SMART WATER MANAGEMENT

Case Study Report

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SMART WATER MANAGEMENT

Case Study Report

Foreword from K-water

It is my great honour to publish this Smart Water Management (SWM) Case Studies report, led by K-water and the International Water Resources Association (IWRA), which presents exemplary SWM projects from around the world to share the benefits of SWM implementation and lessons learned so far. The contributions of the IWRA and the participating case studies in leading the way to SWM, and the value of their efforts, will continue to be appreciated in the future.

Thanks to their dedication, SWM has already been achieved in many areas, offering solutions for improved water management and also assisting to achieving our global common goal of sustainable development. Many recent studies and demonstrations of SWM have been conducted worldwide to address issues and challenges made increasingly severe by climate change, such as flooding and drought, water access, water quality, groundwater management and efficient irrigation. To support the future successful implementation of SWM around the world, this report discusses the technological, social, economic, environmental and integrated governance considerations, in the contexts of Information and Communication Technology such as intelligent water supply networks, and real-time information exchange system through smart metering and networking.

This report shares the benefits of SWM and the lessons learned from these SWM projects from around the world, and in doing so encourages the sustainable use of water through using innovative water resource management. By accurately monitoring and optimizing forecasting systems, SWM can minimize economic, social and environmental risks from water-related disasters. It can also maximize the efficiency and effectiveness of water supply and sanitation by saving water and energy, by reducing costs, and most importantly by meeting consumers' needs and interests.

We can assist with achieving the SDGs around the world by adopting SWM where better water management strategies are needed, and by establishing guidelines and a roadmap for SWM to transition towards more sustainable use of water in the future. While there are still many water challenges being faced globally, this report shows the potential for SWM to assist not only in achieving SDG 6 directly, delivering water and sanitation for all, but also by affecting a positive impact on the mitigation of poverty, food security, quality education, gender equality and much more.

Lastly, this report presents the key findings and recommendations to provide key insights for decision-makers interested in supporting the future implementation of SWM in their own countries and regions. It is my ardent hope that SWM will advance our endeavours to achieve the SDGs. I am indeed grateful for this publication on SWM case studies and confidently expect that through our on-going joint efforts monumental achievements will be made in the not-so-distant future.

Dr. Haksoo Lee
CEO
Korea Water Resources Corporation (K-water)
15 October 2018

Foreword from IWRA

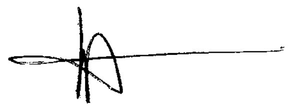
Water challenges are increasingly impacting every region around the world, with both developed and developing regions facing the effects of a changing climate, urbanisation, as well as aging and absent infrastructure. Thankfully, at the same time we are seeing a rapid increase in innovative, smart solutions continuing to provide a way forward. As we work together to resolve these water challenges, governments, water utilities and industry have the opportunity to advance how they manage water, and to resolve many of the issues we face today through the use of smart, integrated solutions.

The Government of the Republic of Korea and K-water have championed Smart Water Management over the past decades by supporting and developing innovative solutions for current water challenges faced domestically and around the world. During a special session at the IWRA XVI World Water Congress on Smart Water Management (SWM), IWRA and K-water decided to work together to better understand and promote the benefits of SWM solutions, as well as to understand the challenges faced by those looking to implement SWM. As water plays a pivotal role in achieving the Sustainable Development Goals, it was also of great interest to understand the role SWM can play in reaching these goals, not only SDG 6 for water and sanitation for all but most of the others as well.

On behalf of IWRA, our extended network of water professionals and the broader water community, I wish to extend my gratitude to the Republic of Korea and K-water for their dedication to SWM and for the remarkable collaboration that has been established to share these lessons with the world. This report reflects that excellent collaboration and I look forward to further collaborations and knowledge sharing with K-water in the future.

Finally, it is my hope that this report encourages water utilities, industries and water users around the world to move forward in implementing SWM solutions, in order to achieve great success in resolving the current water challenges we face. SWM provides us with a great potential to reach not only a better way forward for water management, but also a new set of solutions to help us achieve sustainable, integrated and smart water management and help to attain the global SDGs together.

Patrick Lavarde
President
International Water Resources Association (IWRA)
15 October 2018



Executive Summary

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I. Introduction

This report is the major output of the Smart Water Management (SWM) project, a joint effort led by K-water (the Korea Water Resources Corporation) and the International Water Resources Association (IWRA), with contributions from over 40 organisations from around the world. The report showcases ten exemplary SWM projects based in both developed and emerging regions, along with 9 upcoming and potential SWM projects, which address the use of innovative smart technologies and solutions to address a wide range of water challenges across a number of scales (from household to transboundary). Table 1 below shows the SWM projects and their smart solutions in the order they appear in the report. The map below shows the global distribution of these projects and the text boxes included within the report.

Table 1. Case study location, project name and SWM solutions

Case study location	Project Name	SWM Solution
South Korea (national)	K-HIT	Flood and drought integrated network
Paju, South Korea	Paju Smart City	Water quality real-time monitoring for drinking water
Seosan, South Korea	Seosan Smart City	Smart sensors and real-time display increased leak detection and community satisfaction
Paris, France	SIAAP	Integrated network for improved real-time water quality in sanitation
Guantao County, China	Handan Pilot	Groundwater monitoring and modelling to reduce over abstraction
Mexico City, Mexico	PUMAGUA, UNAM	Smart sensors for drinking and wastewater quality and leak detection
Thailand, Tanzania, Kenya, Uganda, Rwanda, Burundi, Benin, Burkina Faso, Cote d'Ivoire, Ghana, Mali and Togo	Flood and Drought Monitoring Tools (FDMT)	Flood and drought monitoring and planning using satellite data
Zimbabwe, Mozambique, Tanzania	Small-scale agriculture productivity and efficient irrigation in Southern Africa	Efficient irrigation using real-time soil monitors and an Agricultural Innovation Platform (AIP)
Spain, The Netherlands, United Kingdom and France (SW4EU)	Smart Water for Europe (SW4EU)	Four demonstration sites addressing leak detection, water quality, community satisfaction and energy optimization using smart sensors and DMAs
Toronto, Canada	Stormwater SmartGrid	Real-time rainwater collection and monitoring for household stormwater management

The following section provides an overview of the ten SWM projects selected by K-water and IWRA for development into case studies as part of this report. From the case studies received, the ten identified for inclusion were selected to present a diverse range of scales, geographic locations in both developed and developing regions, water challenges faced, and technology solutions implemented. The report also includes 9 upcoming 'project highlights' looking to implement SWM or in the beginning of their implementation. These are presented as text boxes in the relevant sections of the report.

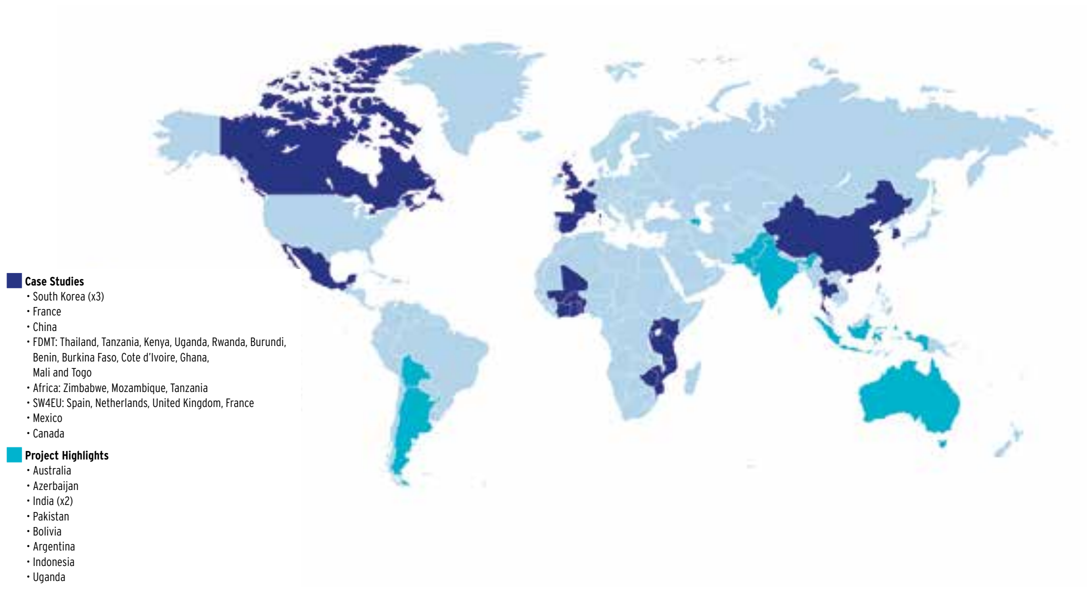

Figure 1: Map showing location of SWM Project case studies and text boxes

The purpose of the SWM report is to:

1. Demonstrate the potential for SWM implementation in a range of contexts, geographic locations, scales, and water challenges in both developing and developed countries.
2. Provide cross-case analysis of the case studies to illustrate the various enablers, barriers and lessons learned in each project during SWM implementation and operation.
3. Provide policy recommendations based on the findings of the analysis to support future SWM implementation.
4. Demonstrate the potential for SWM to assist in reaching the Sustainable Development Goals (SDGs).

SWM has become an area of increasing interest over the past decade as governments, industries and utilities move towards real-time data collection and use to optimise their operations and knowledge. K-water has championed the development of SWM during this time, developing various tools and technologies to address a range of water challenges. Within this report K-water will share their projects and the lessons learned of SWM over the past decade, to provide insight into the solutions available and to present the challenges that are still to be overcome. To present a broader view of the possibilities of SWM, case studies from around the world will also be presented to show how SWM technology has been implemented, at various scales and across various contexts, and the successes, and at times challenges, that these projects have faced.

The case studies within this report demonstrate the role smart technology can play in assisting to resolve numerous water challenges (e.g. water access and quality, efficient irrigation, reduced demand, flood and drought management and planning and inclusive governance and data management) across a diversity of scales. It also shows the potential for SWM projects to aid in the achievement of the Sustainable Development Goals (SDGs) (e.g. by improving livelihoods and economic and gender equity, reducing hunger, broadening access to knowledge and education, enhancing health and wellbeing, adapting to climate change and improving safety).

The full edition of this report on SWM includes policy recommendations aimed at stakeholders looking to adopt SWM policies at the local, national and regional level, as well as pointing to next steps to support the continued successful implementation of SWM across the world.

II. What is Smart Water Management?

Box 1. Definition of Smart Water Management

Smart Water Management (SWM) is the use of Information and Communication Technology (ICT) to provide real-time, automated data for use in resolving water challenges through IWRM.

SWM can be used for planning and operational purposes, from daily use to organisational and policy planning at a range of scales, across contexts and regions.

SWM enables governments, industries and utilities from around the world integrate smart principles (using ICT) into their urban, regional and national strategies. The potential application of smart systems in water management is wide, and includes solutions for water quality, water quantity, efficient irrigation, leak detection, pressure and flow, ecosystems, floods, droughts and much more.

By applying SWM infrastructure such as sensors, monitors, GIS, satellite mapping and other data sharing tools to water management, real-time solutions can be implemented and broader networks can work together to reduce current water management challenges.

SWM is a response to the need for shared information, collaborative practices and automated responses across the field of integrated water resource management (IWRM), in order to increase security and efficiency while decreasing risk and uncertainty. A key assertion of SWM is that by introducing real-time data and automation, services will become more efficient, water management will become more reliable, while decision-making will become more inclusive and knowledge-sharing and collaboration will improve.

The Republic of Korea has championed SWM since 2008 in an effort to achieve smarter technologies and more efficient and reliable water resource management. Since then Korea has developed world class projects in SWM which they will share within this report to demonstrate the potential of SWM and to support other countries interested in investing in SWM in the future.

III. International cooperation

Part of the Republic of Korea's policy on SWM is aimed at becoming a leader and role model for smart technologies in water management, in particular so as to impart its experience and expertise to developing countries through international cooperation.

As a country that has experienced rapid urbanization and economic growth in the past 50 years, transitioning from a developing to a developed economy, the Republic of Korea understands better than most both the challenges and needs faced by developing countries and the potential for improvements and lessons learned by developed countries. The Republic of Korea can therefore act as a messenger between the two, sharing the possibilities of smart technologies to both developed and developing countries interested in investing in SWM.

In order to meet the complex water challenges currently facing developing countries and to mitigate and adapt to an ever-changing climate, technological advances will need to be introduced. For some developing countries limited access to electricity or wireless internet connections, or limited basic water infrastructure, can result in challenging barriers to the successful implementation of SWM. Without basic infrastructure and resources, smart technology may seem limited in its potential. Nonetheless as shown within this report, not all smart tools required extensive physical infrastructure to succeed, and many challenges can be resolved. To support developing countries to participate in the emerging field of SWM, developed countries can provide access to smart tools and technologies, but to ensure the sustainability of these projects in the long-term, it is critical that capacity building and knowledge sharing be at the core of SWM development.

To demonstrate the types of projects not yet using smart technology that could greatly benefit from SWM implementation, this report also includes short textbox case studies on projects from around the world either in the initial stages of SWM implementation, or looking to introduce SWM once solutions are found to the barriers currently in place. It is intended that by sharing these stories and the challenges they face in adopting SWM, solutions can be found to enable their future implementation.

As water challenges vary greatly around the world, from water access concerns in dry climates to flooding in temperate and tropical climates, it was considered important to showcase SWM projects that cover a wide range of water challenges across both cities and regional areas. SWM projects located in cities face challenges such as improved water and sanitation quality, stormwater management, leak management, community engagement and decision-making. In regional and rural areas the projects focused more on water access, water quality and efficient irrigation.

It was also considered important to present a broad geographical range of projects as technologies are developed at varying speeds and in different ways in every country and region, based on knowledge, capacity, funding, and need. While some countries are already in the process of including smart technologies as a core element to their IWRM approaches, others are yet to begin this process. By sharing the lessons learned and solutions to challenges faced from the countries and regions where SWM has been successfully implemented, the aim is that countries interested in SWM will be able to better overcome or deal with the challenges faced by the early adopters of SWM presented within this report.

IV. Core elements of Smart Water Management

The analysis showed numerous benefits from the implementation of SWM as shown in Box 2. Across the 10 case studies, certain factors for success appeared consistently as critical for successful SWM implementation, across scales, geographic locations, levels of development and the water challenges being addressed. These factors for success are detailed in Box 3.

Box 2. Benefits of Smart Water Management Implementation

Social benefits

- **Access to clean water and sanitation** through water treatment and monitoring
- **Health improvements** through increased access to clean, safe water
- **Improved livelihoods** through job creation, greater opportunity for further education, higher productivity and other opportunities
- **Increased training and capacity building** for the local community and staff
- **Increased sharing of solutions** to support sustainable development
- **Increased decision-making opportunities** through increased engagement and knowledge-sharing
- **Greater collaboration with community** through engaging with local stakeholders at the beginning of the project
- **Greater security** by improving water security and increased resilience to climate change
- **Increased trust** in water suppliers and the safety of water sources
- **Improved access to data and information** through real-time data sharing with all water users
- **Increased gender equality** through increased opportunities for capacity building and further education
- **Reduced conflict over water access** leading to increased trust and willingness to engage in collective action

Economic benefits

- **Increased efficiency** in irrigation systems and wastewater treatment systems
- **Reduced waste** by the reduction of water loss through leakages
- **Job and opportunity growth** through job creation through SWM project research, design, development and implementation
- **Improved capacity** in water systems improving their capacity to manage flows and reduce damage during storms/floods
- **Reduction in future infrastructure costs** by integrating smart technology tools to improve capacity/efficiency, resulting in less need for additional infrastructure
- **Mobilisation of funds** from public and private sources, as well as international funding sources

Environmental benefits

- **Improved water quality** through reduced pollution and contamination in waterways
- **Improved ecosystem health and protection** through improved water quality and quantity

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- **Reduction in groundwater depletion** through reduced over abstraction
- **Reduced land degradation** through flood and drought management and reduced nutrient loss in the soil
- **Reductions in CO² emissions** through energy optimisation and reduced energy consumption
- **Reduced water consumption** through leak detection and reduced demand and increased reuse

Governance benefits

- **Improved management and knowledge**, as measurement is critical for effective management
- **Improved accuracy of data**, as real-time data should also be SMART (specific, measurable, actionable, relevant and time-bound) data
- **Increased community-led decision-making opportunities** as water users can make decisions based on real-time water use and information
- **Improved transparency** as water users have access to water use and quality in real-time

Technology benefits

- **The opportunity to test and develop** new and innovative tools for water management
- **Innovative technologies created** with the potential for commercialization
- **Identification of the remaining gaps** in technology adoption (e.g. standardisation of software and tools to make it easier to adopt the 'right' mix of tools for each situation
- **Showing the potential for SWM tools** to deliver successful outcomes and in turn lead to significant social, environmental, governance and financial impacts

Box 3. Factors for success

Cross-cutting factors

- Political commitment from government at all levels
- Support from national government policy, legislation, and regulation
- Use of two-pronged approach (i.e. combining the use of SWM tools with engagement, governance and/or a strong business model) to support the implementation and increase the adoption for, and positive outcomes from, SWM technologies.
- Strong stakeholder engagement from the beginning of the project across and within sectors, (especially) including local agencies and communities, to ensure active community participation and decision-making.
- A multidisciplinary approach (both across sectors and within sectors) to ensure all factors can be taken into account (e.g. environmental, technical, scientific, policy, regulation, financial, maintenance, etc.).

Social factors

- Active stakeholder engagement from the beginning of the project
- Local stakeholders to be involved in decision-making and implementation
- Improved livelihoods from job creation and increased opportunities such as time for further education and skill development
- Increased trust in the community towards water suppliers and water resources
- Education, training and capacity building for local communities

Economic factors

- Long-term investment to enable on-going research, development, testing and implementation, to support taking SWM solutions to market
- External financial support to assist in the implementation of projects in the short-term/ financial support from both public and private investors
- Consideration of the non-financial benefits (e.g. environmental, social, governance), which are often apparent in the short-term, alongside the financial returns, which are medium- to long-term
- Strong business cases to support replication and scaling
- Demand management and improved efficiency as a means to water and energy savings

Environmental factors

- Regulations, economic instruments and information to encourage behavioural changes to improve water quality, efficient water use, natural resource protection
- National plans to improve/resolve water challenges
- Commitments from international funding bodies to meet and address the Sustainable Development Goals, including water
- Commitment from leading organisations and stakeholders to address these environmental challenges

Technical factors

- Allowing adequate time to design, develop, test and adjust technology for greater/more accurate results
- Undertaking a baseline assessment of the challenges and what needs to be addressed to ensure that the right mix of technology and non-technological solutions are implemented.
- Collaborating with all sectors to ensure adequate and accurate data (e.g. electricity data) are shared to support decision-making
- Integrating smart tools and systems across networks to enable collaborative decision making
- Integrating smart tools with traditional infrastructure
- Willingness of water utilities and governments to test the possibilities of smart technologies

V. Replication and scaling

Each of the projects report in these case studies has the potential to be scaled up and out, scaled down (for small-scale projects) and replicated in both developed and (under the right circumstances) developing regions to assist with resolving water challenges . As every project presented in these case studies is specific to the area and country where it was implemented, replication mandates an understanding of the different contexts faced by the initial project and the adopting region. An assessment on whether the conditions are similar enough to attempt the same approach, and what additional support is required prior to planning the replication is also recommended. However, with the right financial, policy and technology support, knowledge sharing and collaborative decision-making, each of these projects has the potential to be adopted in both developed and developing regions with long-term success.

To support other areas interested in adopting SWM, these case studies provide directions and identify factors of success; and equally important they identify the barriers faced during implementation. In is the hope that future projects can learn from these experiences so that they can easier and more quickly overcome these challenges.

The pilot projects (e.g. Paju, Seosan, Mexico, IWA, Africa, China, Canada), show how SWM can be adopted in stages, from minor adjustments to improve the efficiency of a system, to introducing a whole new suite of tools to change the way a challenge is addressed. While smaller in scale when compared with some of the larger citywide projects, these case studies show the significant benefits that can be achieved through adopting a SWM approach. The larger projects (e.g. K-HIT, SIAAP and SW4E), provide ambitious examples of fully integrated systems, showing what can be achieved when policy, financial and technology resources and strong collaboration are in place.

Based on these findings, the following section provides a series of policy recommendations in relation to social, economic, environmental, technological and governance strategies aimed at policy makers from all levels of government interested in supporting the future successful implementation of SWM in both developed and developing regions. It also provides a classification of the types of SWM implementation that occur and the levels of support required for each type to increase the chances of successful implementation.

VI. Policy recommendations

Table 2: Policy recommendations for Smart Water Management implementation

Strategies	Policy direction
SWM for an improved quality of life (Society)	**1.** Facilitate adoption of SWM tools, especially in developing countries, to support access to basic services, and to support equality for poverty reduction, public health and quality of life. Include capacity development, technology sharing, collaborative business models and community governance and decision-making opportunities.
	2. Build trust and community engagement using SWM tools in areas where the community feel unsafe using the local water sources.
	3. Empower people in developing countries with smart tools to reduce the time spent on water management and increase farm income and time available for other activities (e.g. further schooling, and additional work opportunities).
Investment in SWM for improved resilience and sustainable development (Economy)	**4.** Strengthen collaboration across and within sectors to provide opportunities for networks to share information and data to assist with effective and efficient water management.
	5.Value non-financial benefits (e.g. environmental, social, governance and technical benefits) as equally important as financial benefits for SWM implementation, as they contribute to building resilience to the effects of climate change and increasing populations.
	6. Support long-term investments for SWM implementation to enable adequate research, development and testing.
SWM for protecting and conserving water resources and ecosystems (Environment)	**7.** Introduce policies, regulations and incentives to drive environmental and ecosystem protection through use of SWM.
	8. Encourage SWM solutions to increase water quality, manage demand and use, water reuse, reducing groundwater depletion and increase energy efficiency, etc.
	9. Introduce SWM solutions for climate adaptation plans for flood and drought planning and management and major storm events.
Support evolving smart technology development and adoption (Technology)	**10.** Develop standards to ensure all SWM technologies are compatible (can communicate) with each other to enable tools to be purchased across various suppliers to enable those implementing SWM to create the right set of tools for each context.
	11. Support on-going research, testing and development of SWM tools to advance them to a point where they are robust and require minimum maintenance and are ready to be commercialized (Government policies that support taking SWM tools from R&D to market).
	12. Support technology to assist in regions without built infrastructure or the adequate resources (e.g. electricity), as currently SWM infrastructure is (almost always) reliant on built infrastructure
Building capacity and networks for increased resilience and collaboration (Governance)	**13.** Empower people, especially those in developing countries, by providing them with SWM tools, data and capacity development and education to enhance/support local decision-making.
	14. Strengthen the capacity to adapt to climate change by adopting SWM planning and operational technology.
	15. Plan for water disasters in advance by creating proactive policies instead of reactive policies.

Through this analysis several SWM implementation 'types' became evident. As the context of each SWM project is different, understanding the various types of SWM implementation and the tools and solutions for each type is critical for successful implementation. A description of these types is provided in Box 4 below.

Box 4. Smart Water Management Implementation Types

Implementing SWM technology by itself will not always resolve the water challenges faced by a project. In some cases, a two-pronged approach is necessary to address the complex nature of each challenge. The second element of the two-pronged approach can include community engagement, governance schemes or business models, and is equally as important to the success of many of the projects as the SWM tools themselves.

Based on the case studies presented within this report we have categorised SWM technologies into three different types depending on who is using/adopting the technology. Each type requires a different approach to ensure the technology achieves its potential benefits.

Type 1 – Institutional users

Type 1 addresses technologies aimed at major institutional users such as water suppliers, water managers, mines, water treatment plants, etc. (e.g. SIAAP, K-HIT, China). The implementation of these technologies is mostly straightforward as industries and utilities can be encouraged to adopt SWM through incentives (improving efficiency, environmental benefits) or drivers (meeting regulations or targets) introduced by governments or the agencies themselves. Regulations and policies that encourage these institutions to develop and implement SWM technologies are relatively easy to introduce (depending on the government), and the institutes will more easily fund the necessary research (often with government support) to develop and successfully implement SWM.

Type 2 – Individual users

The second type is the technologies aimed at a large number of individual users such as households and farmers (e.g. Africa and Canada). These are far more complicated to implement, as they require a very large number of individuals to change what they are doing, and they do not always respond in the same way to economic incentives. Often the main benefits are to the society at large, rather than the individual. The savings from introducing smart technologies in homes might be small compared to the cost and inconvenience of adopting it, however the total impact might be significant and therefore the societal benefit high. In this second type, a two-pronged approach is more critical in order to achieve the potential societal benefit.

Type 3 – Institutional and individual users combined

The third type involves a combination of both the institutional and individual user. This is seen when an institution develops and implements the SWM technology but the success of the technology partly relies on the individual user (e.g. Mexico and IWA). This approach requires some engagement, but is less dependent on a second-prong than Type 2, due to the implementation being conducted by the institution.

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VII. Links to the Sustainable Development Goals (SDGs)

As part of developing a stronger understanding of how SWM can assist with moving towards the global aim of sustainable development, it was important to assess how each of the projects presented within this report can assist with achieving the Sustainable Development Goals (SDGs). Beyond the expected links to SDG 6 (Clean Water and Sanitation) and SDG 11 (Sustainable Cities and Communities), the analysis of these SWM projects has shown the breadth of targets that can be assisted through the use of SWM, in areas of poverty, hunger, gender equality, reducing inequalities and climate action.

The following table highlights the targets that the ten SWM projects within this report contribute to. With the continued success of SWM implementation around the world, it is expected that SWM will continue to provide an even greater contribution to reaching the SDGs in the future.

Table 3: SWM links to the Sustainable Development Goals (SDGs)

SDG	Links to Smart Water Management
1. No poverty 1 NO POVERTY	**Target 1.4 – Supporting equal rights to economic resources, natural resources and new technology** through introducing smart soil moisture monitors to assist farmers in increasing irrigation efficiency leading to increased crop productivity, income and improved land management (Africa) **Target 1.5 – Building resilience to climate related extreme events** through adopting flood and drought planning using satellite data across transboundary basins (FDMT) and smart integrated water resource management for national river basins (K-HIT) **Target 1B – Supporting policy frameworks based on pro-poor and gender sensitive development** through supporting community capacity and decision-making opportunities for women in farming (Africa)
2. Zero hunger 2 ZERO HUNGER	**Target 2.3 – Increasing agricultural productivity and incomes of small-scale food producers** through increased irrigation efficiency and reduced nutrient loss using smart soil monitors and Agricultural Innovation Platforms (Africa) **Target 2.4 – Moving towards sustainable food production and resilient practices** through increasing farmers' awareness of sustainable water management and irrigation (China and Africa) and reduced fertilizer use (Africa) and water reuse for aquaculture (see Uganda text box in report)
3. Good health and well-being 3 GOOD HEALTH AND WELL-BEING	**Target 3.9 – Reducing the number of deaths and illness from water pollution and contamination** through improving water quality for drinking purposes (Mexico, France, Paju)
4. Quality education 4 QUALITY EDUCATION	**Target 4.4 – Increasing the number of youth and adults who have relevant skills including technical and vocational skills for employment, decent jobs and entrepreneurship** through job creation in the field of SWM technology development and implementation (Seosan), capacity building in design for water professionals (France), and technical capacity building for youth and adults in the use of SWM technology and implementation (Africa and FDMT).

5. Gender equality	**Target 5.5 – Increasing women's participation and equal opportunities for leadership at all levels of decision-making** through increasing awareness and knowledge-sharing using real-time data leading to better decision-making opportunities for women (Africa)
6. Clean water and sanitation	**Target 6.1 – Achieving universal and equitable access to safe and affordable drinking water for all** through increasing awareness and receptivity to drinking tap water through knowledge-sharing using real-time data (Paju, Mexico). **Target 6.2 – Achieving access to adequate and equitable sanitation and hygiene for all** through ensuring efficient treatment of sanitation using real-time monitoring and automated treatment (France and Mexico). **Target 6.3 – Improving water quality by reducing pollution** through monitoring and filtering contaminants using real-time sensors and treatment (Paju, Mexico, France, SW4EU and Canada). **Target 6.4 – Substantially increasing water-use efficiency** through improved irrigation efficiency (Africa), reduced leakages (Paju, Mexico and SW4EU), reduced consumption (Seosan, China, Mexico and SW4EU), capture and reuse of rainwater (Canada) and increased storage capacity (K-HIT). **Target 6.5 – Implement integrated water resources management at all levels** through integrated river basin and dam management (K-HIT), sanitation and water management network integration (France), transboundary flood and drought management and planning using satellite data (FDMT) and Agricultural Innovation Platforms for integrating governance (Africa). **Target 6.6 – Protect and restore water-related ecosystems** through reduced pollutant loads in wastewater through smart monitoring and treatment, restoring ecosystems and fish populations (France), and reduced stormwater pollution reaching waterways through smart cisterns (Canada). **Target 6A – Expand international cooperation and capacity building to support developing countries** through supporting transboundary basin agencies with flood and drought planning and management using satellite data (FDMT) and replicating successful SWM projects in developing countries (e.g. Seosan project replication in Indonesia) **Target 6B – Strengthening the participation of local communities in improving water and sanitation management** through involving local stakeholders from the beginning of the project (Africa, FDMT and Mexico) and learning from community experiences (China).
7. Affordable and clean energy	**Target 7.3 – Doubling the global rate of improvement in energy efficiency** through energy optimization (SW4EU) and increasing water efficiency, thereby reducing energy intensive processes (Paju, Seosan, Mexico, France, SW4EU and Canada).
8. Decent work and economic growth	**Target 8.1 – Sustaining per capita growth in accordance with national circumstances** through increased job opportunities in research and development, project management and construction (Paju Smart City). **Target 8.2 – Achieving higher levels of economic productivity through diversification, technological upgrading and innovation** through supporting research and development in SWM technology (France and Paju Smart City). **Target 8.5 – Achieving full and productive employment and decent work for all women and men, including for young people and persons with disabilities** through increasing capacity building and reducing the time required for low skilled tasks (e.g. irrigation), thereby increasing the time available for further education and employment opportunities for women and youth in particular (Africa) **Target 8.6 – Substantially reduce the proportion of youth not in employment, education or training** through capacity building and further education (Africa).

9. Industry, innovation and infrastructure	**Target 9.1 – Developing quality, reliable, resilient infrastructure to support economic development** through integrating SWM technologies to traditional infrastructure to improve accuracy and reliability (K-HIT, France and Mexico) **Target 9.4 – Upgrading infrastructure for resource efficiency** through leak detection and water consumption monitoring (Paju Smart City, Mexico and SW4EU).
10. Reducing inequalities	**Target 10.1 – Providing support and income growth for the bottom 40% of the population** through improving agricultural techniques (e.g. efficient irrigation, higher value crops and improve market integration) to increase crop productivity and income (Africa) **Target 10.2 – Empowering and promoting social, economic and political inclusion for all** through providing data to all water users and enabling local stakeholders to be involved in decision-making (Paju Smart City, Africa and China) **Target 10.3 – Promoting opportunities for women and youth** through increased education opportunities, increased decision-making and increased high skilled employment (Africa).
11. Sustainable cities and communities	**Target 11.4 – Strengthening efforts to protect and safeguard the world's cultural and natural heritage** through reducing the impact of natural disasters such as droughts and floods (K-HIT and FDMT). **Target 11.5 – Significantly reducing the number of deaths and numbers of people affected by disasters, including water-related disasters** through integrated operational water management (K-HIT) and future planning for floods and droughts using satellite data and weather predictions (FDMT). **Target 11A – Supporting positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning** through transboundary planning with local basin authorities using satellite data (FDMT). **Target 11B – Substantially increasing the number of cities and human settlements adopting and implementing integrated policies and plans towards resource efficiency, adaptation to climate change and resilience to disasters** through planning (FDMT), increased resource efficiency (China, SW4EU, Mexico) and local storage of water (Canada).
12. Responsible consumption and production	**Target 12.2 – Achieving the sustainable management and efficient use of natural resources** through efficient water use (China), leak reduction (Paju, Mexico, SW4EU), energy optimization (see SW4EU and China) and reduced reagent consumption (France). **Target 12.8 – Ensuring that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature** through increased community engagement and knowledge dissemination using real-time data and results (Paju, Mexico, SW4EU and China).
13. Climate action	**Target 13.1 – Strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries** through optimizing infrastructure to manage crisis situations (France), reducing pressure on centralised infrastructure in the case of flooding (Canada) and by integrating SWM into adaptive planning and forecasting (FDMT). **Target 13.2 – Integrating climate change measures into national policies, strategies and planning** using data and forecasting to integrate plans for future flood and drought events at a national and transboundary level (FDMT). **Target 13.3 – Improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning** through increasing community awareness of the importance of water and their role in its management (Paju, Mexico, SW4EU) **Target 13B – Promoting mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island states** through increasing awareness using real-time data on water consumption and access and future challenges (Mexico and FDMT).

14. Life below water	**Target 14.1 – Preventing and significantly reducing marine pollution of all kinds, in particular from land-based activities, including nutrient pollution** through reducing non-point source pollution (e.g. fertilizer in Africa; stormwater contaminants in Canada); and treating wastewater before returning it to the waterways (France).
15. Life on land	**Target 15.3 – Combating desertification, restoring degraded land and soil, included land affected by drought and floods** through flood and drought planning tools (FDMT) and integrated operational flood and drought management (K-HIT) **Target 15.5 – Taking urgent and significant action to reduce the degradation of natural habitats, halting the loss of biodiversity** through integrated flood and drought management (K-HIT).
16. Peace, justice and strong institutions	**Target 16.6 – Developing effective, accountable and transparent institutions at all levels** through increasing access to data for all water users (Paju Smart City and Mexico) **Target 16.7 – Ensuring responsive, inclusive, participatory and representative decision-making at all levels** through providing a forum for water users to contribute their ideas and access information and real-time data (Africa, Paju Smart City, Mexico, SW4EU, Canada)
17. Partnerships for the Goals	**Target 17.6 – Enhancing regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing** through collaborations between local and international agencies (FDMT, Africa, China) and capacity building for local workers (Paju Smart City, Africa and FDMT). **Target 17.7- Promoting the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms** through enhancing knowledge-sharing through partnerships (K-HIT, Mexico, France and China).

VIII. Conclusions and next steps

The SWM projects included within this report have shown the considerable potential for SWM to assist with numerous water challenges, across various scales, geographic locations and developing and developed regions while also creating social, economic, environmental and governance benefits. These projects have also demonstrated the enormous potential for SWM to assist with achieving the SDGs, across a number of goals and targets.

While it is important to recognise that each project is set within its own context, the overarching lessons that have emerged as part of this report highlight the similarities between case studies to show how SWM can be successfully implemented around the world, and what challenges there are still to face.

As SWM is still an emerging field these projects demonstrate the untapped potential of what can be achieved using innovative SWM technology and solutions. As the field progresses and technologies evolve, the potential for SWM adoption across all contexts will continue to grow, leading to increased opportunities for both developed and developing regions, and innovative solutions for our current water challenges.

In order to continue learning from these case studies, it is important to follow them on their journey to see how challenges are addressed as the technology evolves, and what impact introducing SWM continues to have in their region. This is important when trying to scale up or down, or transfer existing SWM solutions to new locations, baring in mind the adaption necessary to the local context and challenges.

It will also be interesting to see how SWM technology and solutions can move from the research and development stage to the testing stage and finally to market. In other words, how SWM can become self-sustaining without reliance on initial government support in the early phases.

At this stage, many of these projects have shown the potential for SWM technology to successfully resolve water challenges. It is important to now build and develop the business cases for adopting, scaling and transferring these solutions. This is why the monitoring and measuring SWM benefits must continue. The next phase of research would be aimed at capital investors to help them see the benefits and potential of SWM, leading to increased possibilities for future investment.

Now that a wider number of smart tools are on the market, integrated smart networks will start to emerge, and with them increasing opportunities for sustainable cities and regions to integrate their various smart infrastructure, such as smart energy grids. While retrofitting existing cities is possible, the opportunity offered by urbanization and the creation of new cities and suburbs means that these new urban environments offer the greatest potential for smart technology integration.

This report demonstrates how far SWM has already come in a short time and the considerable benefits it can provide in both developed and developing regions, especially when coupled with strong policy support and community engagement. It also explores some of the constraints and barriers encountered to date. In the end, however, it is certain that SWM has nearly unlimited potential to contribute to the realization of the goals of integrated water resource management and sustainable development through smarter management of water.

CHAPTER 1. Introduction

Contents

1. SWM Introduction

1.1 What is Smart Water Management?

Smart Water Management (SWM) is the use of integrated, real-time Information and Communication Technology (ICT) solutions, such as sensors, monitors, geographic information system (GIS) and satellite mapping and other data sharing tools in water management. Over the past decade governments, industries and utilities have moved towards real-time-data collection and use to optimise their operations and knowledge. SWM can provide with them integrated water management solutions, at all scales and across various contexts to resolve current water challenges in both developed and developing countries.

The potential application of smart systems in water management is wide and includes solutions for water quality and quantity, efficient irrigation, pressure and flow management, ecosystems protection, flood and drought management, stormwater and sewage management, future planning and much more. SWM can also address water infrastructure by integrating it into broader networks in order to share data to reduce water and energy consumption, to provide targeted irrigation for agriculture, and to be more efficient in wastewater treatments. In developing countries, it is specifically relevant for taking into consideration urban and regional data and water consumption so that governments can improve public health through the possibility of checking water quality, water resource availability and water distribution in all neighbourhoods of developing cities, towns and rural communities – especially where informal dwellers are settling.

In this report, SWM solutions are presented from a diversity of projects, across both developed and developing regions, from the micro scale (e.g. household) through to the transboundary scale. These case studies demonstrate the potential for SWM solutions to assist in the advancement and integration of traditional water infrastructure in urban settings, with providing simple to use irrigation solutions in rural agricultural settings, along with providing support for improved planning, management and operation of water management for water suppliers and users.

SWM is a high-tech strategy to deal with economic, social and environmental urban and regional issues as a way to better use our water resources while protecting the most vulnerable places and creating innovative types of economy and management. At a time when data is part of people's everyday life, it is a natural step for decision makers to include SWM into their policy strategies in order to provide a more adapted response to urban and regional organization. Taking into consideration current issues communities face, and global commitments under the United Nation's Sustainable Development Goals (SDGs), SWM can provide support to any contemporary integrated water resource management strategy. As such, policy makers around the world are increasingly integrating smart principles into their urban, rural, regional and national strategies, which will in time provide them with a better understanding of the dynamics of cities and regions, leading to more resilient, sustainable and safer living environments.

While interest in SWM has increased rapidly over the past decade, the adoption of SWM into policy has been slower than for other sectors such as energy and transport. To amend this, decision makers must be provided with the research on the benefits of SWM, and how policy can support successful SWM implementation. It is therefore essential that reports such as this one provide these insights for policy makers, while also sharing the knowledge with the broader water community interested in implementing SWM solutions.

The sharing of SWM successes (and challenges) also support water industries, utilities and other users and to better understand the enabling factors and barriers to successful SWM implementation, leading to a greater uptake of successful SWM projects in the future. As SWM has continued to grow over the past decade we are now seeing a variety of SWM solutions, across all scales for a wide range of water challenges and contexts. To assist with the continued growth of SWM, this report aims to share these insights from around the world, to support the continued implementation of SWM and to promote the use of innovation and smart solutions for future water management.

1.2 What is the potential of Smart Water Management?

Water challenges affect everyone in the world, with both developing and developed regions facing increasing challenges in relation to water security, access and management. This is anticipated to increase as climate change results in an increase in frequency and intensity of floods and droughts that must be planned for and managed. In developing regions water quality and security reduce the liveability of certain areas for vast populations, while leak detection, sewage and stormwater management affect urban areas in developed regions.

At the same time smart technologies are developing rapidly around the world providing an evolving suite of innovative and integrated solutions. While sensors and monitors have become standard for energy monitoring, the idea of using smart technology in water management is only a recent one. As technology is developing rapidly, so are the opportunities for smart solutions to an array of water challenges, from the household scale (e.g. smart monitoring of water use or rainwater collection), to the site and city scale (e.g. leak detection and water quality monitoring) through to national and transboundary scales (e.g. flood and drought monitoring and management). SWM solutions have the potential to allow for major advances in water solutions, through integration of solutions into broader networks. SWM solutions may also add value to current water projects, reducing the need for new infrastructure, and may allow us to access and act on a situation in real-time, increasing knowledge and security for our water systems. SWM also has the potential to improve future planning through increased localised data and climate scenarios based on real-time data.

Other sectors could also be addressed by SWM including urban resilience, agricultural efficiency and coastal water management. Indeed, many environmental risks are now linked to either too little or too much water. Droughts, storms and floods are more intense and more frequent and some regions are more exposed to risks related to water. Overall, SWM should allow for the better identification of those disasters and a more efficient response to it, as SWM has the potential to integrate several solutions to provide a holistic approach. The possibility to generate water stocks in case of drought would allow countries to reduce the consequences of such hazards, allowing essential activities such as irrigation for agriculture to occur to ensure adequate food supply. Conversely, the ability to reuse and better manage floodwater may provide wetter regions a complementary and sustainable source of energy.

In the face of climate change, a more sustainable use of water is essential. The risk of water scarcity and poor water resources, as well as water pollution due to high industrial activities is real. SWM focuses on an integrated management system, allowing all water departments to communicate and share their data. Adapting existing networks and infrastructure is a way to shift over to a more modern, sustainable and smart economy. Indeed, SWM has the potential to put water into a data cycle, going from freshwater resources, to treatment of wastewater and management of irrigation and floodwater.

As water plays such a crucial role in the future sustainable development of the world, it is no surprise that 11 of the 17 Sustainable Development Goals directly relate to water. SWM can offer innovative water management solutions to assist with addressing these goals, and potentially to assisting in other areas of sustainable development including community building and capacity development, efficient energy use and improved livelihoods for people in developing regions.

1.3 Purpose of the report

The purpose of this report is to test whether these assumptions are accurate. Through this research we aim to better understand why people are investing in SWM, what their expectations are for SWM, and whether SWM can provide the solutions as expected. To do this, this report brings together the knowledge and insights of water experts and practitioners from around the world who have led the way in implementing SWM solutions to resolve current water challenges. The case studies and projects presented within this report show the successes achieved (and challenges faced) in these SWM projects, to demonstrate the potential for smart, integrated solutions to resolve these water challenges and to support the continued successful implementation of SWM projects in the future.

The report contains 10 case studies from around the world, from across all scales to demonstrate the variety of SWM solutions available and the impact these solutions can have in various contexts. Beyond the traditional technical challenges faced in water management, this report demonstrates how SWM can also assist with challenges such as community involvement and engagement, building community trust and increasing opportunities and capacity. In doing so, this report shows the potential for SWM to assist decision makers, water utilities and industries to achieve not only their economic and technological benefits, but also social, environmental and governance benefits.

Through analysing these case studies, the report provides insights into the drivers for SWM adoption, the enabling factors supporting successful SWM implementation and also the barriers that have slowed or prevented SWM projects from succeeding. By sharing these findings, it is hoped that those interested in adopting SWM will reduce, and possibly avoid many of the challenges faced by these projects. For those interested in supporting SWM (e.g. governments and the private sector), it is hoped that the report will provide an insight into how they can best contribute to supporting the successful implementation of SWM in the future.

In addition to supporting future successful SWM adoption, one of the key focuses of this report is to identify what support SWM can offer in achieving the Sustainable Development Goals (SDGs). With water playing such a key role in achieving the SDG targets, it is with great interest that we identify the ways in which SWM can assist with this process, as we work together over the next decade to move towards achieving the SDGs.

In summary, this report aims to:

1. Demonstrate the potential for SWM implementation in a range of contexts, geographic locations, scales, and water challenges in both developing and developed countries.
2. Provide cross-case analysis of the case studies to illustrate the various enablers, barriers and lessons learned in each project during SWM implementation and operation.
3. Provide policy recommendations based on the findings of the analysis to support future SWM implementation.
4. Demonstrate the potential for SWM in reaching the Sustainable Development Goals (SDGs).

It is hoped that the insights provided within this report, along with policy recommendations built on those insights, will support the continued implementation of SWM and promote the potential for the use of innovation and smart, integrated solutions for improved water management around the world.

1.4 Who is involved?

The Korea Water Resources Corporation (K-water) is the government agency for comprehensive water resource development in the Republic of Korea, with a large pool of practical engineering expertise regarding water resources. Over the past decade the Korean government and K-water have made a serious commitment to developing and implementing SWM technology solutions. By drawing upon Korea's advanced technology and knowledge, K-Water has been able to become a leader in SWM and an advocate for SWM implementation in both developed and developing countries. Through SWM Korea has been able to address some significant challenges in the Korean water sector, including infrastructure maintenance, drought, the economic and environmental waste of non-revenue water and bottled water use, and community perceptions of potable water quality.

The International Water Resources Association (IWRA) is an international NGO consisting of a broad network of scientific and policy experts in the field of water resources, and focusing on sharing knowledge on all issues related to water with its broad network of water experts and the broader water community.

K-water and the IWRA worked with water experts from around the world, from universities, NGOs, water utilities, the private sector, local farmers and international agencies, from both developed and developing countries, and from a wide range of contexts, to present this report on successful SWM case studies from around the world. In addition, a panel of IWRA experts in the Smart Water Management Task Force was instrumental in the design and analysis of this report.

1.5 Methodology of the report

This Report adapted a multi-framework approach, using multiple-case study design (Yin 2006) to structure the study and a Logic Model framework (see Weiss 1997) as the basis for contextualising each SWM case study.

Logic Models have been at the core of sustainable development evaluation for decades, providing a clear illustration of the steps taken to achieve desired outcomes and impacts in sustainable development programs and projects. Weiss' theory on the use of Logic Models for evaluation and planning spurred the development of numerous variations of the framework, spanning several fields. While Logic Model frameworks vary, the core concepts of a Logic Model (i.e. the inputs, outputs, outcomes, impacts, assumptions and external factors of a project) remain the same. In addition to understanding the core concepts of each project, it was considered valuable to explore the enabling factors and barriers each of these projects faced to gain a better understanding of how SWM projects can best be supported, and what can slow, or stop completely, the successful implementation of SWM projects.

1.5.1 Research Design

The development of the SWM Case Study Report was designed to follow three stages: Phase 1 (Design), Phase 2 (Development) and Phase 3 (Analysis). In Phase 1, a greater understanding of the Smart Water Management concept and current achievements in this area was prioritised. This allowed for the creation of a thematic Case Study Matrix to be developed, ensuring a diversity of SWM case studies were selected for the research and report. During this phase a Case Study framework was also developed outlining the key themes to be addressed by each of the case study authors. Phase 2 focused on the selection and development of the SWM case studies with support provided throughout this phase by IWRA to case study authors. In Phase 3, the final phase, the case studies were brought together and analysed using cross-case analysis. A flowchart outlining each step within the phases is shown in Figure 1 below.

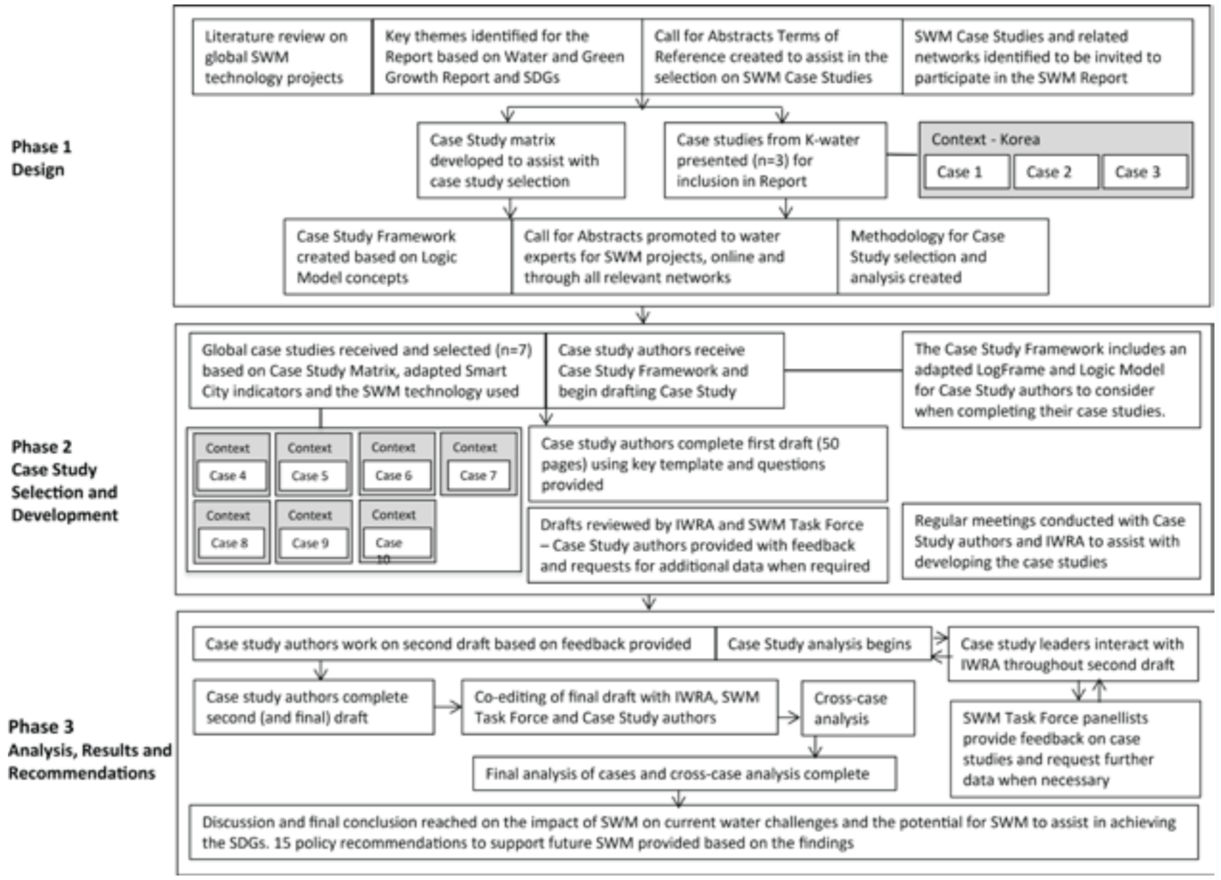

Figure 1. Research design for SWM Case Studies Report

1.5.2 Case study selection

The SWM Case Studies Report analyses 10 SWM projects (three from cities within Korea and seven from selected countries around the world), of varying scale, geographic location and technical SWM solution. Selecting cases from various countries and regions enables to the report to highlight the diversity of SWM technology and uses currently being implemented around the world.

The selection of Case Studies was assisted by K-water, who identified three key projects within Korea with which they are currently involved. The additional seven cases from various regions around the world were selected based on a Call for Abstracts, which was distributed by IWRA and K-water to relevant networks, water experts and promoted online. In addition to this promotion, exemplary case studies were identified during the literature review at the beginning of the project, and were directly approached via email with an invitation to submit an abstract. SWM projects of all scales, geographic locations, technical solutions and water challenges were encouraged to submit an application.

In the Call for Abstracts, a definition of SWM was provided to ensure the projects would align with the definition used for this report. While definitions of SWM vary to some extent, for the purpose of this report the definition of a SWM project was decided as any water project that *'uses* (near) *real-time, automated and integrated information and communication technology (ICT) solutions to address current water challenges'.* It is important to note the *use* of data in SWM, as there are many cases of water management projects worldwide that collect and monitor data (e.g. weather management, water quality monitoring etc.) without using the data for improved sustainable water management. In SWM, it is the use of this data to improve sustainable water management that sets it apart.

To determine the content of the potential case studies, each abstract author was provided with a series of key themes to address regarding their project. These themes included a contextual background of the project (i.e. social, environmental, economic, political and technical factors); details of the project (e.g. inputs, outputs, outcomes and impacts); enabling factors and barriers faced within the development of the project; and any identified links between the project and the SDGs. For this final request, a link to the SDGs was provided for each author to assist with this task.

During the six-week Call for Abstracts period, 32 projects were received. After a thorough selection process, seven projects from around the world were selected to participate in the report as in depth case studies and nine projects selected for inclusion within the report as 'upcoming projects in SWM'. This coupling of both in depth case studies and upcoming projects enabled the projects to show their successful, while also providing a greater insight into the diversity of SWM projects, and interest in including SWM into other projects, currently seen around the world.

To ensure a diverse selection of case studies was selected for the report, a Case Study Matrix was developed to classify each case study by: geographic location, scale and water challenge. Technical SWM solutions (e.g. sensors, GIS and satellite mapping or monitors) used by each case study were also considered to ensure a mixture of solutions within the report. In addition to the Matrix and technical solutions, a set of indicators developed to monitor Smart City solutions (CITYkeys, Horizon 2020 project) was considered during the selection process, and adapted to reflect the broader scope of Smart Water management. These indicators were considered relevant as Smart Water Management stems from the Smart Cities concept. To reflect the broader scope of Smart Water Management, the Smart Cities indicators were adapted to include water challenges faced outside of the urban setting, including agriculture, irrigation, water access and water quality in regional and remote areas (see Box 1 below).

Box 1. Smart City indicators (CITYkeys) adapted to reflect the scope of SWM

People: *health, safety, access to water, education and quality of life*
Planet: *water quality, climate resilience, ecosystem, and disaster management*
Prosperity: *employment, equity, green economy, economic-performance, innovation, attractiveness and competitiveness, water-food-energy nexus*
Governance: *organisation, community involvement and multi-level governance*
Propagation: *scalability and replicability*

Within our report we have adapted the smart city indicators to look at people, planet and prosperity within the context of the triple bottom line (society, economy and the environment), while addressing the governance actions that can support the successful scaling and replication of integrated SWM.

1.5.3 Data collection

Data collected for the SWM Case Studies Report followed a semi-structured approach, with each case study author provided a Case Study Framework to guide them with their writing. The Framework consisted of key themes and questions for the case study authors to reflect on, while also allowing the authors the freedom to provide an individualised narrative for their case study. This supported interesting stories to emerge for each case study, while also enabling comparability across the cases for analysis. Case study authors were also provided with a Logic Model framework to review and complete as part of their case study. While it was anticipated that all authors would consider the themes of the Logic Model while writing their case studies, it was not expected that case study authors would complete a detailed Logic Model framework, as most of these projects were not based on the Logic Model methodology and therefore to retroactively request the authors to shape their projects into this framework is both challenging and often unhelpful. Instead, the authors were asked to consider the themes within the Logic Model methodology while writing their case studies, and to reflect on the inputs, outputs, outcomes and impacts across all of the factors mentioned (i.e. social, economic, environmental, governance and technological).

During Phase 1 of the case study development process, case study authors were encouraged to work with IWRA to fully develop their case studies. To achieve this, case study leaders discussed their progress with IWRA regularly to reflect on ideas that had emerged during the writing stage. After a three-month writing period, a full draft was provided to IWRA and the SWM Task Force to review, and returned within a month with feedback and questions to ensure the case study provided the data required for strong analysis and represented the full story. Case study leaders were then provided with a final three months to complete their case studies (Phase 2) prior to the final analysis stage (Phase 3).

As in all case study research, the context surrounding each SWM case study provides great insight into the project itself, and the related successes and challenges faced within the project. As such, key questions on the external factors impacting each study were addressed. These factors include, but are not limited to: the GDP (Gross Domestic Product) of the region, population and growth rate, research and development (R&D) access, cultural, political and environmental climate and the priorities in the region. These factors were considered to paint a picture of the context of the project, however it is reasonable to assume that not all of the factors that impact each project are represented in these background context summaries.

1.5.4 Analytical framework

This Report uses a multi-framework approach for the contextualisation and analysis of each case study. The core analytical framework for the study applies Weiss' Logic Model theory (1997), and adapts it to include links to the Sustainable Development Goals. In addition to the Logic Model, a LogFrame was provided to the case study authors and adapted to include a ranking system to allow for key (social, environmental, economic, political, governance and technological) factors to be assessed in terms of perceived importance. Since its introduction in the early 1970's, the Logic Model framework has been used to evaluate program and project success in a number of areas including sustainable development. This framework allows for clear analysis of the value provided by projects, programs, events and institutions against key goals set. Knowlton and Phillips (2008) state that the Logic Model framework is beneficial in evaluation as it: 1) documents and emphases explicit outcomes, 2) clarifies knowledge about what works and why, 3) identifies important variables and 4) offers a strategic means to critically review and improve thinking. The Logic Model is useful in project evaluation as it illustrates a sequence of cause-and-effect relationships, between inputs, outputs, outcomes and impacts. While visually Logic Model frameworks vary depending on the project's needs, all Logic Models contain the same core elements. These elements include: the situation the project plans to address (problem statement), the resources you have available to address it (inputs), the activities you plan to conduct with these resources (outputs), the results you aim to achieve within the project (outcomes) and the longer-term results you hope the project will contribute to in the broader context (impacts). In addition to these elements, Logic Models also address the external factors that may impact the project, and the assumptions that may have been made about the project and its participants during the planning and implementation stages.

The Logic Model framework was selected for this project for three reasons: 1) it allowed each case study to unpack their projects into stages, identifying the key factors that impacted their projects; 2) it enabled a clear cross analysis of each case across the factors, highlighting which stages of the implementation process were critical in SWM and which were flexible; and 3) it provided the ability to link the projects impacts to the SDGs.

To provide an overall analysis of the case studies, the following key questions were assessed across each case study:

1. What were the drivers and enabling factors, which lead to this projects success?
2. What challenges or barriers did this project face that either delayed, or halted the progress or success of this project?
3. What were the lessons learned by the project team during this project?
4. How can this project assist with achieving the Sustainable Development Goals?

For each case study these questions were explored in detail, and as themes emerged key findings were established across these four questions to show whether certain themes were consistent between cases, geographic locations, scales, or solutions. Cross analysing the case studies in this manner is considered to be a reliable approach to provide greater insight into a topic across various contexts (Yin 2003).

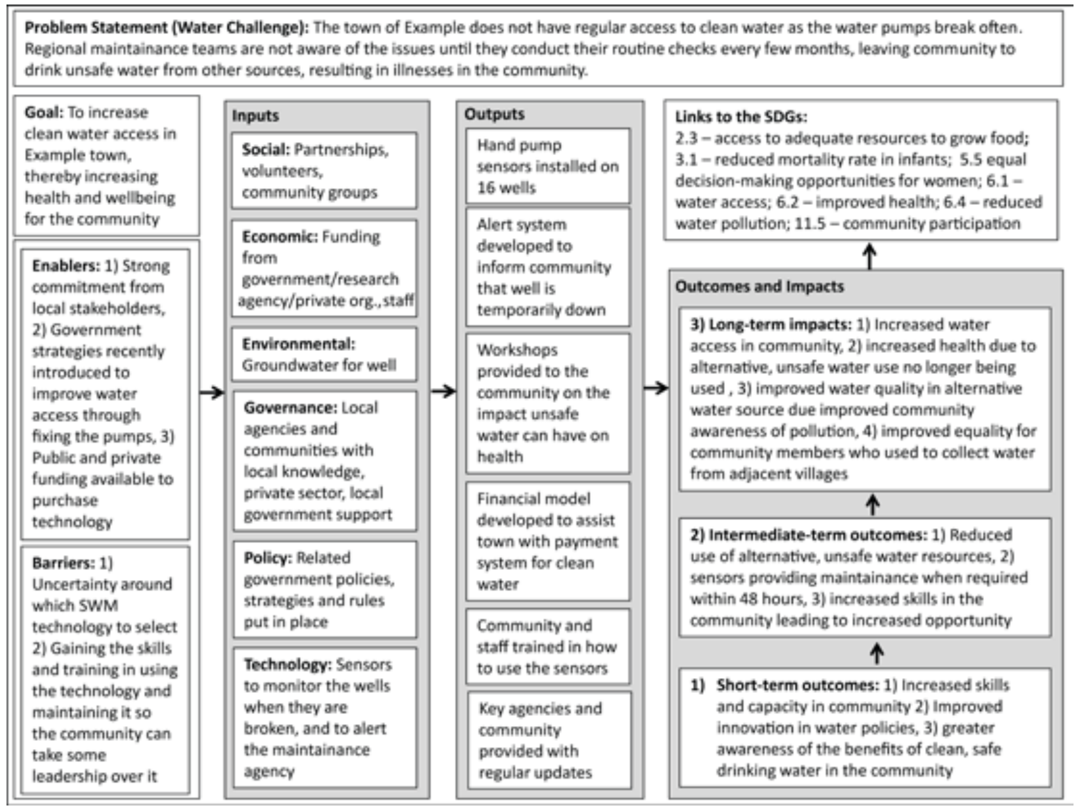

Figure 2. Example Logic Model concepts based on example case study

1.6 Structure of the Report

Following this introduction and methodology, the report presents ten case studies from around the world. As Korea, and indeed K-water, have been instrumental in championing SWM for the past decade one of the key ideas behind this report was to share the lessons Korea have learned along the way through this report. Therefore we open the case studies by presenting three case studies from Korea that address a variety of water challenges and smart solutions. The first case, based on a national project titled 'K-HIT', addresses integrated flood and drought management; the second case in Paju Smart City addresses community perception of potable water quality and reducing bottled water use; and the third in Seosan Smart City addresses the issue of leak detection and non-revenue water. Through these case studies we can see the incredible results achieved by K-water and the Korean government through SWM solutions, including an increase in tap water drinking rates from 1% to 33% in Paju City in three years, and a decrease in non-revenue water by 20% in Seosan City. These case studies show the potential for rapid and dramatic results when using real-time, SWM solutions.

Following the case studies from Korea, we have seven international case studies from around the world, from both developed and developing countries. These case studies have been order based on their 'Implementation Types of SWM' (see Box 2 below).

Box 2. Smart Water Management Implementation Types

Implementing Smart Water Management technology by itself will not always resolve the water challenge faced by a project. In some cases, a two-pronged approach is necessary to address the complex nature of the challenge. The second element of the two-pronged approach can include community engagement, governance schemes or business models, and is equally as important to the success of many of the projects as the SWM tools themselves.

Based on the case studies presented within this report we have categorised SWM technologies into three different types depending on who is using/adopting the technology. Each type requires a different approach to ensure the technology achieves its potential benefits.

Type 1 – Institutional users

Type 1 addresses technologies aimed at major institutional users such as water suppliers, water managers, mines, water treatment plants, etc. (e.g. France, K-HIT, China). The implementation of these technologies is mostly straightforward as industries and utilities can be encouraged to adopt SWM through incentives (improving efficiency, environmental benefits) or drivers (meeting regulations or targets) introduced by governments or the agencies themselves. Regulations and policies that encourage these institutions to develop and implement SWM technologies are relatively easy to introduce (depending on the government), and the institutes will more easily fund the necessary research (often with government support) to develop and successfully implement SWM.

Type 2 – Individual users

The second type is the technologies aimed at a large number of individual users such as household users and farmers (e.g. Africa and Canada). These are far more complicated to implement as they require a very large number of individuals to change what they are doing, and they do not often respond in the same way to economic incentives. Often the main benefits are to the society at large, rather than the individual. The savings from introducing smart technologies in homes might be small compared to the cost and inconvenience of adopting it, however the total impact might be significant and therefore the societal benefit high. In this second type, a two-pronged approach is more critical (i.e. combining the use of SWM tools with engagement, governance and/or a strong business model) in order to see a total societal benefit.

Type 3 – Institutional and Individual users combined

The third type involves a combination of both the institutional and individual user. This is seen when an institution develops and implements the SWM technology but the success of the technology partly relies on the individual user (e.g. Mexico and FDMT). This approach requires some engagement, but is less dependent on a second-prong than Type 2, due to the implementation being conducted by the institution.

The ‘implementation type’ for each case study was chosen based on the analysis of each case study during the cross-case analysis. The implementation types were then discussed with each case study author for their input.

While SWM is a relatively new idea in each of these projects (though some cases such as France can be seen retroactively as SWM) the results seen in most of these case studies are in the short- to medium-term. Despite this, the results seen so far show great promise for the medium- to long-term results and impact of SWM. The projects that do have results across a longer time span (8+ years; e.g. France and Mexico) have clearly shown the benefits of SWM solutions. We have also included text boxes of a number of projects where SWM is starting to or could make a difference, with the right support.

In addition to the ten case studies selected as part of this report, embedded within the report are examples of water management projects, which highlight a certain aspect of SWM. These include projects where:

- SWM would be an advantage in the future
- SWM has improved an element of the project
- Small scale cases that could be up-scaled or replicated

By sharing these upcoming projects and the support they require for continued success, it is hoped that they can receive further support from their governments to ensure they are provided with the new opportunities for successful SWM implementation.

The case studies and upcoming projects are followed by a detailed discussion and analysis of the 10 case studies, which looks at the social, economic, environmental, governance and technology factors that enabler and create barriers for successful SWM implementation. The output of this discussion is a set of 15 policy recommendations, which provide decision makers with the tools to support the future implementation of successful SWM projects. Following the discussion is a short summary of the conclusions and next steps for SWM.

This report is aimed at different audiences to enable them to gain insights from its findings to support them in moving forward with SWM. For the decision makers, the Executive Summary and Discussion and Analysis sections provide the key elements required to support upcoming SWM projects (such as the Policy Recommendations). For water utilities and industries, the factors for success and enablers and barriers provide insights into the areas that can be used to support SWM, and the areas that still require support. For those interested in implementing SWM projects in both developed or developing regions, the case studies provide detailed lessons on what has worked and what has not been as successful, with recommendations on where to from here. As such, it is hoped that this report can act as a guide for all of the readers interested in SWM implementation and the impacts it can provide in improving sustainable, integrated water management and helping to achieve sustainable development.

DR

CHAPTER 3. Discussion and policy recommendations

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3.1 Core elements of Smart Water Management

The broad benefits of SWM projects are made clear by the case studies in this report (see Box 1). While financial investments in most SWM provide medium- to long-term financial returns, non-financial benefits such as environmental, social, governance and technical benefits are all seen within the short-term and should be equally valued as a return on investment, as evidenced in most of the case studies in this report. Many of the activities that utilize SWM relate to improving water quality, access and efficiency, which have a significant role to play in reaching the Sustainable Development Goals (SDGs). Other activities utilizing SWM focus on ecosystem protection, planning and decision-making for increased climate change resilience, which will improve the environment and livelihoods for the people living in rural as well as urban areas.

Box 1. Benefits of Smart Water Management Implementation

Social benefits

- **Access to clean water and sanitation** through water treatment and monitoring
- **Health improvements** through increased access to clean, safe water
- **Improved livelihoods** through job creation, greater opportunity for further education, higher productivity and other opportunities
- **Increased training and capacity building** for the local community and staff
- **Increased sharing of solutions** to support sustainable development
- **Increased decision-making opportunities** through increased engagement and knowledge-sharing
- **Greater collaboration with community** through engaging with local stakeholders at the beginning of the project
- **Greater security** by improving water security and increased resilience to climate change
- **Increased trust** in water suppliers and the safety of water sources
- **Improved access to data and information** through real-time data sharing with all water users
- **Increased gender equality** through increased opportunities for capacity building and further education
- **Reduced conflict over water access** leading to increased trust and willingness to engage in collective action

Economic benefits

- **Increased efficiency** in irrigation systems and wastewater treatment systems
- **Reduced waste** by the reduction of water loss through leakages
- **Job and opportunity growth** through job creation through SWM project research, design, development and implementation
- **Improved capacity** in water systems improving their capacity to manage flows and reduce damage during storms/floods
- **Reduction in future infrastructure costs** by integrating smart technology tools to improve capacity/efficiency, resulting in less need for additional infrastructure
- **Mobilisation of funds** from public and private sources, as well as international funding sources

Environmental benefits

- **Improved water quality** through reduced pollution and contamination in waterways
- **Improved ecosystem health and protection** through improved water quality and quantity
- **Reduction in groundwater depletion** through reduced over abstraction
- **Reduced land degradation** through flood and drought management and reduced nutrient loss in the soil

- **Reductions in CO_2 emissions** through energy optimisation and reduced energy consumption
- **Reduced water consumption** through leak detection and reduced demand and increased reuse

Governance benefits

- **Improved management and knowledge,** as measurement is critical for effective management
- **Improved accuracy of data,** as real-time data should also be SMART (specific, measurable, actionable, relevant and time-bound) data
- **Increased community-led decision-making opportunities** as water users can make decisions based on real-time water use and information
- **Improved transparency** as water users have access to water use and quality in real-time

Technology benefits

- **The opportunity to test and develop** new and innovative tools for water management
- **Innovative technologies created** with the potential for commercialization
- **Identification of the remaining gaps** in technology adoption (e.g. standardisation of software and tools to make it easier to adopt the 'right' mix of tools for each situation
- **Showing the potential for SWM tools** to deliver successful outcomes and in turn lead to significant social, environmental, governance and financial impacts

A common thread across all SWM projects in this report is the need for infrastructure such as integrated systems, sharing of automated data and collaborative decision-making and learning processes. This applies to rural and urban areas in both developing and developed countries. However, as each country and region has its own context, and as institutional or industrial end-users require a different approach to individual end-users such as households or irrigators, a one-size-fits-all approach is not suitable for Smart Water Management. Instead, each region must assess how smart technologies can support them to better protect their water sources, to improve efficiency and to help to build resilience for the future. To assist with this, each region needs to select the appropriate policies for its own situation to drive and support SWM implementation. The research, development, testing and maintenance of SWM systems should be a priority for both public and private investments, with the government and institutes particularly able to support successful SWM in a number of ways.

3.1.1 Environmental factors

Most of the projects included in this report began with a shared desire among the government, civil institutions and the people living in these regions to improve human interactions with natural resources, including water, land and energy. Across the case studies, government policies and regulations put in place to improve water quality standards, protect groundwater resources and improve efficient use of water have acted as a driver for these projects to adopt innovative measures to protect the environment.

These case studies have demonstrated examples of environmental indicators that have resulted from collaborative efforts among governments, municipalities, research institutions, local agencies and communities, farmers, industry and the private sector:

- Significant improvement in water quality (e.g. Paju, France, Mexico, Canada, SW4E)
- Ecosystem protection (e.g. France, Canada)
- Reduced land and soil degradation (e.g. K-HIT, Africa, China, FDMT)
- Efficient energy consumption (e.g. SW4E, China, Canada)
- Flood management (e.g. K-HIT, Canada, SW4E, FDMT)
- Drought management (e.g. K-HIT, FDMT)
- Groundwater protection (e.g. China, Canada)
- Efficient use of water resources (e.g. Africa, Seosan, France, China, SW4E, Mexico)

This shows the potential for policies to support the protection and restoration of our environment and natural resources through Smart Water Management projects such as the ones shown in this report.

3.1.2 Economic factors

In many of the case studies, long-term investment in SWM led to a higher chance for successful implementation of SWM projects and increased benefits, including benefits that are both financial (e.g. increased efficiency and job opportunities) and non-financial (e.g. improved water quality, building trust in the community and opening opportunities for collaborative decision-making).

Support from governments and institutions (such as universities and international agencies) was also shown to be essential for many of the projects, which relied on initial financial inputs to support research, development, testing, technology acquisition and implementation. As SWM technology is a relatively new field, the evolving nature of SWM tools also leads to projects upgrading existing technology as it becomes available, requiring secure sources of funding. As shown in many of the case studies, financial return on investment is likely to occur in the medium-term (e.g. in Paju Smart City the recovery period is anticipated to be achieved in 8 years). Despite this, short-term return on investment is possible, as seen in Africa where investments in monitoring tools provided noticeable financial benefits to irrigators within one year. For projects that require medium-term cost recovery, as often seen within the water sector, short-term non-financial benefits (see Box 1) play a key role in securing the interest in SWM implementation and replication. With banks and governments focusing on short- to medium-term budget cycles, this is a challenge that must be considered.

Future cost saving was also considered a key driver for many of the case studies, as integrating SWM technologies and systems into current infrastructure enabled many of the projects to reduce future augmentation/investment in new infrastructure. By supporting the existing infrastructure with SWM technology the Paju and Mexico cases were able to reduce future augmentation costs, and by integrating the current systems together SIAAP (France) was able to both increase cross-sector network decision-making and avoid significant future capital costs. In the case in Africa, by adopting SWM tools and an innovative governance scheme (the AIP), water extraction was significantly improving overall supply reliability and easing the pressure on existing infrastructure and reducing conflicts over water access increasing the willingness to pay for water and participate in maintenance work. In the Flood Drought Management Tools (FDMT) case, SWM tools were used to assist water users and decision makers to develop resilience plans to manage/avoid future risks caused by floods and drought, reducing the future impact and costs of future land degradation and disaster management for local communities and agencies.

Job creation and increased opportunities were noted in several of the case studies, with new roles being developed both in the design and implementation phases of the SWM technology and systems. In the case of Paju, the project led to the creation of a new 'Clean Water Environment Project Team', which included a total of 98 workers working in waterworks, sewerage, environmental facilities and cityscapes. The Paju Smart City project also involved the hiring of a local construction company, resulting in 238 jobs in water related fields being established during the duration of the project. Other projects saw reductions in the time required to work (e.g. through increased irrigation efficiency), however as the profit remained the same (if not increased) this reduction in work lead to increased opportunities to use that time for other activities, including further education and training. In agencies such as the SIAAP, major teams are dedicated to the development and management of the SWM systems, creating new roles providing opportunities for staff to increase their capacity in research and opportunities to discover and develop new and innovative SWM solutions for water management.

Strong business models were also shown to be important to ensure the uptake of tools and to improve the potential for replication and scalability possibilities. For example, the Africa case

team were aware that despite the positive outcomes already seen in the project, distribution of free equipment to farmers does not guarantee longevity of use and continuing impact. In the Canada case, the current business model has faced challenges as it involves high costs for individual systems (with limited financial return on investment for users, at least initially), resulting in an inability to scale up despite the potential for the technology to have a strong environmental, governance and social benefits. Hence, developing a strong business model that can sustain the production and implementation of the tools will be the focus for both of these cases in Phase 2 of the African project. Collaboration with governments and industry, and developing co-payment schemes, are two options that can lead to improved business models to ensure the longevity of the projects and to enable the possibility of replication and upscaling.

Finally, most of the case studies indicated a high level of cooperation among the public and private sectors, institutions, and individual interests to adopt SWM technology. While additional policy support will only strengthen the value of the contributions from each sector, partnerships among all stakeholders, especially local agencies and community, are essential for the successful adoption of SWM strategies.

3.1.3 Social and community factors

The benefits of SWM go beyond increased access to, and improved efficiency and quality of, water. The social and community benefits associated with these outcomes are significant. By increasing access to clean drinking water and sanitation, communities in rural and lower socio-economic areas are provided with the equal rights to basic services, improving health and well-being in the community. By increasing irrigation efficiency, farmers in Africa have more time for other opportunities. As irrigation is predominantly the role of the women in the family, this opens up the potential for women to have greater access to further education and to consider other work opportunities which are of interest to them, bringing more equality into the farming practices in Africa. By increasing the quality of water and the information provided on the quality of the water, communities begin to gain trust in their water suppliers and governments, resulting in changes in behaviours from relying on bottled water to drinking tap water, significantly reducing the costs for the community for drinking clean water.

In addition to these benefits, SWM can support communities with awareness raising, learning/education and decision-making. This can be done through information sharing tools (e.g. Canada, Mexico, Paju), education tools (e.g. Africa) or decision-making platforms (e.g. FDMT, China). By increasing the awareness in the community about water-related challenges, it opens up the opportunity for them to make decisions based on this information, and to act accordingly. This increases the trust placed in the community and the role that individuals play within their community to work together to resolve these water challenges. By enabling communities to contribute in this way, trust builds and motivation to support implementation and adopt new ideas/technologies is secured. By involving local stakeholders, solutions for the fair use and allocation of water can be reached more easily.

SWM tools can also be used for learning, as seen in Africa, where farmers were encouraged to test and understand the equipment themselves to identify the patterns they were seeing. This led to their increased understanding of their land and water resources, which enabled them to make decisions based on what they had learned, instead of acting based on information provided to them. This builds capacity, knowledge and skills in these communities, where farmers can now better understand how to get the best results for their farms while still protecting their natural resources. Other areas where capacity building has benefited from SWM tools include the transboundary basin project in Africa and Thailand, where SWM tools assist in building the capacity of local agencies to plan for and adapt to the changing climate. This builds resilience in areas where climate change will have some of the greatest impacts. Involvement of local communities in SWM approaches improves the environment and livelihoods, and encourages social cohesion and resilience.

3.1.4 Innovation and technology factors

SWM technological solutions can increase water availability through water savings (e.g. increasing efficiency and detecting leaks), and increased water quality (through contamination control). They can improve the environment through flood and drought management and ecosystem protection. They can improve livelihoods and opportunities in local communities through reducing costs, building trust, and increasing engagement and decision-making potential for users. In addition, innovation and new technology can also create business and job opportunities.

A wide range of SWM technical solutions are available to support these changes, including water quality monitors and sensors, efficient irrigation systems, groundwater modelling, satellite data for forecasting and planning, GIS mapping, sensors and controls for leak detection and reduction, rainwater cisterns for the reduction of stormwater, (sub) district metering areas for increased accuracy of data, energy optimisation tools, and engagement platforms to support water user decision making. Each of these tools can be used to address current water challenges in regions trying to implement water demand/consumption management, improve water and sanitation quality, plan for the changing climate/increase resilience, improve community decision-making and build trust in the community.

To better support the implementation of SWM technology, several key factors for success are addressed throughout these case studies. These include:

- long-term investment to ensure research, development, testing and implementation can be completed successfully;
- external funding support to enable projects to be successfully implemented in the short-term; value placed on non-financial benefits of SWM technology (as described above);
- policy support for standardisation of technology systems to ensure all technology and its software is compatible to enable users to build the 'right mix' of tools for their context;
- transparency of new technology updates to ensure users can choose the right time to invest;
- improved business intelligence awareness to shift water utilities and users from traditional approaches to data sharing and integrated systems.

These changes can be addressed though improved policy support, regulations and cross- (and within) sector collaboration and engagement.

3.1.5 Governance factors

There are many aspects of governance that can benefit from increased data and knowledge sharing. With measurement playing a critical role in effective management, improving the accuracy and access of data can provide new opportunities for governance and community-led decision-making. Smart technologies also offer improved transparency as water users have access to water use and quality in real-time, allowing for decisions to be made based on current conditions. Governance and policy factors are discussed in more detail in section 3.3.1 below.

3.2 How to adopt the lessons learned from the case studies

Case studies are interesting and often inspiring examples of what works in a particular region within a particular context. They can also be used as valuable lessons for policymakers interested in further supporting the causes presented. A brief analysis follows highlighting how policymakers who are motivated to support SWM may wish to move forward. It is important to note however that every project and context is different, and therefore replicating a project exactly as it has been done in other regions without adapting it to local conditions nor gaining local stakeholder support and engagement is not recommended. There is no one SWM technology or solution that will solve every challenge. Instead, SWM technologies should be considered as a range of options that can be adopted and adjusted to suit the needs and challenges of each situation.

3.2.1 Possibility of scaling up or down

Many of the projects shown within this report (e.g. Mexico, Canada, SW4EU, China) have started on a smaller scale with the aim to scale up as the benefits were shown and more participants showed interest to come on board. In the African project the SWM tools and processes were piloted within six schemes in three countries with the intention to scale out and up once the tools have been taken to proof of concept. E.g. in the Africa case proof of concept was achieved in phase one which generated funding for the out and upscaling in phase 2.

To enable the scaling of projects both up and down, once the technology has been tested (i.e. when the results and benefits have been seen), the government should support projects to extend their projects to other areas/regions to test out the possibility of replication and scaling. International organisations can also take lessons learned from pilots and test them in other areas and countries to support cross-nation knowledge sharing and solutions, while NGOs can assist in sharing information and knowledge about these projects to support future implementation.

Some of the larger scale SWM projects (e.g. France) are quite ambitious and have been implemented over a long timeframe. Therefore, the complexity of such large projects should be taken into consideration when considering replication. It is recommended those interested in implementing similarly advanced projects seek advice from/consultation with the project managers of the original projects to gain a better understanding of the exact approach taken and what might need to be adapted to implement it successfully in your region.

As the implementation cost of SWM projects can be high, in many cases it might be considered best to start small and scale up as successes are seen. However, as shown in the Canada case, starting too small can lead to reduced government support/funding, as legitimacy of smaller projects is not as evident as in larger projects. Therefore, it is best to ensure that the scale of the pilot will provide sufficient benefits can be shown during the pilot phase, to attract sufficient support for ongoing success and up and out scaling.

3.2.2 Possibility of replicating in the same or similar regions

As demonstrated in the Mexico case, replication in the same or similar regions is not always simple. Even within a short geographical distance, considerable differences (e.g. socio-economic, infrastructure, policy support) can occur completely altering the context in which the initial project succeeded. To address this, collaboration is needed between the organisations implementing the project and governments within the original implementation region and the receiving region to ensure that technology and skills transfer can be seen in regions where it is needed most. In contrast, projects that have been successful in a particular country or region may be easily adopted in similar regions (e.g. Africa, FDMT, China) although, this will depend on the interest level and support from local stakeholders and decision-makers, including the community. Major SWM infrastructure (e.g. France) could be replicable in other major cities of a similar development status, with the right support and guidance (and if given the same amount of time to implement it properly).

3.2.3 Transferability to different regions

While transferring SWM solutions across regions presents more complexity than within regions, it can be achieved. This has been demonstrated by K-water who are currently replicating their Seosan project in Bali, Indonesia. Despite the circumstances of both regions being vastly different, K-water have partnered with the Indonesian government to ensure on-going policy and financial support to drive interest in the project. Creating this kind of transfer can be challenging, however by engaging the right stakeholders early in the project and with policy support and accessible resources, it is possible to transfer SWM projects across regions.

3.2.4 Conclusions

Each case study has its own specific context, based on its scale, geographic location, policy support, socio-economic status and the water challenges faced. While it is important to recognise the context of these project successes and challenges, with the right political commitment, stakeholder engagement and enabling conditions these projects can act as examples for other regions interested in replicating the benefits seen using SWM technology.

3.3 Proposed policy recommendations for successful SWM implementation

Throughout these case studies the importance of political support has been evident. This has been through both regulations ensuring targets for improved water quality, access or efficiency were achieved, or policy support for providing increased funding and resources to agencies looking to develop innovative solutions to water challenges. It is therefore important to reflect on policy as a key driver for successful SWM implementation, and to provide a direction for policy makers to move towards to support future SWM implementation in both developing and developed regions.

3.3.1 Overview: Policy, planning and governance

The following factors were key elements to the successful implementation of SWM in many of the case studies:

- **Long-term investment from outside funding** (both governmental and institutional) as it allowed on-going research, development and testing of new technologies
- **Funders valuing non-financial short-term benefits** (e.g. environmental, social, governance, and technical benefits) of SWM, with the awareness that financial-benefits (return on investment) can be seen in the medium- to long-term (i.e. willingness to pay was high from supporters) (e.g. France and Mexico)
- **Engaging within and outside of their sectors/institutions** to implement a collaborative project/network, including the sharing of data and capacity to improve outputs
- **Support from the top-down** (as well as engagement from all stakeholders and levels) enabled the enthusiasm of the project to continue throughout the development and implementation stages
- **Promoting the potential for SWM** to reduce the need for additional infrastructure (e.g. France)
- **Engagement and collaboration with all stakeholders** from the beginning, especially local agencies, of the project to ensure the complexity/context of the project was well understood and all stakeholders are on board with the SWM implementation and decision-making
- **Policy and government support** and incentives/regulations to drive the project
- **An understanding that SWM technology approaches vary** depending on who is implementing the tools (i.e. institutions, individuals or mixed), with additional support (e.g. engagement, governance or business models) required for successful individual adoption
- **Trust built in the community** through the use of and engagement with real-time data improving awareness of water conditions, decision-making and positive behaviour change (e.g. Mexico, Paju)
- **Building strong business models** and creating new jobs and opportunities for the water users and community
- **Using a two-pronged approach** to SWM by including engagement tools, governance networks and business models to strengthen the potential for successful long-term SWM implementation
- **Training and capacity building** for locals to ensure on-going successful management of the SWM tools and systems
- **Short-term results** (e.g. reduced water consumption, increased water quality, more efficient management, reduced conflicts over water access) lead to more enthusiasm for continued SWM implementation

Cross-cutting challenges faced by the case studies included:

- **Lack of standardisation** of SWM technology, leading to users being restricted to technology from the one manufacturer
- **Technology evolving rapidly** so it is challenging to know when there is a new technology coming out that might be better suited to their context
- **Time delays and loss of data** when stakeholders were not willing to share information/ data or community/water users were not supportive of the project (due to lack of initial engagement)

Based on these findings, Table 1 presents a suggested policy framework for successful SWM implementation.

Table 1. Policy recommendations for Smart Water Management implementation

Strategies	Policy direction
SWM for an improved quality of life (Society)	**1.** Facilitate adoption of SWM tools, especially in developing countries, to support access to basic services, and to support equality for poverty reduction, public health and quality of life. Include capacity development, technology sharing, collaborative business models and community governance and decision-making opportunities.
	2. Build trust and community engagement using SWM tools in areas where the community feel unsafe using the local water sources
	3. Empower people in developing countries with smart tools to reduce the time spent on water management and increase farm income and time available for other activities (e.g. further schooling, and additional work opportunities)
Investment in SWM for improved resilience and sustainable development (Economy)	**4.** Strengthen collaboration across and within sectors to provide opportunities for networks to share information and data to assist with effective and efficient water management
	5. Value non-financial benefits (e.g. environmental, social, governance and technical benefits) as equally important as financial benefits for SWM implementation, as they contribute to building resilience to the effects of climate change and increasing populations
	6. Support long-term investments for SWM implementation to enable adequate research, development and testing
SWM for protecting and conserving water resources and ecosystems (Environment)	**7.** Introduce policies, regulations and incentives to drive environmental and ecosystem protection through use of SWM.
	8. Encourage SWM solutions to increase water quality, manage demand and use, water reuse, reducing groundwater depletion and increase energy efficiency, etc.
	9. Introduce SWM solutions for climate adaptation plans for flood and drought planning and management and major storm events
Support evolving smart technology development and adoption (Technology)	**10.** Develop standards to ensure all SWM technologies are compatible (can communicate) with each other to enable tools to be purchased across various suppliers to enable those implementing SWM to create the right set of tools for each context
	11. Support on-going research, testing and development of SWM tools to advance them to a point where they are robust and require minimum maintenance and are ready to be commercialized (Government policies that support taking SWM tools from R&D to market)
	12. Support technology to assist in regions without built infrastructure or the adequate resources (e.g. electricity), as currently SWM infrastructure is (almost always) reliant on built infrastructure
Building capacity and networks for increased resilience and collaboration (Governance)	**13.** Empower people, especially those in developing countries, by providing them with SWM tools, data and capacity development and education to enhance/support local decision-making
	14. Strengthen the capacity to adapt to climate change by adopting SWM planning and operational technology
	15. Plan for water disasters in advance by creating proactive policies instead of reactive policies

Box 1. Smart Water Management Implementation Types

Implementing SWM technology by itself will not always resolve the water challenges faced by a project. In some cases, a two-pronged approach is necessary to address the complex nature of each challenge. The second element of the two-pronged approach can include community engagement, governance schemes, learning processes and business models, and is equally as important to the success of many of the projects as the SWM tools themselves.

Based on the case studies presented within this report we have categorised SWM technologies into three different types depending on who is using/adopting the technology. Each type requires a different approach to ensure the technology achieves its potential benefits.

Type 1 – Institutional users

Type 1 addresses technologies aimed at major institutional users such as water suppliers, water managers, mines, water treatment plants, etc. (e.g. France, K-HIT, China). The implementation of these technologies is mostly straightforward as industries and utilities can be encouraged to adopt SWM through incentives (improving efficiency, environmental benefits) or drivers (meeting regulations or targets) introduced by governments or the agencies themselves. Regulations and policies that encourage these institutions to develop and implement SWM technologies are relatively easy to introduce (depending on the government), and the institutes will more easily fund the necessary research (often with government support) to develop and successfully implement SWM.

Type 2 – Individual users

The second type is the technologies aimed at a large number of individual users such as household users and farmers (e.g. Africa and Canada). These are far more complicated to implement, as they require a very large number of individuals to change what they are doing, and they do not often respond in the same way to economic incentives. Often the main benefits are to the society at large, rather than the individual. The savings from introducing smart technologies in homes might be small compared to the cost and inconvenience of adopting it, however the total impact might be significant and therefore the societal benefit high. In this second type, a two-pronged approach is more critical in order to see a total societal benefit.

Type 3 – Institutional and Individual users combined

The third type involves a combination of both the institutional and individual user. This is seen when an institution develops and implements the SWM technology but the success of the technology partly relies on the individual user (e.g. Mexico and FDMT). This approach requires some engagement, but is less dependent on a second-prong than Type 2, due to the implementation being conducted by the institution.

3.4 Economic lessons: Ensuring support and investment for SWM

3.4.1 SWM as a long-term investment

Projects with long-term government, industry or institutional support and investment appear to have the best chance for on-going success in SWM implementation (see France, K-water, SW4E, China, Africa case studies). One reason for this is the time required to successfully implement SWM. In the case of France, it took 20 years of investment in research and engineering in the field of real-time control to implement the MAGES system. Other projects required 3-10 years for development, with many considering it an on-going process. This shows the importance of allowing time for on-going research, design, development and testing, and providing the opportunity to innovate as technologies evolve. This is especially important for large-scale projects that involve integrating SWM technology with current technology, infrastructure and networks.

As it is an emerging field, SWM technology and tools are rapidly changing. This necessitates ongoing research and development to ensure the best tools are used for each context and challenges faced. By encouraging on-going long-term funding, it allows the evolutionary nature of SWM technology and tools to be an advantage instead of a disadvantage to any SWM project. In contrast, the projects provided with limited or short-term funding and government investment (e.g. Mexico) show excellent initial success, but begin to face difficulties when looking to replicate in regions where the benefit could be even greater, as increased resources (both financial and human) are needed for research and to invest in new technology and maintenance of the current technology.

In the early stages of any SWM project, funding for maintenance and adjustments is required (including funding for staff and the training required to upkeep the technology). This can be an unexpected additional cost for some projects (see Mexico), and therefore should be included into the initial budget. Despite the initial maintenance requirements of SWM technology, it is expected that as more projects test and adopt SWM technology in different contexts, the technology and systems will continue to advance or evolve to a point where they become more robust and require less maintenance. Longer time frames also provide greater opportunities for stronger stakeholder engagement (which has been shown to be one of the keys to successful SWM implementation) and for long-term impact assessments. While developing and adopting a new SWM system can take time, innovative solutions can result in significant change (e.g. see Africa) in more areas than just sustainable water management (see links to the SDGs).

For projects that are independently funded (e.g. Canada), limited financial resources and support can become a barrier to implementation, as long-term financial input is typically required to test ideas on a large scale. Without this support the successful implementation and demonstration of the potential for the technology is hindered. This highlights the importance of government funding, which often has the opportunity to provide long-term support.

3.4.2 Outside funding support for successful implementation

Due to the medium- to long-term nature of successful SWM project implementation, most projects relied on funding from either governments or institutions to ensure the successful implementation of their projects. This government support and investment also played a major role in ensuring short- to medium-term financial return on investment. For example, in the Seosan Smart City case they will see the return on investment in 8 years, while other projects may rely on longer-time frames to see the financial benefits.

Government funding came from both municipal (e.g. Seosan city) and central budgets (e.g. Seosan, France and China), through drought budgets, water management plans and ministries. This funding was predominately provided for research and development, technology investment, operating and maintenance costs to be used within the region it was provided for.

Institutional funding came from a range of sources (e.g. universities, national research agencies and international funding bodies). This funding was provided with a stronger focus on research, innovation and understanding how SWM could work to address various water challenges, with the aim to share knowledge and to replicate/upscale the project to other regions where the needs were equal or greater (e.g. Africa, FDMT, SW4Europe and Mexico). Financial support is also appreciated as large-scale demand or production of smart meters (and other smart technology) has not yet been achieved in some countries, and therefore the production costs are still currently higher than traditional water technology. As with any technology however, as interest in/demand for SWM technology increases, it is anticipated that economies of scale will reduce the production and installation costs of SWM. This is already the case in Korea, where large-scale water facilities are planning to update their traditional water systems with smart technologies, increasing the demand rapidly.

3.4.3 Cost recovery

While early input costs occur, a financial return on investment is likely to occur in the medium to long-term, as water costs reduce (e.g. through identifying and reducing non-revenue water, reducing consumption, and improving efficiency), or as water prices are increased slightly to recapture costs (e.g. K-water). In addition to this, like most technologies, once smart tools evolve and the market expands, costs will likely decrease and there will be more opportunity for short-term cost-benefits of SWM to be seen.

In terms of recovering costs through reduced water tariffs, it was acknowledged that for some countries (e.g. Mexico and Korea) the tariffs for tap water are often quite low (or in the case of UNAM zero) and therefore reducing the water use in these countries does not necessarily lead to reduced costs in the short-term. However other benefits, such as reduced infrastructure costs in the future will result in financial benefits. Despite the delay on the return of financial investments, each of the case studies appears confident that SWM was the right decision for them and that it will pay off in numerous ways, including financially, in the future.

3.4.4 Moving beyond cost benefit analysis when assessing the value of SWM

Despite the initial financial deficits seen in many of these projects, the funding bodies supporting them are willing to invest in SWM due to the other benefits it achieves, such as improved quality of life, natural resource protection and climate change adaptation (e.g. Paju Smart City). In the case of Paju the government realised it was more important to have indirect benefits (e.g. reduced bottled water consumption and increased community health and well-being), than to have short-term direct financial benefits.

Many of these projects have shown the importance of moving beyond a cost-benefit analysis approach to determine whether SWM is a sound investment. In the France case, there has been no assessment as to whether a financial return on investment has been achieved at this stage, due to the on-going investment in evolving technology and maintenance. Despite this, the non-financial benefits (e.g. increased efficiency, capacity, data availability, collaboration and decision-making capabilities) and impacts (e.g. safer water for the greater Paris region and ecosystem protection) have been strong enough drivers for SIAAP to actively promote the continued use of SWM as the core of their operations.

This has been shown in the other cases as well with non-financial benefits including:

- Increased community awareness and decision-making opportunities for water uses (e.g. Mexico, Africa, FDMT)
- Improved customer satisfaction (e.g. Seosan, SW4Europe)
- Improved water quality, natural resource management and ecosystem protection (e.g. Mexico, France, Canada)
- Reduced land degradation (e.g. FDMT, China)

- Increased food productivity and capacity for planning and resilience to climate change (e.g. K-HIT, Africa, FDMT)

For projects where it is likely that short-term returns on investment could be seen (e.g. Africa), it is interesting to note that this has not been the focus for assessing the success of the project. Instead increases in productivity, efficiency and increased decision-making capacity have been the strong drivers for the project to continue. With this in mind, sustainable return on investment may be a better measure for these projects, as it encompasses social and environmental returns on investment as well as the economic benefits.

3.4.5 Future cost savings (infrastructure and planning)

One way that financial returns on investment have been seen in these case studies is through the reduced future costs of building new infrastructure (by supporting existing infrastructure instead with SWM technology). This was seen in the France case where they used SWM to co-ordinate the current networks to adapt current infrastructure instead of building a new facility, saving significant future capital costs. This is also the case in Africa, where implementing major infrastructure is often the approach taken for improving agriculture. By implementing smart tools and the Agricultural Innovation Platform to support the current infrastructure instead, the need for major infrastructure projects is removed saving implementation significant costs along with unwanted maintenance costs. In the FDMT case, smart tools are instead used to help water users and decision makers to develop resilient plans to manage floods and droughts, reducing the future impact of climate change on the land and water resources and saving damage costs in the future.

3.4.6 Willingness to pay for or adopt SWM

From a water user perspective, willingness to pay for SWM technologies and tools also appeared to reflect non-financial benefits when the costs of the tools were low, as shown in the case in Africa where farmers were most interested in improving their productivity (by reducing nutrient leaching and increasing nutrient availability), efficiency (reducing time required to irrigate) and opportunities (increased time available for other purposes, including education), than in financial gains. Willingness to pay also increased when the farmers understood and saw the results of the tools and saw the potential for the tools to increase their knowledge and understanding of their land, helping them to save time and also increase their income.

In the case where the costs were initially higher (i.e. in the Canada case), the willingness to adopt the technology remained relatively high, with participants in the pilot case stating that they were interested in the non-financial benefits (e.g. rainwater capture for irrigation, reduced pollution in waterways, etc.). Due to the high cost of producing any technology on a unit scale, in order to expand the project enough to have the desired impact, the willingness to adopt the technology must also come from the municipalities and water utilities who could support the project through providing grants or rebates (or other incentives for residents).

For a government (or other funding agency) to support this type of residential project the evidence of its impact would also need to be shown at a larger scale (beyond a small pilot study). This is a task which typically constitutes one of the key challenges that the project faces with getting the technology off the ground. Context is also important when assessing the willingness and ability to pay for SWM implementation, as shown in the Africa case, where the willingness to pay varied across the schemes. In this case, 70% of farmers in two of the schemes (Tanzania and Zimbabwe) showed a high willingness to pay for the tools, in comparison to only approximately 40% in Mozambique.

3.4.7 Strong business models for long-term sustainability of SWM

Strong business models are required to ensure the uptake of tools and the potential for replication and scalability is possible; this is particularly the case for 'Type 2' SWM implementation (where individuals implement SWM, see Introduction). For example, in the Africa case the project team is aware that, despite the positive outcomes, distribution of free equipment does not guarantee longevity of use and continuing impact. Hence, one of the objectives of Phase 2 for the project is to develop a business model that can sustain the production and spread of the tools. Business models include: the public sector paying for the technology, private sector paying and loaning the technology, co-payment of the technology, developing a payment scheme to return the costs, rebates for the technology, etc. In the Canada case study, the current business model did not succeed as it involves high costs for individual systems (with limited financial return on investment for users, at least initially). The business model for this type of project will likely involve collaboration with the municipalities who will benefit from the technology if 40% of community implement the systems (rebates are an option for this, as used for solar PV implementation). This involves strong collaboration with municipalities and could lead to potential financial support for the project.

3.4.8 Will SWM replace jobs or create jobs?

While some projects resulted in the reduction in staff needed in particular areas (e.g. in manually metering water use), other roles were found for these staff including managing the remote meter readings and customer service (see Seosan). In Paju, the SWM project lead to the creation of new jobs, with a 'Clean Water Environment Project Team' established which included waterworks, sewerage, environmental facilities and cityscapes and included a total of 98 workers. In addition to this, Paju City has hired local construction companies for the implementation of the project, which has resulted in 238 jobs in water related fields being established for the duration of the project. In the Africa case, while the time required for the farmers to irrigate their farms was reduced, and therefore the time required to 'work' on the farm was reduced, the profit made by the farmers remained the same (if not increased) due to increased productivity of the crops, resulting in the farmers having increased opportunities to take on additional work elsewhere or to continue with further education (or other opportunities) as desired.

While many of the case studies boast of efficiencies in the technology requiring fewer staff to manage the water system, which can result in reduced job opportunities, other cases have shown the benefits to increased efficiency and technology use, including new jobs, increased skill capacity and opportunities for education and additional work. For example, the Mexico and France cases show that SWM implementation can result in the creation of new roles and collaboration across otherwise separate sectors, leading to increased opportunities for integrated management. In addition to this, the France case showed that major teams are dedicated to the development and management of the SWM systems, describing working on new SWM technology as a great opportunity for them to discover the innovation potential for SWM tools and technology and to gain new skills in the area. In the Africa case study the SWM technology both reduced the time required for farmers to irrigate their land while also increasing the productivity of the crops. This resulted in a positive benefit particularly for women, who are traditionally in charge of managing the irrigation. These women now have more time for other opportunities such as accessing education or gaining additional income from alternative activities. If SWM can maintain income levels while reducing the need for staff, then staff can be retrained for other roles, ensuring loss of jobs is minimised, as seen in the K-water case studies where employees who were carried out manual monitoring were retrained into customer service roles. However it is important to note that retraining of skills is not always a simple process and opportunities for staff whose positions will be replaced should be considered carefully.

3.5 Social: Increased engagement, knowledge and decision-making

3.5.1 Engage with stakeholders early in the project for successful adoption

Working with the community and other stakeholders was seen to be one of the best approaches to ensure a successful uptake of technology. Including them in decision-making and training them to use the tools and to understand the information provided by the tools led to even greater success (e.g. Mexico, France, Paju, and China). For example, in Mexico community participation was considered of the upmost importance to the implementation of the SWM technology. While water leakages could have still been detected without the school community's support, the increased use of water fountains, improved water efficiency and better treatment and management of water were all-reliant on behaviour change. Community engagement was achieved through a two-pronged approach, both through the Water Observatory and also through in person workshops and training. The option for water users in the university community to have access to real-time updates on the water quality provided assurance that the water was safe, while community workshops used the knowledge gained by the smart technology to develop behaviour change. By partnering the two, the university community made significant changes to their behaviour, including reducing bottled water consumption considerably. For SIAAP (France) it was the engagement with all of the stakeholders in the joint water network that was essential from the beginning of the project to ensure they would all still be able to use their own platforms once the SWM was implemented instead of creating a new platform. Significantly reducing the retraining time for each stakeholder, and also ensuring the motivation for the project continued throughout its development.

In Paju, community engagement and information sharing played a major role in increasing tap water drinking rates. One of the key factors K-water attributes this is involving the community in the public activities of the project from the beginning of the project. The other two are the community's belief in the visible results shown during the project, and the open-access to real-time data via the community electric signboard (which will be discussed more further down). In contrast, the China case study shows what can happen if you do not engage with stakeholders from the beginning. In China it was the farmer's cooperation that was the most important for the smart systems installation and functional operation. In the beginning of the project the farmers were not initially consulted which led to substantial challenges as farmers removed or damaged the smart technology assuming it was being installed to charge them higher prices for water. This resulted in a meaningful delay in the results and loss of reliable data that had been collected. The team now acknowledge that the successful operation of the metering system and water saving facilities will rely on the farmers' cooperation. They are therefore working with the farmers, providing them with more information about the SWM tools and how they can benefit from them (along with compensation for their initial attempts to install without consulting them). This shows that collaborating and building trust with local stakeholders first before starting this kind of project can also lead to shared data, willingness to develop the best tools with you, on-going maintenance in the future.

3.5.2 Bringing the right stakeholders together at the beginning

It is not only important to bring all of the stakeholders together at the beginning of a SWM project lead to successful implementation of SWM technology, but bringing the 'right' people together (usually referring to local agencies) at the beginning can effect the most rapid change. For example, in the Africa case, engagement with the farmers and local agencies is essential from the beginning as they have been living with these issues for a long time and know what has and has not worked. In the same case, the crucial nature of the first phase of stakeholder engagement was highlighted by the initial 'visioning' step as it enabled participants to be confident that their issues had been heard and explored sufficiently. This takes time and care needs to be taken when options to consider the streamlining of the process are considered. For

France, strong stakeholder relationships with the partners were essential to ensure the shared objectives were being met. This resulted in a strong network of water professionals all working towards the same ambitious goals.

For the FDMT project in Africa and Thailand, engaging with local stakeholders in these regions prior to the implementation of the project was stated as one of the greatest enablers for the project's success. This ensured the local stakeholders were involved from the beginning of the project and could be part of the decision-making process from the beginning. For projects where strong stakeholder relationships need to be developed at the beginning of the project, time should be given to allow for this to develop to ensure trust can be developed between the stakeholders. Involving local stakeholders in the development and the dissemination of information was also shown to be a benefit (see FDMT, Africa, Mexico). For the Africa case, a local facilitator for the Agricultural Innovation Platform (AIP) was a critical component of the AIP. The project found that a local facilitator should ideally be someone with natural facilitation skills and with sufficient incentive to maintain the momentum and motivate and coordinate the breadth of stakeholders. Facilitation may then in the future become the new role for extension officers in Africa creating future job opportunities.

3.5.3 Local stakeholder engagement and support essential

The Paju case highlighted the importance of community-based organisation involvement in order to reflect the various needs at the local level. This kind of local stakeholder engagement and support is even more important when looking to replicate a smart urban water scheme in a new region, as each context is different and there is no 'one size fits all' solution. SWM projects could be successfully adopted in other regions around the world by working with a local and diverse stakeholder engagement group to ensure appropriate solutions are developed with local circumstances in mind. The case in Africa demonstrates that this kind of engagement can take a lot of time and resources, and is only sustainable in the long term if run by locals for locals. Therefore it is important to ensure that local stakeholders who will be trained as part of project are involved in the decision-making from the beginning of the project to ensure motivation and engagement is sustained once the initial implementation is completed. Working with non-traditional stakeholders and partners can also be beneficial as it allows new ideas and solutions to come into the discussion (see Africa case study).

3.5.4 SWM for community awareness raising and decision-making

Canada, Mexico, FDMT, Africa, Paju and China all highlight the potential for SWM to be used for community awareness raising and decision-making. This can be done through information sharing tools (Canada, Mexico, Paju) or decision-making platforms (e.g. FDMT, China) or a combination of the two (Africa). In Africa the value of the SWM monitoring tools has been recognised beyond improving efficient irrigation and farming practices, but is now also see as essential for building a learning system that supports the irrigation schemes. The awareness raised due to the data reported by the monitors has been disseminated to stakeholders outside of the project, benefiting an even greater number of people. In the FDMT case the satellite data acts as a decision-making tool for basin agencies when addressing potential future scenarios for climate change related floods and droughts. Already, the Thai stakeholders within this project have used the platform to start to develop their strategies for the basin.

3.5.5 Increasing community trust through SWM

Several cases showed the link between SWM and increased community/water user's trust in water quality (e.g. Mexico, Paju, SW4Europe). While real-time technology is often implemented in order to have reliable and constant information on water quality and consumption, it can also help to build trust in users who express concerns that manual monitoring is irregular with potential human inaccuracies. In Mexico, the university community showed a significant increase in trust when the water quality was monitored using automated technology, than when it was manually monitored. This resulted in a considerable increase in the community drinking tap water (which they could now see was clean in real-time) and in turn drinking less bottled water. Through the Mexico project, it was found that people are much more trusting of automated data than they are of people manually monitoring and updating data. This became evident throughout this project as people started to trust the drinking water quality when they knew the monitoring was automated, and when they could see the results for themselves on the Water Observatory platform. This was also observed during talks with the UNAM community, where all community members responded positively when informed that real-time automated data was available for the water quality of UNAM water taps every 5 minutes. This shows that people appreciate having access to real-time data for water quality as it assures them of the safety of the water. Automated monitoring plays a role in increasing trust in water quality in comparison to the manual monitoring of data, which is incapable of providing updated, accurate data on water quality every 5 minutes.

This approach could be adopted by the governments in Mexico (and other regions) to improve the community trust of water resources in the community, with the aim to increase tap water consumption (in areas where it is safe) and decrease bottled water consumption. In some cases (e.g. Paju) it was not the water quality itself that was the issue, but the trust in water quality. SWM helped to build this trust and now many more people drink the tap water. This trust was built as water users can directly check the quality of water coming from their taps using real-time status monitoring. Initially only 1% of the population in Paju was drinking tap water (5% on average in Korea), despite high water quality. Compared to Japan (52%). At end of project, drinking rate up to 36.3% (a significant increase). This raises the possibility for utilities in developing countries to use SWM as a way to develop trust in the water supply in their communities.

3.5.6 Engagement and learning as an on-going process

Community engagement and learning need to be on-going processes in SWM implementation, both for the water users and those implementing the technology. While initial implementation of the tools can be a quick process, for water users to truly understand the potential for the tools they are using it can take time. The case in Africa demonstrated one approach where water users were encouraged to learn the potential for these tools by themselves to ensure they are driving their learning about the technology. Mexico, Paju and FDMT (and SW4E?) trialled another approach where training and capacity building workshops were developed to ensure the users of the tools understood how to use them and the benefits they would get from them.

3.5.7 Engaging with stakeholders you usually would not engage with

Smart water tools can become a benefit for many water users. It is therefore suggested that those wishing to implement smart tools in a community think broadly about who could benefit from the SWM implementation and what information they may wish to know more about. This might include talking with farmers about soil moisture, efficient irrigation and groundwater, or universities about water quality and consumption. In the Africa case, this involved talking with youth and women (two groups not usually part of the discussion about farming), and brought them into the decision-making process. This opened up many opportunities for these groups and increased the opportunities for women in these areas to have a say on the decisions for the farm.

3.5.8 Engagement tools using various tools and approaches

Various engagement tools were used throughout the projects to provide the community with real-time updates of the water conditions, to increase interest and trust, to support behaviour change and to support decision-making and planning. Examples of the smart technology used include:

- The **smart phone app and signboards** used in Paju Smart City. These smart tools were installed to make real-time data accessible to the public and to ensure any barriers (e.g. such as those unable to install or unaware of the app) were removed so the public had access to the quality of the water in real-time.
- The **Water Observatory online platform** in UNAM, Mexico City. This platform provides an accessible tool for the water users in UNAM (and anyone else with an interest and online access) to check the water quality of the water devices in the main campus. The platform also acts as an internal data storage and analysis site for PUMAGUA.
- The **Agricultural Innovation Platform** (AIP) in Africa. This governance tool brings stakeholders together to develop a vision for what they would like to achieve using smart tools and approaching it together. It was developed to ensure local farmers would have a strong, self-sustaining network to make decisions with and a strong business model to ensure the project continues sustainably in the long-term.
- The **Flood Drought Management Tool portal** developed by FDMT and DHI provides a planning tool for climate change adaptation and planning for water utilities and transboundary decision-makers using satellite data.
- **Real-time water quality data water fountains** installed in apartments and schools in Paju act as a trust building and engagement tool as well as increasing access and incentives for water users to drink the tap water.
- **Mobile phone games** were used within the SW4EU projects to raise awareness of water consumption and efficiency in the community and schools.
- **A groundwater mobile phone game for farmers** in China. The app will be developed for farmers to better understand the use of water and electricity when pumping from the wells, and the impact it can have on the groundwater levels. This 'game' is intended as an engagement and education tool for farmers to increase their interest and understanding about the project
- The **RainGrid online platform** in Canada. This platform provides real-time updates for SmartGrid users to assess their current water collection and predict their future water collection, enabling them to adjust their behaviour as necessary.

3.5.9 In the long-term local management of tools should be supported

In the two cases based in Africa (e.g. Africa and FDMT) initial support was provided by external agencies. However, both of these cases have developed to ensure that the management of the tools and supporting platforms will be run by locals. Deploying monitoring tools across countries can be a challenge and local production of these tools can help address this. This can also help to boost local economies and reduce reliance on external manufactures. As is the case with many new technologies, particularly those with sophisticated components deployed across multiple national boundaries, there have been some challenges in regard to delivery and keeping pace with demand. However, increased team support and movement of production to within the region will enable these issues to be addressed (see Africa). The context of the SWM project is also important in determining how tools should be chosen and utilised. Typically only local stakeholders have the knowledge and experience to most effectively adapt a SWM project successfully, but externally provided technology and capacity development may also be required at least initially to ensure all skills are available for successful implementation.

3.6 Environment: Protecting our natural resources and ecosystems

SWM tools are often developed with the goal in mind to address a particular water challenge. In these cases, it was shown that SWM tools and systems can also assist with supporting and protecting the environment and natural resources beyond what they initially set out to achieve. The SWM tools to address these challenges are described below.

3.6.1 Water quality

Water quality was the most prominent challenge addressed within the SWM case studies, with over half providing solutions to address water quality using various approaches. In the Paju, Mexico and SW4EU projects, the quality of potable (drinking) water was addressed and monitored to both increase the safety of drinking water through early detection of bio-contamination, and to improve community receptivity to drinking tap water. The Canada case addressed the quality of stormwater, looking to reduce non-point source pollutants entering the waterways and ecosystem by reducing stormwater flow at the local level. In France, SIAAP addressed water quality through monitoring and controlling water quality in the sanitation treatment system.

3.6.2 Ecosystems

Smart water tools have the potential to provide ecosystem protection through reducing pollutants entering the waterways and groundwater. In the Canada case, by collecting water at the source (i.e. from the household roof) pollutants collected from roads and pathways are no longer collected with the rainwater, reducing the level of contamination reaching the groundwater and waterways. SIAAP in France have shown that reducing contamination in sanitation can also protect ecosystems: Now that the MAGES project is able to provide higher quality water for the river Seine fish species are returning and fish population sizes are at an all-time high.

3.6.3 Land degradation

By reducing nutrient degradation the Africa efficient irrigation case study was able to return the soil to a healthy state, reducing land degradation and ensuring improved production of crops on the land. The Flood and Drought Management Tools project in Africa and Thailand and the K-HIT project in Korea looked to reduce land degradation by managing floods and droughts to ensure the land was protected from extreme weather events. In China, the reduction of groundwater abstraction also supported improved land protection along with groundwater resources.

3.6.4 Efficient energy consumption

Alongside improving water resource efficiency, smart tools also have the potential to improve energy optimisation. This was shown through the SW4EU project, where (explain project). Energy consumption were also reduced indirectly in the China and Canada projects through reduced use of water abstraction (China) and reduced pumping of water when collected at the source (Canada). Energy conservation plays a major role in reducing the impact of climate change, and therefore by adopting smart water management tools that can also assist in energy optimisation and reduced consumption we can improve the use of two of our most essential resources, water and energy.

3.6.5 Flooding

Flooding was addressed at the national and regional scale both through integrated operational solutions (e.g. K-HIT) and through flood management and planning solutions based on predicted weather patterns (e.g. FDMT), and at the local scale (e.g. Canada) through reduced stormwater runoff.

3.6.6 Droughts

In addition to addressing floods, both the K-HIT and FDMT projects showed the potential for smart solutions to address droughts through storage of water and planning. Droughts could also be addressed through many of the technologies, which provided solutions for increased water access, water quality and reuse as improved water efficiency supports water access in times of drought.

3.6.7 Groundwater

Groundwater over abstraction is an area of great concern in many countries, and an area which can be addressed through the use of modelling using real-time electricity and water data as shown in the China case. This kind of technology provides the opportunity for countries where groundwater has become a key source of water for irrigation to ensure accurate reports on the current levels of groundwater are current and can also engage with the local farmers to show the importance of efficient groundwater use.

Groundwater depletion was also addressed through the Canada project with stormwater collected at the household scale then returned to the groundwater.

3.6.8 Efficient use of water resources

With over 40% of water supply in most cities being lost to non-revenue water (i.e. water leakages), the Mexico, SW4EU and Seosan city projects have shown the importance of smart technologies for the efficient use of water uses. Community engagement was also used to support the community to reduce water overuse.

3.7 Governance: Decision making and collaboration

3.7.1 Interdisciplinary collaboration leads to successful SWM

Many of the projects showed the importance of interdisciplinary teams and collaborations as one of the keys to their success. In the Mexico case study, PUMAGUA consists of scientists, engineers, regulation experts, maintenance staff, teachers, and communication experts, with each team essential for understanding the issues that were being addressed, and for implementing the project. The PUMAGUA team also found it highly beneficial to have the support of the whole university, as it ensured support water provided when the teams needed it.

This interdisciplinary nature was also highlighted in the French case study, were SIAAP worked closely with the other water agencies in Greater Paris to integrate their current networks and operation systems, instead of building a new facility and operation network. This enabled each of the teams to continue working with the systems they were familiar with, while also increasing their capacity. Similarly the SW4EU project involved the collaboration of more than 20 stakeholders, enabling the partners to test and develop new technology, different sites, to identify which tools worked best for which contexts, and to learn from one another.

In both the FDMT and the Africa case studies, external agencies in water management, technology and research (e.g. universities and international NGOs) supported local agencies (e.g. water utilities and basin authorities) to develop and implement their smart projects. In these cases, the knowledge from the local agencies was deemed crucial to the success of the project. In Korea, the K-HIT project involved internal collaboration of several interdisciplinary teams within K-Water to develop the technology and tools for floods, droughts, hydro and planning, alongside external collaborations with the government for support.

In contrast, a lack of collaboration was also shown to cause major delays if not stalled starts all together. In the China case study the lack of collaboration between the project team and the electricity sector resulted in major delays for the project. As the electricity sector would not share electricity data, the project team relied on collecting their own electricity data from meters installed in local wells. When the electricity readings were found to be inconsistent, it took several months until the two teams collaborated together and were able to realise that the electricity meters had not been installed correctly. Reinstallation of the meters was ultimately required, resulting in significant delays. This highlights the need for close cooperation with the electricity sector, not only for technical expertise support and their ownership of the technology, but also for their knowledge and access to the data, which was required for successful implementation of the project. Similarly in the Canada case, had the project created strong collaborations early in the project with water utilities and municipalities, it would have built a stronger business model, strengthening the future potential and opportunities for the project and the trust from future participants in the project. Lack of this collaboration at this early stage seems to have caused the project to stall.

DISCUSSION AND POLICY RECOMMENDATIONS

3.7.2 Understanding the challenges from the beginning leads to success

One of the key lessons that many of the projects learned throughout their projects was the importance of having a strong understanding of the challenges and context of their location prior to implementing SWM technology. Having this understanding enabled the most suitable tools and technology to be selected from the beginning.

For example, prior to PUMAGUA (Mexico case study) a baseline assessment had never been performed at UNAM, resulting in the team having very little understanding of the key issues related to water at the university, or the extent of these issues. To address this PUMAGUA conducted a full diagnosis of the situation including water quality assessments, water consumption and surveys of the university community. A key outcome of this diagnostic stage was the conclusion that smart technology (i.e. sensors and monitors) would provide them with the most comprehensive understanding of their current challenges while also helping to direct the project to achieve tangible solutions to these challenges.

Now that these SWM tools have been implemented for the past 8 years, PUMAGUA has an even better understanding of what is needed for the future and which technologies and tools they would like to implement to improve the system even further. This shows that as SWM technology evolves, regular reassessment of the situation and context of the project is necessary to ensure the correct suite of technologies are being used for each situation.

This staged approach was also shown in Seosan, where stage 1 involves an assessment of the challenge; stage 2 analysis of the data and diagnosis; and stage 3 adjustments are made to ensure the tools work to the best potential. This staged approach is particularly important in developing regions where baseline assessments of the issues unique to that region are often not available.

3.7.3 Concrete outcomes and objectives increases motivation and funding

To guarantee on-going support and motivation both SIAAP and K-water found it important to have concrete outcomes agreed between all stakeholders. For example, the MAGES project (France) started with two concrete outputs for all the parties: 1) rainfall data treatment and 2) setup of a real-time data sharing platforms between the SIAAP and each one of the partners, leading to increased motivation to reach these outcomes. K-water was required to improve the water supply network and stability of tap water supply using ICT. These concrete outcomes/outputs were requested in return for mid- to long-term budgets, which significantly supported the success of these projects. The Mexico case study provides an example of how setting specific targets can help deliver results: In their case, a target was set to reduce water consumption by 50% from 2008 values, and has so far decreased it by 25% despite the university community increasing by 37% in this time.

3.7.4 Choosing the right tools for the context of the project

The diversity of these projects and the challenges they have faced and overcome demonstrates the importance of understanding the context of the project to implement SWM successfully. The following factors have been shown as important to consider at the beginning of a SWM project to gain the most comprehensive understanding of the context and how best to approach SWM implementation:

- Technical capacity and knowledge of all stakeholders (especially the water users who will be using the tools)
- Access to technology and tools locally, or reliant on external partners
- Maintenance capacity (both financial and human) for the tools
- Financial capacity (and for how long will this support be available)
- Regulations and policies in place (including incentives and disincentives)
- Community engagement potential (and tools that might help the community to engage fully with the project)
- Collaboration potential (which stakeholders will be interested and how willing will they be to collaborate)
- Access to resources (e.g. internet access, electricity, infrastructure to monitor, data storage capacity)

By considering these factors, a better base understanding can be developed at the beginning of the project, which can in turn assist in identifying any early barriers that may occur or opportunities that can support the project.

3.7.5 Involving water users in decision-making

In addition to involving water users through engagement and awareness raising, SWM also offers the opportunity to involve water users proactively in decision-making. These decision-making processes can be seen by involving the water users in the discussion from the beginning (e.g. the farmers in the Africa case) or by providing them with decision-making tools once the system is in development (e.g. FDMT, Mexico) or once the project has been developed (e.g. Paju). By providing these tools to water users with real-time data and the information required to make informed decisions, they can feel more in control of their actions and decisions as a water user. This demonstrates the potential for SWM tools to be used to increase decision-making opportunities for water users and could be easily replicated and adopted in regions were there is interest for water users to make their own decisions in regards to water use.

3.7.6 Project management and roles must be determined from the beginning

SWM projects are often developed and implemented in collaboration with several partners. These partnerships are often made up of external partners (those from outside the area of implementation) who assist with the initial development and implementation, and local partners who continue with the project once it has been implemented. As SWM projects and technology tend to require ongoing maintenance (at least in the short-term) it is important to identify at the beginning of the project who will be in charge of this management and maintenance in the future, and also to ensure a budget is available for the future management of the project. It is also important to clarify at the beginning of the project how often upgrades are likely, when or if scaling of the project will occur, if replication is a consideration and who will manage these stages of the project.

For example, in the case study in Africa it was essential to identify early in the project who would be responsible for each part of the SWM tools and their maintenance. In the Africa case it was also important for the irrigation association of each scheme to develop a clear mandate to enable the farmers to ensure the governance of the project continued smoothly and sustainably in the future. In the case of SIAAP, strong commitment from the top management of each partner ensured everyone knew who was managing each part of the system, and how it would be managed in the future. This is particularly important for projects where funding partners are involved only during the first phases of the project, i.e. where the local partners must maintain and pay for future augmentations of the project in the future to ensure the projects are sustainable.

3.8 Policy: Policy support for SWM implementation

3.8.1 Policy support and regulations a major driver for SWM implementation

Throughout these case studies is was clear that many SWM projects are driven by regulation requirements (e.g. water quality in Mexico and Paris, efficiency targets in Paris and depleting groundwater resources in China). For example, Mexico's regulations on water safety were a significant driver for PUMAGUA to assess drinking water and wastewater quality. While the regulations did not stipulate that real-time technologies were required to meet the requirements, having the requirements in place created the driver for PUMAGUA to assess their situation, which may not otherwise have become a priority. In Paris, the increased regulations on water quality in the Seine resulted in SIAAP having to advance their systems, and as smart technologies had been part of their management approach for over a decade, integrating their smart networks with other water agencies enabled them to meet the increasing regulations. It is therefore important for regulations (e.g. to increase water use efficiency, reduce leak detection or improve water quality) to be introduced in areas were further drivers are needed to support future SWM implementation.

In countries where SWM has become a priority for governments (e.g. Korea), having strong policy support for SWM has also made implementing successful SWM much easier and has acted as a driver for SWM developers (such as K-water) to participate in the development of projects such as Paju Smart City. Policy support also often includes significant funding for research and development (R&D) into SWM, with funding for SWM in Korea expected to reach 8.7 million (USD) by 2020 in Korea. The planning and execution of the drought policy, existing laws and systems played an important role in the implementation and support of the Seosan project. In addition to this, government budget support for the project facilitated its implementation.

Local plans and policies can also play a role as a driver for SWM implementation. The Seosan Smart City project was initiated on request from the City of Seosan, who requested smart technology implementation as a drought measure when national drought plans were introduced, with financial support provided by the national government. This shows the potential for policy support to act as a major driver for adopting SWM projects, when coupled with supportive funding to meet the targets. Governments supporting major SWM projects also drive interest and support for SWM (see K-HIT, Korea).

In contrast, when government support is not provided it can hamper the implementation of SWM project. For example, in the Canada case study, municipal support could have enabled the use of rebates for the SWM technology to encourage the 40% of the population to uptake the technology to ensure the results could be seen. As this type of technology also supports the actions the municipal governments are aiming for (e.g. improved stormwater management and improved water quality), rebates or other financial support from municipalities or water agencies would be a great first step in supporting the successful implementation of household and site-scale SWM project.

It is also worth considering the other types of policies which could support SWM implementation. With SWM technology offering a number of opportunities for community engagement and decision-making, introducing policies requiring improvements in these areas could also increase interest in smart tools.

3.8.2 National acts also play an important role in government support

Along with policies, national acts also play an important role in government support. In Korea, the *Framework Act on The Management of Disasters and Safety* encouraged the government and public institutions to plan drought measures and the *Countermeasures Against Natural*

Disasters Act enforced the federal government and local governments to restrict water supply and electricity generation and to maintain drought-overcoming facilities. Without these government Acts in place, this project may not have been supported.

3.8.3 The importance of standardisation and integrated solutions

Some of the key barriers reported by the case studies were a lack standardisation and integration of SWM technologies and a lack of transparency from manufacturers on future technologies. As standardisation is not currently regulated, future policies can also assist in supporting SWM implementation by addressing some of these challenges currently faced by these projects. Due to the lack of standardisation, current SWM systems are often not compatible, which leads to projects being 'locked in' to one manufacturer or supplier and reduces the potential to use the 'best fit' of tools for the context of the project. Standardisation of technologies on the market to make them compatible with one another would therefore reduce the reliance that many projects have on one manufacturer. Standardisation would also support future projects, as it would encourage manufacturers to work with SWM project managers. This would increase transparency about upcoming technology to ensure large investments are not made using technology that is soon to be upgraded, and would benefit the manufacturers with real feedback from the project implementation team to ensure the most important upgrades to the technology are made.

3.9 Technology: Supporting the evolution and adoption of SWM technology

Countries with ready access to SWM technology and capacity (e.g. Korea) will have the 'easiest' transition to SWM implementation (e.g. Seosan, France) however countries without these resources can still benefit from SWM through collaboration with these countries (if only to learn from them).

3.9.1 Planning for successful SWM technology implementation

When planning SWM projects and technology installation, a few key factors were shown to assist with successful implementation.

Firstly, project managers must ensure all installation requirements are met (e.g. inlet pressure, flow-rate, data connectivity) prior to investing in the technology. This includes understanding logistical challenges such as underground installation which can be solved but require additional technology or equipment. It is also important to understand how the technology will integrate with the other systems used in the project and whether the systems are compatible across the technologies, or require different systems or platforms. Real-time data becomes far less useful if it is provided in several different units that cannot be easily converted and integrated.

Care should be taken in order to prevent the use of SWM technology creating a dependence on one particular commercial product or manufacturer. It would be desirable for companies to have products compatible with each other in order to have different options. Compatibility would also likely accelerate their response time to project inquiries and issues.

If selecting a range of technology from various manufactures, integration of the data sent by different systems to one data platform can be a challenge. Often different manufacturers require different software to read the data from the signals, and for reading the incoming data. In some cases, metering companies will make their money from installing meters at a low cost and then provide paid services for the customers after installation (see China case study). This results in the data being sent to the companies servers, and can reduce access to the data. It can also result in the data being collected in different formats, resulting in a challenge when integrating it to provide an overarching picture of the data. Having a full understanding the challenges faced and how SWM technology can assist with these challenges will help to ensure the right mix of tools are selected for the context of the project. The tools used in a project in one country or region may be useless in another context. It is essential to understand which suite of tools suit the scale, location and challenges faced in the project area.

For projects where location accuracy of the data is essential, the implementation of District Metered Areas (DMAs), or Sub District Metered Areas (SDMAs) can assist in improving the data accuracy of the region as it separates the area into subareas (see SW4Europe, Seosan, Indonesia text box).

There are standard issues which need to be considered and prepared for across all SWM projects, such as clogging of filters, drop out of Internet service, and maintenance requirements still impact SWM technology. For example, interrupted Internet connections can result in missing data and loss in trust in the data collected. It is therefore essential that a secure and reliable connection is established for all real-time technology. Communication networks are also important for SWM implementation. If traditional communication networks or electricity are not available, other options can be found (e.g. data uploaded to the cloud when the mobile is connected to the internet as shown in the Africa case study, or solar power used to support irregular electricity supply as seen in the Uganda aquaponics project).

3.9.2 Evolving technology can be both a disadvantage and an advantage

As SWM is an emerging field, smart technology for water management is constantly being updated and as a result can become out-dated quickly. It is therefore important to study which technology will be the most suitable, and also to conduct research on whether there are any new technologies soon to come on to market that might be more effective than the technology currently available. For example in the PUMAGUA case, sensors that use radio frequency were chosen, requiring additional infrastructure to ensure the radio waves reach the entire campus. Mobile frequency sensors are now available that do not rely on additional infrastructure, that may have been more cost effective in the long-term. This evolution can also be seen as beneficial for new projects starting to implement SWM, as the constant evolution of technology provides new solutions and opportunities to create the 'right mix' of tools for the context of the project.

3.9.3 Various approaches to implementing SWM

While many projects introduce new SWM technology infrastructure as part of their project (e.g. Canada, K-HIT), SWM technology can also be used as a retrofit or upgrade to current infrastructure (see Mexico and Seosan), or as an alternative to introducing new infrastructure (see Paris and Africa cases). By combining the existing water management in Seosan City with Smart Water Management tools, the efficiency was significantly improved. SDMA (Sub District Metering Area) system technology, which subdivides existing DMA systems into smaller units to improve the revenue water ratio, is one example of this. These cases also provide an example of SWM complementing traditional infrastructure by enriching the results and validity of the information. The Paris and Africa case studies further demonstrate that SWM technology can greatly reduce the need for future infrastructure, resulting in significant future cost savings.

3.9.4 Monitoring tools can be used as an education tool

Many case studies have also shown the potential for SWM tools to be used as engagement and educational tools. A good example is provided by the Africa case study, from which the farmers gained a stronger understanding of the benefits of efficient irrigation through the use of the real-time soil monitors. Instead of informing the farmers that reducing irrigation could provide a range of benefits, the tools allowed the farmers to come to this conclusion on their own, building their knowledge of how their land works and increasing their capacity to better manage their farms. The case study in Mexico also demonstrated the use of real-time water quality and consumption as an education tool for the university community, with students learning how they could make a difference through changing their water use behaviour, and seeing the results in real-time.

3.10 Replication and scalability: the potential and challenges

Based on the successes seen in many of the SWM projects, the potential to replicate the projects or scale them up or down in other regions is an area of great interest for many of these projects.

3.10.1 Early successes and knowledge sharing can support replication and scaling up

In the Africa case study, once the farmers recognised the value of the SWM tools, demand for the tools increased. Farmers involved in the project have expressed interest in scaling up the project and trying out SWM tools on different crops, and many other farmers are now interested in SWM tools. This interest provides strong incentives for project partners and potential new partners to help with scaling up the project and distributing the SWM tools more widely. As a result irrigation practices are changing faster than expected, and this knowledge could be expanded into other areas if the project was to be replicated elsewhere.

It is also important to recognise that initial excitement and enthusiasm for a project does not guarantee long-term success. The provision of long-term results, continued comparisons and feedback from other projects, long-term learning goals and in some cases continued evolution or expansion of the project may all be necessary to maintain stakeholder interest.

3.10.2 Challenges in replication and scalability

Each of these projects has shown interest in scaling up or replication in some way. However, it is important to note that what is a challenge in one context may not be a challenge in another context, and vice versa. Challenges faced by the projects so far are described below.

3.10.2.1 Lack of basic infrastructure reduces options for SWM implementation

In the Mexico case study, PUMAGUA demonstrated the difficulty of replicating pilot projects into regions with a highly varied context. In the case of PUMAGUA, the SWM tools that were successful in a university setting faced instant barriers when introduced into a lower socio-economic area of Mexico City. While both sites were within the same city, they faced very different water challenges. The university faced issues with water quality and leak detection, the areas in Mexico City faced limited infrastructure or infrastructure of low quality, and irregular water access. Concluding that it was near impossible to implement effective monitoring systems where there is little to monitor, PUMAGUA used the SWM technology and approaches they had developed to focus on monitoring the houses that did have a reliable water connection. At the same time a long-term goal was set to expand upon and replicate this project in other areas.

3.10.2.2 Lack of resources to support replication in some regions

The success of most of these SWM projects has been in part due to funding support from governments. While K-water is looking to replicate their successes in other regions (see Bali text box), they acknowledge that not every country will have the strong governmental support for SWM offered in Korea, and therefore that investing in this kind of project can be a challenge in other regions. Beyond financial support, many regions looking to introduce SWM technology into their regions face barriers of access to the technology, resources (such as electricity or Internet access) and capacity. Therefore it is important to assess what would be needed for each project to be successful elsewhere, and what support would be needed for a project that was successful in a large city in a developed country to be successfully replicated in a small city in a developing country.

3.10.2.3 Economies of scale and evolving technologies

As shown in the Canada case study, there can be challenges in scaling up a project to improve the economies of scale prior to the technology reaching high-demand in order. Therefore, scaling up is considered challenging unless external support is provided at least in the short-term. In addition to this, as technology is in a constant state of evolution, many of the case studies commented on the difficulty of knowing the right time to purchase and install SWM technology, especially if in purchasing the technology results in the project becoming locked in to one supplier or manufacturer.

Despite these challenges, each of these projects is interested in upgrading, replicating, scaling or sharing their knowledge to support future projects. The more SWM projects are developed and implemented around the world, the more can be learned about which technologies work best for each context to best support every region with implementing SWM to assist with resolving their water challenges.

3.11 Sustainable development: How SWM can assist in addressing the SDGs

The case studies presented in this report show the considerable potential for Smart Water Management to contribute towards reaching many of the Sustainable Development Goals and their targets. These projects show the potential for SWM to assist with the SDGs beyond SDG 6 (to provide clean water and sanitation for all). For example by moving towards zero poverty and hunger, improving quality education, supporting sustainable cities and the consumption of clean energy, implementing sustainable consumption and climate action, alongside supporting partnerships to reach these goals together.

The following section details how the projects presented in this report can assist in addressing these goals. While the number of targets these projects are able to assist is already substantial, the diversity of SWM projects around the world leads to potential for SWM to assist with meeting an even greater number of SDG targets through future implementation.

SDG 1. Towards zero poverty

The projects in southern Africa, Mexico and Korea each provide assistance for moving towards zero poverty through supporting equal rights to economic resources, control over land, natural resources and new technology (target 1.4); through building resilience and reducing exposure and vulnerability to climate-related extreme events and other shocks (target 1.5); and by supporting policy frameworks that are based on pro-poor or gender sensitive development strategies (target 1B).

Each project approaches this in a different way. In southern Africa, the project shows the potential to move towards zero poverty through identifying and improving institutions that reinforce inequity with a particular interest in gender, youth, end-users, social capital, access to natural resources, economic well being and agency in decision-making. As the farmers also have direct use and control of appropriate technology, this strengthens their control over their land and increases their decision-making potential, increasing their resilience for the future crop production and income potential. This project also aims to build resilience through enhancing individual and community capacity (knowledge, empowerment and agency), reducing conflict, building strong networks and advocating for policy change through the African partners of the project (an element of the project which will be accelerated in Phase 2). In the Mexican case study, this support is shown through its efforts to enhance water availability for the next generations of UNAM's community, as well as for the inhabitants of Mexico City where equal rights to water is currently an issue in many regions. In Seosan City, Korea resilience is built through ensuring access to water in all regions, including those which have had limited access in the past and rely on it for drinking purposes and sustainable irrigation.

SDG 2. Towards zero hunger

As shown in the Africa and China case studies, SWM technology can be used to improve irrigation practices, leading to increased crop productivity and income. The Africa case study has shown this through increasing agricultural productivity and incomes of small-scale food producers, access to land and other resources (target 2.3) through increasing the farmers incomes and yields. Farmers have also increased their awareness of sustainable irrigation practices and reduced water and fertilizer use, moving towards sustainable food production and resilient practices (target 2.4). In the China case study the use of an irrigation calculator and web tool enables the farmers to calculate irrigation water demand, providing a plan for sustainable agriculture through ensuring equitable water for irrigation and improving crop productivity (targets 2.3 and 2.4). The project in Uganda (see page *), also shows the potential for SWM to assist with aquaponics projects in regions where food sources are scarce, and fish sources act as the main source of protein for the community.

SDG 3. Good health and wellbeing for people

With clean water playing a major role in human health, improving the quality of water sources through SWM techniques has the potential to substantially support *reducing the number of deaths and illness from water pollution and contamination* (target 3.9).

SDG 4. Quality education

One of the surprising benefits of SWM implementation has been the increased opportunities presented for further education and capacity development, leading to *an increase in the number of youth and adults who have relevant skills, including technical and vocational skills, for employments, decent jobs and entrepreneurship* (target 4.4). This was shown in the Africa case study, where the reduced time required for women to irrigate crops led to available time for further education. In addition to formal education, acquiring vocational skills in technology design and development, community engagement and water and agricultural management has become one of the great social benefits to SWM implementation throughout these projects.

SDG 5. Gender Equality

Women's participation and equal opportunities for leadership at all levels of decision-making (target 5.5) was shown in the case study in Africa providing women with key roles in the government scheme (Agricultural Innovation Platform). The role of real-time community engagement tools also increases the role women can play in decision-making at a local level, as shown in the Paju case study. Another benefit as shown in the Africa case study was that as women's incomes have increased, joint decision-making and female decision-making has increased, and household conflict has reduced.

SDG 6. Clean water and sanitation

While the link between SWM and SDG 6, to improve access to safe water and sanitation and to improve sound management of freshwater ecosystems, may not be surprising, the variety of ways in which SWM can assist the achievement of this goal are worth noting.

To achieve universal and equitable access to safe and affordable drinking water for all (target 6.1) the Mexico case focused on improving water quality and education for the water users to increase receptivity to drinking tap water. In the Paju project, water quality was already safe, however the perception of the water quality led water users to buy bottled water. By using real-time data and communication approaches, Paju City was able to increase awareness and trust

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in the community, and as a result the increase in water users drinking tap water increased from 1% to 33% over three years.

To achieve access to adequate and equitable sanitation and hygiene for all (target 6.2) SIAAP integrated their sanitation networks and introduced real-time monitoring and mesh networks to treat the wastewater as it moved from one treatment facility to the next, resulting in increased water quality and improved ecosystems. In Mexico, the treatment of wastewater using real-time monitoring increased the safety of the water.

The use of SWM to improve water quality by reducing pollution (target 6.3) was addressed in numerous projects, including to treat wastewater (see France), reduce non-point pollution from fertilizers and stormwater runoff (see Africa and Canada), capture and treat rainwater (see Canada), and monitor and reduce contaminants in drinking water (see Mexico, SW4EU). One of the main goals of the MAGES project (France) was to reduce the pollutant loads discharged into the receiving water, especially during rain events. By monitoring and adjusting the levels of these pollutants in the Seine, SIAAP is able to contribute to improved water quality in the Greater Paris region. On a global scale, SIAAP is sharing knowledge on the technologies they have developed, providing the potential for these technologies to be replicated elsewhere in the world in the future.

To substantially increase water-use efficiency (target 6.4), SWM was used to improve efficient irrigation (see Africa), reduce leakages (see Paju, Mexico, SW4EU), reduce consumption (see China, Seosan, Mexico, SW4EU), capture and reuse rainwater (see Canada), increase storage of water (see K-HIT). In the case of China, water meters were installed to evaluate water saving methods, giving valuable annual feedback to decision-makers to enable them to adjust irrigation plans. In addition to this, by increasing the farmers' awareness of their water use and savings using real-time data, they were able to adjust their irrigation practices to irrigate more efficiently.

To implement integrated water resources management at all levels (target 6.5), K-water developed K-HIT, to integrate the management of numerous river basins and dams to provide a holistic action plan for water management in Korea, and to support rivers upstream and downstream with flood and drought resilience and improved water quality and quantity. In France, the SIAAP implemented integrated water and sanitation networks across Greater Paris (France), the Africa case study integrated water-use efficiency across the schemes using SWM tools and knowledge sharing platforms. For the FDMT project, integrated water resources management is one of the key management processes incorporated into the FDMT applications, including transboundary basins.

To protect and restore water-related ecosystems, including rivers (target 6.6), SIAAP reduced pollutant loads by treating the wastewater to a high quality to improve water quality in the Seine, restoring the ecosystem of the Seine, which has seen the return of over 30 fish species since the implementation of SWM in the Greater Paris sanitation network (see France).

To expand international cooperation and capacity building to support developing countries (target 6A), the case studies have shown that both planning and operation support and capacity building can be achieved. For example, the FDMT project equips transboundary agencies with the information and tools required to complete comprehensive assessment and plans to prepare for flood and drought disasters using satellite data, while K-water is currently supporting Indonesia with replicating their Seosan project to reduce leakages and improve water quality. The potential for further international cooperation and capacity building is also strong for SWM, though the context of each project must be taken into consideration, and local stakeholders engaged with from the beginning to ensure successful adoption and implementation of SWM.

Many of these projects show the potential for supporting and strengthening the participation of local communities in improving water and sanitation management (target 6B). This has been demonstrated through involving local authorities and the community in the projects from the beginning (e.g. Africa, FDMT, and Mexico) and learning from their experiences for how best to proceed (e.g. China). By supporting and engaging with local agencies and communities, these projects also empower local organisations and stakeholders to be better informed and to engage in decision-making.

SDG 7. Affordable and clean energy

As shown in the SW4EU case study, energy optimization can be implemented using SWM technology, increasing the efficient use of electricity and reducing energy use, supporting the target to *double the global rate of improvement in energy efficiency* (target 7.3). Treating water also uses a considerable amount of energy, therefore each of the projects introducing approaches to use water more efficiently and to reduce leakages (see Mexico, Paju, Seosan, France, SW4EU, Canada) in cities play a major role in improving energy efficiency.

SDG 8. Decent work and economic growth

Many of the case studies show the potential for increased jobs and economic growth through their SWM projects. Namely, K-water has shown within each of their case studies that by introducing SWM projects in Korea the job market has increased (for researchers and developers, project managers and construction) (target 8.1 and 8.2). In the Africa case, it was shown that household incomes have increased during the duration of the project, and reductions in irrigation time have led to opportunities to establish new small businesses or to undertake additional labour work for other farmers (target 8.5). There has also been an increase in youth farming in the schemes in Africa (target 8.6).

SDG 9. Industry, Innovation and Infrastructure Resilience

SWM links closely to targets 9.1 to *develop quality, reliable, resilient infrastructure to support economic development* and 9.4 to *upgrade infrastructure for resource efficiency.* One example of this is the MAGES system as demonstrated within the France case study. By introducing MAGES to SIAAPs traditional infrastructure, SIAAP was able to enhance the performance of the whole system to make it more adaptable to changing situations, enhancing resilient wastewater infrastructure in Greater Paris. The MAGES system also reduces energy and reagent consumption, contributing to making the system more sustainable. In the Mexico case study, PUMAGUA upgraded their disinfection system and wastewater treatment plant infrastructure to improve resource efficiency, sustainability and resilience.

SDG 10. Reducing inequalities

SWM implemented in developing countries can go a long way to reducing inequalities. This can be by providing support and income growth for the bottom 40% of the population (target 10.1; see African and Uganda), *empowering and promoting social, economic and political inclusion for all* (target 10.2; see Africa, Argentina), and *promoting equal opportunities* (target 10.3; see Africa, Uganda, Argentina) for women and youth.

SDG 11. Sustainable cities and communities

To build sustainable cities and communities, cities and human settlements must be made to be inclusive, safe, resilient and sustainable. Several of the case studies have shown how SWM can contribute to building these types of cities and communities through protecting natural and cultural heritages sites (target 11.4; see FDMT case study) and reducing the number of deaths and economic losses caused by flood and drought (target 11.5; see K-HIT, FDMT, France and Canada). For example, K-HIT demonstrates this through efficiently supplying water to drought using integrated SWM systems and by minimizing damages caused by water disasters in preparation for floods.

The protection of human settlements is also supported at various scales within the FDMT and China projects, through *strengthening national and regional development and planning* (target 11A; FDMT), and *increasing cities integrating plans, resources efficiency and adaptation to climate change* (target 11B; see FDMT, China, SW4EU and Canada). In addition to the informative tools and research that the China project provides the government for decision making and planning for resilience to extreme weather and emergency situations, their findings also enable policy recommendations to be made to the government to assist other developing nations to implement smart tools and technology.

SDG 12. Responsible consumption

To ensure sustainable consumption and production patterns, SDG 12 requires *strong national frameworks integrated into national and sectoral plans, practices and consumer behaviour*. Sustainable management and efficient use of resources (target 12.2) is addressed by several of the case studies (see Paju, Seosan, France, Mexico, SW4EU, China, Canada) through efficient water use, leak reduction, energy optimisation and reduced reagent consumption. To *ensure relevant information and awareness for sustainable consumption and development* (target 12.8), many of the projects placed a high importance on education and information dissemination (e.g. Paju, Mexico, SW4EU, China), insuring water users have the relevant information for sustainable consumption.

To *support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns and consumption* (target 12A), programmes such as UNAM's PUMAGUA act as a model for developing countries by sharing the scientific and technical lessons they have learned while implementing SWM, building the capacity for developing countries to leapfrog any challenges they have faced throughout their implementation. Other projects look to develop capacity by providing training (see FDMT, Africa) and scientific experience (see Indonesia text box).

SDG 13. Climate action

Every country in the world is affected by the climate change and its impacts. As a result all countries need to strengthen their resilience to climate-related hazards and natural disasters (target 13.1), such as floods and droughts. Three of the case studies directly address this target by optimizing infrastructure to manage crisis situations (e.g. see France), reducing pressure on centralised infrastructure in the case of flooding (e.g. see Canada) and by integrating SWM into adaptive planning and forecasting (e.g. see FDMT).

In order to integrate climate change measures into national policies, strategies and planning (target 13.2) the FDMT case uses climate data and forecasting to integrate plans for future flooding and drought events in developing regions. The planning tools utilized through the FDMT platform, encourage improved preparations and effective decision-making based on climate data and forecasting of hazards to be incorporated into national plans, especially in least developed countries such as those in the Volta and Lake Victoria pilot basins (target 13.B). Furthermore, the stakeholder training and information dissemination conducted throughout the FDMT project contribute to target 13.3 *in improving human and institutional capacity to handle climate change impacts*.

Increasing awareness of climate change adaptation has also been a key focus of the case studies in Mexico and SW4EU. A significant aspect of the PUMAGUA program was in education and information dissemination, through the Water Observatory and several communication campaigns, in order to increase awareness and participation. This aligns with several targets within the SDGs including 13.3 (to improve capacity for climate change impacts). The Canada and SW4EU projects both enabled community participants to be better informed about their local climate and rainfall data. The projects also showed the potential for SWM projects to raise capacity for climate change management in developing countries (target 13B, see FDMT and Mexico).

SDG 14. Life below water

While SWM often focuses on water for irrigation, human consumption, industry and sanitation, we must also consider how it can support our oceans, seas and marine sources. One way in which SWM is already doing this is through reducing marine pollution (target 14.1). By increasing irrigation efficiency, nutrient leaching reduces leading to reduced nutrient runoff and non-point source pollution into our rivers (see Africa case). By collecting rainfall at the source and reducing stormwater, non-source pollution from roads and footpaths is reduced (see Canada case study). By reducing contaminants in sanitation and returning the water in a clean state to our waterways, ecosystems can be restored, including fish stocks returning to their former numbers (see France). In this way, SWM is already providing considerable assistance to protecting and conserving our waterways, both inland and marine waterways. In the future, direct management of marine sources using SWM is a possibility, and one that could assist in protecting life below water even more.

SDG 15. Life on land

To protect life on land, land degradation must be reduced. To this end, both the K-HIT and FDMT projects provide flood and drought management to address land degradation (target 15.3) through operational action (see K-HIT) and planning approaches (see FDMT). By reducing land degradation to achieve neutral land degradation, terrestrial ecosystems can be protected, leading to reduced destruction of natural habitats and loss of biodiversity (target 15.5).

SDG 16. Peace, justice and strong institutions

One of the important aspects to promoting inclusive societies for sustainable development is ensuring responsive, inclusive, participatory and representative decision-making at all levels (target 16.7). As shown in through these case studies, the sharing of SWM data and engagement tools within the community opens up the opportunity for participatory decision-making. This has been shown consistently throughout the case studies (e.g. Africa, Paju, Mexico, SW4EU, Canada, FDMT). By providing real-time data, communities gain a greater awareness of the challenges faced, and are able to make decisions based on this data instead of based on the information passed on to them by other governing agencies. This has been shown to increase trust (see Mexico and Paju), develop stronger institutions (see Africa) and improve responsiveness and inclusivity (see China and SW4EU).

Another important aspect addressed by the SWM is the potential to develop effective, accountable and transparent institutions at all levels (target 16.6). With real-time data available at all levels, transparency is now increasingly possible, making each actor accountable for their actions and opening opportunities for more effective collaboration for SWM.

SDG 17. Partnership for the Goals

In order to reach global sustainable development, strong partnerships, cooperation, knowledge sharing and capacity building are essential. Each of these projects have shown the potential for SWM to support collaboration and skill and knowledge transfer. This has been shown through collaborations between local and international agencies (see FDMT, Africa, China), capacity building for local workers (see Paju, Africa, FDMT) and enhancing knowledge sharing through partnerships (see K-HIT, Mexico, France, China). By sharing the lessons each of these projects has learned during their SWM implementation, upcoming projects in other countries gain experience and knowledge in what has worked in the past, what technologies can be used and what could work in the future in their region. By providing this support, these projects are supporting future projects to leapfrog any past challenges, and to implement successful SWM in the aim of reaching global sustainable development together.

CHAPTER 4. Conclusions and next steps

The SWM projects included within this report have shown the considerable potential for SWM to assist with numerous water challenges, across various scales, geographic locations and developing and developed regions while also creating social, economic, environmental and governance benefits. These projects have also demonstrated the enormous potential for SWM to assist with reaching the SDGs, across a number of goals and targets.

While it is important to recognise that each project is set within its own context, and therefore the results seen within these projects are also contextual, the overarching lessons that have emerged as part of this report highlight the similarities across contexts to show how SWM can be successfully implemented around the world, and what challenges there are still to face.

As SWM is still an emerging field these projects show the very beginning of what can be achieved using SWM technology and solutions. As the field progresses and technologies evolve, the potential for SWM adoption across all contexts will continue to grow, leading to increased opportunities for both developed and developing regions, and innovative solutions for our current water challenges.

In order to continue learning from these case studies, it is important to follow them on their journey to see how challenges are addressed as the technology evolves, and what impact introducing SWM continues to have in their region. To follow how the scaling up or down of a SWM project can affect its impact, and whether replication in various contexts results in new challenges to be addressed. It will also be interesting to see how SWM can move from the development and pilot stage to market - in other words, how SWM can become self-sustaining without reliance on initial government support in the early phases.

At this stage, many of these projects have shown the potential for SWM technology to successfully resolve water challenges. To build a business case for scaling and transferring these solutions, monitoring and measuring the benefits of SWM solutions must continue. In this way, capital investors will see the benefits and potential of SWM, potentially leading to future investment.

Now that a wider number of smart tools are on the market, integrated smart technologies to form smart networks will start to emerge, and with it increasing opportunities for sustainable cities and regions to integrate their smart systems.

This report demonstrates how far SWM has already come in a short time and the considerable benefits it can provide in both developed and developing regions. It also explores some of the constraints and barriers encountered to date. In the end, however, it is certain that SWM has nearly unlimited potential to contribute to the realization of the goals of integrated water resource management and sustainable development through smarter management of water.

CHAPTER 5. Glossary of Acronyms and Abbreviations

4MRRP	Four Major River Restoration Project
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AESN	Seine-Normandy Water Agency
AfDB	African Development Bank
AI	Artificial Intelligence
AIP	Agricultural Innovation Platform
AMI	Automated Metering Infrastructure
AMR	Automated Meter Reading
AMZ	Automatic Meter Readings
ANN	Artificial Neural Network
ANU	Australian National University
BBN	Bayesian Belief Nets
BCP3	Community Based Public Private Partnerships
BED	Binomial Event Discrimination
BOD	Biochemical Oxygen Demand
BRAIN	Bio-reactor Plants
CAADP	Comprehensive African Agricultural Development Plan
CCA	Causal Chain Analysis
CCTV	Closed Circuit Television
CDMA	Code Division Multiple Access
CFPD	Comparison of Flow Pattern Data
CGS	Chinese Geological Survey
CIGEM	Centre for Migration Management and Information
COD	Chemical Oxygen Demand
CONAGUA	National Water Commission, Mexico
CPA	Consumption Prediction Algorithm
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSL-CDA	Customer-side-leakage Discrimination Algorithm
CSO	Combined Sewer Overflows
DBM	Dynamic Bandwidth Monitor
DMA	District Metered Area
DMZ	Dematerialised Zone
DSS	Decision Support Systems
EA	Electrically actuated
EDEN	Environmental Data Exchange
EIP	European Innovation Platform
EMF	Electro Magnetic Flow
EPA	Environmental Protection Agency

ETH	Swiss Federal Institute of Technology Zurich
EVT	Energy Visualisation Tool
FAO	Food and Agriculture Organisation
FAS	Flood Analysis System
FDMT	Flood and Drought Management Tool
FMZ	Flow Monitoring Zones
FRC	Free Residual Chlorine
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gases
GI	Green Infrastructure
GIOS	Generation Integrated Operation System
GIS	Geographic Information Systems
GIWP	General Institute of Water Resources and Hydropower Planning and Design
GPRS	General Packet Radio Service
GPS	Global Positioning System
GRDP	Gross Regional Domestic Product
GUI	Graphical User Interface
GWP	Global Water Partnership
ha	Hectare
HB	Hydraulic Balance Algorithm
HPC	High Performance Computer
HWL	High Water Level
IC	Integrated Circuit
ICT	Information and Communication Technology
IDB	Inter-American Development Bank
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IW	International Waters
IWA	International Water Association
IWA	International Water Association
IWRA	International Water Resources Association
IWRM	Integrated Water Resource Management
IWRMS	Integrated Water Resource Management System
K-HIT	K-water Hydro Intelligent Toolkit
K-water	Korea Water Resources Corporation
KMA	Korea Meteorological Administration
KRW	South Korean won
LAN	Local Area Network
LCD	Liquid Display Crystal
LEC	Local Electrification Company
LID	Low Impact Development
LIFT	Leaders Innovation Forum for Technology
LPWAN	Lower Power Wide Area Network

LRV	Log Reduction Values
MAGES	Model Assistance for the Management of SIAAP Effluents
MCA	Multi Criteria Analysis
MNCM	Minimum Night Consumption Monitoring
MNF	Minimum Night Flow
MODFLOW	Modular Hydrologic Model
MOLIT	Ministry of Land, Infrastructure and Transport
NASA	National Aeronautics and Space Administration
NB-IoT	Narrowband Internet of Things
NEMA	National Environment Management Authority
NGO	Non-governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
NRW	Non-revenue Water
O&M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
OFID	OPEC Fund for International Development
OPEC	Organisation of the Petroleum Exporting Countries
P3	Private Public Partnership
PFS	Precipitation Forecasting System
pH	Logarithmic scale used to specify the acidity or alkalinity of an aqueous solution
PIR	Project Implementation Reviews
PMA	Pressure Management Area
PMF	Probable Maximum Flood
PMU	Project Management Unit
PoE	Power over Ethernet
PRV	Pressure Reducing Valve
PUMAGUA	Program for Management, Use, and Reuse of Water
QPF	Quantative Precipitation Forecast
R&BD	Research and Business Development
R&D	Research and Development
RCP	Representative Concentration Pathways
RHDAPS	Real-time Hydrological Data Acquisition and Processing System
RSSUT	Residential Stormwater Smartgrid Utility Technology
RTC	Real-time Control System
RTMMS	Real-time Reservoir Turbidity Monitoring and Modelling System
RwH	Rainwater Harvesting
RWSS	Reservoir Water Supply System
SAMS	Stochastic Analysis Modelling Simulation
SAP	Strategic Action Programme
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SDMA	Sub District Metering Area
SHP	Small Hydropower

SIAAP	Interdepartmental Syndicate for the Sanitation of Greater Paris
SICT	Sensing, Information and Communication Technology
SMART	Specific, Measureable, Actionable, Relevant and Time-based
Smart T-M	Smart Tele-metering
SMS	Short Messaging Service
SPI	Standardisation Precipitation Index
SSA	Sub-Saharan Africa
SVM	Support Vector Machines
SW4EU	Smart Water For Europe
SWC	Smart Water City
SWG	Smart Water Grid
SWING	Smart Water Innovation Network in the city of BurGos
SWM	Smart Water Management
TDA	Transboundary Diagnostic Analysis
TP	Total Phosphorus
TRMM	Tropical Rainfall Measuring Mission
TWIST	Thames Water Innovation and Smart Technology
UFW	Unaccounted for Water
UN	United Nations
UNAM	National Autonomous University of Mexico
UNEP	UN Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USD	United States Dollar
UV	Ultra violet
VIA	Virtual Water Academy
VIP	Vitens Innovation Platform
WAN	Wide Area Network
WB	World Bank
WDS	Water Distributed System
WFD	European Water Framework Directive
WHO	World Health Organisation
WRF	Water Research Foundation
WRIAM	Water Resource Issue Assessment Method
WSP	Water Safety Planning
WWTP	Wastewater Treatment Plant

CHAPTER 6. References

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