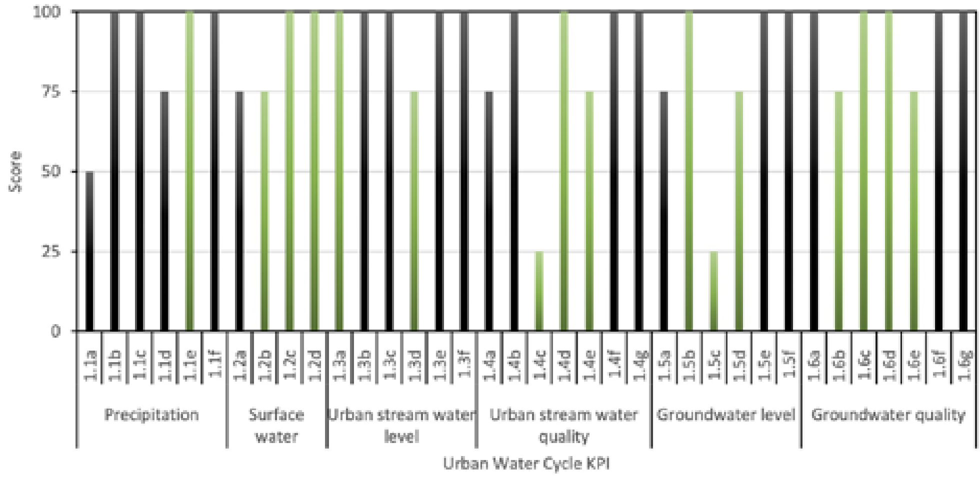
Drawing from the outcomes of the analysis concerning water resource management and the provision of water services in BEDC, a multitude of insights and recommendations emerge. To enhance clarity, we categorize these findings into two distinct sections: technical and governance, highlighting their unique characteristics.

Technical pillar Assessment and recommendations

The smart water city evaluation for Busan Eco Delta city, as part of the Busan Metropolitan city, is presented for each category in Figure 12. The horizontal axis pertains to the individual key technical key performance indicators, while the vertical axis describes the final scoring for each KPIs. Black bars represent the KPI evaluations that are focused on the urban water characteristics of the Busan Eco Delta City, while the colored bars represent the KPI evaluations that used the urban water data provided by Busan Metropolitan city.

4. Article 63 (Busan Metropolitan City Administrative Organization Establishment Ordinance (Busan City Ordinance No. 6972, July 5, 2023

Figure 12. Busan Eco Delta City smart water evaluation scores on Technical Pillar urban water cycle category



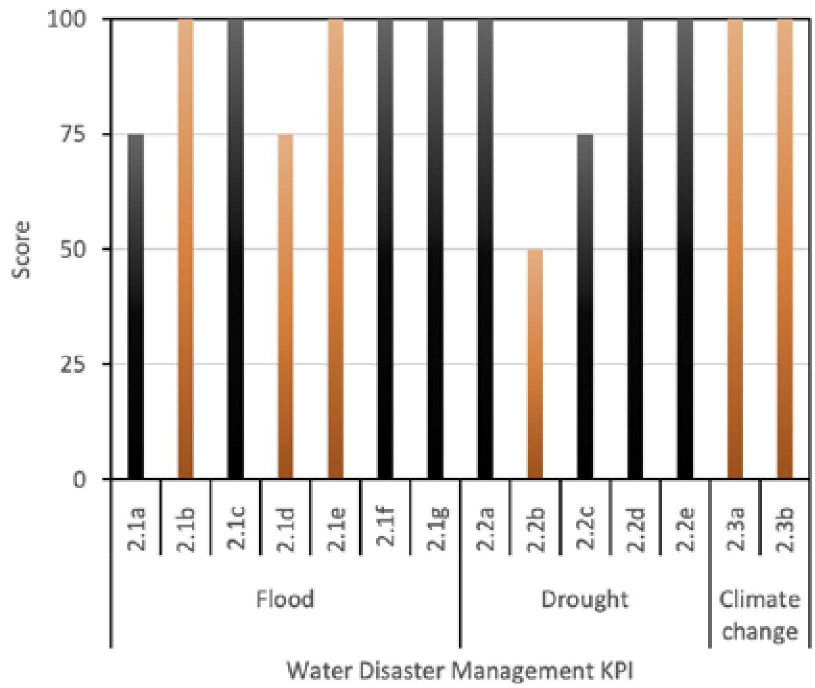
For the urban water cycle category, Busan Eco Delta City obtained full score in several smart water city indicators, including the observation station monitoring coverage density for stream water level and groundwater quality; monitoring frequency for rainfall, stream water level, stream water quality and ground water level; percentage of missing or error data for rainfall, stream water level and groundwater quality; ICT-based data collection process for rainfall, stream water level, stream water quality, groundwater level and groundwater quality; data accessibility for rainfall, stream water level, stream water quality, groundwater level and groundwater quality; establishment of waterfront facilities, application of LID and green infrastructures; and water quality standards for stream and groundwater. This implies that the Busan Eco Delta city, and Busan Metropolitan city, exhibit smart water management in facilitating and monitoring of urban water data. Due to the effort of the responsible agencies on the thorough spatial and temporal observation of the hydrological parameters, application of ICT in the observation and accessibility to data, the community can become well aware of the current status of the city's urban water hydrology. The excellent scoring for stream water quality and groundwater quality standards suggests that the current level of pollutants in the water sources are within the acceptable limit, indicating the good health of the urban water. In addition, the high percentage of the application of nature-based solutions in the construction of pathways, retention facilities, etc. indicates the city's efforts to preserve the quality of urban water through natural procedures.

According to the evaluation, it can be perceived that the city needs improvement in limiting the missing data information specifically for stream water level and groundwater level data. Missing hydrological data can lead to biases in model simulations, leading to erroneous data interpretations that can affect the forecasts of future water level trends. In addition, the number of installed rain gauge stations within the city needed to be improved to properly monitor the changes in the spatial distribution of rainfall in high-dense population areas.
For the administration of water disaster management in Busan Eco Delta City (and Busan Metropolitan City), the effectivity of the city's disaster preparation and mitigation strategies is apparent based on the full score obtained in the following aspects: including the flood property index, flood risk area index,

flood hazard mapping, integrated disaster information system, urban flood prediction and early warning, drought damage index, drought information and availability of emergency water supplies, drought prediction system, as well as the implementation of city-scale climate adaptation planning, the usage of renewable energy and implementation of energy saving strategies. The results signify that the city's smart water management performed exceptionally in the prediction and mitigation of localized flood events. This disaster management involves the utilization of modern technologies in flood hazard mapping, application of integrated water disaster information system, city-scale flood and drought forecasting, and flood early warning. The city also facilitates climate preparatory strategies by taking initiatives in climate change actions, adaptation measures, and prioritizing the application of alternative renewable energy sources in public activities. Because of these measures, the city managed to maintain low risks in flood damage and flood-susceptible areas. The efforts conducted by the city to reduce these hazard risks are significant indicators of smart water management.

The analysis emphasized the vulnerability of the city to climate risk events, pertaining to the records of drought events and flood-related casualties occurred in the city in recent years. Even though the city managed well in majority of the water disaster management indicators, some deficiencies are also observed, such as in the relatively low percentage of completed flood preventive structures, as well as the usage of advanced drought forecasting and impact assessment in drought hazard mapping. The construction of levees and dams to prevent river overflow during flood events aids in reducing the risk to urban residents. In addition, modern procedures used in drought hazard development ensure the accuracy and efficiency of drought prediction.

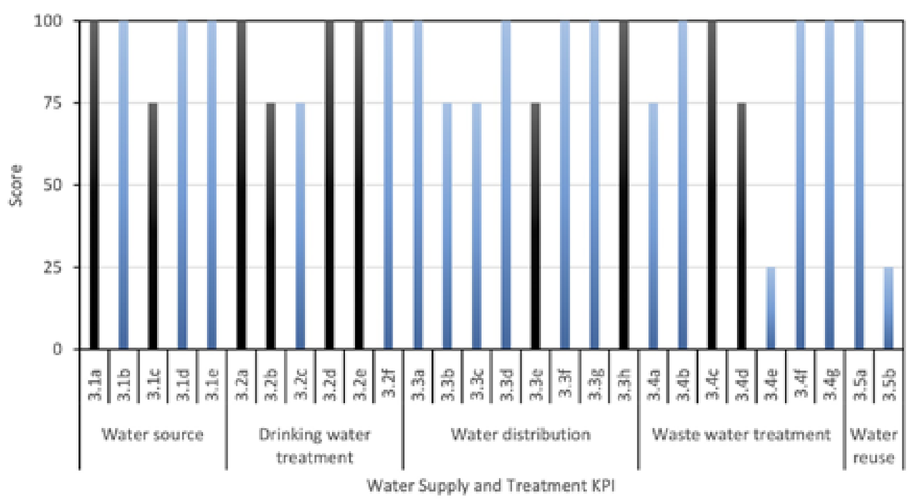
Figure 13. Busan Eco Delta City smart water evaluation scores on Technical Pillar water disaster management category



Lastly, the city managed to obtain exceptional points in the water supply and treatment management, specifically in the monitoring frequency of water source and wastewater; in the application of ICT-based technologies in collection process of water source and drinking water treatment data; in the availability of consumable water and capacity of water treatment plants; in the compliance in the standards of safe drinking water; in the extent of service coverage of water supply distribution; in the accessibility to water source, drinking water treatment and water supply distribution data; in the application of advanced technologies in treating drinking water and wastewater; in the maintenance of water supply and sewage pipelines; in the installation of smart meters; in the acceptable quantity of aged pipelines; and in the high percentage of treated wastewater that is being recycled. These results demonstrate that the city exhibits smart water city characteristics in the proper management of water supply, drinking water treatment and wastewater treatment. Due to the efforts conducted by the respective agencies facilitating the water supply, citizens can guarantee the safety of drinking water and the extent of services the facilities can make. These indicators also ensure the efficiency of water distribution, minimizing non-revenue water that is critical in water conservation.

However, relatively lower scores are obtained in the application of separated sewage network and recycling of wastewater sludge materials. The implementation of separated storm and sewage system ensures the consistency of storm water flow during flood events, while the application of biowaste recycling helps in the reduction of wastewater byproducts that can affect the health of the ecosystem, if not disposed properly.

Figure 14. Busan Eco Delta City smart water evaluation scores on Technical Pillar water supply and treatment category



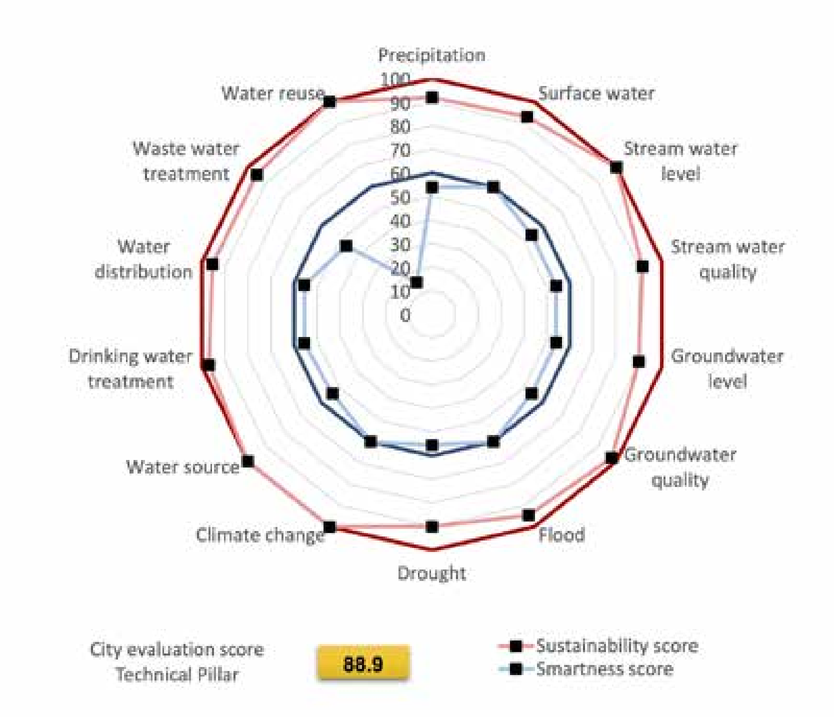
The overall smart water city assessment of Busan Eco Delta city in all categories of the technical pillar is shown in Figure 14 and Table 9. The overall scoring of the technical evaluation is computed by weighing the Sustainability and Smartness scores.

Table 9. Busan Eco Delta city smart water city technical evaluation scores

Category	Subcategory	Sustainability score (%)	Smartness score (%)
Urban water cycle	Precipitation	80.0	90.0
	Surface water	82.5	100.0
	Stream water level	100.0	90.0
	Stream water quality	78.8	90.0
	Groundwater level	75.0	90.0
	Groundwater quality	93.8	90.0
Disaster management	Flood	86.3	100.0
	Drought	75.0	92.5
	Climate change	100.0	100.0
Water supply and treatment	Water source	100.0	90.0
	Drinking water treatment	92.5	92.5
	Water distribution	88.8	92.5
	Wastewater treatment	87.5	77.5
	Water reuse	100.0	25.0
Technical evaluation total score		88.9	

For the Sustainability aspect, the city scored exceptionally well in Stream water level, Climate change, Water source and Wastewater reuse. This implies that the city is effective in implementing sustainable management in adequately monitoring the stream water level directly affecting the water resource, through the adequate number of installed water level stations, recording frequency, and negligible amount of error data; its initiatives to take climate change actions and adaptation strategies; monitor and manage the city's primary water sources through high monitoring frequency and reliability of water source; and the ability of the city in effectively recycle treated wastewater. Under the Smartness category, the indicators under the Surface water, Flood and Climate change achieved full score. This is due to the city's application of low impact development and green infrastructures in naturally aiding the urban hydrological flow, the utilization of advanced flood hazard mapping, integrated disaster information center, and urban flood forecasting and early warning during flood events; and lastly, the city's efforts to maximize the usage of renewable energy and energy saving strategies. The application of these efforts shows the qualification of Busan Eco Delta city to be labelled as a smart water city.

Figure 15. Busan Eco Delta City final score on Technical Pillar



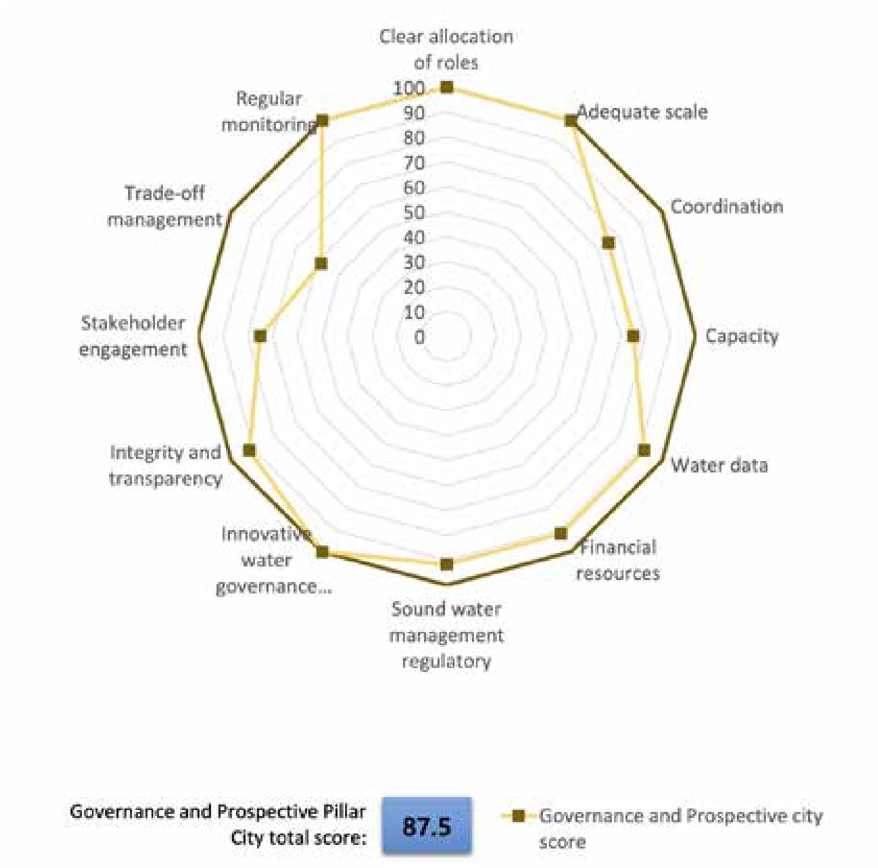
Based on the overall evaluation, the technical assessment of the Busan Eco Delta City highlights the application of smart water city technologies and strategies in the management of its urban water. Smart water cities leverage the usage of advanced technologies and smart water management techniques to optimize the urban water management, ensuring the consistent monitoring, efficient water usage, ensuring the health of the population and the environment. Further improvement can be suggested on the following areas:

Reducing the quantity of errors or missing data in stream water quality and groundwater level observation, through consistent instrument calibration and performing data quality control. Moving forward, it is also advised to provide priority in the installation of separated storm water and sewage water pipelines to prevent flood water contamination in segregating sanitary wastewater and storm water runoff. It is recommended to find more ways to increase the amount of sludge materials being recycled, such as use as fertilizers in agriculture, use as ingredients in cement making in construction, etc. Lastly, it is advisable to install more rainfall monitoring stations within the city to ensure the accurate recording of rainfall distribution that is critical for city-scale weather forecasting and flood early warning.

Governance and prospective pillar Assessment and recommendations

With the scores given to each of the 36 KPIs of the Governance and Prospective pillar, a radar chart has been created to illustrate Busan's performance. The yellow line on the graph represents the city's overall score in the evaluation. The analysis indicates that Busan, overall, excels in water governance, particularly in clearly delineating roles and responsibilities, adopting an integrated approach to water resource management, and implementing innovative policies. Busan's strengths also lie in generating sufficient water data and effectively monitoring policies. These aspects showcase the city's proficiency in water governance, offering valuable lessons that can be shared with other cities and countries.

Figure 16. Busan Eco Delta City final score on Technical Pillar



Busan's success in defining roles and responsibilities within water governance has many advantages. It fosters accountability and streamlines decision-making processes and establishes a foundation for transparent and effective governance structures in water management. Korea's progress on adopting an integrated approach to water resource management is well presented in the Busan case. The recent developments in Korea considering the interconnectedness of water sources, ecosystems, and local needs have equipped Busan is with a more balanced approach to deal with environmental, social, and economic factors in decision-making. Busan is also an example on how to introduce innovative policies to deal with emerging challenges. The BEDC highlights the importance of embracing technological advancements, research, and forward-thinking initiatives in water governance. This perspective has been supported by the development of timely structures to gather accurate and up-to-date data. Other cities and countries can also learn from the country's emphasis on robust data collection and monitoring mechanisms, recognizing them as essential tools for the success and sustainability of water governance initiatives.

However, there are areas where there is room for enhancement, including trade-off management, stakeholder engagement and capacity-building. These aspects present opportunities for further development and refinement in order to bolster the city's water governance practices. By focusing on these areas, Busan, and indeed Korea, can continue to strengthen its overall performance in water management.

The KPIs related to trade-off management score the lowest in the case of Korea and Busan. This score should not overshadow the notable progress that has been made. Particularly, the efforts and success in advancing integrated water resources management and the recent introduction of environmental impact assessments demonstrate the awareness of Korean authorities regarding the competing demands of different water uses and the necessity to balance and integrate development with environmental preservation. The score may be attributed to a focus on expanding water services availability and industrialization in the country. Nevertheless, ongoing efforts to emphasize the nexus between water, energy consumption, and food production will undoubtedly shift the focus towards recognizing the interdependence and the necessity to explicitly outline policy strategies for dealing with trade-offs.

To enhance stakeholder engagement, good examples can be drawn from cities that have established regular communication channels with key stakeholders, including community groups, non-governmental organizations, businesses, and residents. This can be achieved through the organization of periodic forums, town hall meetings, and consultations focused on water-related policies and initiatives, which can take place in a regular manner. Indeed, providing timely updates on ongoing projects, challenges, and progress in water governance through newsletters, social media, and public announcements ensures that stakeholders have the opportunity to contribute their valuable insights. Korea has only recently included the stakeholders in local policy making, so it is still early to see substantial progress, but it is indeed an area that can be further reinforced.

As for capacity building, improvement can be made to bolster comprehensive training programs and workshops for relevant local staff members involved in water management. These programs could cover a range of topics considered lagging behind, such as conservation strategies or regulatory compliance. For this, Korea has substantive experience at the national level that local authorities can draw from. Furthermore, fostering partnerships with educational institutions and research organizations can offer access to specialized training resources and expertise. This collaborative approach will equip the local workforce with the necessary skills and knowledge to excel in water governance.

CHAPTER 12
PILOT CITY EVALUATION OF SEMARANG CITY, INDONESIA

Semarang, one of Indonesia's ten largest cities, is located on the northern coast of Java, nestled between Mount Ungaran and the Java Sea. Indonesia, recognized as the world's largest archipelago, comprises five major islands—Sumatera, Java-Madura, Kalimantan, Sulawesi, and Papua—along with approximately 30 smaller groups of islands. As the capital of Central Java province, Semarang plays a crucial role as an economic and cultural hub in the region. The city is crisscrossed by rivers like the Semarang River and Gajahmungkur River, which significantly contribute to its water resources.

Semarang was chosen as a pilot city for the Smart Water City project due to its robust commitment to addressing water-related challenges, including issues like land subsidence, water pollution, and ensuring water services. The pilot evaluation took place from June to October 2023, involving extensive data exchange and a face-to-face visit in October 2023 for interviews and data verification. Presented here is the most relevant information regarding the technical and governance aspects of the city, gathered through collaboration with local, provincial, and national authorities.

BOX 1. KEY FEATURES OF SEMARANG

City Population: 1 659 975 (2020)
Population density 4441 people per km2
City population growth: 1.93% annual change
Gross Domestic product per capita: 137.12 (IDR million) (2022)
Geography: Coastal, mountain-sea border
Climate: Tropical climate
Water consumption: 49,213,480 m3 (2017)

1. General features of Semarang

Semarang is a rapidly growing city in Indonesia spanning 373.70 square kilometers. Its diverse population reflects the rich cultural, social, and economic makeup of Indonesia, including Javanese, Chinese, Arab, and other ethnic groups. Positioned strategically, Semarang serves as a vital link between major cities in Java such as Jakarta, Surabaya, Surakarta, and Yogyakarta.

Geographically, Semarang ranges from 2 meters below sea level to 340 meters above sea level. The coastal area forms a strip, stretching approximately 2 km to the west and up to 11 km to the east. Inland, there are hills extending from east to west, reaching heights of up to 340 meters above sea level.

In terms of governance, Semarang serves as its provincial capital of Central Java. As the other 34 provinces in Indonesia, Central Java is led by a Governor (Gubernur), who is the head of the provincial government and is elected through a democratic process, and has a Regional People's Representative Council (Dewan Perwakilan Rakyat Daerah Provinsi or DPRD Provinsi), which is the provincial legislative body, elected by citizens and responsible for making regional laws and regulations, overseeing the regional government's policies, and representing the interests of the people in the province.

Provinces in Indonesia are further divided into regencies (kabupaten) and cities (kota). These regencies and cities have their own local governments led by Regents (Bupati) and Mayors (Walikota), respectively. In the case of Semarang, the city is led by an elected Mayor who functions as the chief executive, overseeing policy implementation and municipal affairs. Semarang elects a city council which is the legislative body making decisions on local laws, budgets, and administrative matters. Semarang is further divided into 16 administrative districts known as "kecamatan," each managed by a representative called "camat." These districts are subdivided into 177 smaller administrative units, or "kelurahan" (villages), each headed by a village leader.

Main water stakeholders

At the national level, various ministries play key roles in managing water resources and providing water services in Semarang. The Ministry of Public Works and Housing is in charge of formulating and developing policies for water resources infrastructure management and water provision in the country; the Ministry of Environment and Forestry defines the regulations for water standards for water pollution control; the Ministry of Agriculture formulates and implements policies for the provision on water infrastructures and other facilities in agriculture. Additionally, other ministries, such as the Ministry of Energy and Mineral Resources and the Ministry of National Development Planning, also contribute their perspectives and input to the overall governance of water resources and services in the region.

At the local level, the main water actors in Semarang encompass a diverse group of entities. First, the Mayor holds a central role in shaping water-related policies and initiatives: they are involved in the running of local services, zoning regulations and land use plans, etc., and coordinate responses to natural disasters within their jurisdictions. The mayor directs and is assisted by the Development Planning Agency (BAPPEDA), which plays a pivotal role in planning and coordinating development programs and activities in Semarang, including those related to water infrastructure. BAPPEDA formulates regional development plans, assesses development needs, and coordinates efforts to achieve socio-economic progress in line with regional priorities and national development goals coordinating urban development plans.

Another fundamental player is PDAM Tirta Moedal, which functions as the public Water Company for Semarang, tasked with the responsibility of providing clean and safe water to the citizens of Semarang. In contrast to water supply service, sanitation programs and infrastructure are managed directly by the local government, by the Housing department, under the direction of the mayor. Additionally, the Water Resources and Drainage Division, of the Semarang City Public Works Agency, or Prevention and Preparedness Division for the Semarang

City Regional Disaster Management Agency have also crucial roles when it comes to floods and disaster control, whereas the Environmental Agency for Semarang City holds powers for water pollution controls.

Main challenges

Semarang faces a host of complex water challenges, but three of them stand out: land subsidence, deficient water network to meet the needs of all population, and water quality deficits. Addressing these interconnected issues requires integrated solutions and proactive measures to ensure the sustainability and resilience of Semarang's urban environment.

Land Subsidence and floods

Semarang currently faces significant land subsidence issues, particularly in its northeastern region. Experts have identified a concerning trend, indicating that from 1999 to 2011, the rate of sinking in Semarang fluctuated between 6 to 7 cm per year and escalated to a more alarming range of 14 to 19 cm per year. The intensive extraction of groundwater is considered the main cause for the elevated risk of land subsidence.

Land subsidence also has an impact on Semarang's heightened vulnerability to tidal flooding, a concern that has become increasingly pronounced in recent years. This susceptibility is compounded by the city's downstream location, where it receives water discharge from upstream rivers. The challenging topography, characterized by substantial variations in altitude, further complicates the situation in the city. Indeed, this circumstance facilitates the rapid downstream flow of rainfall starting from elevated upstream areas, intensifying the impact of land subsidence on Semarang's landscape.

Population coverage

Semarang is also facing a challenge derived from the limited reach of its water network, leaving a considerable segment of residents unconnected to the regional water distribution system. Due in part to Semarang's topography, the water service company is unable to serve all of the city's population. Presently, PDAM Tirta Moedal covers only approximately 40% of the water supply, with the remainder relying on alternative sources such as community initiatives (PAMSIMAS) or private wells. Regarding sanitation, no connected wastewater network exists; 86% of households rely on individual septic tanks, while 14% lack a functioning toilet.

Although an estimated 90% of households have access to safe drinking water through these diverse means, systematic documentation of these alternatives is lacking, complicating their integration into existing water management strategies (Al'Afghani et al, 2019). Also, the absence of universal access to a shared water network increases the disparities in water availability and quality across different neighborhoods within the city, while the absence of a common wastewater network has environmental concerns and contribute to waterborne diseases, such as diarrhea, highlighting the need for comprehensive sanitation solutions.

Semarang's water challenges are not unique, but reflect a broader issue in Indonesia, where reliable access to safe drinking water remains limited. Semarang has made important progress in enhancing water services and eradicating open defecation, but these achievements come with significant financial and technical implications. Trade-offs between network expansion and renewal are unavoidable, enhanced by the fact that much of the piping network date back to the Dutch colonial era and risk breakages and leaks. According to city officials, Semarang deals with a non-revenue water percentage estimated at around 42%.

Addressing these issues requires substantial investments in planning and resources for the entire urban water sector. A comprehensive assessment of current water access, identification of informal water sources, and the formulation of inclusive strategies are imperative to ensure fair and sustainable water distribution throughout the city.

Water pollution

Another great challenge revolves around the heightened levels of water pollution in both coastal waters and freshwater bodies, stemming from unregulated disposal of industrial and household waste into the waterways. This pervasive water pollution not only jeopardizes human health but also degrades the environment, escalating the operational and maintenance costs necessary to guarantee secure access to water resources.

Commendable strides have been taken to enhance water pollution in projects such as the Jatibarang reservoir and improving water pollution controls. Also, large improvements have been made to safe water services provision, which have resulted in nearly uninterrupted water flow to PDAM Tirta Moedal customers in many parts of the city. However, water challenges persist. While "good" water provision is predominant in central and southern Semarang, with improvements in the drinkability of water concerning safety and taste, however, a significant portion of Semarang's population faces with issues related to unsafe water quality resulting from water pollution.

Dealing with water pollution at the source can make water safer, protecting people's health and keeping ecosystems in balance. To really tackle these issues, different groups in the local community, like public works agencies and community organizations have to work together. Given Semarang's position as a downstream city, it is important to extend this collaborative effort to encompass the broader river basin and provincial levels.

2. Results of the pilot evaluation in Semarang

The assessment Semarang took place from June to November 2023. This evaluation involved the collection of written assessments and interviews with local, regional, and national stakeholders. The gathered information underwent verification and was cross-referenced with analyses of official documents, legislation, and reports from international organizations, which served to apply corrections to the self-evaluation scores.

The assessment presented an opportunity to scrutinize the effectiveness of the Smart Water City Index in a vastly different context compared to the Busan Eco Delta City. Specifically, it allowed for an in-depth examination of an established city within a large developing country. Semarang has demonstrated a steadfast commitment to addressing significant challenges associated with climate change and population growth within its local water sector. Looking ahead the identified challenges underscore the need for continued efforts in refining governance structures and enhancing resilience to future environmental shifts. In terms of the Index itself, the assessment has also serve to draw key lessons. The pilot evaluation in Semarang has highlighted the need for providing clearer guidelines to local actors, especially concerning the comprehensive examination of the water in the urban water system, beyond just focusing on water services provision. The present chapter reflects on these lessons.

Evaluation Results on Technical Pillar

Indicator 1.1a Coverage extent of precipitation monitoring stations

For Semarang City, the agency responsible for regional rainfall monitoring is the Meteorology, Climatology and Geophysical Agency (BMKG). The city (373.70 km2) has three functional rainfall stations: namely Maritim, Ahmad Yani and Klimatologi stations, making the precipitation coverage density to be 124.6 km2 per rainfall station.

Score assigned	**1**

Indicator 1.1b Monitoring and recording frequency of precipitation instruments

The rainfall data that can be retrieved at the BMKG website are daily data. However, according to an onsite interview to the personnel in BMKG-Semarang City Maritim station, the automated rain gauge records at 10-min intervals, while the manual rainfall recordings are conducted at 3-hourly.

Score assigned	**3**

Indicator 1.1c Percentage comparison of missing and error of observed precipitation data to the total observed data

The BMKG rain gauge instruments in Jawa Tenga, Ahmad Yani, and Maritim Tanjur Emas stations located in Semarang city were installed in 1970, 1976 and 1977, respectively. Based on the data gathered from BMKG website (since 2010) (dataonline.bmkg.go.id/akses_data), the averaged missing rainfall data for the Semarang city rainfall stations is 13.9%.

Score assigned	**2**

Indicator 1.1d Quantity of observed precipitation data that is recorded electronically and the calibration status of precipitation recording instruments

The rainfall monitoring instruments in Semarang city are conducted both automatically and manually. The automatic rain gauges utilized in measuring rainfall use Microcontroller ATMEga 128 program. The rainfall instruments are calibrated at least once every two years.

Score assigned	**3**

Indicator 1.1e Process of precipitation data collection using ICT-based technologies

BMKG Maritim station in Semarang city operates Automated weather stations (AWS), sensor raingauges, doppler radar, satellite data, numerical weather prediction model forecasts and observations.

Score assigned	4

Indicator 1.1f Status of public accessibility to precipitation data records

Semarang city rainfall station data can be accessed on the BMKG website at dataonline.bmkg.go.id/akses_data, while real time data can be viewed in ppid.maritimsemarang.com. Information can be downloaded upon registering using an active email address.

Score assigned	4

Indicator 1.2a Percentage comparison of impervious surface to the total surface area

According to the Feasibility Study Rechanneling Final Report 2022 by the Semarang city Regional Development Planning Agency (Badan Perencanaan Pembangunan Daerah-BAPPEDA), the total impervious surface and total surface area of Semarang city are 141.08 km2 and 373.70 km2, respectively. Therefore, the impervious surface area percentage is 37.9%.

Score assigned	4

Indicator 1.2b Percentage comparison of the nature conservation area to the total surface area as related to the status of urban stream biodiversity

According to the Semarang city Park data 2023 by the Semarang city Department of Housing and Residential Area (DISPERKIM), the total nature reserved park area and city total surface area are 0.38 km2 and 373.70 km2, respectively. Therefore, nature conserved area percentage is 0.10%. Based on the onsite interview with Semarang city Department of Public Works (DPU), the city aims to achieve 25% green space in the future.

Score assigned	1

Indicator 1.2c Establishment of urban waterfront or water space facilities

Based on the onsite interview with DPU, the city has pond parks that serve as retention ponds, rainfall harvesting facilities, leisure space, walking trail and ecological habitat.

Score assigned	2

Indicator 1.2d Percentage comparison of applied Low Impact Development and Green infrastructure area and total surface area

According to DPU, Semarang city currently does not implement LID and green infrastructures in the construction of the public facilities but plans to implement these strategies in future projects.

Score assigned	0

Indicator 1.3a Coverage extent of urban stream and coastal water level monitoring stations

For Semarang city, the agencies that monitor the status of river water level and coastal tide level are BPBD and BMKG, respectively. The total rivers and streams extent within the city are 330.94 km, with a total of 8 stream gauge stations. Therefore, water level monitoring is performed at 41.37 km extent per station.

Score assigned	**1**

Indicator 1.3b Monitoring and recording frequency of water level instruments
According to the onsite interview with BPBD, the water level monitoring instruments that serve as early warning for flood mitigation records at 10-min interval. These water level monitoring instruments are located in Pudakpayung, Tugu Soeharto, Jatibarang, Mayang Sari, Bendungan Plumbon, Mangkang Kulon, Banjir Kanal Timur and Bringin districts.

Score assigned	**4**

Indicator 1.3c Percentage comparison of missing and error of observed water level data to the total observed data
For Semarang city, the agency that handles the river water level data is the BPBD. However, recorded archive data for river water level has not been provided.

Score assigned	**0**

Indicator 1.3d Quantity of observed water level data that is recorded electronically and the calibration status of water level recording instruments
The agency that handles the river water level data for Semarang city is the BPBD. The river water level monitoring devices are recording automatically, however no information regarding the calibration status is provided.

Score assigned	**1**

Indicator 1.3e Process of water level data collection using ICT-based technologies
The water level monitoring instruments managed by BPBD and DPU to record the stream water levels critical for flood early warning employ automatic water level sensors and data loggers.

Score assigned	**2**

Indicator 1.3f Status of public accessibility to water level data records
The real-time water level data of river flood points in Semarang city can be accessed in BPBP-Semarang city real-time water level data website (103.101.52.85:777). The current status of water levels in each of the 8 installed sensors can be viewed, identifying safety, keeping alert, and danger signs. However, archive water level data is not available on this site.

Score assigned	**3**

Indicator 1.4a Coverage extent of urban stream water quality monitoring stations
For Semarang city, the Environmental Agency (Dinas Lingkungan Hidup-DLH) is responsible for monitoring rivers and streams water quality within the city. A total of three stream water quality inspections are conducted (upstream, midstream, and downstream) on the 9 major rivers in Semarang city. A total of 27 inspection points for the city's total surface area of 373.70 km2 concludes stream water quality monitoring coverage of 13.84 km2 per water quality inspection.

Score assigned	3

Indicator 1.4b Monitoring and recording frequency of stream water quality sampling instruments

According to the onsite interview with DLH-Semarang city, river and stream water quality inspections are done at least once a year for rivers and at least once a month for industrial waters.

Score assigned	1

Indicator 1.4c Percentage comparison of missing and error of observed water quality data to the total observed data

For Semarang city, the Environmental Agency (DLH) handles the data for river water level data. However, the archive river water quality data has not been made available for evaluation.

Score assigned	0

Indicator 1.4d Standard quality of urban stream water

The Environmental Agency (DLH) conducts the river water quality testing for Semarang city. However, the archive water quality test data has not been made available for evaluation.

Score assigned	0

Indicator 1.4e Quantity of observed water quality data that is recorded electronically and the calibration status of water quality recording instruments

For Semarang city river water inspections, water samples are collected manually and brought back to the laboratory for testing. The Environmental Testing Laboratory is accredited by the National Accreditation Committee SNI ISO/IEC 17025. The water quality instruments used by the agency are calibrated once a year.

Score assigned	2

Indicator 1.4f Process of water quality data collection using ICT-based technologies

The Semarang city Environment Agency (DLH) utilizes stream water quality sensors, spectrophotometers, and GPS (global positioning system) devices to conduct the water quality testing for the city rivers.

Score assigned	3

Indicator 1.4g Status of public accessibility to water quality data records

According to Semarang City Environment Agency (DLH), the river and stream water quality test results data can be obtained through an official letter request to the Agency.

Score assigned	2

Indicator 1.5a Coverage extent of groundwater level monitoring stations

For Semarang city, the Central Java Province Department of Energy and Mineral Resources (ESDM) facilitates the groundwater level and quality monitoring for the city. Based on the ground water monitoring data accessed in siat.esdm.jatengprov.go.id, there are a total of 23 groundwater monitoring wells within Semarang city. Given the city's total surface area of 373.70 km2, the groundwater level monitoring coverage density is 16.25 km2 per station.

Score assigned	3

Indicator 1.5b Monitoring and recording frequency of groundwater level instruments

According to the groundwater data provided by ESDM, the groundwater level monitoring of the groundwater observation wells within the city is performed once daily.

Score assigned	3

Indicator 1.5c Percentage comparison of missing and error of observed groundwater level data to the total observed data

For Semarang city, the groundwater stations include Anjasmoro, Bitratex, BPBD Semarang, ESDM, Jateng, Geoundip, Karyadeka, KWS Candi, LH TPKTUGU, Mangkokmas, Mankokmas, Pt CCBI, Pt Savana, Pt USG, PTDSSAT4 2, PTDSSAT4 3, Pu Ungaran, Sinarsosro, SMK N 10, SMK N1 Semarang, UNDIP PS, WJ Kusuma and Workshop stations. The daily groundwater level data recorded from these stations is provided by the Central Java Department of Energy and Mineral Resources, however, incomplete data are collected from individual stations.

Score assigned	1

Indicator 1.5d Quantity of observed groundwater level data that is recorded electronically and the calibration status of ground water level recording instruments

According to ESDM Central Java, ground water monitoring wells are calibrated and maintained depending on the available solar cell battery energy, but usually are performed once a year.

Score assigned	2

Indicator 1.5e Process of groundwater level data collection using ICT-based technologies

The province of Central Java utilizes groundwater level sensors and remote sensing instruments for groundwater level monitoring, based on the information gathered from the Central Java Department of Energy and Mineral Resources website siat.esdm.jatengprov.go.id.

Score assigned	2

Indicator 1.5f Status of public accessibility to groundwater level data records

Groundwater data can be accessed through siat.esdm.jatengprov.go.id. However, the website is still in the process of uploading data, therefore available data is still incomplete.

Score assigned	3

Indicator 1.6a Coverage extent of groundwater quality monitoring stations

According to the research "Spatial distribution change of groundwater quality in deep aquifer of Semarang alluvial plains area in the past five years" data gathered from the Central Java Department of Energy and Mineral Resources, there are a total of 199 groundwater wells (as of 2020) inspected to analyze the trend of groundwater quality for Semarang city. Considering the city's total surface area of 373.70 km2, the groundwater quality observation density is 1.87 km2/station.

Score assigned	**4**

Indicator 1.6b Monitoring and recording frequency of groundwater quality sampling instruments

Based on the information gathered from the "Spatial distribution change of groundwater quality in deep aquifer of Semarang alluvial plains area in the past five years" study by Susanto et al (2021), annual average groundwater quality data from 2016 to 2020 are assessed.

Score assigned	**1**

Indicator 1.6c Percentage comparison of missing and error of observed groundwater quality data to the total observed data

For Semarang city, ESDM Central Java manages the groundwater quality data. However, groundwater quality information has not been made available.

Score assigned	**0**

Indicator 1.6d Standard quality of urban groundwater water

Semarang city follows the groundwater regulatory standards based on the Health Ministry standards of Indonesia, according to the onsite interview with ESDM Central Java personnel.

Score assigned	**3**

Indicator 1.6e Quantity of observed groundwater quality data that is recorded electronically and the calibration status of groundwater quality recording instruments

The groundwater monitoring well instruments are calibrated and maintained usually once a year, according to the onsite interview with ESDM Central Java personnel.

Score assigned	**2**

Indicator 1.6f Process of groundwater quality data collection using ICT-based technologies

According to ESDM Central Java the groundwater wells installed in Semarang city utilize groundwater quality sensors and remote sensing instruments for monitoring groundwater quality.

Score assigned	**2**

Indicator 1.6g Status of public accessibility to groundwater quality data records

Groundwater data can be accessed through siat.esdm.jatengprov.go.id. However, the website is still in the process of uploading data, therefore available data is still incomplete.

Score assigned	**2**

Indicator 2.1a Flood casualty index as an indicator of the city population's vulnerability to life-threatening flood events

For Semarang city, the agency responsible for flood monitoring and disaster management is the BPBD. According to the Review of Semarang City Disaster Events Annual Report (accessed at bpbd.semarangkota.go.id), flood-related casualties occurred in the city from 2013 to 2022.

Score assigned	0

Indicator 2.1b Flood damage index as an indicator of the city's vulnerability to property damages caused by urban flood events

Based on the Semarang City regional disaster agency data, the average flood property damage for 2016-2020 is 2,496,000,000.00 RP (Rupiah)/year. Considering the GDP per Capita of Semarang city for 2021 is 647,007,010,000.00 RP, the average Flood Property Damage Index for the city is 0.0000038.

Score assigned	4

Indicator 2.1c Percentage comparison of the flood-prone areas to the total surface area

According to the Annual Flood Inundation Survey 2023 for Semarang city, about 12.82 km2 of the city is susceptible to flooding, which accounts for about 3.43% of the city's total surface area. These types of floods include shallow flooding (0.07%), pluvial flood (1.28%), and tidal or storm surge flood (1.098%), and more.

Score assigned	3

Indicator 2.1d Percentage comparison of completed stream levee structures to the total stream extent

Based on the onsite interview with representatives from Department of Public Works (DPU), the city does not keep record on the on-going and completed levee structure construction for flood protection. No data for levee structure percentage can therefore be assessed.

Score assigned	0

Indicator 2.1e Application of city-scale flood hazard maps

Semarang city applies integrated flood maps (urban, riverine, and coastal) that were made based on historical flood survey data. These maps are posted to the website of the Semarang city Spatial Planning Department (DISTARU) distaru.semarangkota.go.id. These flood prone areas are presented as flood warning maps categorized into low, moderate, and high in terms of potential flood depth.

Score assigned	2

Indicator 2.1f Implementation of city-scale integrated disaster information system and application of ICT-based technologies in flood management

The BPBD created SIGAB (Sistem Inventarisasi Genangan Banjir), the city's flood inundation inventory system that provides real-time information on the location of flood inundation. The information can be accessed at sigab.semarangkota.go.id.

Score assigned	4

Indicator 2.1g Operation of urban flood prediction system and advanced real-time alarm services

The city established city-scale urban flood prediction and early warning system through flood early warning devices and CCTV cameras installed throughout the city. The real-time records of these early warning devices can be accessed on the inventory website sigab.semarangkota.go.id.

Score assigned	2

Indicator 2.2a Drought damage index as an indicator in identifying the city's vulnerability to drought events based on the percentage of population affected by drought-related limited water supply

In addition to flood management, BPBD is also responsible for monitoring and predicting the effect of drought events on Semarang city. Based on the information responded by BPBD personnel, supported from the Daily Event Report 2023, the computed Drought damage index for Semarang city is between 0.4 to 0.6.

Score assigned	2

Indicator 2.2b Recent drought occurrences affecting water supply and distribution

According to response gathered from the Semarang city BPBD personnel, supported by the Report on the Implementation of Daily Activities Emergency Section 2023, there had been an occurrence of drought event within the last five years.

Score assigned	3

Indicator 2.2c Application of ICT-based drought mapping

BPBD established SEMARISK, a service that conducts the monitoring of educational system and implementation of disaster information. The website provides integrated disaster information, including drought maps that were created using historical data of drought events in the city. These drought maps are categorized into drought threat map, drought susceptibility map, drought capacity map and drought risk map.

Score assigned	1

Indicator 2.2d Operation of city-scale emergency water supply facilities and drought information system

According to BPBD-Semarang city, there is an established city-scale drought monitoring information service, including drought hazard maps that can be accessed in bpbd.semarangkota.go.id. Emergency water supply facilities are also made available in the event of water shortage due to drought.

Score assigned	3

Indicator 2.2e Operation of drought advanced warning system and advanced information services

Based on the onsite interview with BPBD personnel, the city utilizes GIS (geographic information system) in drought hazard mapping. Drought information is dissipated through their website SEMARISK bpbd.semarangkota.go.id.

Score assigned	2

Indicator 2.3a Application of city-scale climate change adaptation planning

According to the onsite interviews with Semarang city representatives from BPBD and BMKG, the city utilizes climate projected hazard maps and establishes climate adaptation measures, such as community capacity building and educational trainings.

Score assigned	**2**

Indicator 2.3b Application of renewable energy and energy-saving strategies

Based on the information gathered from the BPBD and the Environmental Agency (DLH), the city utilizes renewable energy, including solar, biomass and hydropower energy, and conducts rainwater harvesting for emergency water sources.

Score assigned	**2**

Indicator 3.1a Monitoring and recording frequency of water source monitoring instruments

For Semarang city, the Perumda Air Minum Tirta Moedal (PDAM Tirta Moedal) is the regional public company that facilitates drinking water management, including water source monitoring, for the people of Semarang city. The raw water sources for the city include spring water, deep wells, and surface waters. According to the data gathered from the agency, the monitoring of water source quality for spring water, deep wells and rivers are conducted yearly, every 6 months, and weekly.

Score assigned	**2**

Indicator 3.1b Water source availability based on the total volume of available water and consumed water

Based on PDAM Tirta Moedal data, the averaged water reliability index (water availability over water consumption) for spring water, deep wells (city, west and east mountain), river and water dam are 2587.8%, 674.6%, 356.7%, 268.2%, 134.5% and 141.5%, respectively. Therefore, the average water reliability index for Semarang city is more than 100%.

Score assigned	**4**

Indicator 3.1c Quantity of observed water source data that is recorded electronically and the calibration status of water source recording instruments

PDAM Tirta Moedal employs systems that record water source data using a combination of manual process and automated technology. Standard operating procedures are conducted for quality assurance of water quality measuring instruments. This procedure aims to care for a system of measurement, inspection and testing of equipment that is calibrated and maintained. This guarantees the tolerance stability of the inspection and test equipment used.

Score assigned	**3**

Indicator 3.1d Process of water source data collection using ICT-based technologies

PDAM Tirta Moedal utilizes ICT-based technologies in some of the water source monitoring instruments installed. The water treatment facilities utilize water quality sensors, spectrophotometers, turbidimeters, conductivity meters, pH meters, automated data loggers, real-time wireless communicators, and remote-sensing based instruments.

Score assigned	4

Indicator 3.1e Status of public accessibility to water source data records

Information on PDAM Tirta Moedal can be accessed at pdamkotasmg.co.id. However, water source data is only available via direct request procedures to Semarang City Water company.

Score assigned	2

Indicator 3.2a Drinking water quality compliance with the established drinking water quality standards

The drinking water quality tests are carried out by PDAM Tirta Moedal on a regular basis in order to maintain the quality of drinking water for Semarang city. The water quality parameters are tested physically, chemically, and biologically, following the quality parameter standards. According to the latest water quality inspection results (2022), all of the 81 monitoring instruments record good results, therefore the percentage water quality standard compliance for Semarang city is 100%.

Score assigned	4

Indicator 3.2b Monitoring and recording frequency of water quality monitoring instruments in Water purification treatment plants

In PDAM Tirta Moedal drinking water treatment plant, water quality assurance is performed periodically on a weekly basis, once a month, and once every 6 months, in accordance to established procedures. Sampling points for customers are taken at the furthest point of the service.

Score assigned	1

Indicator 3.2c Quantity of observed drinking water treatment data that is recorded electronically and the calibration status of drinking water recording instruments

The water purification process at the PDAM Tirta Moedal uses a combination of manual recording and automated recording through SCADA program. Standard operating procedures are applied to calibrate measuring equipment for water quality monitoring.

Score assigned	3

Indicator 3.2d Process of drinking water treatment data collection using ICT-based technologies

Based on the information provided by PDAM Tirta Moedal, the facility uses technologies such as pH meters, turbidity meters, flow meters, pressure transmitters, automatic switch pumps, sludge finder, motorized valve, variable speed drives and dosing pumps, to conduct drinking water quality monitoring.

Score assigned	4

Indicator 3.2e Status of public accessibility to drinking water treatment data records

Drinking water treatment output data is only available upon direct request to PDAM Tirta Moedal.

Score assigned	2

Indicator 3.2f Application of advanced water purification treatment process in the Drinking water treatment facilities

The drinking water treatment processes in PDAM Tirta Moedal are performed in accordance to the complete treatment standards required by the Indonesian government based on the technical guidelines of the Ministry of Public works. The drinking water treatment processes include pre-sedimentation, coagulation, flocculation, sedimentation, filtration, and sludge drying bed.

Score assigned	2

Indicator 3.3a Percentage extent of water supply distribution based on the number of populations with access to water supply

The drinking water services by Semarang city PDAM Tirta Moedal are performed in accordance with the scope of administrative objectives of the municipality. According to the information obtained from the company, the total number of the population with access to drinking water supply network is 669,619 people or 40.34% of the total city population.

Score assigned	1

Indicator 3.3b Percentage of aging and deteriorating water supply pipelines

The water supply pipelines in the service of PDAM Tirta Moedal have a variety of pipe aging status. The percentage of pipelines installed more than 30 years ago is 32.5%, about 141,870 m total aging pipe extension as compared to total water supply pipe extension of 436,081 m.

Score assigned	1

Indicator 3.3c Percentage of revenue and non-revenue water

The total volume of water consumption for Semarang city in 2022 is 54,058,365 m3, while the total water production is 105,145,179 m3. The percentage of revenue for water is therefore 51.4%. The amount of water loss is almost half (48.6) of the total water production for that year.

Score assigned	1

Indicator 3.3d Water storage effective capacity of water treatment facilities

PDAM Tirta Moedal has 18 reservoir units with a total water capacity of 21,900 m3. The total water production and designed maximum capacity are 3,266.6 m3 and 4,138.70 L/s. The calculated total water storage effective capacity is 78.9%.

Score assigned	2

Indicator 3.3e Quantity of observed drinking water quality data that is recorded electronically and the calibration status of water quality recording instruments

The data collection and quality services carried out by PDAM Tirta Moedal are performed through a combination of conventional and real-time automatic systems. The conventional system is carried out by collecting data directly from the field, while the automatic system is carried out by reading SCADA-based instruments at several points. The data collection is in the form of discharge data and distribution network pipe pressure.

Score assigned	3

Indicator 3.3f Implementation of water supply pipe maintenance system

The process of repairing the pipe network by PDAM Tirta Moedal is in accordance with the standard operating procedure of the company. The agency utilizes ICT-based instruments, such as CCTV cameras, in monitoring leak detection.

Score assigned	2

Indicator 3.3g Application of smart water meter reading

The smart water meter system at PDAM Tirta Moedal has not been fully accommodated in the main meter reading system and customer meters. However, some of them are installed in several locations.

Score assigned	1

Indicator 3.3h Status of public accessibility to drinking water treatment data records

The water supply and distribution data are available via direct data request procedures from PDAM-Semarang city water company.

Score assigned	2

Indicator 3.4a Percentage extent of sewage service distribution based on the number of populations with access to sewage system

The wastewater treatment for Semarang city is managed by the Department of Housing and Settlement Areas of the City of Semarang (DISPERKIM). The wastewater treatment facilities for the city is currently undergoing construction, SPALD-T (Centralized Domestic Wastewater Management System) will be built in 2024 by the Ministry of Public Works and Housing. Currently, around 86% of the city households have individual septic tanks, while 14% have no working toilet.

Score assigned	0

Indicator 3.4b Percentage of aging and deteriorating sewage pipelines

According to the onsite interview with Department of Housing and Settlement Areas of the City of Semarang (DISPERKIM), most of the sewage pipes were built 2014 onwards. However, specific values of construction are not recorded, therefore exact percentage cannot be computed.

Score assigned	0

Indicator 3.4c Monitoring and recording frequency of wastewater monitoring instruments in the Wastewater Treatment facilities

Monitoring of wastewater treatment is carried out by the UPTD PAL (Pengelolaan Air Limbah) (Wastewater Management Service Technical Implementation Unit) of the Housing and Settlement Area Office of the city of Semarang. Based on the onsite interview, the wastewater quality testing is performed by the Environment Agency (DLH) once a month, through manual sampling and testing.

Score assigned	2

Indicator 3.4d Quantity of observed sewage data that is recorded electronically and the calibration status of wastewater recording instruments

According to the onsite interview with representatives from DISPERKIM, wastewater data is recorded manually and calibrations are performed.

Score assigned	1

Indicator 3.4e Application of separated wastewater and storm water network

Most of the households in Semarang city are not connected to the centralized wastewater network. Individual household septic tanks and storm water sewers are not connected to each other. However, no documented records of the specific values are recorded.

Score assigned	0

Indicator 3.4f Implementation of sewage network maintenance system

Based on the onsite interview with Semarang city Housing and Settlement Agency, no ICT-based instruments nor modern technologies are used for the sewage pipe maintenance. These instruments are set to be built when the SPALD-T infrastructures are built.

Score assigned	0

Indicator 3.4g Application of advanced sewage treatment process in the Wastewater treatment facilities

No treatments are performed within the wastewater collection process for Semarang city. Further advanced wastewater treatment will be performed when SPALD-T is built.

Score assigned	0

Indicator 3.5a Percentage of reused and recycled wastewater

Based on the onsite interview with staff from DISPERKIM, after being collected, the water is directly discharged to the canals. No data is recorded for the recycled and reused wastewater.

Score assigned	0

Indicator 3.5b Percentage of recycled sewage solid waste materials

Based on onsite interview with personnel from DISPERKIM, sludge materials are reused as planting medium in Semarang city parks. Residents also come and take some of the manure for fertilizers. However, no wastewater reuse tracking and recording are performed, therefore, percentage cannot be calculated.

Score assigned	0

Evaluation Results on Governance & Perspective Pillar

Indicator 1.1.a. Existence of a clear allocation of responsibilities in water resources management and water services provision

Semarang has allocated responsibilities for water resources management and water services provision. This distribution of responsibilities derives from the Law 17/2019 on Water Resources, which establish the main competences of the national level, the provinces and the local authorities

Score assigned	4

Indicator 1.1.b. Existence of department(s) at the city level in charge of local water-related responsibilities

Not one single department at the local level, but a number of them, belonging to different tiers of government, which have water related responsibilities. The organization most directly in charge of water service provision in Semarang is the regional company PDAM Tirta Moedal1. The Department of Housing and Settlement Areas of the City of Semarang (DISPERKIM) has an important role in the provision of sanitation services. As for the management of water resources this is also distributed amongst various departments including BAPPEDA (Regional Development Planning Agency) which prepares regional satiation management plans and strategies, and the DHL (Environment Agency), which monitors effluent discharges and pollution.

Score assigned	3

Indicator 1.1.c. Existence and implementation of mechanisms to review roles and responsibilities, to diagnose gaps, and to adjust when need be

One of the main mechanisms to review the roles of public authorities in Indonesia and propose modifications is the audit exerted by the Supreme Audit Agency (BPKP)2. In 2022, BPKP examined the performance of the Regional Drinking Water Company (PDAM) Tirta Moedal of Semarang City.

A second important instrument has been benchmarking. In 2019 the Supporting agency for the Improvement of Drinking Water Supply System (BPP SPAM), under the Ministry of Public Works and Housing, evaluated the performance of 380 public water supply operators according to a series of indicators on quality of service, financial stability, infrastructure development, operational performance, etc. This has been

As for adjustments, the national government has reserved for itself the power to remove responsibilities from the provincial and the local governments if performance from local or regional bodies is not considered adequate (Law 17/2019).

Score assigned	3

1. Regional Regulation of Semarang City Number 2 of 2019 regarding the Regional Drinking Water Company (Perumda) Tirta Moedal of Semarang City.
2. Regulated by Government Regulation No. 60 of 2008 regarding Government Internal Control Systems (SPIP) stipulated BPKP as a government internal auditor which responsible directly to the President and assigned to conduct internal supervisory over the state financial accountability and fostering the implementation of government internal control systems.

Indicator 1.2.a. Existence and level of implementation of integrated water resources management policies and strategies that include the urban level and cities' features and water status

The current legislation recognizes river basins as crucial components for integrated water resources management, aiming to achieve sustainable benefits and ensure the well-being of the people. Integrated water resources management involves strategies for conserving, utilizing, and controlling damage to water resources (refer to Article 22, Law 17/2019).

Indonesia, with its numerous rivers, designates river basin watersheds through Presidential Decrees. In Semarang, seven main rivers contribute to the city's water system: Garang, Times Pengkol, Kreo, Banjir Kanal Timur, Babon, Kripik, and Dungadem.

Score assigned	4

Indicator 1.2.b. Existence and functioning of institutions managing urban water (not necessarily exclusively) at the hydrographic scale

River Basin Organizations (RBOs) are considered by law as the primary institutions responsible for water management. RBOs are overseen by representatives from government agencies and community stakeholders. Their responsibilities include harmonizing interests among different sectors, regions, and stakeholders in water resources management within the river basin. Additionally, RBOs provide guidance to the Central Government and/ or Regional Governments on the execution of water resources management. They play a crucial role in monitoring and evaluating the implementation of programs and plans related to water resources management in the river basin.

Score assigned	3

Indicator 1.2.c. Existence and level of implementation of co-operation mechanisms for the management of water resources across water-related users and levels of government, including the local level.

According to the legislation, various tools exist for ensuring cooperation at the river basin, including the development of River basin management plans, meetings for shared information, and common water allocation plans and environmental charges, amongst others. The interviews conducted in Semarang indicated that these tools are however not systematically and regularly employed, with scope for improvement for management at the river scale.

Score assigned	3

Indicator 1.3.a. Existence and implementation of cross-sectoral local policies and strategies promoting policy coherence between water and key related areas, in particular local environment, health, energy, agriculture, land use and spatial planning

Legal provisions emphasize the importance of coordinating water resource management at the national, regional, local, and river levels (as outlined in Articles 64 to 66 of Law 17/019). The Republic of Indonesia has also connected water resource planning with spatial planning and land use at the intersectoral level, recognizing challenges related to expanding water networks to meet service demands and controlling floods (refer to Spatial Planning Law 26/2007).

However, the practical application of these measures has been inconsistent. This challenge is not unique to Semarang but extends across the country and involves central government institutions (Republic of Indonesia, 2020). During interviews in Semarang, participants highlighted coordination issues due to the division of tasks and functions among various local agencies. This fragmentation necessitates significant efforts to ensure effective coordination.

Score assigned	**3**

Indicator 1.3.b. Existence and functioning of an inter-departmental body or institutions at the local level for horizontal co-ordination across water-related policies

The National Water Resources Council and the Regional Water Resources Council have been instituted to formulate policies governing water resources management at both the national level, specifically for strategic considerations, and the regional/local level, focusing on more localized and operational aspects (pursuant to Law 17/2019). These councils assemble representatives from the government as permanent members and representatives from various water stakeholders as non-permanent members.

In Semarang, the Council convenes representatives from several key horizontal agencies, including the Department of Energy and Mineral Resources of Central Java Province, the Environmental Agency of Semarang City, the Department of Housing and Settlements of Semarang City, the City Planning and Development Agency of Semarang City, the Public Works Department of Semarang City, and the Regional Water Supply Company of Semarang City.

Score assigned	**4**

Indicator 1.3.c. Existence and implementation of mechanisms at the local level to review barriers to policy coherence and/or areas where water and related local practices, policies or regulations are misaligned.

Local stakeholders have highlighted that the primary means of ensuring policy coherence concerns the development of plans for water service provision and resource management. Frequently, this involves convening key local actors. However, they have indicated that the execution and subsequent monitoring of the agreed-upon policies reveal a lesser degree of coordination, a deficit acknowledged by several interviewees. At the national level, there is a awareness of the important role that coordination plays. Initiatives such as the adoption of a government business process framework aim to bolster the implementation of e-government and "One Data Indonesia" cohesively, encompassing governance, ICT infrastructure, and service.

Score assigned	**3**

Indicator 1.4.a. Existence and level of implementation of hiring policies based on a merit-based and transparent professional and recruitment process of water professionals independent from political cycles

In the majority of activities conducted by national and subnational administrations, civil servants are formally chosen through open competition, wherein their knowledge and competencies are evaluated. This system is designed to ensure equal opportunities and selection based on merit. In addition, for certain activities across different administrations, contract workers are also engaged. Such is the case of PDAM Tirta Moedal, where all personnel is contracted, and also some other roles for the local government, which are outsourced. Despite efforts to uphold meritocracy, issues related to favoritism persist, often challenging identification due to their covert nature. Illustrating a challenge in the professionalism of state apparatus, data from the Indonesian Civil Service Commission reveals that only six out of 34 ministries have effectively implemented merit-based practices (Republic of Indonesia, 2020).

Score assigned	**3**

Indicator 1.4.b. Existence and functioning of mechanisms to identify and address capacity gaps in local water institutions

The various organizations engaged in water resources and water services provision in Semarang have developed diverse tools to recognize and tackle capacity gaps. Interviewees how these instruments have aided in pinpointing instances of mismatched skills and understaffing, revealing the existence of an outdated segment within the task force that consistently lacks the required skill set.

Score assigned	**3**

Indicator 1.4.c. Existence and level of implementation of educational and training programs for local water professionals

Training programs are organized for city officials and water sector staff. Most notably, PDAM Tirta Moedal organizes training activities covering various aspects, for staff at different levels: junior, intermediate and senior, in both technical and no-technical aspects. The national government also plays a significant role as a training provider for local staff, and national agencies are actively involved in training activities for local users, such as fishermen and coastal workers, to raise awareness of water-related risks.

Interviewees have also highlighted training activities facilitated by international cooperation for the development of local staff. Through collaborative efforts, Dutch water authorities and international organizations like UNICEF have provided local personnel with access to a diverse range of skills through training opportunities. Despite the existence of these instruments, capacity gaps and understaffing persist. This circumstance underscores a larger issue of skill shortages and competency gaps that extend beyond the local level, requiring attention for more effective governance and administration, not only in Semarang but also throughout Indonesia. These challenges have broader implications for areas such as investment, exports, and overall productivity systems.

Score assigned	**3**

Indicator 2.1.a. Existence and functioning of updates, timely shared, consistent and comparable water information systems at the local level.

By collecting data for the technical pillar in Semarang, we have revealed evidence of both the current data sources and the gaps in the information available. While information is consistent and comparable in areas such as drinking water provision and meteorological aspects, there is a noticeable scarcity in other areas, such as wastewater treatment and pollution control.

Score assigned	**3**

Indicator 2.1.b. Existence and functioning of public institutions, organizations, or agencies in charge of producing, coordinating and disclosing standardized, harmonized and official local water-related statistics.

There are institutions and organizations responsible for generating, coordinating, and disseminating information about Semarang water sector, notably PDAM Tirta Moedal, but also Environment Agency, and provincial and national institutions. The main difficulties concern the water resources uses that are not accounted for particularly water abstractions and non-revenue water

Score assigned	2

Indicator 2.1.c. Existence and level or implementation of mechanisms to identify and review local water data gaps, overlaps and unnecessary overload.

The various organizations responsible for data collection in Semarang have devised specific mechanisms to identify gaps and have established protocols for data collection. However, a primary challenge highlighted in the Semarang assessment is the limited instances in which this information is compiled and shared collaboratively among these organizations, which makes it difficult to identify common gaps and overlaps in information.

Score assigned	2

Indicator 2.2.a. Existence and level of implementation of governance arrangements that help local water institutions collect the necessary revenues to meet their mandates and drive water-sustainable and efficient behaviors

Access to water services is a main priority for the Indonesian government, which aims to reconcile service affordability and the sustainability of the measures. In this sense, the mechanisms to collect water revenues are intervened by local political authorities, which ultimately determine the tariffs for water services.

As for water resources, the law 17/2019 establishes the existence of Water Resources Management Service Fee (BJPSDA). This is a fee imposed, either partially or in full, on users of water resources. The central, regional and city governments determine the unit value of BJPSDA in the different rivers by involving relevant stakeholders (articles 11, 14, 16), and are also in charge of collecting the fees. Funds collected from BJPSDA must be utilized for improving services in the management of Water Resources in the relevant River Basin. This makes this fee potentially very effective for water management. This fee, however, has not been systematically implemented.

Score assigned	3

Indicator 2.2.b. Existence and functioning of a dedicated institution in charge of collecting water revenues and allocating them to the right level

Various institutions are in charge of water revenue collection: A service fee applies for water resources users uses, managed by different administrations. The river basin organizations charge for uses of freshwater water resources (irrigation permits) and the Central Java representation of the Ministry of Energy and mineral resources, for abstraction permits.

A service fee is applied to water users for processed drinking water by PDAM Tirta Moedal. After processing raw water for water supply, customers are charged a fee for its use. Fees are regulated under MoHA Regulation (Permendagri) 23/2006. Also, DISPERKIM has established regulations governing the management of septage. The department enforces a fees for solid waste/ sanitary service and septic tank desludging services. These charges apply to both private and public companies that provide domestic waste disposal services by truck to local customers.

Score assigned	**3**

Indicator 2.2.c. Existence and level of implementation of mechanisms to assess short -, medium- and long-term investment and operational needs and ensure the availability and sustainability of such finance

PDAM Tirta Moedal follows a procedure for setting water supply prices that starts by soliciting input from local experts and stakeholders. These individuals contribute valuable perspectives on planning objectives and the community's willingness to pay. PDAM Tirta Moedal makes a proposal to the Semarang authorities, which, after listening to other local departments, makes the decision regarding water tariffs.

National legislation dictates that while tariffs should cover costs, attention is given to the capacity of water users to pay. To address this, the national government authorizes subsidies for regional water supply companies, as outlined in Ministry of Public Works Regulation 70/2016 on Guidelines for Regional Governments. In Semarang, a specific cap of 4% of income is imposed on the water tariff for those earning regional minimum wage. In practice, the local water tariffs often barely cover operating costs. In Semarang, the latest tariff was established in 2019, and no specified date exist yet for establishing the new one. Observers note that local governments hesitate to raise tariffs due to the pressure to keep services affordable. Consequently, due to the resulting lack of financial autonomy of local actors, water investments are contingent on decisions made by the national government.

Score assigned	**3**

Indicator 2.3.a. Existence and level of implementation of a sound water management regulatory framework to foster enforcement and compliance, achieve regulatory objectives in a cost-effective way, and protect the public interest

There is no economic regulator for the water sector in Indonesia. It does exist in the DKI Jakarta service area, but not in Semarang or Central Java.

The regulatory framework for achieving regulatory objectives for water resources management and water services provision is established by legislation by the national and provincial governments, and the city of Semarang3.

Score assigned	**2**

3. Via Regional Regulation of Semarang City Number 2 of 2019 concerning the Regional Public Water Company Tirta Moedal in Semarang City; Mayor Regulation of Semarang City Number 45 of 2021 concerning the Minimum Service Standards for Drinking Water; Mayor Regulation of Semarang City Number 31 of 2019 concerning the Provisions of Drinking Water Tariffs.

Indicator 2.3.b. Existence and function of dedicated public institutions responsible for ensuring key regulatory functions for water services and resources management at the city level

No dedicated public regulatory institution exist to this extent; the authorities responsible for the management of water resources and the provision of water services carry out the activities to ensuring that their obligations are met.

However, the Indonesian government established the BPP SPAM. This agency assist the national and regional governments to improve the operation of drinking water supply system. As such, they gather information on the activities of the regionally-owned water supply enterprises, and publish performance evaluation.

Score assigned	**3**

Indicator 2.3.c. Existence and level of implementation of regulatory tools to foster the quality of regulatory processes for water management at city level

Evaluations are carried out by BPP SPAM on the performance of all regional publicly owned water supply companies, focusing on 4 categories: financial, service, operation and human resources. The results of these evaluations provide information to the national government in determining future program and policy decisions concerning water supply.

In addition, measures exist to promote efficient water use and pollution and water abstraction control and prevention, including administering charges against for criminal activities that endanger water infrastructure, cause pollution, disrupts water conservation efforts or causing the disturbance of the conditions of the watershed. These charges include imprisonment and fines up to 10 billion rupiah (articles 68 to 74, law 17/2019), as sanctioned by a court.

We have not found clear evidence of the existence of administrative sanctions as a result of failing to meet environmental standards or (such as written warnings, cease and desist orders, freezing the license, revocation of the license, and administrative fines). When the a pollution incidents or illegal abstraction is identified in Semarang, it refers the case to the police for action.

Score assigned	**3**

Indicator 2.4.a. Existence and level of implementation of policy frameworks and incentives fostering innovation in water management practices and processes at the local level

Indonesia has indicated its interest in making a priority of Smart Water Management practices. Although management is basically conventional In Semarang, some efforts have been evidenced in the launch by PDAM Tirta Moedal of a customer information application system in 2021. Through a smartphone application, customers get a variety of services such as reading their own meters, water bill info, registering new connections online to complaint channels. These initiatives attempt at improving customer service and facilitating data gathering.

Score assigned	**3**

Indicator 2.4.b. Existence and functioning of institutions encouraging bottom-up initiatives, dialogue and social learning as well as experimentation in water management at the local level

Some local institutions encouraging dialogue at the local level include Diponegoro University, the Indonesian Association of Environmental Engineering Experts, and the Indonesian Water Supply Companies Association (PERPAMSI) of Central Java. These institutions, while external to the local government administrations, participate in consultation activities and facilitators of information for PDAM Tirta Moedal, providing assistance and intelligence for policy makers.

Score assigned	3

Indicator 2.4.c. Existence and level of implementation of knowledge and experience-sharing mechanisms to bridge the divide between science, policy and practice at the local level

Interviewees refer to an external organization to the administration worth referring to is the Indonesian Association of Water Supply Companies (PERPAMSI), which provide influential input for decision making for regional water companies and provincial and local authorities.

Score assigned	3

Indicator 3.1.a. Existence and level of implementation of legal and institutional frameworks (not necessarily water-specific) on integrity and transparency

Indonesia has enacted a robust legislative framework to favor transparency and integrity. The general approach is based on the Law on Corruption Eradication (Law No. 30/2002), which has established the actions that Indonesia is to put in place to prevent and eradicate criminal acts of corruption, such as coordinated efforts, supervision, monitoring, investigations, indictments, prosecutions, and the court, and the law of on Public information openness (Law No. 14/2008), which establishes what information public and non-public bodies should make available to the public.

Specifically in the water sector, many regionally-owned water companies, including PDAM Tirtal Moedal, have adopted set of rules for Good Corporate Governance. Resulting from the adoption of these principles, PDAM Tirta Moedal as adopted a vigorous policy of information disclosure and transparency, with many of their decisions and status being made available in their website.

Score assigned	3

Indicator 3.1.b. Existence and functioning of independent courts (not necessarily water-specific) and supreme audit institutions that can investigate water-related infringements and safeguard the public interest

The Audit Board of Indonesia, known as Badan Pemeriksa Keuangan (BPK) in Indonesian, is an independent government institution responsible for auditing and examining the financial management and accountability of state finances. Established under the Constitution of the Republic of Indonesia, the BPK operates as a state audit agency with the primary objective of ensuring transparency, accountability, and efficiency in the use of public funds. The BPK conducts audits of government agencies, ministries, and other state institutions to assess their financial management practices, compliance with regulations, and the effectiveness of their programs. The board plays a crucial role in promoting good governance and preventing corruption by holding government entities accountable for their financial decisions and actions.

In addition to the BPK, Indonesia has established a Commission for the Eradication of Corruption (KPK), which is a State agency with powers to investigate instances where corruption is suspected, bringing the case, if considered appropriate, to the courts. The KPK coordinates investigations and prosecutions against criminal acts of corruption; it requests information from institutions, arrange opinion hearings and meetings, and undertakes activities seeking to prevent corruption practices. The courts of general Jurisdiction Indonesia have authority over general criminal and civil matters, including corruption cases. Specialized Anti Corruption courts have been established to check and decide on corruption cases proposed by the KPK.

The law on public information openness created the Indonesia's Information Commission, which is a independent institution responsible for the implementation of transparency rules, establish technical guidance of information sharing and resolving disputes on the topic. The commission consists of Central Information Commission, Provincial Information Commission, and if required, Regency/ Municipal Information Commission. The Information Commission of Central Java, set in Semarang, evaluates and benchmark public bodies, including PDAM Tirta Moedal, according to their degree of transparency

Score assigned	**4**

Indicator 3.1.c. Existence and level of implementation of mechanisms (not necessarily water-specific) to identify potential drivers of corruption and risks in all water-related institutions at different levels, as well as other water integrity and transparency gaps.

Audits and investigations are carried out to identify corruption risks and encourage transparency. KPK and the Public prosecutor office in Semarang city have the power to request information to other agencies, initiate investigations, undertake financial audits and performance controls, etc. Indonesia has also adopted protection measures for whistleblowers. In addition, benchmarking is also used to gather and publish information on the functioning of different public organizations, particularly with regards to their transparency practices, which the purpose of improving performance by comparison

Score assigned	**4**

Indicator 3.2.a. Existence and level of implementation of legal frameworks to engage stakeholders in the design and implementation of local water-related decisions, policies and projects

The general basis for facilitating the participation of local water stakeholders in the decision making is the national law 17/2019 has established the conditions for stakeholders participation. The National law establishes the means for participation, including public consultations; deliberations; partnerships; supervision, and other involvements.

Score assigned	**4**

Indicator 3.2.b. Existence and functioning of organisational structures and responsible authorities to engage stakeholders in local water-related policies and decisions

BAPPEDA serves as the institution responsible for regional planning and development in the water sector. It has the ability to coordinate the interests and programs of all stakeholders involved in water management. BAPPEDA assist the Semarang Mayor in carrying out the supporting functions of Government Affairs in the fields of planning, research and development. The interviews have shown that BAPPEDA seems to have more influence and decision making responsibilities than the river basin organization when it comes to water resources planning.

Score assigned	4

Indicator 3.2.c. Existence and level of implementation of mechanisms to diagnose and review stakeholder engagement challenges, processes, and outcomes

Externally, audits by BPKP can identify the instances where stakeholder engagement is insufficient. Internally, PDAM Tirta Moedal has a Supervisory board, appointed by the mayor, which is responsible for overseeing and monitoring the activities and decisions of the management to ensure compliance with laws, regulations, and the interests of stakeholders.

Score assigned	4

Indicator 3.3.a. Existence and level of implementation of formal provisions or legal frameworks fostering equity across water users and generations at the local level

Indonesia has expressed deep awareness of the competition in the use of water, particularly between agriculture, manufacturing, and housing (Republic of Indonesia, 2020).

In light of the existence of this rival uses, the national law establish certain key provisions related to the management and utilization of water resources, with emphasis on equality among users. Thus, it establishes the protection of users of water for basic daily needs, subsistence agriculture and other activities that are not considered business activities (article 58). These activities are exempted from paying water resources charges (BJPSDA). All other activities that require uses of water resources require to pay for water fees destined to the protection of the common interest.

At the local level, PDAM Tirta Moedal and Semarang city authorities have agreed on a Drinking water security plan (Rencana Pengamanan Air Minum) and a business plan (Rencana Bisnis) that refers to measures for ensuring the continuity and sustainability of water services provision in Semarang.

Score assigned	4

Indicator 3.3.b. Existence and functioning of a local Ombudsman or institution(s) to protect water users, including vulnerable groups

The Republic of Indonesia has established a national Ombudsman (Ombudsman Republik Indonesia). It is an independent and impartial institution that addresses complaints and grievances related to administrative actions or decisions made by government agencies. The Ombudsman's role is to ensure that public services are delivered fairly, transparently, and in accordance with the law. The Ombudsman of the Republic of Indonesia has a Representative for the Central Java Province, with responsibilities for the city of Semarang

Citizens can file complaints with the Ombudsman if they believe they have been treated unfairly or if they encounter problems with government services. The Ombudsman investigates these complaints, facilitates resolutions, and works to improve the quality of public administration.

Score assigned	**4**

Indicator 3.3.c. Existence and implementation of mechanisms to manage trade-offs across users, and/or over time in a non-discriminatory, transparent and evidence-based manner at the local level

Low income households are subsidized to get water through the Hibah Air (water grant) program. The water grant program enables the central government to pass on grant funding to local government that are prepared to invest in the development to their water systems to expand services to the urban poor. In Semarang, in accordance with national law, the water tariff is capped at 4% of the income for those that are on a low income.

The national government has also put in place "feasibility studies" that examine the implementation of preventive measures and compensations for citizens and other parties affected by strategic water projects. This feasibility study looks at what parties might be affected by the project, looks at the impact of the project, and determines, inf necessary, the compensations. In the case of Semarang, this has been put in place for the Semarang Barat project,

Score assigned	**4**

Indicator 3.4.a. Existence and level of implementation of policy frameworks promoting regular monitoring and evaluation of water policy and governance

A regulatory and institutional framework has been established to ensure the monitoring and evaluation of water policy and governance. Particularly so since 2019 with the latest adoption of a law of water resources, which provides clarity to the distribution of responsibilities, including regular monitoring and evaluation of water policy , but also before with Government Regulation 122/2015, which provides guidance for drinking water utilities .

Score assigned	**3**

Indicator 3.4. b. Existence and functioning of institutions in charge of monitoring and evaluation of water policies and practices and help adjust where need be

BPP SPAM has the task of assisting both the national and the regional governments to improve the operation of the drinking water supply system which is carried out by state-owned and/or regionally owned enterprises. In 2017 the government reinforced the role of the provinces to monitor the regionally owned companies such as PDAM Tirta Moedal in Semarang, with the help of BPP SPAM.

Score assigned	**3**

Indicator 3.4.c. Existence and level of implementation of monitoring and evaluation mechanisms to measure to what extent water policy fulfils the intended outcomes and water governance frameworks are fit-for-purpose
The main instrument is via the regular performance evaluations undertaken to more than 380 water service providers in Indonesia. The evaluation focuses on the performance of the providers, according to 4 categories: financial, service, operational and human resources aspects. The results of this performance evaluation informs the national government and has an impact on the decisions taken at the national level with regard to the policies to put in place (articles 26, 27, 28 of the Minister of Public Work and People's housing regulation number 27/2016 on the management of water supply system). In Semarang, PDAM Tirta Moedal has systematically scored well.

As for water resources protection, the most important instrument have been the Permits to ensure that water quality and limits are maintained (article 51, law 17/2019), such as pollution and abstraction permits. However, the mechanisms for monitoring the adherence to the permitted limits have not been carried out optimally and periodically.

Score assigned	**3**

3. Smart Water City Certifying (rating) and Recommendations

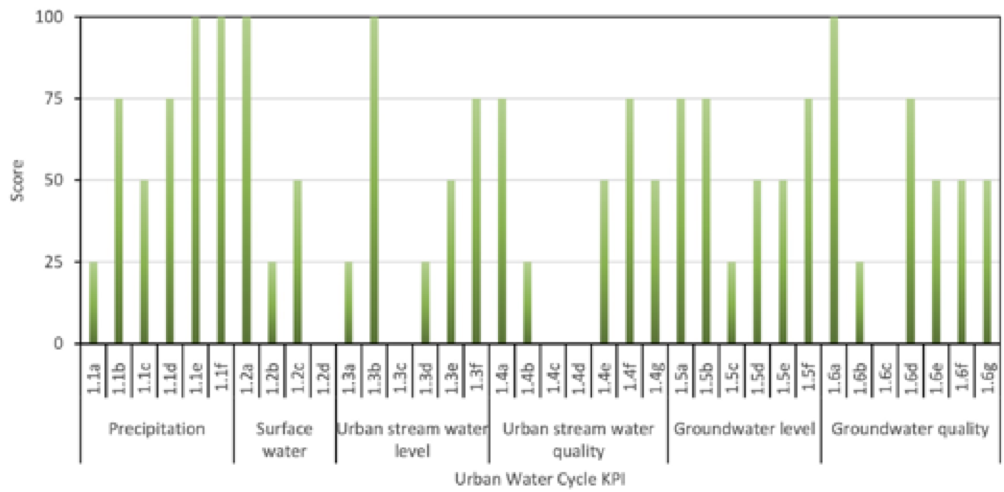
Analyzing water resource management and water services in Semarang reveals numerous insights and recommendations. Similar to the BEDC case, we organize these findings into two sections—technical and governance—to emphasize their distinct characteristics and facilitate key takeaways.

Technical pillar Assessment and recommendations

Considering all the results calculated for the smart water city evaluation of Semarang city, graph representation of the three categories in technical pillar are presented (Figure 17). The horizontal axis pertains to the individual technical key performance indicators, while the vertical axis defines the final scoring for each KPIs.
For the urban water cycle category, Semarang city performed well in managing and monitoring the urban hydrological flow, specifically in the utilization of ICT-based technologies in precipitation monitoring, public accessibility to precipitation data, adequate percentage of impervious surfaces, the frequency of stream water level observation, and the groundwater quality observation coverage density. With this regard, the Semarang city meteorological agency (BMKG) uses automated weather stations, sensor rain gauges, doppler radar, satellite data, and numerical weather prediction systems to closely monitor the spatial and temporal variation of rainfall in the city. These rainfall data have been made easily accessible to public usage through the internet. The stream gauge instruments managed by the city's disaster management agency (BPBD) records at high-frequency intervals. The groundwater quality observation wells within the city, installed by the Central Java provincial Energy and Mineral Resource Agency (ESDM), are adequately distributed. Lastly, the percentage of pervious surfaces such as rice fields, ponds, etc. are abundant enough to aid the natural flow of the hydrological cycle. These indices are good indicators for a smart water city.

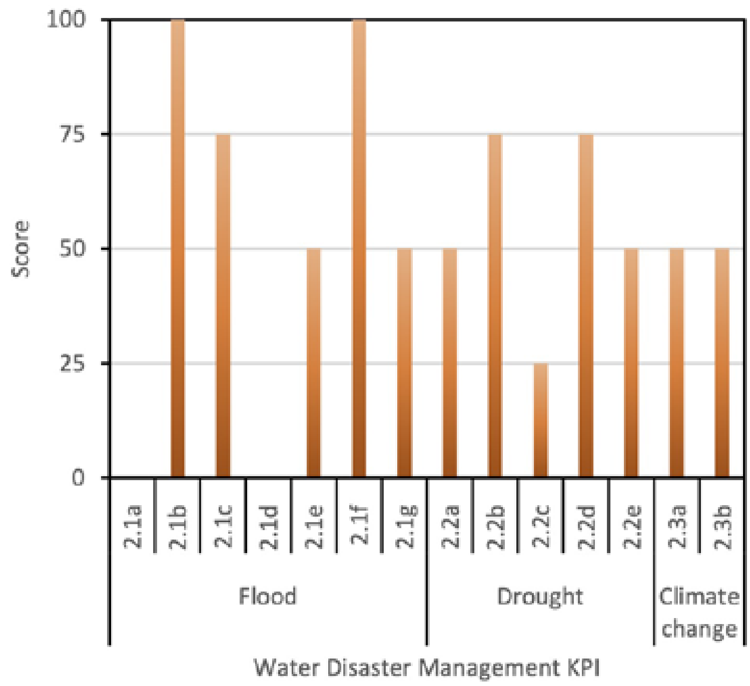
However, the city's urban water management is limited in some respects. In particular, according to the city's department of public works (DPU), the city does not apply and keep track of low impact development strategies or green infrastructures in the construction of public and government spaces. These strategies are designed to reintroduce the natural process of soil water absorption in storm water management and eco-system conservation. There is also a critical lack of availability of stream water level and water quality data, as well as for groundwater quality information. Due to the difficulties in obtaining this information, the status of river water quality and groundwater quality standards for Semarang city cannot be fully determined. These data are critical in assessing the health and present condition of the water source, which directly affects the safety of water for public consumption.

Figure 17. Semarang city Smart water city evaluation scores on Technical Pillar urban water cycle category



The effectiveness of water disaster management in Semarang city can be perceived in the flood property damage index and their application of integrated flood and drought disaster information system. The cost of flood property damage, including damage in residential, commercial, and agricultural facilities, in relation to the city's gross domestic product per capita is relatively low. In addition, the city's disaster management agency (BPBD) utilizes ICT-based technologies in flood monitoring in the form of stream gauge water level sensors, CCTV cameras, and in flood and drought information development and dissemination in the form of flood and drought threat, vulnerability, capacity, and risk maps, that are easily available to public online. However, the annual number of flood disaster related casualties in the city are still considerably significant, with an annual average of 3.6 flood-related deaths since 2013. This can be attributed to various reasons such as insufficient flood mitigation strategies, lack of flood prevention structures such as levees and dikes, or the inherent vulnerability of the city to climate-related hazards.

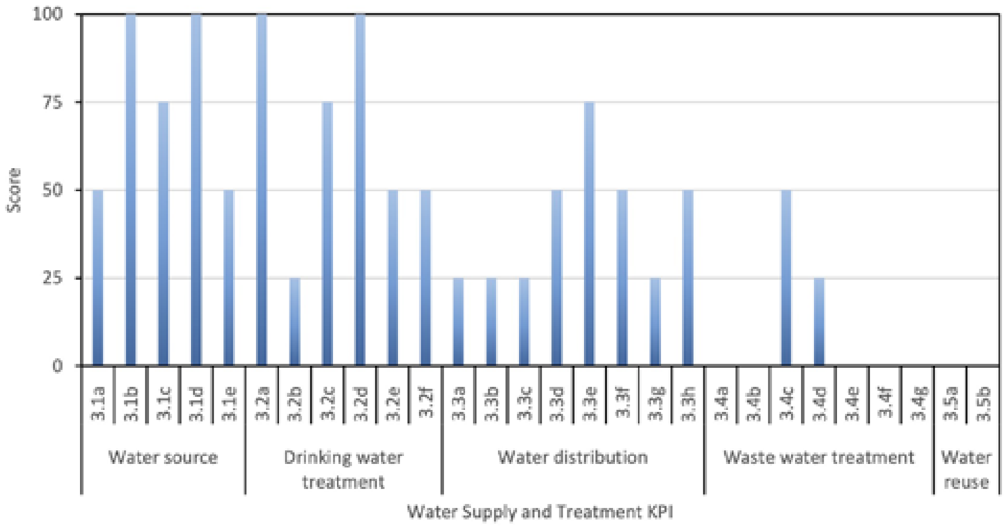
Figure 18. Semarang city Smart water city evaluation scores on Technical Pillar water disaster management category



For water supply and treatment, attributing to the efforts of the Semarang city Water company (PDAM), Semarang city has shown reliability in the availability of water resources, utilization of ICT-based technologies in water source and drinking water treatment monitoring. This implies that the city has sufficient water reserve in case of limited water supply, and modern technology devices are used in the process of water source and drinking water treatment. Some of these technologies include water quality sensors, pH sensors, flow meters, analyzers, and spectrophotometers. Because of this, the water quality standards resulting from inspections of the quality of drinking water throughout the city is satisfactory. Hence, Semarang city exhibits smart water management in the availability and quality standards of water supply distributed to the community.

On the contrary, there is a serious need to provide solutions for the limitations in the monitoring and management of wastewater distribution, aging sewage pipelines, sewage treatment process, and the application of separated sewage network, sewage pipe network maintenance and recycling of wastewater byproducts. According to the city's department of housing and settlement area (DISPERKIM), as of 2023, the city does not have proper wastewater treatment facilities; 86% of the urban households use independent septic tanks, while about 14% do not have functional toilets. Sewage structure status and maintenance are not being kept on record. There is also no proper management of wastewater treatment, and sludge materials are not adequately disposed or recycled. This imposes significant risk in public health and the environment, causing water source pollution and groundwater contamination resulting in the spread of waterborne diseases and harming of the aquatic ecosystem.

Figure 19. Semarang city Smart water city evaluation scores on Technical Pillar water supply and treatment category



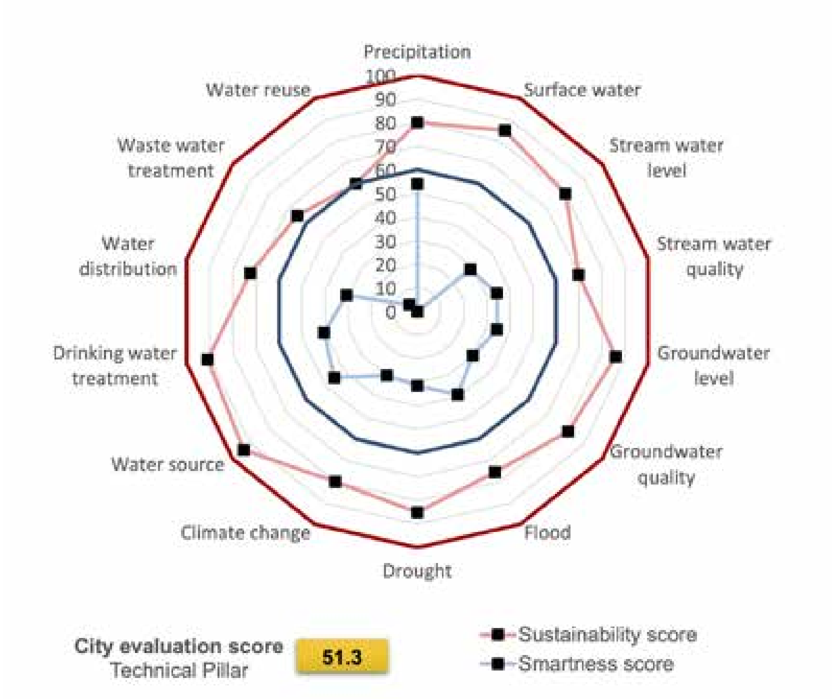
The overall smart water city technical assessment of Semarang city for all categories can be seen in Figure 20. The overall scoring of the technical evaluation is computed by weighing the Sustainability and Smartness scores.

Table 10. Semarang city smart water city technical evaluation scores

Category	Subcategory	Sustainability score (%)	Smartness score (%)
Urban water cycle	Precipitation	50.0	90.0
	Surface water	62.5	0.0
	Stream water level	50.0	47.5
	Stream water quality	25.0	57.5
	Groundwater level	65.0	57.5
	Groundwater quality	53.8	50.0
Disaster management	Flood	38.8	65.0
	Drought	62.5	52.5
	Climate change	50.0	50.0
Water supply and treatment	Water source	85.0	75.0
	Drinking water treatment	77.5	67.5
	Water distribution	31.3	51.3
	Wastewater treatment	12.5	7.5
	Water reuse	0.0	0.0
Technical evaluation total score		51.3	

For the Sustainability assessment, Semarang city performed well in the water source and drinking water treatment services. This implies that the Semarang city water company (PDAM) can effectively facilitate the water availability in the primary water sources and ensure the standard quality of drinking water to the residents. It is also commendable to note that groundwater level monitoring and drought disaster management also obtained relatively high scores due to the efforts of the respective agencies in improving the coverage density and recording frequency of groundwater level stations (ESDM), and the availability of alternative water sources in the occurrence of drought events (BPBD). Under the Smartness category, the precipitation monitoring managed by the regional meteorological agency (BMKG) scored the highest through the application of ICT-based technologies in rainfall observation and forecasting, frequency of rainfall observation and the accessibility of rainfall data to the public. This is followed by the ICT-based technologies used in water source monitoring and drinking water treatment instrument processes.

Figure 20. Semarang city final scoring on technical pillar



Based on the overall evaluation, these are the recommendations to have Semarang city improve their urban water management:
Primary recommendations: Serious considerations in the proper management of the city's wastewater treatment, disposal and recycling are highly recommended. Specifically, the implementation of centralized collection of wastewaters from households, commercial building, and public facilities to the sewage treatment plant. The sewage network system must provide services to the majority of the population. The status of deterioration of aging sewage pipelines must be consistently tracked, replacing old pipes, and fixing broken connections. The utilization of modern technologies in wastewater quality monitoring and application of advanced purification processes in wastewater treatment are fully encouraged. Reuse and recycling of byproducts of wastewater treatment are also necessary in sustaining the water cycle, easing the extraction of raw water from natural reserves, and decreasing the biosolid waste to the environment. This can include reuse of treated sewage water in irrigation, sanitary sewer usage, street cleaning and dust control, etc. Sewage sludge materials on the other hand, have a potential to contribute in the materials used for construction, in brick and cement making, or used as fertilizer in agriculture. According to the city regional housing and settlement area department (DISPERKIM), the wastewater management project for Semarang city, the SPALD-T (Sistem Pengelolaan Air Limbah Domestik Setempat Terpusat) or the Central Wastewater System, planned to provide wastewater collection and treatment to 10 districts in the city: Semarang Tengah, Genuk, Semarang Utara, Semarang Timur, Gayamsari, Semarang

Selatan, Pedurungan, Candisari, Semarang Barat and Gajah Mungkur. The initial phase of the project will start on 2023-2026 and will finalize on its fourth phase on 2037-2041. With regards to this, Semarang city is already making progress in solving the issues in wastewater management. In addition, the application of low impact development and green infrastructure strategies are recommended to aid the natural flow of the urban water cycle, these techniques include retention panels, infiltration trenches, porous concrete, rain barrels and more. The application of these techniques in water cycle management is a significant indicator of smart water cities.

Supplementary recommendations: In addition to the fundamental proposition to strengthen the city's sustainability, further recommendations are presented to advance the city's foundation in urban water management to exhibit traits that are quantifiable as smart water city. For urban water cycle, consistent monitoring and provision of hydrological data are recommended, specifically the data for stream water level, stream water quality, ground water level and groundwater quality are necessary for urban water sustainability. The reduction of missing and error data resulting from instrument malfunction can be achieved by performing regular instrument calibration and data quality control. It is also recommended to install more rain gauge stations to fall within the appropriate rainfall observation coverage of at least one monitoring instrument per 20 km2; install additional stream gauge stations to achieve at least one station with 10 km river extent; install automated stream water quality testing instruments that record the quality of water at least once a day, and groundwater quality testing that are performed at least once every three months. For water disaster management, it is encouraged to utilize hydrometeorological parameters in drought hazard mapping, these methods include the standard precipitation index (SPI), hydrological drought index (HDI), etc. These drought hazard maps can be further improved through the application of climate forecast and drought impact assessment. And lastly, for water supply and treatment, it is advised to perform higher frequency water quality monitoring (at least once a week) in the drinking water treatment facilities. Provide wider coverage of water supply services to at least 90% of the urban population. Reduce the quantity of deteriorated pipelines to less than 15%. Increase the availability of water production in the water treatment plants to 80%. Install more smart water meters to achieve 10%. And install automated water quality monitoring instruments to record the real time water quality in the sewage treatment plants.

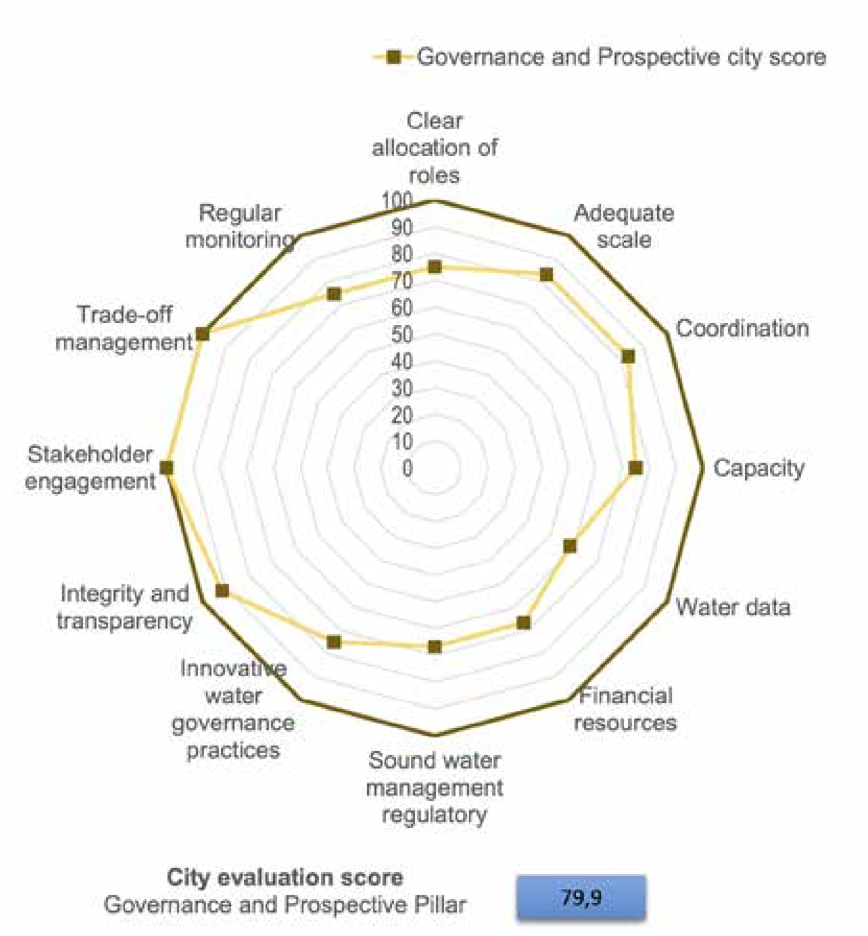
Governance and prospective pillar Assessment and recommendations

Securing water resources, improving water services provision, and flood control have been a top priority for the Indonesian government (Republic of Indonesia 2020). Despite notable improvements, the growing population and climate change effects increase the urgency of tackling these issues. As demands on water resources intensify and climate-related challenges persist, the need for comprehensive urban development, environmental and water management strategies is becoming ever more critical.

Our examination of Semarang has provided insights into the functioning of existing governance structures. In Figure 21 the scores of the 12 subcategories are presented. The identification of single issues is complicated by numerous and simultaneous challenges, further exacerbated by factors such as population growth, climate change, and human activities. Nevertheless, three main areas demand primary attention, as they are identified as the weakest aspects:"

(1) the need to support the implementation of a integrated water resources management approach via the reinforcement of the river basin organizations
(2) the need to further develop financial resources of the local authorities and local actors;
(3) the demands for improved water data and data management -this involves developing information data sources to improve the capacities of the different administrations to make diagnosis.

Figure 21. Semarang city final scoring on governance pillar



River Basin Authorities as main water resources management unit

Indonesia has established River Basin Authorities as a crucial unit for management and analysis, aligning the country with the implementation of an Integrated Water Resource Management approach. This approach enhances coordination across sectors, promotes sustainable water use, and addresses challenges like pollution and scarcity. IWRM considers interconnections between surface water, groundwater, and ecosystems, optimizing water use while accounting for environmental, social, and economic factors.

The assessment of Semarang highlights the need to strengthen the river basin as a fundamental unit of management in the country, and the participation of cities in it. While River Basin Organizations exist, emphasizing their role can foster more coherent water resource management. Strengthening river basin authorities is crucial for cities like Semarang, as their water challenges are intricately linked with broader interests and sectors within the larger catchment area. Active participation from upstream and downstream cities in the River Basin board and plans is essential for a sound water management and regulation, which is deficient. This approach facilitates overcoming administrative boundaries, coordinating diverse interests, and reconciling conflicting political agendas related to shared water resources. Achieving this change needs efforts to build consensus and establish collaborative frameworks, emphasizing the importance of transcending existing administrative and political decision-making limitations.

Financial resources

The examination of the Semarang case highlights the crucial need to secure funding for vital water projects, ensuring the sustainable management of water and sanitation to tackle the city's significant challenges. Addressing escalating demands requires increased investments in water and sanitation.

Indonesia's water goals, aimed at improving water services and resource management, have been supported by a robust national funding plan since the early 2000s. Public spending on water supply tripled in real terms from 2001 to 2016, constituting 1.7% of total national spending in the water sector. Despite this increase, Indonesia remains among the countries with the lowest investment in water and sanitation, allocating only 0.2% of its national GDP in 2016—below the recommended levels for East Asian countries (0.5%) and the United Nations (1%).

To bridge this gap, a key recommendation is to persist in exploring new financing sources and optimizing existing ones. Recognizing this lesson is vital for effectively addressing water challenges, meeting growing demands, and reinforcing the resilience of water systems amid evolving circumstances.

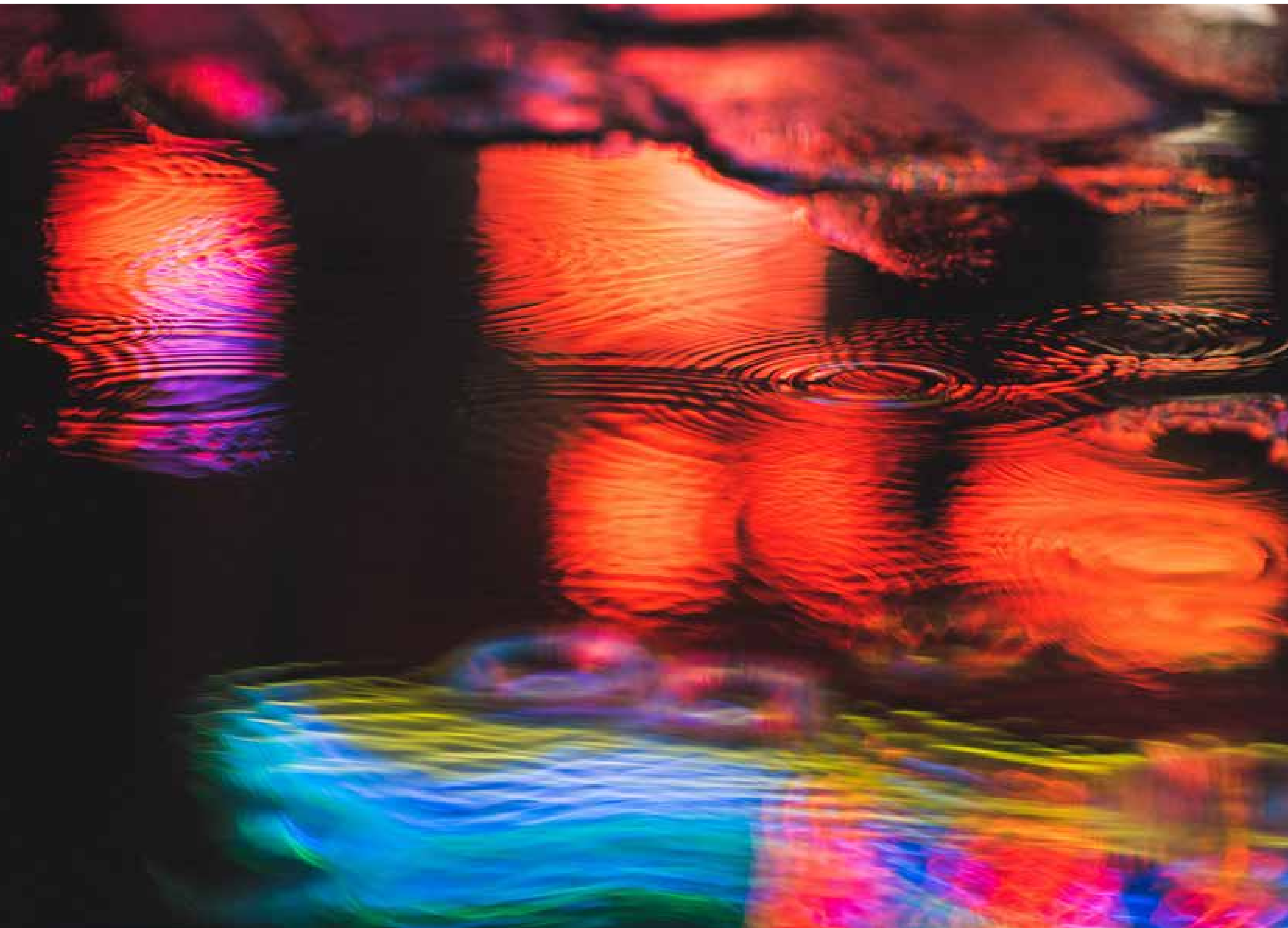
Water data generation and sharing

A key lesson learnt from the Semarang case study concerns the importance of generating and sharing of local water data. The dynamics of water resource management demand a comprehensive understanding of the local hydrological conditions, consumption patterns, and environmental impacts. Consequently, the quality, accuracy, and accessibility of water-related information play a pivotal role in shaping successful strategies for sustainable water management.

The Semarang case study brings to light a critical challenge in water governance—instances where authorities lack accurate information regarding the quality and quantity of water resources, as well as the specific characteristics of water services. This deficiency in data poses significant hurdles to effective decision-making and comprehensive water management strategies. Without precise data, it becomes challenging to identify potential contamination sources, monitor water pollution levels, or predict variations in water availability. This lack of insight hampers the formulation of targeted interventions and preventive measures, leaving the region vulnerable to water-related crises. In addition, authorities may face challenges assessing the overall reliability of water infrastructure, which may lead to inadequate resource allocation and hinder the planning of necessary upgrades.

Addressing these information gaps is necessary. By enhancing the accuracy and availability of water-related information, authorities can make informed decisions, implement targeted interventions, and foster sustainable water management practices that align with the specific needs and challenges of the region. Equally crucial is the aspect of sharing this data across various stakeholders, including government agencies, local communities, and environmental organizations. Open access to comprehensive water data fosters transparency, collaboration, and a shared understanding of the challenges at hand. It enables stakeholders to collectively address issues related to water scarcity, pollution, and infrastructure planning. In this sense, this lesson empathizes the development and implementation of standardized protocols for data collection and sharing to improve the consistency, comparability, and reliability of information, facilitating effective cross-sector collaboration and policymaking.

CONCLUSIONS



1. Benefits of Smart Water City Certification Scheme

Urban areas worldwide face critical challenges in delivering water services and managing water resources. Issues like water scarcity, pollution, flooding, limited access to clean drinking water and sanitation, and deteriorating infrastructure have become widespread. These challenges significantly impact the well-being, growth, and safety of both cities and their residents, often affecting their overall quality of life. These challenges result from a combination of natural limitations, "megatrends" like climate change and population growth, and human-made factors such as mismanagement of water resources and financial constraints.

Assessing cities' capabilities to overcome these challenges is vital for building resilient and sustainable cities. This report explores how the Smart Water City Index and Certification scheme can serve as a valuable tool for evaluating the status of water in cities and the measures in place for managing water resources. It shows how this novel and innovative instrument has the potential to contribute to facilitating the integrated and smart urban water management of cities around the world. It offers a comprehensive evaluation of a city's water status and the technical and governance measures in place for resource management. The technical pillar of the Index scrutinizes the infrastructures and innovations throughout the urban water cycle, while the governance pillar assesses the institutions, regulations, and stakeholders responsible for organizing urban water resources. Participating cities receive a thorough assessment of their urban water management's functionality and a comprehensive plan for improvement, encompassing technological recommendations and measures to enhance their financial, human, and regulatory capacities.

Tools to assess cities' capabilities in overcoming these challenges are imperative for building more resilient and sustainable urban environments in the future. Evaluating successes and learning from experiences is the initial step towards informed, evidence-based policymaking.
This approach empowers cities to recognize their strengths and areas for improvement, facilitating targeted decision-making for optimized water management practices. The Index helps pinpoint necessary steps for enhancing performance while identifying gaps and deficiencies in applicant cities' infrastructure and institutional setups.

Developing this index into a fully-fledged Smart Water Certification scheme is the next stage of this work. A certification can have multiple advantages. With it, cities can showcase their dedication to superior urban water management and service provision, adhering to high standards in both technical and governance aspects. The Certification could allow local administrations to scrutinize and refine local water practices, introducing reforms to enhance their capabilities. An exclusive logo, indicating the achieved distinction (Gold, Silver, or Bronze), will be designed for a Smart Water City Certification, which awarded cities can prominently display in all relevant communications.

To take this step, the pilot evaluations undertaken in Semarang and BEDC have served enormously. They have provided the opportunity to examine how the Index performs under very different circumstances, and to draw several lessons.

2. Lessons learnt and next steps

Conducting pilot city tests in the city of Semarang and in the Busan Eco Delta City has been an invaluable experience that has shed light on crucial aspects of urban water management and urban water services provision, both in the technical and the governance aspects. Crucially, this work has also highlighted several key elements that need to be taken into account for the successful development of a future certification scheme for Smart Water Cities, and more broadly, for the establishment of a meaningful instrument able to examine and compare urban water management in city around the world. Here are some of the essential lessons learned from the pilot tests, which encompass different aspects related to the gathering of adequate information, liaising with the right local organizations and individuals, and the demand to address qualitative evaluation biases, amongst many others:

Lesson 1: Establishing a Strong Lead Authority in the Pilot City

The pilot tests underscored the critical importance of designating and liaising with a lead authority within the pilot city. This entity, endowed with the necessary authority and influence, plays a pivotal role in orchestrating the evaluation process effectively. In the case of Semarang, this lead authority was embodied in the Mayor of Semarang. The mayor had the power to request cooperation from local organizations, ensuring they facilitated information sharing, hosted evaluators, and facilitated necessary meetings. This central coordinating body was instrumental in overcoming logistical hurdles and expediting the assessment process.

For this reason, moving forward, it is imperative to ensure that future evaluations select a local counterpart with the requisite authority. This ensures that the evaluation can proceed smoothly and efficiently. The lead authority should possess the capacity to mobilize resources, engage key stakeholders, and navigate bureaucratic processes, ultimately enabling the evaluation team to access the information and resources required for a successful assessment. By prioritizing the establishment of a capable lead authority, future evaluations can greatly enhance their chances of success.

Lesson 2: Gathering Comprehensive Information on City Performance

One of the primary challenges encountered during the pilot tests was the need to collect accurate and detailed information about the cities' water system performance. This proved to be a complex task for various reasons. Firstly, gaining access to the right individuals with a comprehensive understanding of the water system's intricacies was a critical factor. This required establishing connections with key stakeholders, including city officials, water utility managers, and local experts, who could provide the necessary insights. Additionally, time constraints emerged as a significant hurdle. These stakeholders, often inundated with their responsibilities, needed to allocate precious time to provide thorough and meaningful responses. Overcoming language barriers further compounded the issue. Effective communication was vital to ensure that vital information was not lost in translation, necessitating the involvement of facilitators or translators. Moving forward, the expansion of the pilot cities evaluation needs to take account of the demands for detailed information, so to plan for adequate time and resources.

Lesson 3: Balancing Comprehensiveness and administrability of the Smart Water City Index

In the course of pilot city analysis, the quest for equilibrium between comprehensive evaluation and practical administration has emerged as a critical focal point. The Smart Water City Index, replete with over 100 indicators, promises a comprehensive evaluation, yet it presents administrative challenges. Nowhere is this more apparent than within the governance pillar, where a wide spectrum of topics demands careful examination. Effectively addressing this challenge necessitates strategic decision-making to strike a harmonious balance between developing a comprehensive city assessment and ensuring its operational manageability. To achieve this balance, two distinct approaches need to be examined. Firstly, the reduction of the number of indicators might be considered. This can allow for a streamlined evaluation process, but attention needs to be taken to safeguarding the assessment's depth and quality. Alternatively, maintaining the same level of comprehensiveness demands a careful accounting of the associated time and human resource costs. Each approach presents its unique merits and considerations.

Lesson 4: Recognizing the Significance of the Informal Water Sector

The pilot tests underscored the importance of considering the informal sector when evaluating the water sector in certain countries and cities. This sector, which can be easily overlooked in formal assessments, plays a substantial role in providing water services to communities, particularly in developing countries. Assessing the role of the informal sector is complex because, by nature, it is difficult to identify and examine: acknowledging the presence and influence of the informal sector requires engaging with a diverse range of stakeholders, including community leaders, small-scale water providers, and local entrepreneurs, which complexify the analysis. In addition, lack or of clearly established responsible authorities, decision-making processes, lack or insufficient data records, etc. might be common circumstances. For this reason, if future assessments choose to focus exclusively on the formal sector, the limitations in the scope need to be explicitly acknowledged. If the informal sector wants to be accounted for, the evaluation time and resources will have to be adjusted.

Lesson 5: Prioritizing Data Standardization and Accessibility

The pilot tests highlighted the critical need for standardized data collection methods. Ensuring uniformity in data formats, definitions, and metrics across different cities and regions proved to be essential for meaningful comparative analysis. The guidelines provided to the local actors need to be carefully reviewed to ensure that they are clear and applicable to the pilot city analysis, and at times the information needed to be treated to be made comparable. In the future, the demands of this clarification and measures need to be clearly acknowledged to ensure that the procedure is transparent.

Lesson 6: Implementing measures to mitigate evaluation biases

While applicable to both pillars of the Smart Water City Index, this lesson applies more directly to the governance pillar. With the Governance KPIs, given the qualitative nature of the evaluation, it is imperative to implement measures to counteract potential biases from the evaluators. Subjectivity, even unintentional, can introduce distortions in the assessment process. To address this concern, structured evaluation frameworks, clear assessment criteria, and rigorous training for evaluators are essential. Moreover, periodic calibration sessions are necessary to ensure consistency in the evaluation process. These sessions can provide a platform for evaluators to discuss their interpretations, share insights, and align their perspectives. Moving forward, this collective effort needs to be implemented to minimize individual biases and enhance the overall reliability of the assessment.

Lesson 7: Adapting to Local Socio-Cultural Contexts

The pilot tests underscored the significance of understanding and adapting to the unique socio-cultural contexts of each city. Cultural norms, historical backgrounds, and community dynamics significantly influence water management practices. Recognizing and respecting these nuances allowed for more nuanced and contextually relevant assessments. Engaging with local communities and leaders, and incorporating their perspectives, proved invaluable in capturing a comprehensive picture of water governance within Semarang and Busan Eco Delta City. In particular, for instance, a prevailing sense of loyalty to the city's functioning and colleagues sometimes hinders candid discussions about areas where improvements are needed. Sensitivity and building trust and rapport with stakeholders is imperative in order to encourage open and honest conversations.

Lesson 8: Embracing Flexibility and Iterative Learning

Flexibility emerged as a key factor in navigating the complexities of water assessments. The pilot tests demonstrated that rigid, one-size-fits-all approaches were often inadequate for capturing the dynamic nature of water systems. Embracing iterative learning processes and remaining open to adapting evaluation methodologies based on emerging insights and challenges has been essential. This lesson emphasized the need for a responsive and agile approach to assessment, allowing for continuous improvement and refinement.

In the technical pillar, this flexibility has contributed to reformulating some KPIs and the values.

3. Questions and checkpoints for Smart Water City Index

This section outlines essential questions for evaluators to ponder, taking into account insights gleaned from the pilot city tests. Conducting comprehensive water governance assessments requires careful planning and consideration of various factors. Drawing from lessons learned, it is crucial to address specific checkpoints before embarking on a future evaluation or expansion of the project to other cities. These checkpoints are designed to enhance the effectiveness and relevance of the assessment process:

1. Assessing Lead Authority and Organizational Capacity:
- Is there a designated lead authority with the necessary authority to facilitate information sharing and logistical support?
- Have we identified a lead authority with the requisite authority and capacity to coordinate and facilitate the evaluation process?
- Is the lead authority equipped to mobilize resources, engage stakeholders, and navigate bureaucratic processes?

2. Index Length and Depth:
- Is the index length optimal, balancing comprehensiveness and administrability?

- Have we considered whether to reduce the number of indicators for a more streamlined evaluation or maintain a comprehensive index with adequate resources?

3. Stakeholder Engagement and Information Accessibility:
- Have we identified and established relationships with key stakeholders who possess comprehensive knowledge of the water system?

4. Language and Cultural Considerations:
- Have we addressed potential language barriers, and do we have access to translation services if needed?
- Have we conducted cultural sensitivity training for the evaluation team to ensure effective communication and understanding?

5. Data Standardization and Accessibility:
- Is there a user-friendly data collection methodology in place?
- Are the different KPIs clearly explained?

6. Recognition of the Informal Water Sector:
- Are we accounting for the contributions and challenges posed by the informal sector in our evaluation?
- If yes, have we identified and engaged with informal water providers and stakeholders within the community? If no, are we providing adequate information to acknowledge this circumstance?

7. Flexibility and Iterative Learning:
- Are we prepared to adapt our evaluation methodologies based on emerging insights and challenges during the assessment process?
- Have we established mechanisms for ongoing feedback and refinement of our approach?

8. Mitigating Evaluation Biases:
- Have we implemented measures to minimize potential biases in our qualitative evaluation process?
- Are evaluators trained to apply assessment criteria consistently and objectively?

9. Prioritizing Relationship-Building:
- Have we invested time in building trust and rapport with key stakeholders to encourage open and honest communication?
- Are we fostering a collaborative environment that encourages stakeholders to share both successes and areas for improvement?

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2023

REPORT | 2023

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ISBN 979-888525026-9

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