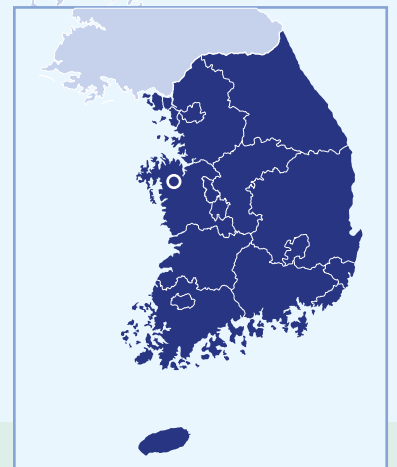


Case Study of Seosan Smart Water Management

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South Korea ○ Seosan

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Summary

Water management has become increasingly important over the past decades with increase of the natural hazards and disasters caused by climate change, deteriorating water management facilities, and increased water consumption due to population growth and urbanisation in Korea. To solve these water challenges and improve the efficiency of water management, K-water has introduced ICT (Information and Communication Technology) in their water management. Water management using ICT, known as Smart Water Management (SWM), enables sustainable water supply to every citizen by water resource monitoring, problem diagnosis, efficiency improvement and harmonising management.

The Smart Seosan City project started when Seosan city asked for a smart metering system for the Seosan local water supply system as a drought measure in January 2016. Seosan city decided to employ smart metering to the local water system when regional and national drought reaction plans were established according to laws and plans. Before this project, K-water was operating smart metering as a pilot project in the Goryeong area (from January to May 2015) and had consigned Seosan’s local water supply. K-water suggested smart metering to Seosan city and the city accepted this suggestion. The main purpose of the project was to construct smart water management systems, which focus on reducing water leakages and consequently improving revenue water ratio by using remote metering, smart meters and Information and Communication Technology. Unlike a human read meter, which relies on a person to manually check the data on a meter on site, these smart meters deliver a user’s hourly water usage via digital meter (smart meter) and wireless communication technology (ICT).

Consequently, the project results show 20% improvement in the revenue water ratio and 190,000 m³ of water per year decrease in leakage. This results in a benefit of USD 590,000 over the next 8 years and the cost benefit is expected to increase. By switching to using remote meters for water use and quality, customers’ satisfaction has been improved as it has become possible to handle complaints promptly and also to provide additional water quality management services. Government support played a major role in the implementation of this project, as the planning and execution of the drought policy, existing laws and system helped state and local government and public institutions plan measures systematically and react in a concerted manner. In addition to this, the government budget support for the project was essential in facilitating the project’s implementation. Seosan smart water management required early facility investment and operating costs but in the long term, an increase in net profit is expected. As the smart water market is becoming more active with many companies competing, future costs are expected to decrease. Smart metering enables a sustainable water supply by reducing water leakages and saving water and energy. When water supply is reduced or limited by drought or other challenges, new water resource development is needed to supply water stably.

1. Background

Country: Republic of Korea (South Korea)

Population: 51.25 million

City: Seosan City, South Chungcheong Province

Population of Seosan City: 173,715

Climate: Humid continental

1.1 The importance of Water Management

Water management has become an issue of increasing importance over the past decades as a number of factors including climate change induced natural hazards and disasters, deteriorating water management facilities, population growth and megalopolitanisation continue to impact already scarce water sources. This reduced water availability leads to an increase in famine and disease, and creates increased water insecurity and conflict in predominately developing countries. Water insecurity is also felt in the Republic of Korea, where drought caused by the changing climate is causing concerns for water access in many areas.

1.1.1 The changing climate in Korea

As the 5th evaluation report published by the Intergovernmental Panel on Climate Change (IPCC) in 2014 predicted that if the average global temperature increased by 2 degrees increases in coastal flooding would create a risk for food production, species and ecosystem protection, and land loss, it is of great concern that Korea's average temperature has already risen by almost half of this (0.89 degrees) over the past 112 years (1990 to 2012).

In addition to increased temperatures, average annual precipitation over the past three decades has also increased from 1,310mm (in the 1980s) to 1,382mm (since 2000). According to the Representative Concentration Pathways (RCP) 4.5 scenario¹ the Korean peninsula will have a higher annual average precipitation growth rate than the world average, increasing by 10.3% in the mid 21st century (2041-2070) and by 19.6% in the second half of the century (2071-2100). At the same time, great regional deviation is expected.

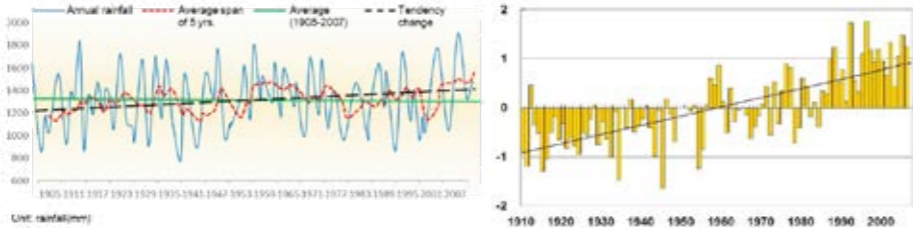


Figure 1. Changes in rainfall and average temperature (6 cities) in Korea (Source: MOLIT (2017) The 4th Long-term Comprehensive Plan for Water Resources (2001-2020), 3rd Revision

1.1.2 Population growth and urbanisation

As the population of Korea has increased from 31.4 million in 1970 to 49.7 million in 2015 (a 58% increase), water shortages already play a major role in Korea. In addition to the rapid population growth rate, a significant increase in both the water supply rate (from 31.2% in

1. The Representative Concentration Pathways (RCPs), which IPCC introduced for the 5th Assessment Report, describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use. RCPs include a stringent mitigation scenario (RCP 2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one scenario with very high GHG emissions (RCP8.5). RCP4.5 means that the carbon dioxide concentration is 540ppm and the greenhouse gas reduction policy has been realized considerably.

1970 to 98.8% in 2015) and urbanization in Korea over the past 50 years (from 40.7% in 1970 to 82.5% in 2015) has resulted in the strong need to focus on water management in Korea.

Table 1. Population and urbanization rate in Korea

Year	1970	1975	1980	1990	2000	2010	2015
Population (thousand)	31,435	34,678	37,406	43,390	45,985	47,041	49,705
Urbanization rate (%)	40.7	48.0	56.7	73.8	79.6	81.9	82.5

Source: Statistics Korea, KOSIS (Korea Statistical Information Service)

1.1.3 Deterioration of water management facility

Annual financial loss due to the deterioration of water management facilities and infrastructure in Korea is estimated at USD 500 million dollars (comparable in per capita terms to the 3.4 billion dollars in the United States, with over 6 times Korea's population). As it is has been predicted that deteriorated water management facility replacement and repairs will cost the United States 334.8 billion dollars over the next 20 years (EPA, 2009); Korea is quickly working towards ensuring they do not also face these high long-term costs for deteriorating infrastructure.

1.2 Present conditions of Seosan

1.2.1 General conditions

The geographical scope of this project is Palbong-myun, Seosan city, Korea. Seosan city is located in the Taean peninsula, north-west of Chungchungnam-do on the west coast of Korea (see Figure 2). Mountains such as Mt. Gaya and Mt. Palbong surround it to the north and the south. Its annual average precipitation is 1,285.7mm and annual average temperature is 17.3°C. Seosan city covers an area of 741.21 km² and (when including Palbong-myun (51.34km²); it consists of 1 eup (town), 9 myun (townships) and 5 dong (neighbourhoods). It has a long and complicated coastline and two lakes, Lake Ganwol (2,164 ha) and Lake Bunam (1,021ha), which were created by the Chunsu gulf reclamation project.

The west coast area, including Daesan Seaside Manufacturing Area, is now developing due to a newly constructed west coast highway and active trade with China; Seosan has therefore emerged as a main city of Chungchungnam-do. The local economy is booming due to the newly built manufacturing area, which includes such companies as Daesan petrochemical complex, Seosan Techno Valley and the recent transfer of the head offices of big enterprises such as Hyundai Oil bank, Hanhwa Total and Hyundai Powertech.



Figure 2. Location of targeted area (Palbong-myun, Seosan city (Source: K-water)

1.2.2 Population Growth and Seosan City's Economy

In line with the national population growth rate, the population of Seosan City has increased by 5% in only four years, from 164,345 in 2011 to 175,132 in 2015. The Gross Regional Domestic Product (GRDP) of Seosan City is 51.5396 trillion won (USD 47.7 billion), which is predominately created through the commerce and services industry (69.3% of the workforce), along with mining and manufacturing (30.1% of the workforce). Only 0.4% of the population works in agriculture and fisheries, demonstrating the highly urbanised nature of Seosan city.

1.2.3 Water supply, drainage facility and water source

Since 2006, Seosan City consigned its water facility to K-water and has been receiving 67,200 m³ of filtered water per day (Statics of waterworks, 2015) from the multiregional water supply of Boryeong Dam, without its own treatment facility. The pipeline of Seosan water supply is 2,041km long and includes 10 distributing reservoirs, 23 booster stations and 22,487 hydrants. In Palbong-myun, the length of the pipeline is 218km and the number of hydrants is 1550. In 2015, Seosan city's water distribution rate was 92% and water consumption per person was 262.5 litres. Respectively, the water distribution rate and water consumption per person in Palbong myun were 97.7% and 191.7 litres. Revenue water ratio of Seosan water supply facility improved dramatically after consignment. Comparing to a rate of 65.3%, before consignment, the revenue water ratio of 2016 had dramatically increased, reaching 82.8%.

Box 1. Water supply system of Korea

In Korea, K-water functions as a wholesaler and supplies multiregional water supply. On the other hand, the local water supply system is supplied by the municipal government, which functions as a retailer. K-water withdraws water from dams and rivers to supply multiregional water supply and industrial waterworks while local government supplies water to residents through its own water source or multiregional water supply. Some of the local water supply system is managed by K-water by consignment¹.

Multiregional water supply

K-water withdraws water from water dams and multipurpose dams, and treats it. It supplies water to local governments and industries. Local governments deliver this water to households. In 2014, K-water operated 35 multiregional water supplies. 60.2% (8,285,000 m³ per day) of the total capacity (13,860,000m³per day) was concentrated in metropolitan areas, consuming 52.9% of the total water supply.

Local water supply system

The Seosan water supply system receives its water from both outside Seosan (from multiregional sources) and local water sources, and supplies its water to households and industries.

In December 2013, there were 162 local water suppliers in Seosan (7 metropolitan cities, 1 metropolitan autonomous city, 1 special self-governing province, 75 cities and 78 districts). The water supply ratio was 98.5% and penetration rate of sewage treatment equipment was 92.1%.

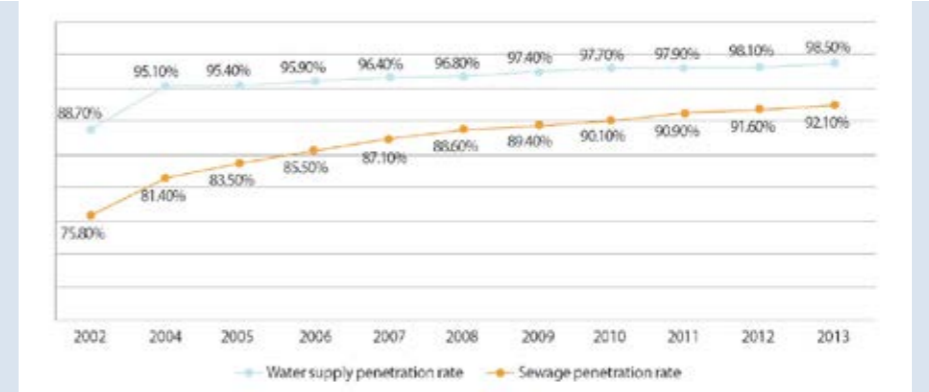


FIGURE 3. Water supply & sewer service ratio

Boryeong dam is the main water source for Seosan city, supplying 240,000 m³ of water per day to the west area of Chungcheungnam-do's 8 cities² and districts (480 thousand people) including Seosan city and 5 thermoelectric power plants. Seosan city is the largest consumer demanding 18 millions m³ of water per year and Chung-yang district is provided smallest amount, 1.2 millions m³ annually. Boryeong dam is quite a small basin area (163.6 km²) despite this it provided approximately 90 million m³ of water to 8 cities and districts in 2013. It provides 84% of its supply capacity, which is approximately 106 million m³ per year.

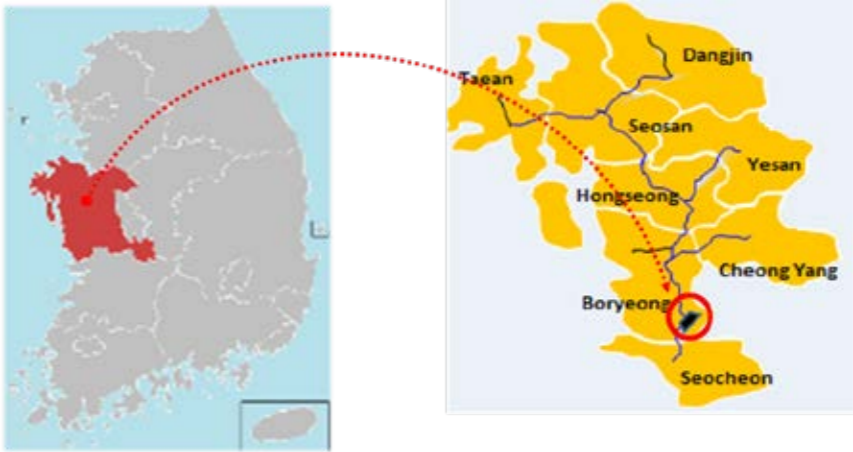


Figure 4. Boryeong dam and the 8 cities supplied water from the dam (Source: K-water)

Status of Facilities in Palbong

Palbong distributing area supplies water to its neighbourhood with 2,099 hydrants supplying 2,431m³ per day. Its revenue water ratio before the SWM Seosan project was estimated at approximately 60%. The whole pipe consists of polyethylene (PE) pipe, which was installed between 2009 and 2011, and small calibre under 15mm supplying 97% of the water.

Table 2. Pipe conduit and hydrant in Palbong

mm	13	15	20	25	32	40	50	Total
Hydrant	2,006	23	47	13	7	2	1	2,099
%	96%	1%	2%	1%				100%

Source: K-water

2. Boryeong, Seosan, Yesan, Hongseong, Taean, Seochun, Dangjin, Chungyang

Palbong is a large mountain area of 54 km² with a non-metallic pipeline of about 218 km, making leakage management very difficult. In addition, despite night minimum flow being relatively high (approximately 47 m³/hour) flow and leakage analysis during the night is limited to two points only (P-A and P-B, see Figure 6).



Figure 5. Minimum night flow of Palbong district (m3/hour), 2015 (Source: K-water)

The District Metered Area (DMA) P-A uses water from a small population of about 1,550 service connections in a large mountain area. On the other hand, the DMA P-B usually consists of larger users such as apartment blocks, shopping malls and the army force accounting for 50% (23 thousands m³/month) of the total supply, and therefore has a higher requirement for regular monitoring.

While the distributing reservoir is located in the hillside (HWL 89m) most of the Palbong district consists of waterfront lowland (EL. 10~30m). Therefore high hydraulic pressure is required (more than 588.4 Kilopascals) in the pipe conduit.

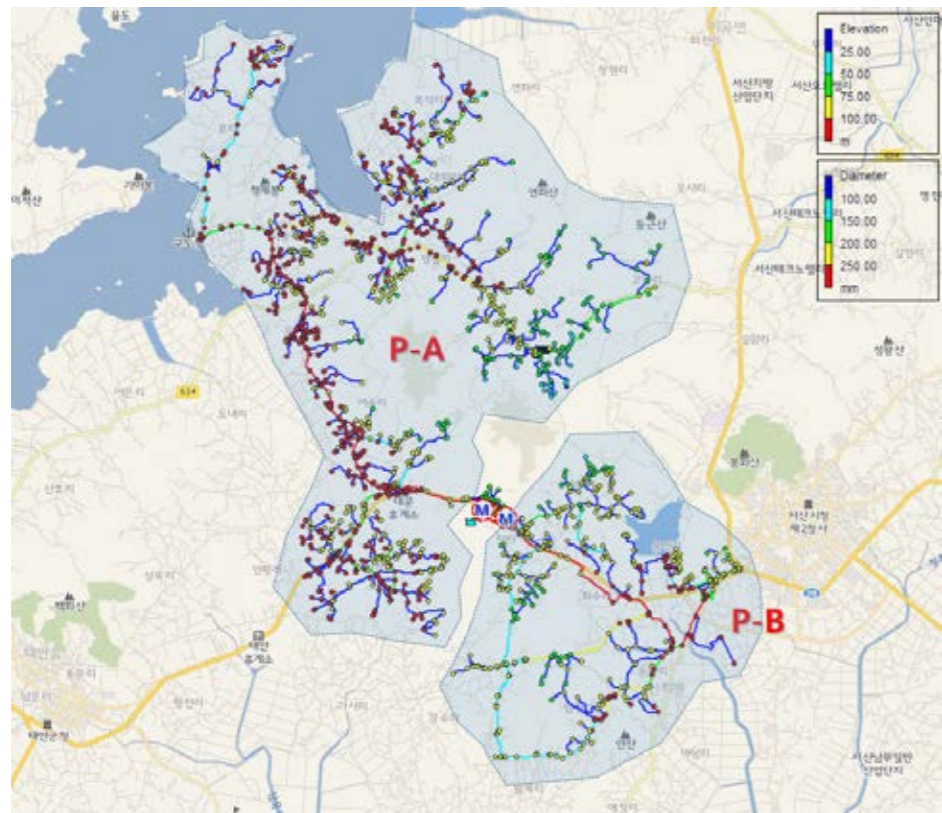


Figure 6. The area of P-A and P-B DMA (Source: K-water)

< Invert Height (EL.m) in distributing area >

< Distribution of hydraulic pressure in the area (m) >

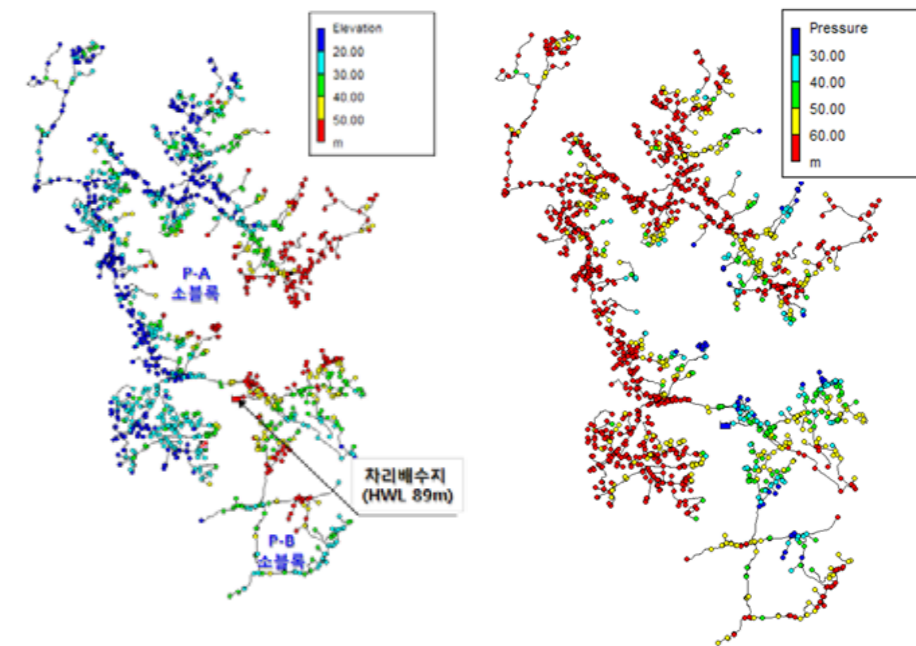


Figure 7. Hydraulic pressure and invert height in distributing area (Source: K-water)

1.3 Challenge description

1.3.1 Drought

Korea has experienced damage caused by intensifying climate variability and increasing frequency of floods and droughts over the past 100 years. Change in precipitation shows a growing tendency from the 1990s with annual precipitation showing considerable variations over the past 100 years from a minimum of 764mm (1939) to a maximum of 1,756mm (2003).

In addition, drought conditions have intensified with 2013 recording only 89% of the average annual precipitation and 2014 recording 90%. In 2015, average precipitation (965mm) was only 72% of that in a normal year (1,342 mm), 3rd lowest in recorded history. Droughts have occurred every 5 to 7 years nationwide since the 1970's and unlike floods, which occur only during summer, droughts can occur throughout the year.

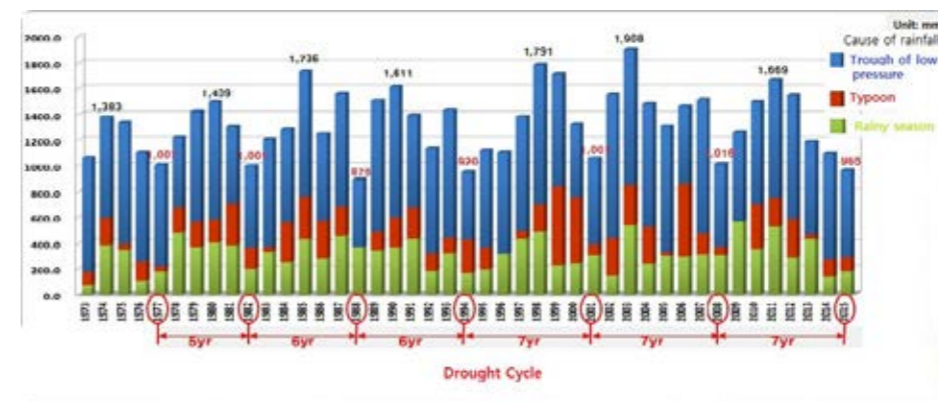


Figure 8. Precipitation by year

Table 3. Regional precipitation in 2015

Area (mm)	Nationwide	Seoul, Gyeonggi	Gangwon Youngseo	Chungnam	Jeonnam	Gyeongnam
Precipitation	964.9	746.8	787.2	811.5	1266.2	1320.3
Average year	1342.0	1359.3	1327.2	1310.9	1403.4	1498.8
Percentage (%)	71.9	54.9	59.3	61.9	90.2	88.1
The Lowest rank	3	1	2	2	18	17

Source : K-water

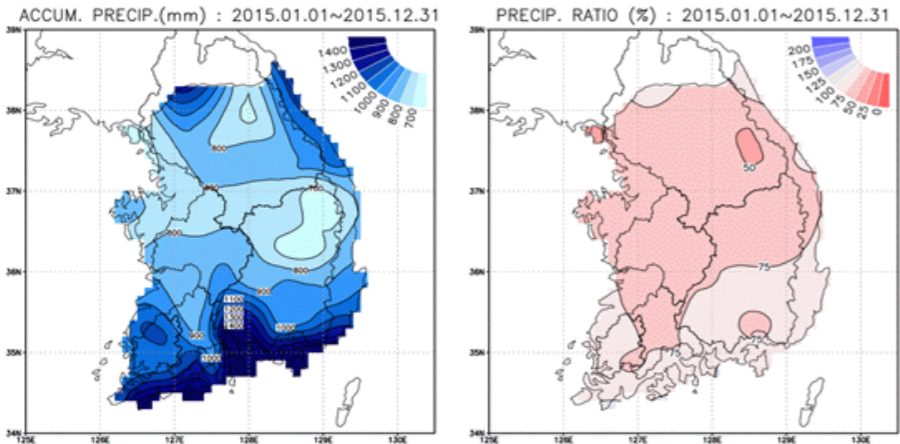


Figure 9. 2015 Korean annual average accumulated precipitation (left) and precipitation ratio compared with that of average year (right)
(Source: K-water)

Box 2. Water challenges in Korea

Water shortage caused by lack of precipitation from 2014 to 2015 started from the upper region of the Han River and spread to the whole country including the Nakdong River. The successive low precipitation of 2014 and 2015 made the drought more serious. In Korea, the accumulation of two years of consecutive precipitation (of 2,162mm) was only 81% of the annual average (2,684mm) and recorded the 5th lowest precipitation in history. A drought in 2015 caused by a shortage of precipitation resulted in 60% of the precipitation occurring during typhoon and rainy season. In the early to mid-rainy season the rain front was located in the southern part of Korea due to the North Pacific high (a semi-permanent, subtropical anticyclone), and did not pass until the late rainy season when the North Pacific high weakened.

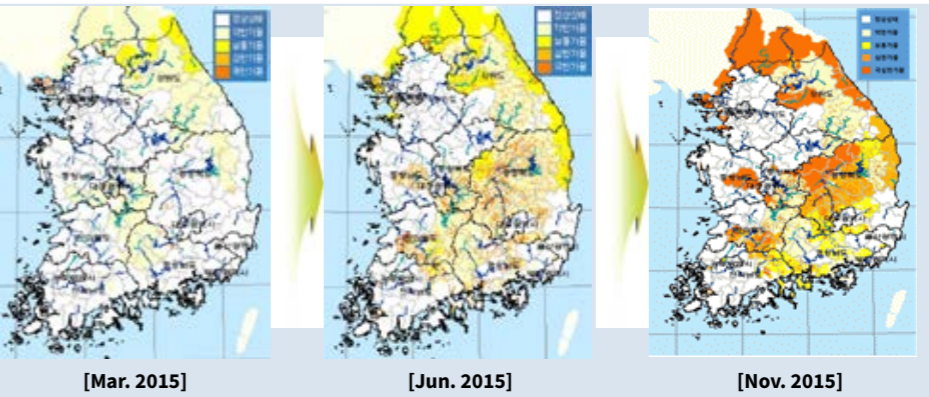


FIGURE 10. Change in Water Supply Drought Index²

TABLE 4. Regional precipitation in 2014-2015

Area (mm)	Nationwide	Seoul, Gyeonggi	Gangwon Youngseo	Chungnam	Jeonnam	Gyeongnam
Precipitation (2014~2015)	2162.2	1549.1	1508.3	1881.7	2781.0	2923.7
Average year	2684.1	2718.5	2654.4	2621.7	2806.8	2997.5
(%)	80.6	57.0	56.8	71.8	99.1	97.5
The Lowest rank	5	1	1	1	22	22

Source: Since 1973, based on 56 local offices of Korea Meteorological Administration (KMA)

In 2015, the total inflow rate in the Boryeong dam was 7.83 billion m³ (43.7% of the average year) and during the summer (July to September), the inflow rate was only 3 billion m³ (25% of the annual average) and drought level of 200 years cycle. After November, the total inflow rate was 7.7 billion m³ (121.7% of average year) due to frequent rain. On January 1st 2016, nine of 18 multi-purpose dams reported deficient pond levels.

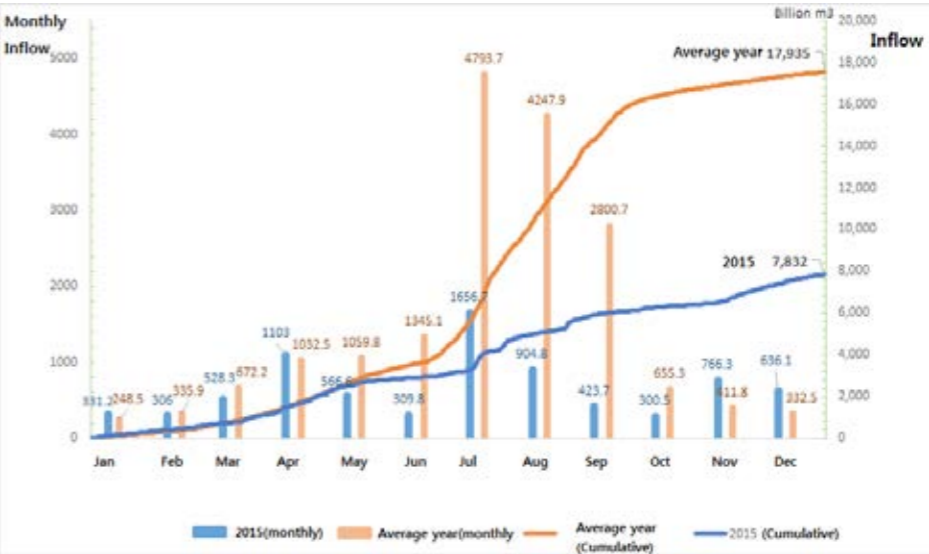


Figure 11. Inflow rate of multi-purpose dam in 2015
(Source: K-water)

1.3.2 Decrease water reserve rate of Boryeong dam and increase supply

The Boryeong dam was constructed from 1998 to April 2016. Investigation results on annual average storage ratios show that the dam storage ratio is decreasing, with the annual average storage decreasing by 25.2% when compared with that in 2014.

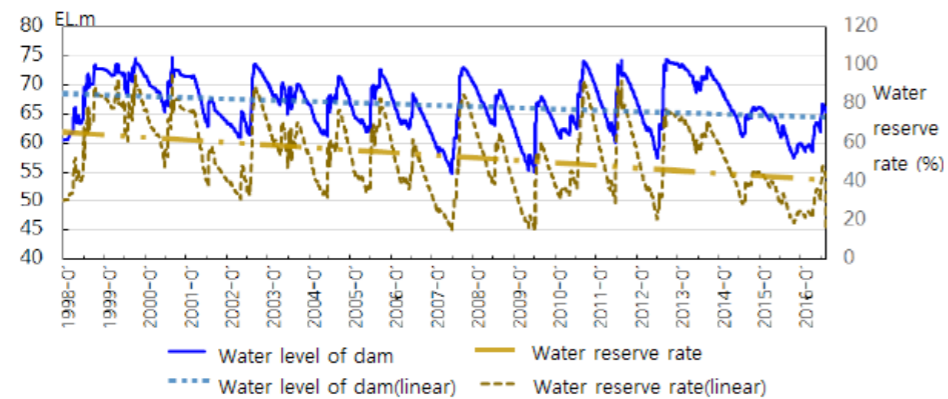


Figure 12. Change in water level of Boryeong Dam and its water reserve rate³ (Source: K-water)

Due to the development of a new city area (Naepo New Town⁴) and power plant and industrial complex construction, water demand and supply are increasing in the Chungnam area. Results from research on Boryeong's multiregional water supply over a 10 year period show that Boryeong supplied 38.253 million m³ of water to 15 water supply contractors in 2005 which increased to 71.613 m³ of water to 23 water supply contractors in 2014. Showing an increase in water supply of 1.87 times compared with that of 2005 and an increase in contracts by 1.5 times⁵.

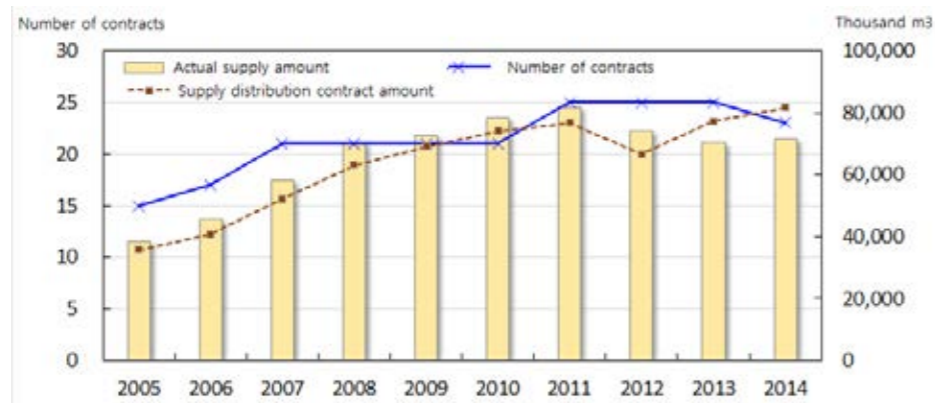


Figure 13. Statistics of annual supply of Boryeong dam multiregional water supply in last decade (2005~2014) (Source: K-water)

Boryeong dam's water supply capability and effective reservoir capacity are very close, creating a major risk if water withdrawals continue during periods without stable rainfall. A one year drought alone is capable of causing serious damage to the water resource supply. The inflow rate of July 2015 to September 2015 (during the rainy season) was just 15.1 million m³, 15.3%, of the average inflow rate of average year, worse than the 200 years cycle of drought.

3. K-water, www.kwater.or.kr

4. Naepo is new town of Chungnam. The construction of Naepo New Town, which becomes the new host city of Chungnam Provincial Office and the Province's new hub city. It settled down in an area of 9,950,521m² over Hongseong and Yesan.

5. A study on assessment water supply capacity of Boryeong dam and drought measures, Chungnam institute, 2016

From January to October 2015, the accumulated inflow rate recorded a minimum after dam construction, and after November, there was 16 million m³ of water inflow, 4 times larger than that of the average year, while the annual total amount was only 42.5% of that of average year. As the drought continued from 2014, the water of the dam recorded its lowest level in history and caused a water supply suspension crisis (dam exhaustion crisis) in western Chungnam area. On October 30th 2015, it recorded 19.7% of the storage ratio and only had 33% of that in an average year (23.07 million m³ in basic date and 70.2 million m³ in average year). This was about 22 million m³ below the historical record low storage amount of 45 million m³ recorded the previous year.

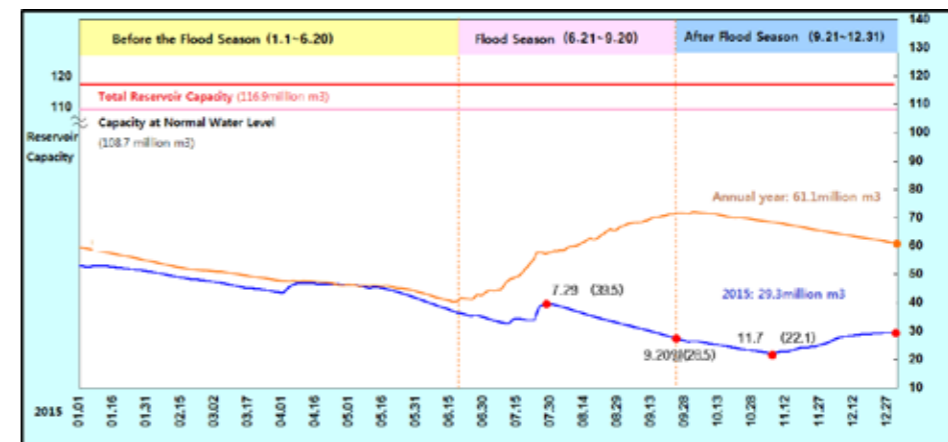


Figure 14. Water reserve rate of Boryeong dam in 2015 (Source: K-water)



Figure 15. Water gate of Boryeong revealing its bottom (2015.10.24) (Source: K-water)

These drought conditions resulted in severe water shortages and concern for domestic water supply. To address this the Ministry of Land, Infrastructure and Transport (MOLIT), K-water and local government established and promoted a reaction plan for dam supply adjustment, water supply system adjustment and a restriction on water supply.

Box 3. Water restrictions at Boryeong Dam

Water restrictions at Boryeong Dam consisted of three stages. The first stage (serious level 1) started from August 18th 2015 and finished on February 15th 2016, lasting a total of 127 days and resulted in saving 4.047 million m³ in only 22 days.

- **First stage (serious level 1):** 91% of dam supply and 9% of water distribution system adjustment. Supply 100% of domestic and industrial water
- **Second stage (serious level 2):** 71% of dam supply and 9% of water distribution system adjustment. Supply 80% of domestic and industrial water
- **Third stage (reached low level of water):** 66% of dam supply and 9% of water distribution system adjustment. Supply 75% of domestic and industrial water.

1.3.3 Low revenue water rate and difficulties in metering

Prior to the SWM project, the total revenue water (water produced and not lost through leaks or other losses) of Seosan city was 83%. While this is quite high in comparison to the revenue water of the Palbong area (of 67%) including Palbong-myun (the area where Seoul is located) the geographical characteristics, wide supply area of 54 km² and low population density of Seosan (Seoul city is 16,500/km² and Palbong-myun is 68/km²; Seosan has 250 times the supply area per person), make leakage detection and prevention very challenging.



Figure 16. Comparing target area and pipeline length
(Source: K-water)

1.3.4 High water pressure of lowland pipe conduit

While the Palbong distributing reservoir is located in the hillside (High Water Level 89m) most of the area is situated in the lowland closed to waterfront (elevation of 10-30m). This geographical characteristic, along with the use of nonmetal (PE) piping, has resulted in low resistance to water pressure causing more leakage when high pressure is required and generated high water pressure of about 490.3-484.5 Kilopascals.

< Invert Height (EL.m) in service area >

< water pressure(m) in service area >

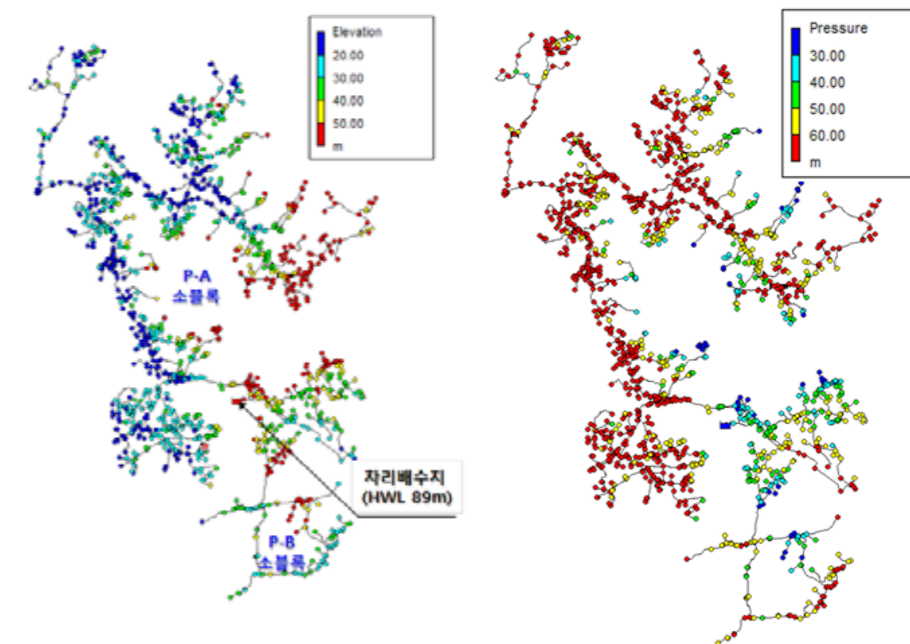


Figure 17. Invert Height and water pressure distribution in service area (Source: K-water)

1.4 Laws and systems related to drought

In Korea, relevant laws and regulations have a central department and local government to establish plans and measures against disaster such as drought. Korean drought measures have been established considering security and disaster management according to the *Framework Act on the management of Disasters and Safety* and *Countermeasures against Natural Disaster Act* (See Box 4 for details).

Box 4. Laws, systems, plans and policies related to drought and water management

Framework Act on the management of Disasters and Safety

The prime minister establishes a basic plan about security management and then each department and public organization establishes an execution plan and develops this into a detailed execution plan. So a safety plan related to natural disasters, such as drought, must include typhoon and flood measures, drought measures and earthquake measures. An implementation plan must then be formulated in 4 stages: prevention, preparation, response and restoration.

Countermeasures against Natural Disaster Act

The Countermeasures against Natural Disaster Act states that the disaster management agency has the responsibility of natural disaster prevention. Therefore the Ministry of Government Administration and Home Affairs, the Ministry of Land, Infrastructure, and Transport (MOLIT), the Ministry of Agriculture, Food and Rural Affairs, the Ministry of Environment, the Ministry of Public Safety and Security, and the Meteorological Administration etc. have to work together to research and investigate drought preventing restrictions on water supply and electricity generation for drought restoring, management and maintenance of facilities and establish mid- to long-term plans for the habitual drought afflicted area.

Comprehensive Plan for Long-Term Water Resource Management (2011-2020)

The Comprehensive Plan for Long-Term Water Resource Management (2011-2020) is the highest plan established to secure stable water resource and intends efficient management in Korea. It presents a future roadmap for water use, flood control, research and development of river environment and water resources. After the 1960's, in its early times, it focused on water resource development and management such as multi-purpose dam development but after the 1990's it established a plan focusing on environmentally friendly and desirable water usage. The 7th plan has now been established.

Within these drought related water management policies, comprehensive plans for long-term water resource management secure a new water resource to counter future water shortages and enhance stable supplies of water resources. These plans also improve efficient use of water, expand multi-purpose water use system as well as construct and advertise smart water management systems to enhance the communities' ability to face future droughts.

Chungnam Water Resource Master Plan (2015.01)

With the national comprehensive plan for long-term water resource management, Chungcheoungnam-do (Chungnam) established a water resource master plan to alleviate permanent water shortages by securing water resources and efficient water use, to develop and preserve rivers. In 2012, when the biggest drought damage occurred in west area of Chungcheongnam-do, they established water resource master plans to alleviate water shortages, thereby securing stable water resources and efficient use, development and preservation of rivers considering regional demands.

According to this plan, the Chungnam area is facing a water crisis in both water quantity and quality and this crisis will be intensified in the future. It is also expected that in this tendency, domestic/industrial water will be face 111.9 thousand m3 of water shortages per day and both deposited water and agricultural water will need 26.4 thousand m3 and 16,318 thousand m3 of water per day. To prepare for water shortages expected in future, Chungcheoungnam-do also focuses on demand management with traditional supply oriented management. The Chungcheongnam-do water demand management comprehensive plan consists of reduction on water supply leakage, water charges rationalization, sewage and wastewater reuse and developing alternative water to enhance water demand management. Including the new city area, it planned to save 50,426 thousand m3 per year (accumulated between 2012-2015) and cost 2.3611 trillion won (2.053 billion USD). This will result in a predicted annual saving of 3.878 million m³ (10,624 m³ per day) by 2025.

National Plan on the Management of Safety (2015-2019, 2015)

According to Article 34.6 of the *Constitution*, Article 22 of *Framework Act on the management of Disasters and Safety* and Article 26 of *Degree of the Framework Act on the management of Disasters and Safety*, it is the highest plan which establishes basic direction for disaster and safety management to protect life, property and body of people from disaster and accidents. The purpose of this plan is confronting changing disaster circumstances such as urbanization, concentration of population, climate change, and epidemics of new infectious disease. It provides directions on planning and operating detailed plans for disaster management agencies including central administrative organisations and local governments by presenting solutions, which enable comprehensive operating national disaster and security management policies and key tasks every 5 years.

Due to a change in governmental structure, the water management functions of the Korean central government are now dispersed. The Ministry of Agriculture, Food and Rural Affairs takes responsibility for agricultural water management and Ministry of Trade, Industry and Energy manages water for hydroelectric power, while the Ministry of Public Safety and Security manages typhoons and floods. Each department plans drought measures. For example, related to safety management, the Ministry of Land, Infrastructure and Transport and K-water, which both deal with water resources and projects divide dams and multiregional water supply, evaluate drought situation and plan measures as detailed execution plan⁶.

Table 5. Ministry of Land, Infrastructure and Transport (Dam)'s response plan according to drought situation

Order	Drought situation (criteria: water supply)	Reaction plan
1st stage (Attention)	Supply 80-90% of basic plan (supply actual demand of domestic/ industrial water, agricultural water and river maintenance water)	<ul style="list-style-type: none">• Install banner for drought overcome• Check the status of drought such as water shortage area• Saving water campaign using broadcast, campaign, brochure• Reduce marginal water of multi-purpose dams and water dams
2nd stage (Caution)	Supply 60-80% of basic plan (supply actual demand of domestic/industrial water and agricultural water) (restriction on river maintenance water supply)	<ul style="list-style-type: none">• Establish and operate drought situation room (Ministry of land, infrastructure and transport, K-water)• Identify drought areas and establish support measures and cooperative system between agencies and governments• operate emergency water vehicle and provide bottled water• consider dam's water supply capacity and supply plan• reduce river maintenance water of multi-purpose dam and water dam. If necessary, restrict agricultural water
3rd stage (Alert)	Supply 50-60% of basic plan (supply actual demand of domestic/industrial water) (restriction on river maintenance water and agricultural water supply)	<ul style="list-style-type: none">• Restrict water on dam area and multiregional water supply municipality• Request local government to secure own alternative water source• Operate emergency water source such as ground water• Supply actual demand of domestic/ industrial water from multi-purpose dam and water dam. If necessary, reduce actual demand of domestic/ industrial water• Consider how to utilize emergency water of dam
4th stage (serious)	Supply under the 50% of basic plan (Supply dead storage of dam) (supply actual demand of domestic/ industrial water and restrict agricultural water and river maintenance water supply)	<ul style="list-style-type: none">• Restrict water supply on dam areas and multiregional water supply municipality• Operate emergency water source• Supply emergency water source of multi-purpose dam

6. Extreme Drought Response and Improvement - Focusing on 2015 Drought, Taewoong Kim, Donghyuk Park, Korean Society of Civil Engineers 63(9), pp25-35 (2015)

Table 6. Major measures related to drought among national plan on the safety management

Measures	Main contents
Prevention	<ul style="list-style-type: none">• promote R&D related to drought prevention such as water use and saving management guideline, drought evaluation and prediction model, developing water use management system by facility, developing water saving program, quantifying drought season prediction and warning criteria.• Establish midterm and long-term plan to alleviate the habitual drought afflicted area. The plan includes study of efficient rainwater management, efficient management of water resource facility including dams, securing diverse water resources (ground water and sea water desalination).• improve drought management system and consider water supply prospect and current status of storage dam by water systems.
Preparation	<ul style="list-style-type: none">• Vitalize research and investigation such as accumulating base line data, expanding research facilities, R&D for preventing drought by disaster management agency• Manage potential drought area. Secure optimal pumping equipment, weather analysis, observe growth and development of crop and etc.• Support water source exploitation in drought concerns phase, implementation of drought measures such as water saving cultivation in agriculture and transform to drought measures promoting system.• Real time monitoring on drought and establish reaction plan. Construct alliance between departments.
Response	<ul style="list-style-type: none">• Establish drought reaction system; operating disaster countermeasures headquarters, emergency duty and etc.• Rapid dissemination of disaster warning and forecast including PR via media• Proceed emergency measures such as temporal use of another water facility including agricultural water, industrial water and power water and utilise ground water wells not in use, emergency water supply facility, water purification system, simplified wide area water supply, private water works and etc., secure equipment and personnel (military, firefighting) for emergency water supply and drinking water manufacturer and etc.• Classify 1st (10%~30% restriction on water supply) to 4th (stop supplying water) stage considering local condition, and establish and proceed step water supply countermeasures for each department and local government• Activate executive measures to minimize damage and spreading of drought• Supply emergency drinkable water to island area using guard ship
Restoration	<ul style="list-style-type: none">• Support damaged crops restoration expenditure and installation of water pump and wells.• Investigate and restore drought damage, complement drought management system and make water supply countermeasures

2. Smart Water Management Solution

The Smart Seosan City project was established in January 2016 when the municipality of Seosan city asked K-water (who operated the local waterworks system in Seosan city) for a smart metering system for the local water supply system as a drought measure. Since 2015 the Boryeong Dam, which supplies water to Seosan City, had reached a water storage minimum of 21%, resulting in the need for urgent measures to be taken. Seosan city invested approximately 500 million won in this project (equivalent to approximately USD 467,500), for K-water to integrate ICT technologies such as smart metering, wireless data transmission and decision making system to reduce water leakage rate of pipelines as a way to secure water in Seosan city.

2.1 Innovative Smart Water Management technology solution proposed

To solve the various water-related problems and improve the efficiency of water management in Seosan, K-water considered various technologies. Recently, Information and Communication Technology (ICT) had been adopted to maximise efficiency in the process of water production and distribution (Byeon et al., 2015). In Korea, there are many projects working together to develop a Smart Water Grid (SWG) (Byeon et al.,2015) and technologies that enable sustainable water supply by connecting water sources and optimising water treatment based on ICT support this effort.

Water management using ICT, also known as Smart Water Management (SWM), enables sustainable water supply to every citizen by water resource monitoring, problem diagnosis, efficiency improvement and harmonising management, resolving many water related challenges (ITU, 2014; Heland et al., 2015).

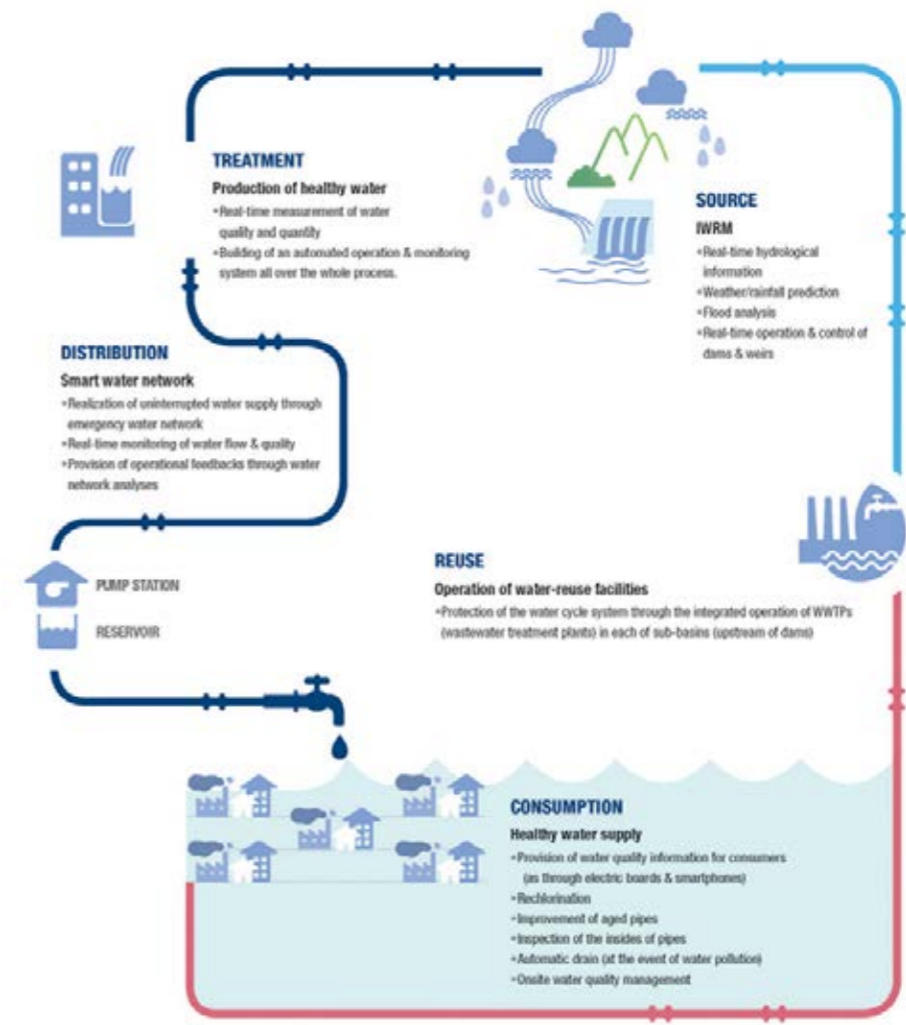


Figure 18. SWM concept map
(Source: K-water)

2.2 Introduction of SWM in Seosan city

Prior to the request from Seosan City, K-water was operating smart metering as a pilot project in the Goryeong area (from January to May 2015) when they were consigned Seosan’s local water supply. K-water suggested smart metering to Seosan city and the city as a solution to their drought concerns, and Seosan City accepted the suggestion. The aim of the project was to construct a smart water management system to increase water supply for Seosan by improving the revenue water ratio through using remote metering, smart meters and ICT, and in the process to improve customer satisfaction of the water supply.

Unlike a human read meter, which relies on a person to manually check the data on a metre on site, smart metres deliver a user’s hourly water usage via digital meter (smart meter) and wireless communication technology (ICT). It is used in revenue water ratio management and remote metering.



Figure 19. Outline of smart metering system (Source: K-water)

Table 7. Smart devices of Seosan SWM

Digital Meter	<p>The digital meter converts measured flow data into electrical signals and transmits them on a time basis.</p> <p>Function</p> <ul style="list-style-type: none">- Measuring data: accumulated flow rate, flow rate- Detection function: overload, backflow, leakage and unused- Data communication	
Remote Transmitter	<p>The Remote Transmitter collects data from the meter every hour and transmits the data every 4 hours.</p> <p>Function</p> <ul style="list-style-type: none">- Direct radio path with base station by 1W high-power transmission- 19Ah capacity battery enables 8 years run-time (2Ah /yr. power consumption)- LCD display for meter reading	
Base Station	<ul style="list-style-type: none">•Wide area wireless transmission coverage with long distance (Transmission distance: approximately 1.5km)•Low operation cost•Low power consumption, ultra-compact, easy to apply in IoT / M2M	
Monitoring System	<p>The monitoring system shows the connection status and end-user meter gauge on a real-time bases. The gauge reading data can be acquired and analysed hourly, daily, and monthly. The monitoring system calculates supplied water volume and provides information on leakage within the water supply network.</p>	

Source: K-water

2.2.1 Remote metering and data transmitting

The smart meters convert the measured flow data into electrical signals and transmit them on a timely basis (hourly, daily and monthly). They perform precise flow measurements by sensing 8 times per an impeller pump rotation. Smart meters installed at the household level transmit data to the waterworks server through a wireless communication network and monitoring system (remote indication center-> base station-> remote system) automatically transmitting metering information such as hourly, daily, monthly water consumption.

The data-transfer procedure of a smart metering system consists of digital meters installed at the end user sites. These digital meters are connected to the remote transmitter through direct wires. Remote transmitters transmit the collected data to the base station through wireless communication such as pagers. The base station transmits the received data to the server and the monitoring system through the internet service. This final step helps system managers to acquire and analyse the data on the web page conveniently.

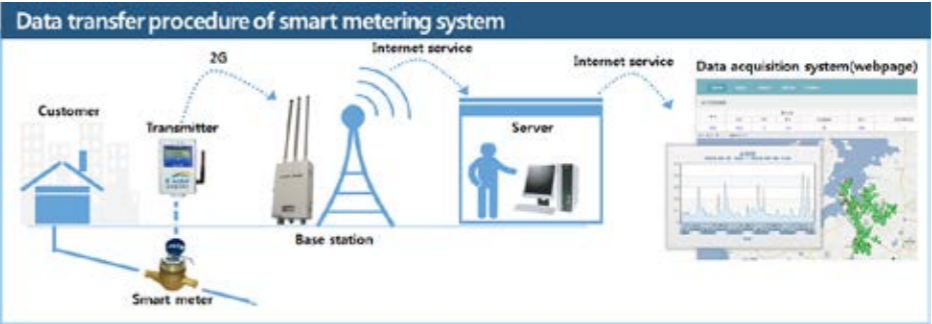


Figure 20. Data Transfer Procedure of Smart Metering System (Source: K-water)

Wireless communication services used in this project use long distance wireless transmission. Long distance wireless transmission has various characteristics and strong points such as wireless coverage of a wide area, clear wireless environment without crossing and interference, cheap modem cost, low communication fees, low electricity use, compact size and adaptability to various IoT/M2M.

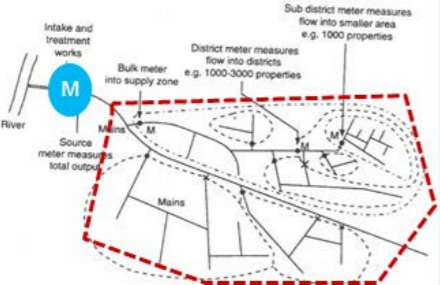
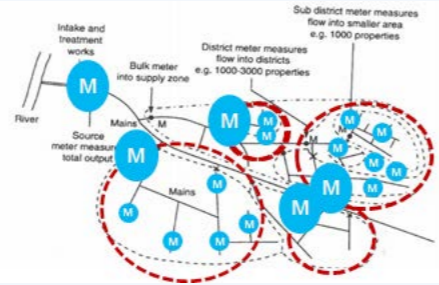
2.2.2 Sub District Metering Area (SDMA) system construction based on smart meter

Through using smart meters and DMA subdivision, a sustainable scientific quantity management system is constructed. From April 20th to July 20th 2016, this project constructed 1,550 units of smart meters, 30 base stations, 9 SDMAs and monitoring systems and propelled pilot operation and revenue water ratio improvement projects for the following two months (July – September 2016). DMA subdivision enables water information data taken by the smart meter to find leakage points easily and investigates abnormal data through analysing user’s hourly consumption pattern to find the user’s interior leakage. It shows smart metering data can be used in a bigger area beyond metering.

This smart technology enables the development of revenue water ratio analysis from a monthly to a daily basis and extends the minimum flow during night point from 3 points to 12 points. It also allows the division of existing DMA (District Metering Area) systems with Tele-Metering (TM) equipment and analogue meters to SDMA (Sub District Metering Area) system (as described below). As a result, existing 2 units are subdivided to 9 units, creating highly data accuracy. SDMA monitors not only allow DMA inflow, but also numerous minimum

flows during the night and they manage the daily revenue water ration to ensure an effective and quick response to leakage.

Table 8. Comparison between (existing) DMA system and (Improved) SDMA quantity management system

	Before (DMA system)	After (SDMA)
Metering area management	1 DMA (500 ~ 1500 meters/BL)	1 DMA + SDMA Subdivision (About 200~300 meters/SDMA)
Quantity management (leakage restoration)	<ul style="list-style-type: none">• 1 inflowTM minimum flow during night monitoring• Monthly revenue water ratio management• Difficulty in quantity management including leakage detection	<ul style="list-style-type: none">• Monitor not only DMA inflow, but also numerous SDMA minimum flow during night• Daily revenue water ratio management• Effective and quick control on leakage
Concept map		

Source: K-water

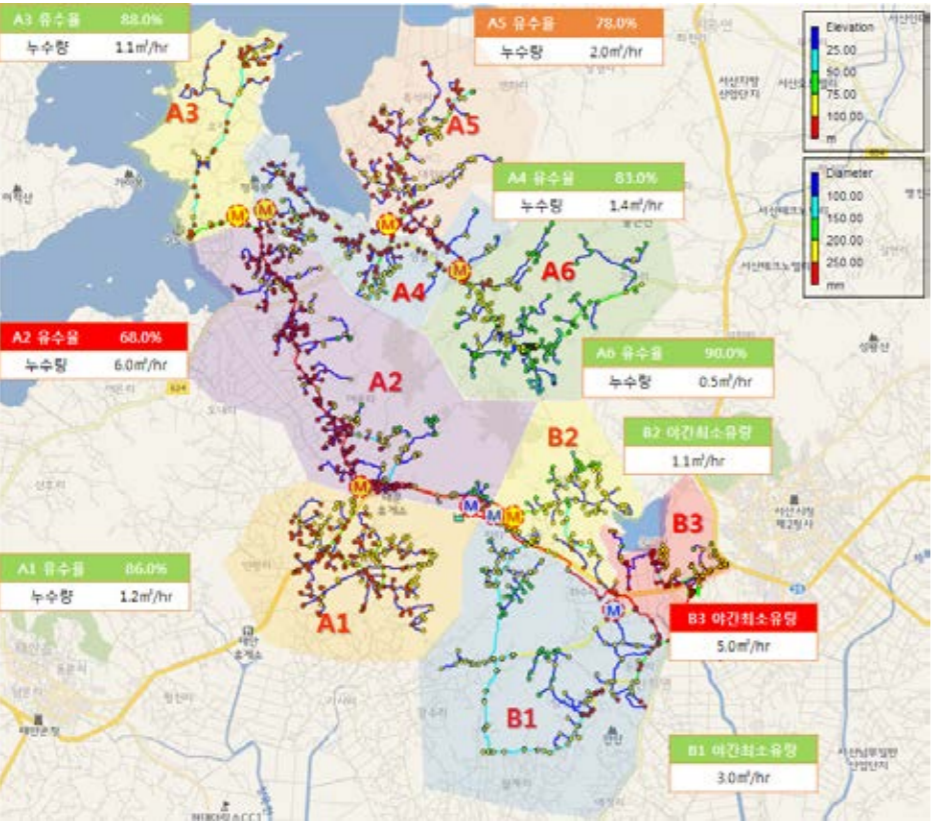


Figure 21. Scientific quantity management by DMA subdivision
(Source: K-water)

2.2.3 Leakage analysis using smart meter data

Nonmetal pipes were buried in the target area, so correlating leakage detection by installing leakage sensors outside of the pipes was inefficient. As a result, a new concept of leakage detection sensors was deployed, in which the sensor is inserted into the pipe using water as its medium. This type of sensor has the advantage of enabling high precision in a low flow velocity with a semi-conductor sensor and it also reduces leakages with a detection and warning function. In addition to this it enables remote meter reading with a built-in communication function.

2.2.4 Construction of water pressure management system with data

By combining smart metering systems with decompression remote control technology it enables the construction of a water pressure management system, which considers the consumption pattern of the user. In order to operate without a booster pump in some of the hillside areas, which were expected to have problems with water supply, K-water installed a Pressure Reducing Valve (PRV) to provide a small decompression amount in every Pressure Management Area (PMA). This enabled us to control decompression in the future based on the pattern analysis of the users.

The system construction consisted of three stages. In the first stage, data on water use was acquired at the critical point of the hillside where problems with water supply were expected when decompression is operated. In the second stage, based on the data, pattern use is analysed and time-based decompression measures were constructed. In the third stage, the pressure is adjusted using an automatic remote control with SCADA, according to the season, holiday period and time of day and flexibly reacts to any water supply problem in the hillside area.



Figure 22. Diagram for water pressure management
Source: K-water

The Pressure Reducing Valve (PRV) is operated by dividing target areas (DMAs) where the water pressure is high (490.3 Kilopascals or more) into four water pressure management areas (turning them into Sub District Metering Areas 'SDMAs'). Water pressure is then decompressed based on each SDMA characteristic, making it possible to prevent pipe breakage due to high water pressure in advance. In addition to this, the amount of background leakage due to unnecessarily high pressure is reduced, which is effective in improving the flow rate.

Table 9. Pressure Reducing Valve Operation
(Unit: Kilopascal)

	SDMA	Control method	First inflow pressure	Second outflow pressure		Decompression
PMA 1	SDMA A1	Time control	637.4 (EL.22)	daytime(03:30~24: 30, 21hr)	490.3	↓147.1
				night(23:30~03: 30, 3hr)	392.3	↓196.1
PMA 2	SDMA A2	Remote control	637.4 (EL.30)	daytime(03:30~24: 30, 21hr)	539.4	↓98.1
	SDMA A4			night(23:30~03: 30, 3hr)	490.3	↓147.1
	SDMA A6					
PMA 3	SDMA A3	Remote control	637.4 (EL.20)	daytime(03:30~24: 30, 21hr)	392.3	↓245.2
				Night (23:30-03: 30, 3hr)	3.5	↓294.2
PMA 4	SDMA A5	Time control	784.5 (EL.5)	Daytime (03:30-24: 30, 21hr)	637.4	↓147.1
				Night (24:30-03: 30, 3hr)	6.0	↓196.1

Source: K-water

<(before)water pressure management: average pressure 6.1kgf/cm²>

<(improved) before water pressure management: average pressure 4.4kgf/cm²>

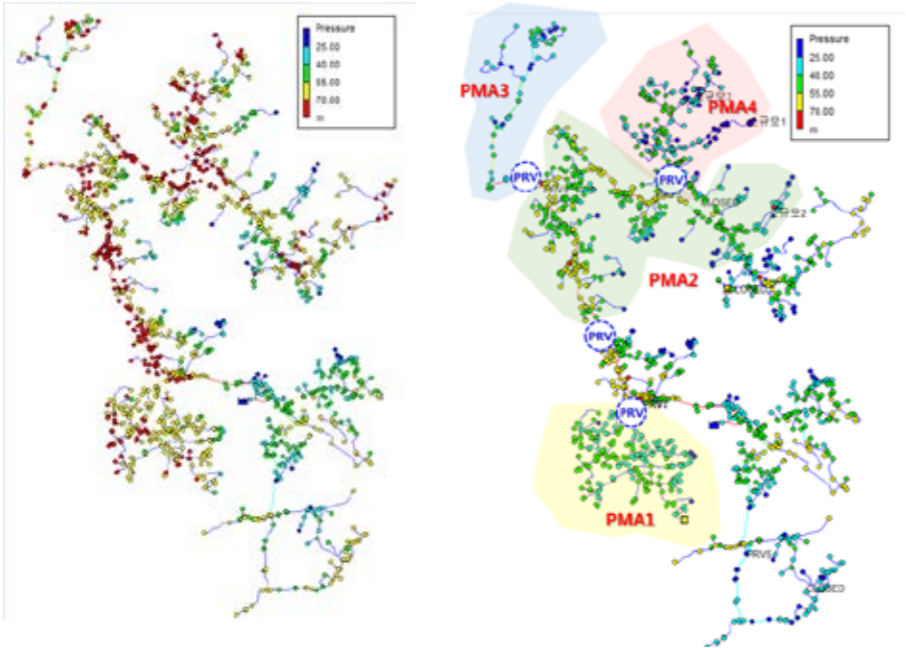


Figure 23. Comparison between before and after water pressure management
(Source: K-water)

2.2.5 Government budget support

Operation of this project was enabled by investment of Seosan city and supported by central government through their drought budget. This project cost 497 million won (approximately USD 464,600) in total, with the purchase of smart meters costing 88 million won (USD 82,000), remote monitoring center (to monitor indicators) costing 154 million won (USD 144,000), replacement and installation 129 million won (USD 120,000), Sub-DMA building 70 million won (USD 65,000) and construction control system 59 million won (USD 55,000).

3. Outputs & Outcomes

3.1 Economic outputs

3.1.1 Decrease in leakage

After applying smart metering and the SDMA system to the target area, the revenue water ratio reached 90%. This was an increase of 20% compared to the first half of 2016 and of 19% compared to that of the previous year.



Figure 24. Revenue water ratio before and after smart meter (2016)
(Source: K-water)

Leakage detection technology in three of the SDMAs found leakages in seven of the units and restored them. As a result, the revenue water ratio in the mentioned SDMAs improved from 17% to 39%.

Table 10. Revenue water ratio in SDMAs

	A1	A2	A3	A4	A5	A6
'16.7	87%	73%	92%	84%	58%	50%
'16.8	89%	86%	91%	87%	69%	78%
'16.9	95%	90%	88%	97%	88%	89%
		↑ 17%			↑ 30%	↑ 39%

Source: K-water

3.1.2 Inner leakage detection of users and restoration

Time-based use pattern analysis of the smart meter monitoring system enabled two cases of interior leakage for the user to be found and restored. As a result, each user saved 55% of water use and 70% of water cost.



Figure 25. Inner leakage detection of users and restoration
(Source: K-water)

Table 11. Economic outcome of inner leakage detection by user

	Customer A		Customer B	
	Usage (m³/month)	Usage Fee (1000W/month)	Usage (m³/month)	Usage Fee (1000W/month)
Before Restoration	60	67.2	59	65.4
After Restoration	25	18.4	28	21.0
Effect	↓35 (↓58%)	↓49.8 (↓73%)	↓31 (↓52%)	↓44.4 (↓68%)

Source: K-water

3.1.3 Find Error in inflow and outflow of distributing reservoir

In the process of revenue water analysis in each SDMA, the result comparing distributing reservoir inflow/outflow rate and distributing inflow/outflow meters found a fault that the meter indicated 430 m³ of over supply per day (about 70%). These meters were replaced and the over-estimated 50 thousand m³ of water which had been regarded as water purchase by multiregional water supply in the past was recaptured. As a result the revenue water ratio of Seosan city increased by 0.2% and the revenue water profit was 20 million won (approximately USD 17,400).

Table 12. Comparative measurement of distributing reservoir's inflow and outflow (measurement: m³/hr.)

	Before replacement of metres (A)	After replacement of metres (B)	Error(C) (A-B)	Error rate (%) (C/B)
Measurement of Inflow(m³)	391.7	363.3	28.4	7.8%

Source: K-water

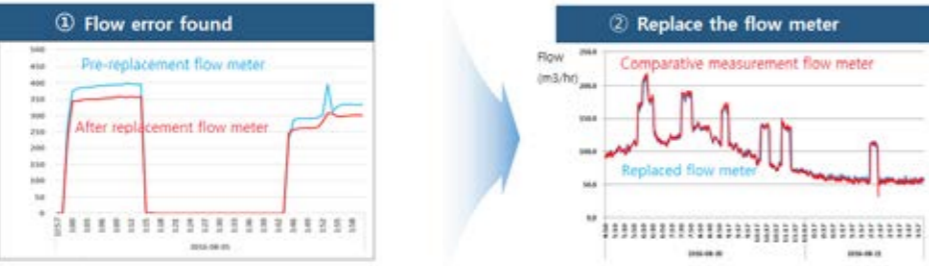


Figure 26. Calibration procedure on distributing reservoir inflow rate
Source: K-water

Figure 26 (1) shows the error in the initial meters installed. You can see this by the gap in the inflow before and after the replacement of the incorrect meters. Figure 26(2) shows that the replaced meters are measuring the data correctly by comparing the correct meters after replacement.

3.2 Social outcomes

3.2.1 Increase in customer satisfaction

By switching to using remote meters for water use and quality, customers' satisfaction has been improved as it has become possible to handle complaints promptly with surveyors responding to every customer concern and also by providing additional water quality management services such as the inspection of customers' indoor pipes.

In addition to this, as the target area for this project was based in a hillside area where the households are quite far apart it was originally too costly for the civil service to visit each traditional meter themselves to monitor the water use. This meant that customers were required to monitor the meters themselves taking them a lot of time and effort. By introducing remote metering it enabled improved monitoring of the meters by the civil service, and as a result the customer satisfaction has increased.

3.2.2 Enablers

The first success factor in enabling SWM projects is Korea's advanced ICT technology. Korea has many small and medium-sized enterprises with excellent technology, and it has a very comfortable base for constructing SWM based on Internet of Things (IoT) because it has a dense communication network in all regions.

The second factor to succeed Smart Water Management in Seosan city is enabling environment include policies, laws, plans that create an environment for integrated water management. Korea has the national and local government plan to respond disaster such as drought. Therefore, governments could allocate funds whose purpose is to adopt smart water management and address water shortage in Seosan city. Consequently, good governance make it possible to implement water solutions successfully.

3.2.3 Barriers

1. The initial investment cost is higher than the existing facility investment.

Seosan SWM project is relatively expensive in comparison to traditional meter installation practices since existing meters need to be replaced with smart meters and additional remote transmitters are required. For example, in the case of a remote transmitter, an additional 100,000 won (USD 91) is added per water service connection, and the cost of a smart meter (13 ~ 15 mm diameter) is 50,000 won (USD 46), which is 50% higher than a general meter (30,000 won (USD 27)). The higher cost is because large-scale demand or production of smart meters has yet to be achieved, and thus production costs have not decreased due to economies of scale. As such, the installation cost for smart meters will likely reduce as demand increases. In Korea, as large-scale water facility managers such as Seoul (supplying water to 2 million households) are planning to install smart meters, this problem will be resolved in the mid to long term.

In addition, 20 remote base stations were installed as part of the Seosan SWM project because the telecommunication infrastructure was not installed, and an RF communication network was used. This cost 1,000 won which is similar to the labour cost for metering ranging from 1,000 to 1,300 won per household. The smart water management business, which is currently being built, will ultimately lower the communication cost to 300 ~ 400 won / household by building the IoT (Internet of Things) network.

2. We should consider the use of existing metering staff.

With the success of the Seosan SWM project, the role of metering staff became unnecessary, but the task of reducing metering staff in a short time period of time was difficult. As a result, half of the existing metering staff had been used continuously to provide metering services including both manual and remote meter reading at the same time. Gradually, the existing metering staffs will be utilized for improving customer services.

3. Low water price in Korea

The water price in Korea is less than about 1,000 won per ton, and the installation cost of the smart meter and remote transmitter (approximately 200,000 won, USD 18] is not economical enough to rapidly expand investment.

4. Link with the Sustainable Development Goals

Seosan Smart City is linked to sustainable development goals 6 (clean water and sanitation) and 11 (sustainable cities and communities). Table 13 lists the specific targets within these SDGs that are addressed by aspects of Seosan Smart City.

Table 13. A list of the SDGs and their specific targets that relate to Seosan Smart City

Sustainable Development Goals and Targets	
SDG 1: Zero poverty End poverty in all its forms everywhere	
1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.
SDG 6: Clean water & sanitation Ensure availability and sustainable management of water and sanitation for all	
6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all
6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
6.b	Support and strengthen the participation of local communities in improving water and sanitation management
SDG 8: Promote sustainable economic growth Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	
8.2	Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labor-intensive sectors
SDG 11: Sustainable cities and communities Make cities and human settlements inclusive, safe, resilient and sustainable	
11.5	By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
SDG 12: Sustainable consumption Ensure sustainable consumption and production patterns	
12.2	By 2030, achieve the sustainable management and efficient use of natural resources

4.1 Goal 6 and target 6.4

Goal 6 of the United Nations (UN) Sustainable Development Goals (SDGs) ensures availability and sustainable management of water and sanitation for all. Target 6.4 of Goal 6 aims at sustainable withdrawals and supply of fresh water to solve water scarcity problems including an increase in water-use efficiency across all sectors by 2030 and a decrease in the number of people who suffer from water scarcity.

Water-use efficiency and water stress levels are indicators to measure target 6.4. Water-use efficiency shows changes in water-use efficiency over time and water stress level measures the percentage of water withdrawal in available freshwater resource. Among them, the water-use efficiency indicator is related to this case. It can be defined as a change in quantity produced in major sectors of whole water withdrawal over time. According to ISIC, the four major sectors presenting water-use efficiency are 1) Agriculture, forest and fishery, 2) manufacturing, construction, mining industry and stone-quarrying industry, 3) electric industry, 4) municipal sector. This indicator embraces agriculture, industry, energy and municipal sector and can be used as a tool for detailed analysis for national plan or decision-making.

4.1.1 Water-supply efficiency of municipal sector

Among the target 6.4, water-supply efficiency of the municipal sector is presented as efficiently providing water to domestic water users and the percentage of water withdrawal from water supply facilities (for example, water distribution efficiency, pipe losses, etc.). Measurement equation is as follows.

$$M_{we} = \frac{Mu_d}{Vm}$$

- M_{we} = Efficiency on water supply of municipal sector
- Mu_d = distribution of local water user(m^3)
- Vm = water intake of municipal sector (public water pipe and etc.)(m^3)

This indicator provides information about water resource's economic, social use efficiency (e.g. water usage in major economic parts or loss of distribution networks). This indicator measures not only the outputs of productive water use in municipal sector but also water use loss. By measuring them, it deals with the target aimed at, 'increasing major water use efficiency in every filed'.

4.2 Economic net profit occurs

The operating results from the pilot project show a 20% improvement in the revenue water ratio and 190 thousand m^3 of water per year decrease in leakage. This results in a benefit of 610 million won (about USD 590,000) for the next 8 years with the cost benefit expected to increase in net benefit (reflecting the pilot result, it is assumed 20% of improvement in revenue water ratio and 809 won/ m^3 of water cost).

This result applied facility investment [500 million won (USD 455 thousand), purchase control system, smart meter and etc.], communication expenses [660 won (USD 0.6)/unit], repair and maintenance cost (2.5 million one per year) as cost, and reflected leakage reduction (water purchase), human metering cost (600 won/unit), leakage exploration cost [11 million won (USD 10,000) per year including service and etc.], meter change cost [54 thousand won (USD 49)/unit] as benefit.

5. Lessons Learned and Conclusions

5.1 Lessons Learned

1) Governance plays an important role in project enforcement

The planning and execution of the drought policy, existing laws and systems played an important role in the implementation and support of this project. In addition to this, government budget support for the project facilitated its implementation.

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.

Also, a comprehensive statutory plan on long-term water resource management, is intended to strengthen the establishment and promotion of smart water management systems for the purpose of securing stable water resources and efficiently managing them. The

Chungcheoungnam-do water resource comprehensive plan established in 2012 to manage water demand during drought periods also assisted, as it encouraged enhancing the existing supply management. According to this plan, leakage reduction for multiregional water supply, enhanced water demand management, rationalising water cost, waste and sewage water reuse and alternative water development are all key priorities. In short, this project was enabled by drought measures and plans established by Seosan city through laws and regulation.

2) Early inputs cost occurs but profitability increases in the long term

Seosan smart water management required early facility investment and operating costs but in the long term, increase in net profit is expected. At the beginning, smart meters and repeater installations will cost a lot but in the middle and long-term, profit will be increased through a reduction in metering personnel, meter change cost and reduced leakage detection cost. This project assumes an average revenue water ratio of 87.7% for eight years and based on this, calculated input cost is 566 million won (approximately USD 492,200) and its benefit is expected as 1,179 million won (approximately USD \$102,500). Therefore the Cost Benefit ratio is close to 2:1.

The investment cost for this project can be recovered in about four years. The smart meter is a battery-based technology, and economic analysis is conducted based on the 8-year replacement cycle. This means that it is possible to recover the investment cost within four years after the initial installation, and the net benefit will be generated for the remaining four years (see figure 27).

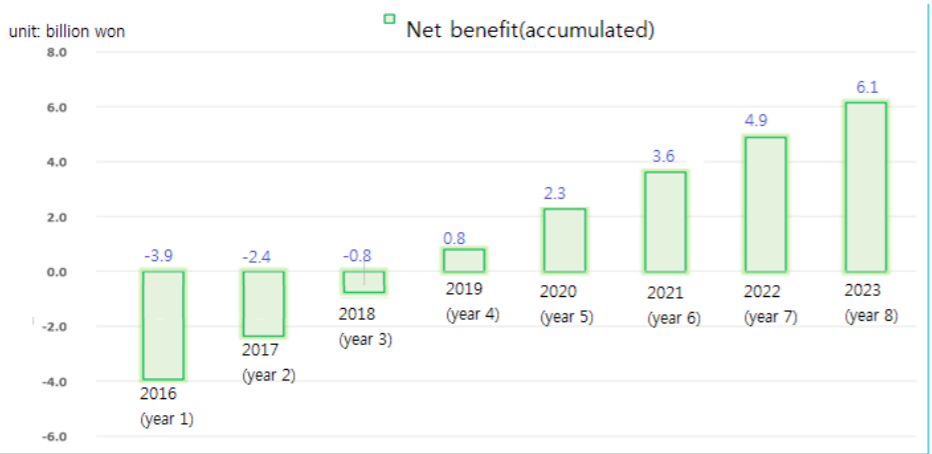


Figure 27. Net project profit by year (Source: K-water)

3) Smart metering improves sustainability in water management

Securing and operating smart water management technology by K-water was also essential. 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 to smaller units to improve the revenue water ratio) is one example of this. Smart metering enables a sustainable water supply by reducing water leakages and saving water and energy. In the situation where water supply is reduced or limited by drought or other challenges, new water resource development is needed to supply water stably. However this can also can be achieved by minimizing water loss through smart

water management techniques. Therefore to solve water problems such as water shortage, implementing smart water management is beneficial.

5.2 Next Steps

Korea is currently constructing a low-cost Narrowband IoT (NB-IoT)⁷ communication network that is optimized for the Internet of things. It is expected that communication costs of about KRW 1,000 (USD 0.9)/ month/water supply will decline to about KRW 400 (USD 0.36) /month/ water supply. Secondly, we have analyzed the big data acquired from many smart meters (instruments) and developed and applied software that supports decision-making. This soft-ware is used for monitoring and decision making to provide information on water quantity and quality, water pressure to improve decision-making in the operation of the water facilities. Despite the low water price in Korea, as the smart water market continues to become more active with many companies competing in the market, it is expected that technology costs will decrease in the future, enabling the costs of SWM to be recovered more rapidly.

K-water has been promoting SWM business by entering overseas based on experience of SWM construction in Korea. In that case, the Asian Development Bank (ADB) is conducting an SWM TA project to build an SMW Pilot in four countries in South Asia, including Bangladesh and India, with about USD 1.25 million for four years. Dhaka is in a serious situation where the groundwater level drops by one meter per year due to the water shortage caused by many leaks and uncontrolled use of groundwater (80% of the total water supply depends on ground-water). To overcome this problem, the Bangladesh government has invested heavily in pipe-line facilities through ADB's large-scale assistance, but there are still many leaks due to the lack of DMA system and measuring sensors to analyse leaks.

K-water has introduced smart meter technology to build a sustainable water management system at low cost (due to strong investment of Seosan City and supported by central government), and installed a smart meter in a deep tube well to build a real-time flow monitoring system. As a result, ADB and the local government of Bangladesh have gained considerable gains, with results measured and monitored through the use of smart meters. In addition, Bangladesh is hoping for a sustainable partnership with K-water at the completion of the pilot project, and it is expected that K-water will participate in the consulting service of the water supply facilities of Dhaka City. ADB also plans to expand K-water's SWM TA project to double its current size, initially expanding from four cities in four South Asian countries to seven cities in six countries.

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7. Narrowband IoT (NB-IoT) is a Low Power Wide Area Network (LPWAN) radio technology standard developed to enable a wide range of devices and services to be connected using cellular telecommunications bands, designed for the Internet of Things (IoT). NB-IoT focuses specifically on indoor coverage, low cost battery life, and a large number of connected devices.

Annex 1: Economic Analysis

[Condition: 20% increase in revenue water ratio (Average revenue water ratio reached 87.7%), sales price and period of project: 8 years]

- Net profit (total savings): about 610 million won/8 years (Cost 570 million won, Benefit 1.18 billion won), B/C: 2.1

		Total	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year
		(million won)	2016	2017	2018	2019	2020	2021	2022	2023
1.Incremental cost (A)		611	497	15	15	16	16	17	17	17
Facility investment	Subtotal	497	497	-	-	-	-	-	-	-
	Purchase smart meter	88	88							
	Purchase remote indication center	154	154							
	Replacement and installation cost	129	129							
	SDMA construction	70	70							
	Monitoring center	40	40							
	Purchase S/W for monitoring system	16	16							
Communication cost	660won/unit/month	95		12.6	12.9	13.2	13.5	13.9	14.2	14.6
Repair and maintenance cost	0.5% of investment	19		2.5	2.6	2.7	2.7	2.8	2.9	2.9
1.Incremental cost(present price)(A')		566	475	14	14	13	13	13	12	12
Installation cost		475	475							
Communication cost		76	-	11	11	11	11	11	10	10
Repair and maintenance cost		15	-	2	2	2	2	2	2	2
2. Improvement benefit(B)		1,456	86	186	192	211	201	192	191	196
Revenue water profit	In sales price	1,212	78	157	159	160	162	164	165	167
Saving on metering personnel	Metering read(60% of service budget)	53		7.0	7.2	7.4	7.5	7.7	7.9	8.1
Saving on meter replacement	Existing meter replacement cost	90	2.2	9.3	13.5	29.7	17.9	6.7	4.0	6.9
Saving on leakage detection cost	Own operating cost	102	6.2	12.7	13.0	13.3	13.6	13.9	14.3	14.6
2.Improvement profit(present price)(B')		1,179	82	170	168	176	160	146	139	137
Revenue water profit		981	74	144	139	134	129	125	120	116
Saving on metering personnel		42	-	6.4	6.3	6.1	6.0	5.9	5.8	5.7
Saving on meter replacement cost		74	2.1	8.5	11.8	24.8	14.3	5.1	2.9	4.8
Saving on leakage detection cost		82	5.9	11.6	11.3	11.1	10.9	10.6	10.4	10.2
3.Net profit(present price)(B'-A')		613	-393	156	154	163	147	134	127	125

Annex 2: SWM Devices

Digital Meter

The digital meter converts measured flow data into electrical signals and transmits them on a time basis. It performs precise flow measurement by sensing 8 times per an impeller pump rotation. The outer shell of the meter made of brass mechanically wraps around the operation part and the flow chamber. This shell is resistant to external impact and low temperature during the winter season.

Rubber packing (O-ring), ultrasonic welding, and epoxy molding prevents water infiltration. Operators can easily check device conditions, flow rate, and functional overview on the liquid crystal display (LCD) panel.



Figure 0. External View of a Digital Meter

The specifications of the digital meter are as follows.

Table 0. Digital Meter Specifications

	Description	
Function	• Measuring data: accumulated flow rate, flow rate • Detection function: overload, backflow, leakage and unused • Data communication	
Advantages	• Application of Semi-conductor sensors for high precision in low flow velocity • No resistance against gear rotations of impeller • Built-in communication function enables remote meter reading • Leakage detection and warning function to reduce leakage rate • Triple waterproof design of operating parts • “Unused” function for an one elderly person household	
Technical Data	Sensor	• MR sensor type
	Battery	• 3.0V, 3,800mA (life expectancy: 8 years)
	Specifications	• Nominal temperature: 0.3 to 30 °C • Nominal pressure: 0.3 to 10 bar • Precision: Q1: ± 5 %, Q2, Q3: ± 2% • Display range: 0.0001 to 99999,9999 (m3) • Installation direction: horizontal • Housing: CAC 203 (brass casting) • Diameter: 15 to 250 mm
	Communication	• DCPLC method, pulse output

Differences between mechanical (pulse) type and digital type are summarized in Figure 1-4.

Remote Transmitter

The main characteristics of remote transmitter are as follows.


	Characteristics
	<ul style="list-style-type: none">• The Remote Transmitter collects data from the meter every hour and transmits the data every 4 hours.• Direct radio path with base station by 1W high-power transmission• 19Ah capacity battery enables 8 years run-time (2Ah /yr. power consumption)• LCD display for meter reading

Table 1. Remote Transmitter Specifications

	Description	
Function	<ul style="list-style-type: none">• Wireless transmission of meter reading data to BS through two-way radio paging network• 24-hour operational• Minimized power consumption (battery use available)	
Advantages	<ul style="list-style-type: none">• Reduced operation costs, Improved transmission performance, and Improved communication reliability• Dedicated frequency by common carrier without interference	
Technical Data	Wireless	<ul style="list-style-type: none">• Frequency Band<ul style="list-style-type: none">- Tx: 923.55Mhz to 924.4505Mhz (40 channels)- Rx: 318.1375Mhz to 319.1375Mhz (40channels)• Output power: 30dBm (1W)• Receive sensitivity: less than -115dBm
	Battery	<ul style="list-style-type: none">• 3.6V/19Ah lithium primary battery
	Power	<ul style="list-style-type: none">• Less than 2Ah/year
	Display	<ul style="list-style-type: none">• Graphic LCD
	Exterior	<ul style="list-style-type: none">• Housing: acrylonitrile-butadiene-styrene (ABS)• Weight: 390g• Dimension: 120mm * 160mm * 40mm
	Features	<ul style="list-style-type: none">• Meter reading data transmission by wireless connection• Reading data display through LCD
	Installation	<ul style="list-style-type: none">• Wired connection with digital meter, Wall mounting

Table 3. Remote Transmitter Specifications

	Description	
Function	<ul style="list-style-type: none">• Wireless transmission of meter reading data to base station through two-way radio paging network• 24-hour operational• Minimized power consumption (battery use available)	
Advantage	<ul style="list-style-type: none">• Reduced operation costs, Improved transmission performance, and Improved communication reliability• Dedicated frequency by common carrier without interference	
Technical Data	Wireless	<ul style="list-style-type: none">• Frequency band<ul style="list-style-type: none">- Tx: 923.55Mhz to 924.4505Mhz (40 channels)- Rx: 318.1375Mhz to 319.1375Mhz (40channels)
		<ul style="list-style-type: none">• Output power: 30dBm (1W)
		<ul style="list-style-type: none">• Receive sensitivity: less than -115dBm
	Battery	<ul style="list-style-type: none">• 3.6V/19Ah lithium primary battery
	Power consumption	<ul style="list-style-type: none">• Less than 2Ah/year
	Display	<ul style="list-style-type: none">• Graphic LCD
	Exterior	<ul style="list-style-type: none">• Housing: ABS
		<ul style="list-style-type: none">• Weight: 390g• Dimension: 120mm * 160mm * 40mm
	Feature	<ul style="list-style-type: none">• Meter reading data transmission by wireless connection• Reading data display through LCD
	Installation	<ul style="list-style-type: none">• Wired connection with digital meter, wall mounting

Base Station

Characteristics of the base station are summarized below.


	Characteristics
	<ul style="list-style-type: none">• Wide area wireless transmission coverage with long distance<ul style="list-style-type: none">* Transmission distance: approximately 1.5km• Low operation cost• Low power consumption, ultra-compact, easy to apply in IoT / M2M

Table 4. Base station Specifications

	Description	
Function	• High power radio frequency (less than 5W) allows wide base station service coverage	
	• Connects between transmitter and monitoring system through wireless paging network	
Advantage	• M2M network cost competitiveness achieved thanks to inexpensive RF MODEM	
	• Lower price service cost than any other wireless solutions	
Technical Data	Wireless specification	• Frequency band - Tx: 318.1375Mhz to 319.1375Mhz(40 channels) - Rx: 923.55Mhz to 924.4505Mhz(40 channels)
		• Output power: Max 5W
		• Receive sensitivity: less than -115dBm
	Power	• AC220±20% / DC 12V 45~65Hz
		• Power Consumption: 33.4W
	Others	• RF channel: Rx 1ch, Tx 1ch
		• Network: ethernet (10 base T, TCP/IP)
	Installation	• Dimension: 220mm * 360mm * 85mm
		• Depending on the field situation

Monitoring System

The monitoring system shows connection status and end-user meter gauge on the real-time bases. The gauge reading data can be acquired and analyzed hourly, daily, and monthly. The monitoring system calculates supplied water volume and provides information on leakage within the water supply network. As the system utilizes graphical user interface (GUI) map originated from the Google map, it is easy to use and identify operation conditions on web pages. If smart metering can be implemented in all the district metered areas (DMAs) and/or sub-DMAs (SDMAs) analytical data on non-revenue water (NRW) and minimum night flow(NMF) can be acquired daily.

Details of the monitoring system are as follows.

Table 5. Monitoring System Specifications

	Description
Function	• Metering status
	• hourly / daily / monthly
	• Statistics
	- hourly / daily / monthly
	- daily peak / monthly peak
	- over last year or month
Advantage	• Failure status
	- meter status / reading status / connection status
	• Customer management
	- Customer management
	- Local group management
	• Systems management
Advantage	• Usage pattern Analysis
	- hourly / daily / monthly
	• Detection of water leakage

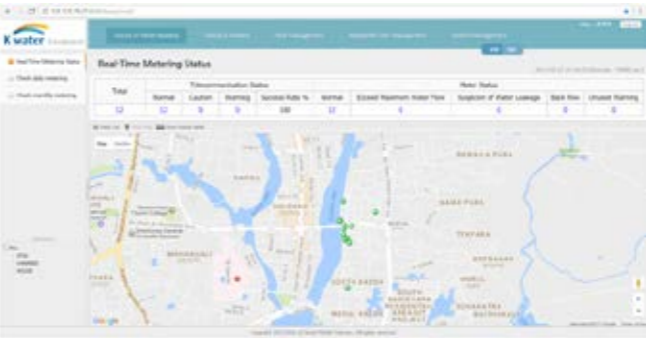


Figure 2. Current Metering Status

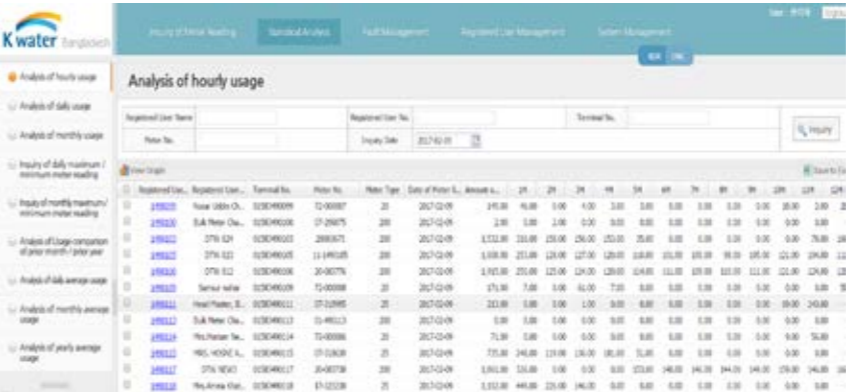


Figure 3. Hourly Usage Data

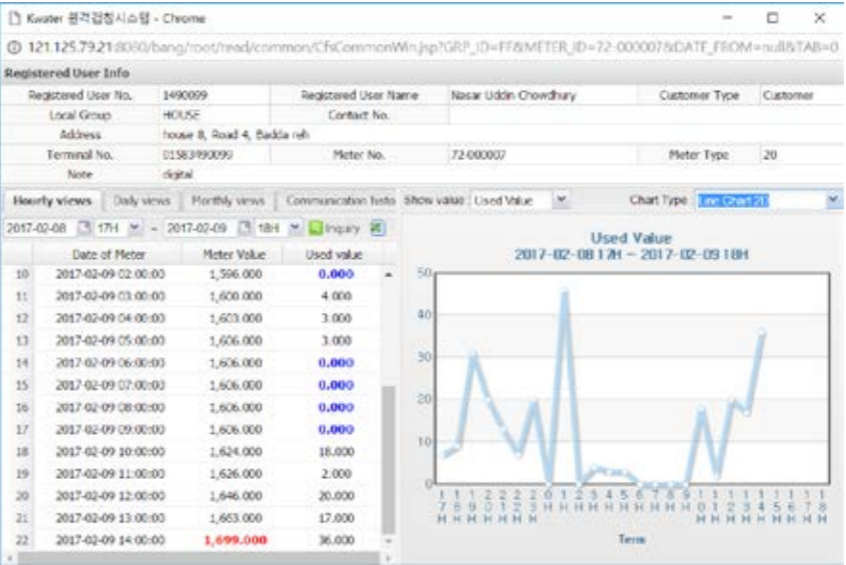
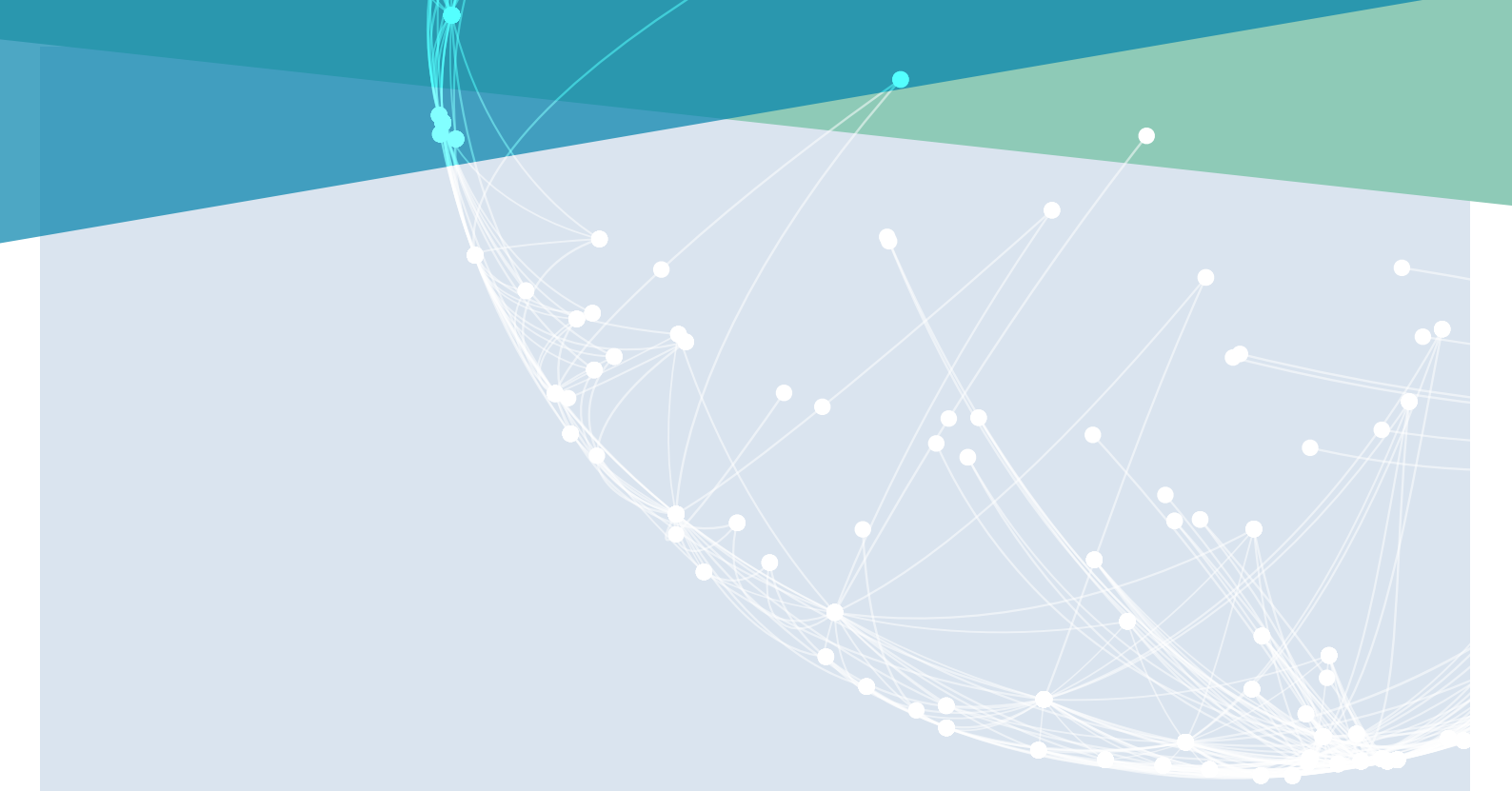


Figure 4. Customer Usage Details

The percentage of secondary industry was lower than that of Chungcheungnam-do (32.8%) and the percentage of tertiary industry was higher than that of Chungcheungnam-do (66.7%). Within tertiary industry, wholesale and retail (13%), lodging and food industry (11.1%), educational service (7%), hygienic and social welfare service industry (6.3%) took largest portions.



K-water (the Korean Water Resources Corporation)
is the governmental agency for comprehensive water resource development in the Republic of Korea, with a large pool of practical engineering expertise regarding water resources that has been championing Smart Water Management for the past decade.

IWRA (the International Water Resources Association)
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