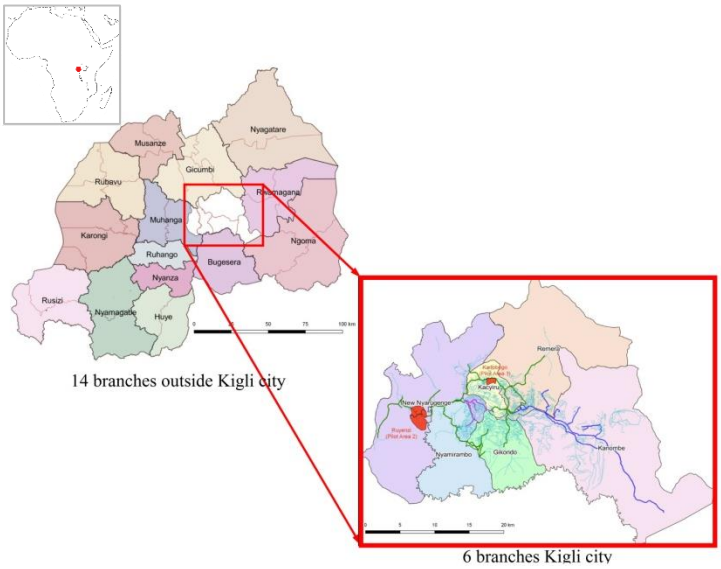
Rwanda
Project for Strengthening Non-revenue Water Control in Kigali City Water Network

February 2022



Republic of Rwanda Project Location Map

1. Project Background and Problems

The Republic of Rwanda (Rwanda), in its long-term development plan "VISION 2020" prepared in 2000, has set a goal to develop the country into a middle-income country by 2020. With respect to water resources development and water supply, the plan aimed at improving the water supply coverage that was 52% as of 2000 based on the definition of the Ministry of Infrastructure of Rwanda (MININFRA) to 100% by 2020. On the other hand, with urbanization progressing, especially in the capital, Kigali City, the rate of growth of urban population was expected to be 4.1 ~5.8% by 2025, but water supply services have not caught up with this rapid population growth. In addition, due to shortage of water resources and enormous water leakage from water supply facilities, recurrent water supply restrictions and water supply stoppages have been enforced. Therefore, the Water and Sanitation Corporation (WASAC[1]) which is in charge of water services under the supervision of MININFRA implemented a plan to double the quantity of water supply by the end of 2017 from the 2015 level to secure sufficient water for Kigali, by constructing a new water treatment plant and expanding an existing water treatment plant. However, since Kigali had a Non-Revenue Water (NRW) rate as high as 38%, it was urgent for WASAC to take measures to reduce NRW and improve the amount of water supply.

of Japan for assistance to implement the Project with the aim of strengthening WASAC's technical capacity and establishing a sustainable implementation system to address the reduction of NRW. Since the piping length (2,400 km) of water supply network in Kigali City is about half that of the urban water supply networks in the entire country, and in anticipation that the results of this project will beneficially influence the other cities

[1] WASAC is an organization formed in 2014 under the supervision of MININFRA by creating an independent entity of the water supply and sanitary departments of the Energy, Water and Sanitation Authority, which was established in 2012 as the organization for implementation, planning, and monitoringof policy regarding energy, water supply, and sanitation.

nationwide, Kigali city was positioned as a model for NRW reduction measures.

The activities of this project in Rwanda began in August 2016 and ended in November 2021. The progress and results of the project are described below.

2. Approach to Problem Solving

2.1 Project Purpose and Outpus

This project aims at capacity strengthening of WASAC to systematically implement measures to reduce NRW in Kigali City. In order to achieve this goal, at the start of the project, four expected Outputs were set out as given below. In addition, objectively verifiable indicators were decided to evaluate the achievement of these outputs and goals.

【Overall Goal】
WASAC conducts NRW reduction measures as planned for Kigali city.

【Project Purpose】
WASAC's capacity is enhanced to conduct NRW reduction measures as planned for Kigali city.

【Output 1】
Planning capacity of NRW reduction of WASAC is enhanced.

【Output 2】
Basic knowledge, skills and technique on NRW control are acquired by WASAC.

【Output 3】
WASAC learned how to conduct NRW reduction measures through the implementation of the Pilot Project.

【Output 4】
4 branches in Kigali establish the system to measure NRW rates accurately.

2.2 Project implementation system

A steering committee ("SC") consisting of the CEO of WASAC, the key staff of WASAC involved in NRW reduction, JICA office, and the team of JICA experts was established as the management organization for smooth implementation of the project.

As the implementation organization of the project activities, (a) a management team consisting of from JICA side; the team of JICA experts and from the WASAC; the Director of the Urban Water and Sanitation Services (UWSS), Director of the Commercial Services (CS), the Financial Officer (FO), and the heads of each department related to NRW reduction side and (b) an action team consisting of the staff of departments relevant to NRW reduction operations were organized.

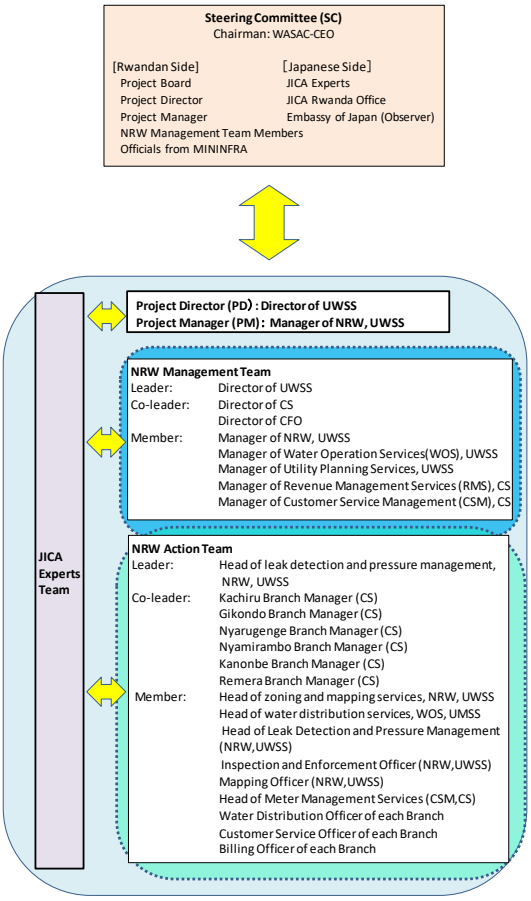


Fig.1: Project implementation system

2.3 Project outputs and approaches

(1) Progress

Originally scheduled for three years, the Project was launched in August 2016 with activities for Outputs 1, 2, 3 and 4 undertaken simultaneously. However, the project period had to be extended until September 2022 due to an unexpected delay in selecting a contractor for monitoring system construction, a one-year travel ban due to the COVID-19 outbreak, and the guarantee period of maintenance of the monitoring system.

In the project, JICA experts were assigned to each specialized field (NRW management, NRW reduction planning, GIS, hydraulic analysis, leak detection, pipe repair/connection, ICT), and WASAC side counterparts (C/P) composed of the management team and the action team were appointed from WASAC headquarters and related departments of its branches. The content and procedures of the planned project activities were shared among the relevant parties and the project activities were proceeded.

(2) Activities regarding Output 1

Despite NRW becoming a huge challenge for the WASAC, WASAC did not have a specific strategic plan to advance measures to reduce NRW. Therefore, by developing a five-year strategic plan for NRW reduction (5YSP) under this project it was intended to materialize the activities of NRW reduction and to improve WASAC's capacity to formulate plans through the preparation process of 5YSP.

In order to formulate the 5YSP, first of all the current situation was surveyed and workshops were repeated and upon grasping the current situation of NRW and sorting out the problems in WASAC's response, and based on the results, concrete activity proposal was drafted. As a result, draft of 5YSP was approved by WASAC's board of directors in April 2018. Thereafter, having the 5YSP been disseminated to all 20 branches of WASAC and the activities started, the implementation status at each branch was monitored through quarterly reports. JICA experts and the C/P side worked together to advance the work shown in the figure below.

Photo1: Workshop

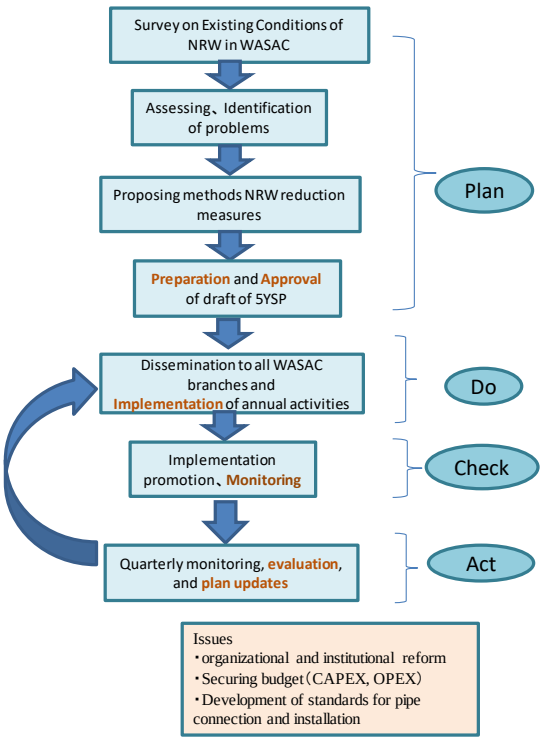
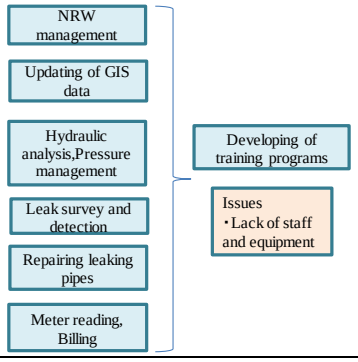


Fig.2: Work flow of Output1

(3) Activities regarding Output 2

As an activity for WASAC staff to acquire basic knowledge, technology, and skills related to NRW

management, in-room and field training were conducted on NRW control, GIS database updating, hydraulic analysis, leak detection, leaking pipe repair and the management of customer meters and water billing. Necessary equipment including leak detection equipment, pipe repair equipment, and customer meter management equipment used for training were provided. Through OJT[2] under the pilot project in output 3 enhancing of basic knowledge, technology, and skills required in the field work was targeted.



No	Subject
1	Introduction to NRW Reduction Activities
2	High-Pressure Management
3	Water Distribution Management
4	Leakage Surveys and Repair
5	Replacement of Water Supply and Distribution Pipes
6	Management of Reservoirs
7	Management of Volume of Water Distribution
8	Maintenance of Charge Collection Data and Customer Meters
9	Monitoring of NRW Rates
10	Preparation for NRW Reduction Activities
11	Handling of Survey Equipment

Fig.3: Work flow of Output2 and Training items


Photo2: Training by OJT

(4) Activities regarding Output 3

A pilot project was conducted with the aim of improving WASAC's capacity to implement measures to reduce NRW. To this end, in the two pilot areas (Area 1: Kadobogo, Area 2: Ruyenzi) established in the water distribution area of the Kacyiru branch and the Nyarugenge branch, concrete measures that are expected to be effective for NRW reduction were tried and the effectiveness was verified by indicators such as NRW rate, Qmnf[3], number of leak repairs, etc. Moreover, cost-benefit analysis was conducted for each individual activity and for the pilot project as a whole. The activities are shown in Figure 4.

In establishing the pilot areas having functions of DMA[4] as a preparation for starting of activities, survey of piping networks and customer positions, adjustment of existing piping for hydraulic isolation from adjacent areas, and installation of flow meters for measuring the amount of water flow into and out of the area etc. were conducted as part of the training under pilot project. After DMA formation, the NRW rate has been calculated by collecting monthly data of the water volume (billed water) used by customers in the area served by WASAC and of the flow in to the area at in-flow points.

In Output 3, the items tried for NRW reduction were survey of water use by customer, customer meter survey and meter replacements, water leakage survey and leakage detection, leakage repairs, installation of pressure reducing valves (PRV[5]) for pressure control, replacement of water distribution and service pipes, etc. Equipment for DMA formation, replacement customer meters, PRV ancillary pipe materials, and replacement water pipe materials was provided, and the installation work was carried out as part of the training.

2 On-the-Job Training, a training method to acquire business knowledge through practice in the workplace.

3 The minimum flow rate during nighttime hours when no water is expected to be used at all during nighttime hours.

4 Abbreviation of District Meter Areas, areas partitioned for control of water supply with water meters

5 Pressure Reducing Valve, Regulator valve to maintain water supply pressure at a constant level

Photo3: Activity for Pilot Project

Photo4: Underground and Surface Leakage

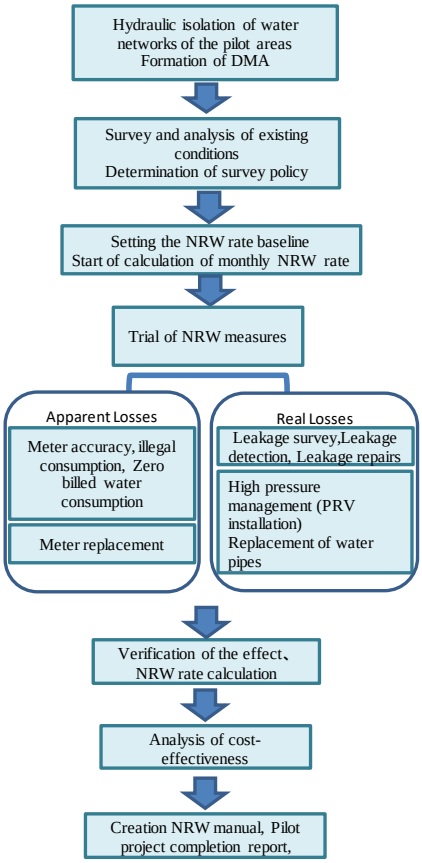


Fig.4: Work flow of Output3

(5) Activities regarding Output 4

The water distribution network in Kigali City is controlled by six branches of WASAC, but it was not possible to individually grasp the NRW rate of each branch. For two of the six branches (Remera and Kanombe), a remote monitoring system was built using the flowmeter manufacturer's server with the support of the Netherlands (SUSWAS[6] Project). For this project, it was required to build WASAC's own remote monitoring system for automatic collection of water distribution data at the remaining four branches (Nyarugenge, Gikondo, Kacyiru, Nyamirambo), and to build a system to calculate the NRW rate for each branch using the obtained data. Since it was necessary to carry out hydraulic isolation among water network of each branch, manholes for the installation of electromagnetic flow meters were constructed at the branch boundaries. In addition, the entire engineering design of the remote monitoring system was carried out.

Equipment procurement and installation work was contracted by a Japanese contractor and started in October 2019. The system was scheduled to be completed in June 2020, but due to measures against the COVID-19 infection, work was suspended from March 2020, resulting in delays in the procurement of equipment and installation work. The work resumed about 1 year later, and finally, in September 2021, the construction of the monitoring system was completed substantially leaving the maintenance period after the system was built. After that, training was conducted on how to use the computer software to calculate the NRW rate using the data collected by the monitoring system. The activities for establishing the monitoring system are shown in Figure 5.

6 A public-private partnership project in which the Dutch government holds a 60% stake and the private sector holds a 40% stake.

Photo5: Data Transmission Facility for Monitoring System

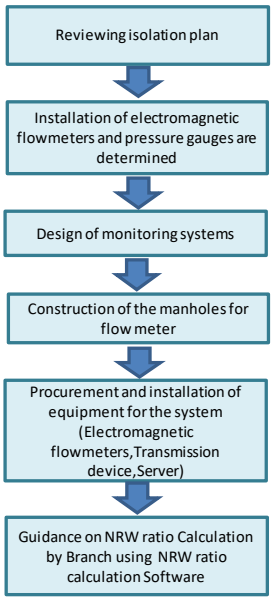


Fig.5: Work flow of Output4

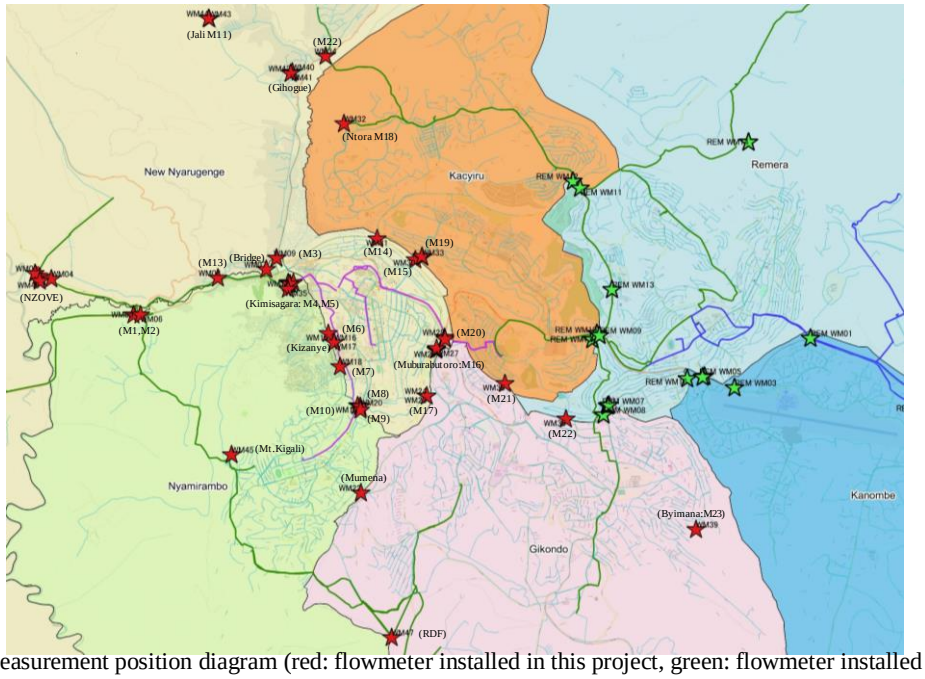


Fig.6: Flow measurement position diagram (red: flowmeter installed in this project, green: flowmeter installed in SUSWAS)

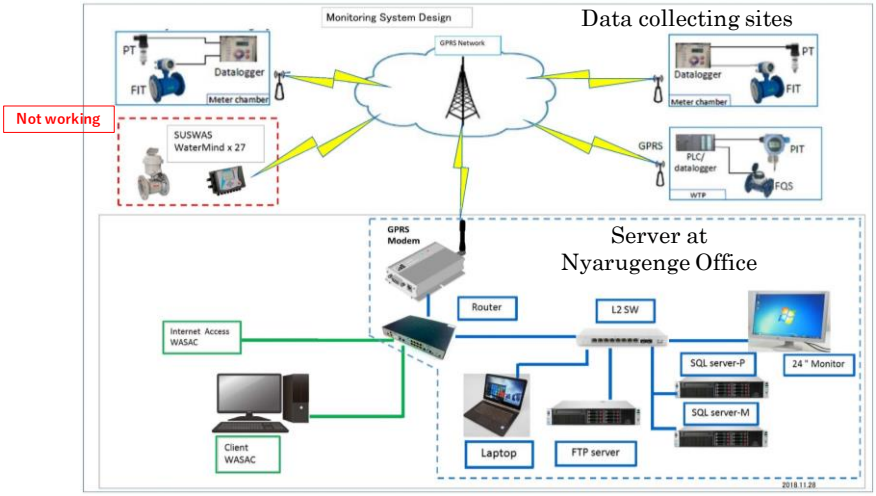


Fig.7: Overview of the monitoring system

(6) Training in Japan and third Countries

With regard to measures against NRW, which is a major issue in the management of water utilities, training was conducted not only as project training within Rwanda, but also three times in Japan and twice in a third-country, for widely observing and listening to the status of NRW countermeasures in other countries as a reference for the implementation of WASAC activities and moreover for increasing the motivation of WASAC staff.

In the training in Japan, the training was conducted for the manager class focusing on the management of water supply utilities and for the engineers, who are participating in activities in the pilot areas of this project, giving emphasis on on-site practices, and they learned about high Japanese technology that attained a NRW rate of less than 10% and the history to that end.

The third country training was conducted in Kenya and Malawi. WASAC felt the need to learn from each other among countries in the same East African region, which have the same challenge of high NRW rates. Accordingly, through workshops and field observations conducted with water supply utilities in relevant areas, lot of learning and stimulation was received.

Photo6: Training

Table1: List of Training in Japan

No.	Timing	Field of training	Number of trainees	Training themes
1	January 23 to 31, 2017	Management Team	5	- Introduction to water service management and NRW - Outline of water facilities in Yokohama and Kobe Cities and other matters
2	August 14 to 30, 2017	Business affairs and GIS matter	5	- Introduction to water service management and NRW - Customer information management, meter management and reading, and water service - Examples of how local governments utilize GIS, purposes of use, and other matters
3	Nov. 13 to 30, 2017	Technical matter	5	Introduction to NRW, pressure management, leak detection, distribution management, and other matters

Table2: Training in third Countries

No	Country	Timing	Field of training	Trainees	Training Themes
1	Kenya	May 7 to 10, 2018	Management Team	2	An introduction and discussion of activity on NRW reduction carried out in Kenya (WASREB, MWI, KEWI, NYERI)
2	Malawi	Sept 22 to 27, 2019	Management and Action Teams	5	An introduction and discussion of activity on NRW reduction carried out in Malawi (LWB, EWASCO)

3. Practical Results of the Approach

3.1 Results of the Project

The "Project Terminal Evaluation" was conducted by JICA's survey team in June 2020. In November 2021, over a year after the terminal evaluation was conducted, as almost all activities of the project were completed, the final SC was held on November 25,2021 to summarize the project result. The results confirmed are as follows:

[Outputs]

(1) Result of Output 1

In the process of formulating a 5YSP, the results of questionnaires and the measures to deal with issues addressed during the workshop were grouped, and five areas regarded as the main components of the action plan were determined. 5YSP was approved by the Board of Directors of WASAC on April 27, 2018. Each branch prepares and operates an annual plan for NRW reduction activities. During quarterly monitoring of 5YSP, the workshops are conducted for branches nationwide to share opinion and create awareness on issues and problems within WASAC. All the processes and challenges of the project are shared through various workshops, seminars, conferences and SC. The PDCA (Plan-Do-Check-Action) cycle from planning that starts with the extraction of issues, implementation, monitoring and evaluation, revision and updating has begun foster, and the Output 1 " Planning capacity of WASAC for NRW reduction is enhanced." was achieved.

(2) Result of Output 2

Training was systematically conducted not only for action teams centered on engineers, but also for management teams centered on managers. A total of 596 staff members were trained. However, although a manual for NRW reduction has been prepared, the stage "the training program formulated by this project will be incorporated into WASAC's human resource development plan", which is expected as a final result has not reached.

In the surveys for leak detection, high water pressure control etc., non-availability of persons to shoulder the work and lack of survey equipment were problems faced due to shortage of relevant staff at the branches, and moreover, the restriction of movement between branches imposed since early 2020 to prevent the spread of COVID-19 also had become an obstructive factor. In the future, it is desirable to incorporate the training program into WASAC training courses in cooperation with WSAC's support service. In conclusion, expected Output 2, " Basic knowledge, skills and technique on NRW control are acquired by WASAC.," was generally achieved.

(3) Result of Output 3

Through implementation of the pilot project, WASAC has learned effective NRW reduction methods: DMA formation, on-site testing of customer meters, leakage survey (flow rate and pressure measurement), leakage detection, high pressure control (pressure survey, PRV installation), replacement plan of distribution and service pipe, installation supervision, customer location map, etc. Through these OJT activities, WASAC counterparts shared their experiences among action team members.

The achieved value of NRW rate was 25% in Area 1 (temporarily achieved below the target value of 20%) and 56% in Area 2. Although, the reduction of the NRW rate did not reach the target, by conducting cost-benefit analysis it was confirmed that there was a financial benefit on the NRW reduction measures. In addition, WASAC recognized that although post-action corrective measures are also important, preventive measures taken from the planning and design stages of water distribution network facilities to prevent the occurrence of NRW are the most important.

The capacity of WASAC's staff to practice NRW reduction measures has greatly improved which was and essential goal of this Output 3, "WASAC learned how to conduct NRW reduction measures through the implementation of the Pilot Project.", and in conclusion, Outcome 3 has generally been achieved. Through implementation of the pilot project, WASAC has acquired knowledge in the following;

1) Breakdown of NRW

As a result of the survey, breakdown of NRW in the Pilot areas became clear. Breakdown shows that physical loss is about 80- 90 % of the total volume of NRW whereas the commercial losses are around 10-20 %. It also revealed that water leakage was a major cause of NRW and of that the underground (invisible) leakage was large.

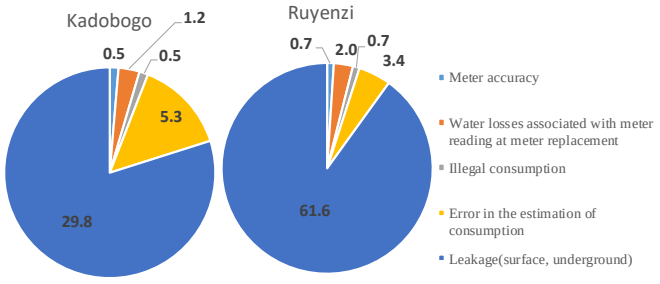


Fig.8: Breakdown of NRW by pilot area

2) Apparent losses

Although meters are installed for almost all of the

customers, the accuracy testing of the customer meters revealed that about 30% of the meters had problems in accuracy and defects etc. Therefore, the degree of improvement in the NRW rate was evaluated by comparing the total volume of the billed water before and after replacement of meters having accuracy below the standard value.

2017/6	2017/7	2017/8	2017/9	2017/10	2017/11	2017/12	2018/1	2018/2	2018/3	2018/4	2018/5	2018/6	2018/7	2018/8	2018/9	2018/10
39	23	24	36	0	0	23	17	14	14	13	10	13	14	13	13	19
7	9	7	7	5	5	5	5	5	4	4	7	0	0	27	9	7
10	10	0	10	12	8	10	5	10	12	14	7	10	12	9	26	10
10	10	0	10	10	11	11	5	10	11	10	7	11	8	10	9	9
0	30	7	6	0	0	0	10	9	0	0	0	0	0	20	0	25
5	8	8	8	10	8	10	10	5	0	11	6	11	10	9	10	8
64	44	36	36	36	29	30	38	47	36	31	38	54	39	42	23	22
9	10	18	12	8	7	16	10	11	8	10	9	12	8	8	10	13
11	14	10	0	19	12	0	0	20	10	9	13	13	11	15	12	13
11	19	29	35	11	18	21	20	21	45	38	31	57	34	37	126	53
8	8	7	0	18	0	13	11	7	8	14	8	9	7	8	10	8
13	0	6	18	20	20	20	20	13	16	0	39	15	16	20	20	16
0	0	0	0	0	0	0	0	35	50	33	201	35	27	24	22	54
0	0	6	18	0	30	13	0	0	0	0	0	0	0	0	0	0
6	0	0	54	18	0	28	0	36	25	22	15	18	22	22	20	15
14	9	9	9	16	15	15	9	17	9	11	5	10	10	10	10	10
15	16	11	11	9	10	10	10	11	16	13	16	18	20	23	23	20
19	20	20	23	21	19	15	22	16	18	12	15	12	14	14	13	18
0	23	10	10	11	0	15	15	0	17	0	20	10	10	21	15	14
9	10	16	10	11	11	13	10	7	6	9	13	12	8	10	11	9
94	101	184	165	156	25	177	92	118	67	145	80	182	113	108	200	142
23	19	23	25	20	17	17	21	26	18	15	19	20	17	20	23	22
49	35	31	40	35	33	28	39	41	33	32	41	35	31	40	44	43
0	14	5	0	0	8	4	7	6	6	6	6	5	2	5	4	6
7	5	5	6	4	5	2	3	5	5	5	5	6	7	7	6	0
0	31	15	0	32	11	5	20	0	27	8	0	0	37	13	11	13
17	25	16	17	24	20	12	19	22	22	18	16	16	18	21	16	15
8	8	8	6	8	7	8	8	0	20	0	0	0	0	0	0	0

Item	Before replacement	After replacement	Ratio
Average monthly billed water consumption: m3	3,314	3,334	1.006

Fig.9: Comparison of billed water consumption before and after meter replacement

In conclusion, in the case of WASAC, the meter installation rate was already as high as about 100%, the reduction effect of the amount of NRW due to meter replacement is small as mentioned above. Meter error is sometimes on the positive side, so it was judged that the direct advantage of reducing NRW to the entire area by meter replacement is small. However, faulty meters and meters with large errors should of course be replaced, and meter accuracy control should be done to ensure fairness and impartiality of billing to customers. In addition to the accuracy of the meter, losses due to illegal use by residents and estimation error in the billing volume when meter reading cannot be done are also including in the apparent loss.

3) Physical losses (leakage)

In the pilot area, as means of reducing water leakage, the leakage detection and repairs, high pressure control by installation of PRV and replacement of water distribution and service pipes having a lot of leaks were tried out. The approximate amount of leakage can be known by measuring the flow volume during the night time when the residents do not use water. The results are as follows:

a. Suppression of Water Leakage with Reduction in High Water Pressure (Effect of PRVs)

Severely undulating terrain being a topographical feature of Kigali City, houses are constructed on hill slopes and lowlands and therefore the water transmission and distribution network facilities are extremely complex. However, transmission and distribution of sufficient volume of water kept as the main purpose, the facilities have not been developed giving consideration to measures against high water pressure. constructed mainly for the without due. Therefore, there is high water pressure in the existing distribution network which easily leads to frequent leakage.

In the activities of the pilot area, it was verified that the amount of water leakage is reduced by reducing high water pressure, and that the management of high-water pressure has a high effect of water leakage control, due to the decrease in the minimum night flow rate and the decrease in the number of leaks as a result of the installation of PRV. Moreover, unless high water pressure is reduced, it was found that even if the leak was repaired, the leak recurred, and the effect of water leakage repair was limited. As shown in the table below, the effect of trial installation of PRV in both areas was effective in reducing the amount of water leakage by 30% to 60%.

Table3: Effectiveness of PRVs (Pilot Area 1)

Item	PM2	PM3
	Qmnf (P)	Qmnf (P)
Pre-installation	0.74 (7.0bar)	9.44 (7.5bar)
Post-installation	0.31（2.5bar）	5.80 (2.0bar)
Effective reduction	0.43(58%)	3.64(39%)

Table4: Effectiveness of PRVs (Pilot Area 2)

Item	PRV1	PRV2	PRV3
	Qmnf (P)	Qmnf (P)	Qmnf (P)
Pre-installation	7.48 (9.1bar)	3.74 (8.7bar)	1.84 (7.0bar)
Post-installation	1.50（2.5bar）	2.60（6.0bar）	0.78 (1.0bar)
Effective reduction	5.98(80%)	1.14(30%)	1.06 (58%)

b. Quality of Material and Installation of Distribution and Service Pipes and Replacement of Leaking Pipes

It has become evident that the cause of the leaks in most cases is attributable to small-diameter (HDPE[7]) distribution and service pipes. In view of the conditions at installation locations, HDPE pipes that are easy to install are widely used. However, WASAC entrusts the procurement of HDPE pipes to customers and they purchase cheap pipes that do not satisfy the required standards. Such pipes being of poor quality cannot withstand high water pressure and get cracked causing leakages in many cases. The customers pay little attention to the pressure resistance when they purchase pipes.

WASAC has recognized the importance of procuring materials that satisfy its standards and standardizing types and grades of materials. Therefore, WASAC should stop entrusting the procurement of materials to the customers. Instead, WASAC should procure pipes that satisfy the standards by itself and install them under appropriate work management. WASAC may consider the possibility of contracting out the procurement and installation works to qualified contractors authorized by WASAC in the future.

The water leakage reduction effect of the water pipe replacement in Area 1 is as given below with the leakages having reduced by more than 40%.

Table5: Effect of water pipe replacement on water leakage reduction

Item	PM1	PM2
Pre-replacement Qmnf (m^3/h)	5.38	2.31
Post-replacement Qmnf (m^3/h)	3.1	0.09
Reduction (m^3/h)	2.28	2.22
Reduction rate (%)	42	96

Photo7: Replacement of Distribution Pipe

c. Confirmation of effect

By carrying out these activities, there was a clear decrease in the amount of water leakage in each area. From the transition diagram, shown below, of the Qmnf value prepared based on the measurement history of Qmnf, it can be seen that Qmnf is clearly reduced due to PRV installation, leak repairs, and replacement of water pipes.

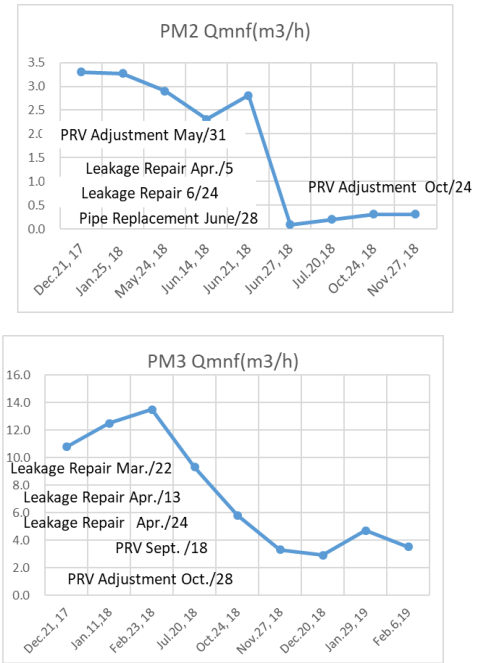


Fig.10: Changes of Qmnf

7 High Density Polyethylene

Further, from the plot diagram of the leaking points, it can be clearly interpreted that the number of leaking places has decreased sharply.

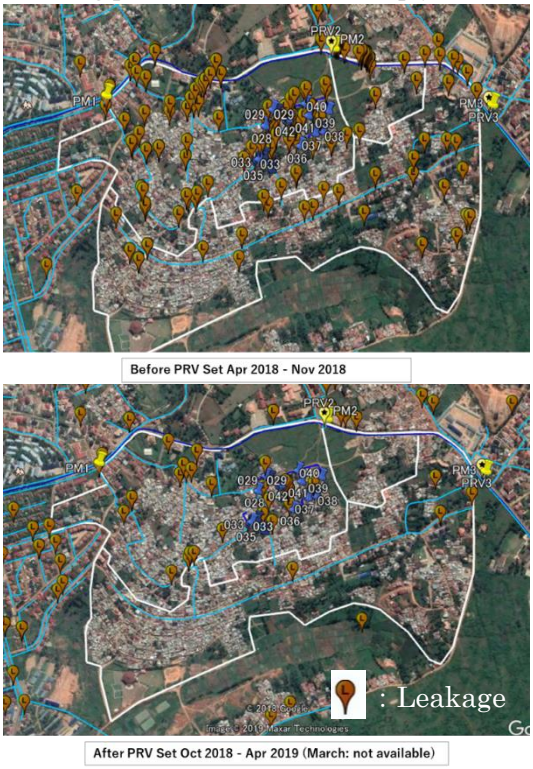


Fig.11: Location of leakage repair points in Kadobogo

4) Reduction in NRW rate

After setting a baseline for NRW in both pilot areas, measurements of NRW rates were taken every month while conducting NRW reduction activities and the results are as follows.

In the Kadobogo area, as a result of water leakage repair, reduction of high-water pressure by PRV, and replacement of water distribution and service pipes, the NRW rate was reduced by 12% from the baseline value of 37% to the attained value of 25%. On the other hand, in the Ruyenzi area, high water pressure reduction by PRV and water leakage repairs were carried out, but since bypass water distribution is done from the reservoir for water supply outside the pilot area, high water pressure could not be effectively reduced in the distribution network, and the NRW rate reduced only by 10% from the baseline value of 68% to the attained value of 58%.

Table6: NRW rates for the pilot project

Pilot area	Baseline	Target	Achieved	Reduction
Area1:Kadobogo	37%	20%	25%	12%
Area2:Ruyenzi	68%	25%	58%	10%

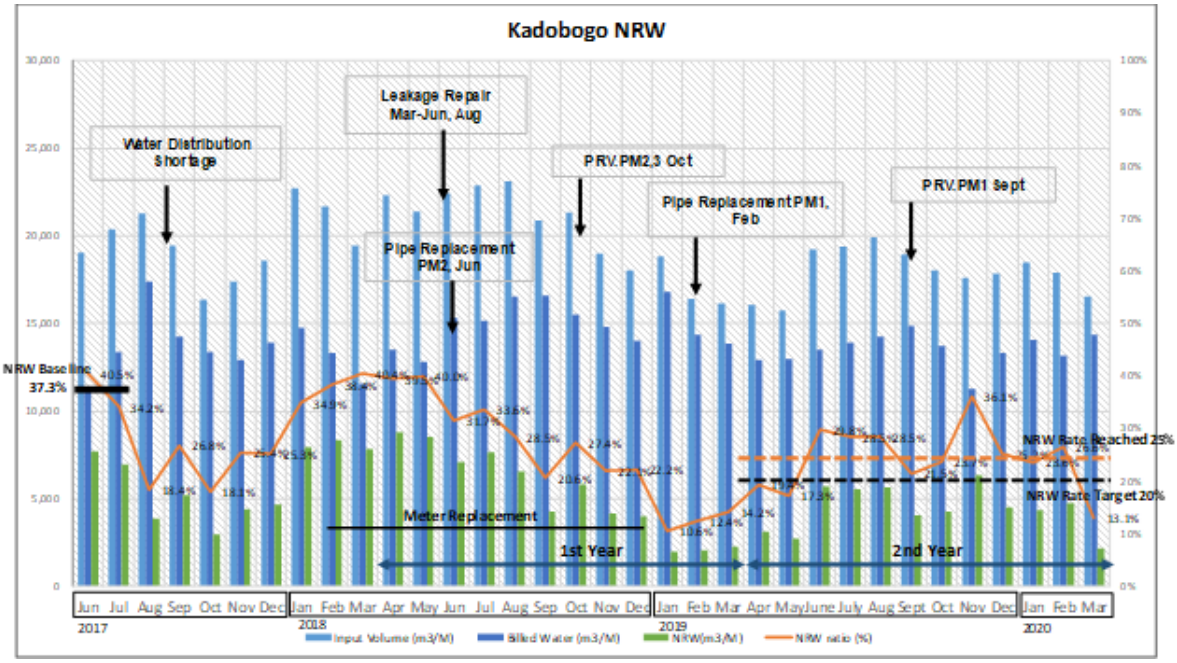


Fig.12: Changes of NRW in Kadobogo

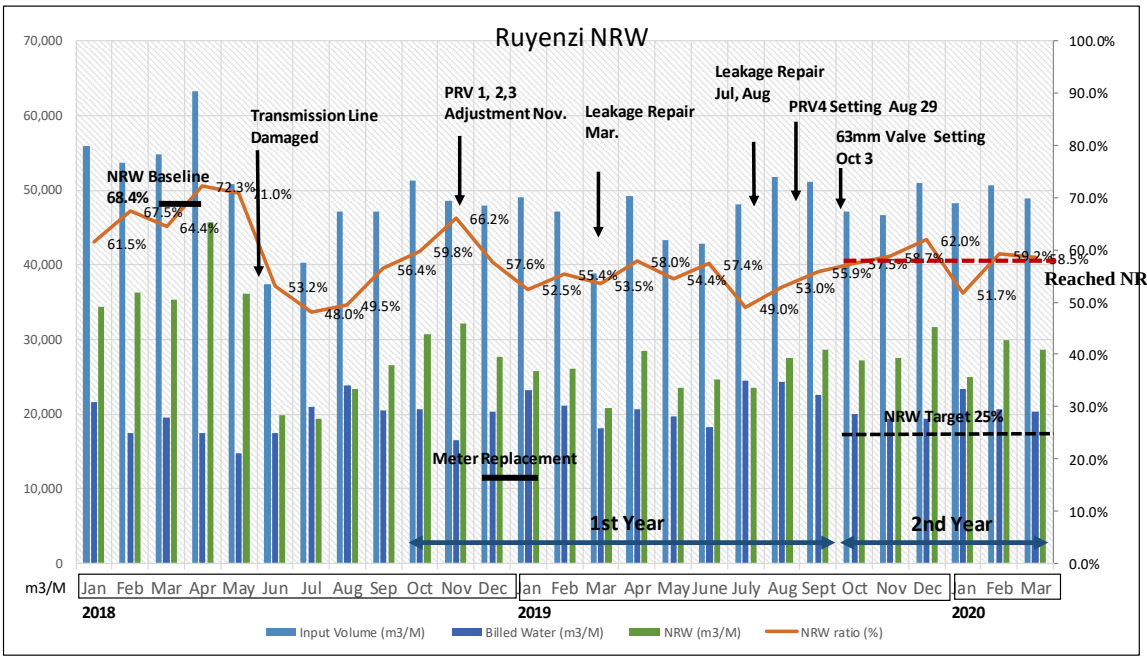


Fig.13: Changes of NRW in Ruyenzi

5) Results of cost-benefit analysis

In the both pilot areas, the target rate of NRW rate could not be achieved. However, from the results of cost-benefit analysis the calculated Net Present Value (NPV) and the Benefit -Cost Ratio (B/C) were (NPV>0, B/C>1.0) clearly showing the effect of the NRW reduction activities in both pilot areas. Kadobogo will recover investment costs from the following year after the NRW reduction activities and at Ruyenzi will in the implementation year. In FY2005, B/C will be 3.6 times higher in Kadobogo and 7.7 times for Ruyenzi.

As the conclusion, it can be said that even if the NRW rate is very high as 68%, such as in Ruyenzi, the investment effect for the NRW reduction activities can be sufficiently achieved if NRW rate can be reduced by some extent (about 10%). Therefore, it is important to actively promote activities with high return on investment, such as reducing high water pressure (installation of PRVs), repairing water leakages (especially underground leaks), and replacing water pipes.

Kadobogo

Year	NRW Reduction	Benefit Water Bill	Cost Capex, Opex	Net Benefit	B/C
	m3/M	Rwf	Rwf	Rwf	
1st year	27,913	15,826,812	46,920,843	-31,094,031	0.3
2nd year	67,241	51,794,327	44,890,896	6,903,431	1.2
3rd year	67,241	83,805,287	42,975,851	40,829,436	2.0
4th year	67,241	114,004,306	41,169,206	72,835,100	2.8
5th year	67,241	142,493,946	39,464,823	103,029,123	3.6

Note: Net Benefit and B/C are yearly cumulative value.

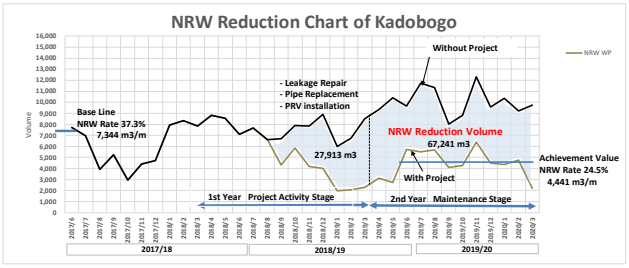


Fig.14: Result of cost-benefit analysis in Kadobogo

Ruyenzi

Year	NRW Reduction	Benefit Water Bill	Cost Capex, Opex	Net Benefit	B/C
	m3/M	Rwf	Rwf	Rwf	
1st year	125,505	74,299,139	42,419,120	31,880,019	1.8
2nd year	121,729	142,283,363	42,347,573	99,935,790	3.4
3rd year	121,729	206,419,424	42,280,076	164,139,348	4.9
4th year	121,729	266,925,141	42,216,399	224,708,742	6.3
5th year	121,729	324,006,006	42,156,326	281,849,680	7.7

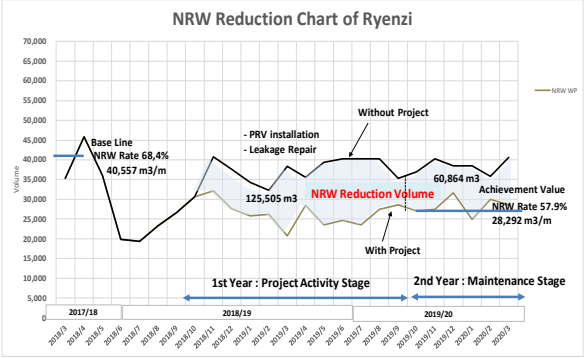


Fig.15: Result of cost-benefit analysis in Ruyenzi

6) NRW reduction procedures

As a result of the pilot project, the procedure for effective NRW reduction activities is as follows:

a) Dealing with physical loss (leakage).

- ✓ Implementation of high water pressure controls
  - ・Setting standard for the maximum hydrostatic pressure in facility design
  - ・New construction and reconfiguration of water distribution facilities that strictly adhere to water pressure standards
  - ・Installation and appropriate operation of pressure reduction facilities (PRV, etc.)
- ✓ Strict adherence to the standards for pipe material used, and appropriate installation
- ✓ Replacement of the pipes with frequent leaks and/or of aged pipes
- ✓ Leakage survey (minimum night flow, step test), leakage repairs

b) Dealing with commercial losses.

- ✓ Customer meter maintenance.
  - ・Meter testing based on results of billing water volume analysis
  - ・Ascertained replacement of faulty meters such as with defects, large error.
  - ・Periodical meter replacement.
- ✓ Optimization of the billing water volume.
  - ・Strict meter reading inspections / reduction of locations needing estimation of billing water volume.
  - ・Investigation and rectification of problems related zero-billed water customers.

(4) Result of Output4

The construction of the monitoring system was almost completed except for some equipment related to flow meters. Only the maintenance period is left.

WASAC, for its part, is now proceeding with the procurement of 16 flow meters and the adjustment of customer registrations due to partial shifting of branch-to-branch boundaries. For this reason, at present, branches in Kigali city cannot calculate the NRW rate separately, but the Output 4 "4 branches in Kigali establish the system to measure NRW rates accurately. " has almost been achieved.

(5) Achievement of Overall Goal of the Project

The Project adopted four approaches: Output 1) planning; Output 2) basic techniques; Output 3) application of basic techniques, and Output 4) establishment of NRW rate measuring system. As a result, WASAC steadily carried out 5YSP activities and their monitoring, through the PDCA cycle, as shown by the achievement status of Outcome 1. For Output 2, the WASAC's staff acquired knowledge and implementation skills through a series of training. As for Output 3, their capacity to cope with actual situations/challenges in the field has also been enhanced through the pilot project. WASAC management is aware of the NRW reduction effect, and the results of the pilot project are being disseminated outside the pilot area. The NRW rate measurement system for Output 4 was completed, only the maintenance period of the installed system remains. As a result, WASAC's capacity to systematically implement measures to reduce NRW

has been improved, and the project goals have been almost achieved.

WASAC, on the other hand, has budget challenges. In terms of the implementation of NRW reduction activities, the actual budget allocation does not correspond to the annual action plan (budget execution is about 20%). The budget shortfall of the NRW Action Plan is a major obstacle to the practical use of technical capabilities acquired through the project. WASAC's inadequate annual budget does not cover all of the NRW reduction activities and the capital expenditure (CAPEX) required to reduce NRW is quite big compared to WASAC's budget. Therefore, WASAC should seek external financing.

4. Other Activities

In addition to the activities mentioned above, the following activities were also carried out in the project.

4.1 Support or Countermeasures Taken Against COVID-19

Although provision of continuous and stable supply of safe water is a major mission of water supply services, WASAC cannot supply clean water to its customers stably through 24 hours daily, because of the frequent occurrence of leakages and cut-off of water supply each time for such leakage repairs, insufficient water distribution, and inadequate maintenance of the water supply and distribution network.

With regard to COVID-19 pandemic, WASAC made an emergency request to JICA in June 2020 for assistance to address the pandemic situation, and JICA decided to urgently carry out the following activities under this project and implemented them.

(1) Procurement of materials and equipment for Reduction of Intermittent Water Supply

As a result of discussions with counterparts, the contents of materials and equipment were decided as follows; "materials for water leakage repair", "materials for replacement of water distribution and service pipes in pilot area 2", and "float valve for distribution reservoir in Kigali City". Counterparts and local project staff discussed with experts in Japan in online meetings to survey and select the materials and equipment.

The materials and equipment (total cost approximately US$193,000) procured through the project were handed over to WASAC in November 2021 from JICA.

(2) Emergency water supply to people with limited access to clean water

Emergency assistance was provided to install temporary water supply tanks in areas where water supply is insufficient in the WASAC's water distribution network, and to transport water by private water tankers

The temporary water tanks (10m3) were procured and they were installed at 23 sites in WASAC's four branches in Kigali city (Kanombe, Remera, Kacyiru, Nyarugenge), and operated as public taps.

The water transportation work was entrusted to two contractors in Kigali City who own water tankers. The operation was carried out for 11 months from November 2020 to September 2021. The total water supply volume was 43,200 m3 and the total cost was 259,500 USD, and about 5,200 households (about 26,000 people) benefited from the emergency COVID-19 prevention measures.

Photo8: Operation of Emergency Water Supply by Water Tanker

4.2 Water Utility Regional Partnership (WURP) Activities

WASAC concluded an agreement of cooperation with the Lilongwe Water Board (LWB) in Malawi in July 2017, to promote mutual learning on subjects, including NRW reduction.

In November 2018, the first workshop, "Workshop on the Benchmarking of NRW Reduction Measures," was held in Rwanda, with the participation of Embu Water & Sanitation Company (EWASCO) from Kenya, effectively launching the Water Utility Regional Partnership (WURP), a regional coordination framework among water utilities of the three countries: Rwanda (WASAC), Malawi (LWB) and Kenya (EWASCO). The second workshop, hosted by LWB was held in September 2019 in Malawi.

After that, the third workshop, to be hosted by EWASCO in Kenya in 2021, has been put off due to the COVID-19 Pandemic. Since then, it has not been possible to hold workshops gathering in one country due to the impact of the COVID-19 Pandemic, but the progress of NRW reduction activities is reported on online meetings that are held every two months.

An environment has been created in which water utilities with the same NRW issues in East African countries having the same level of economic growth and development, can work together to solve problems.

The JICA Offices and experts in ongoing projects in the three countries provide the necessary support, with advice etc., for these partnership activities. The Regional Partnership is making headway, backed by the friendly relationship among the members, and is expected to develop further.

5. Initiatives adopted and lessons learned during project implementation

5.1 Initiatives adopted

WASAC's counterparts participate in this project while performing normal work of WASAC, but it is important to always be conscious that activities in this project are also part of normal work. The purpose of this project is to further clarify, streamline, and sustain WASAC's operations to reduce NRW, and is an extension of normal operations. The purpose is to enable WASAC itself to produce the results in its normal work. To that end, WASAC and a team of JICA experts shared the status and problems of their activities through regular meetings and close communication on a daily basis, thereby raising motivation.

Regional partnership between water utilities in Rwanda, Malawi and Kenya were established through project support. As a partnership activity, the common NRW reduction activity items were set and their progress and results have been discussed at an online workshop held every two months. In addition, workshops are held to visit each country. Such exchange opportunities serve to motivate them as an effective platform to teach and learn from each other.

5.2 Lessons Learned

A distribution reservoir has functions not only to control the volume of water distributed but also to

reduce high transmission pressure to distribution areas. However, there are many cases in the existing pipe network of WASAC where water is supplied to distribution areas at high altitudes using bypass pipes without passing through distribution reservoirs, or using a pipe that directly branches off from a transmission pipeline between the treatment plant and a distribution reservoir. This means, highly pressurized water is supplied to the distribution areas which has become a major cause of the leakage in the distribution networks.

Despite the severely undulating topography of Kigali, the existing water distribution facilities are not designed giving consideration to controlling high-water pressure. In order to prevent leakage, the design water pressure should be set, and the water distribution facilities should be arranged so that excessive pressure does not occur in the water distribution network and their related facilities.

For arranging the facilities, the water distribution area needs to be segmented into blocks based on elevation differences, with a certain range of pressure set with reference to the design pressure. However, block segmentation of an existing water distribution network usually requires substantial cost and time for survey, design and construction works. Therefore, returning to the basic rule, water distribution facilities have to be designed giving due attention, right from the planning stage of project implementation, to precautionary measures to prevent NRW (water leakage) from emerging.

By executing this technical cooperation project on NRW and through trial NRW reduction activities in the pilot project WASAC gained expertise in addressing NRW reduction. Although the project tried to disseminate those skills and expertise across the entire area of WASAC, due to organizational and financial challenges inside WASAC and the limitations in the scope of activities covered by a technical cooperation project, NRW reduction in the entire area of Kigali city is not achieved.

Unless wide-area investments in the range of branch-level are made sequentially in order to reduce the NRW rate across entire Kigali City, a visible effect cannot be expected.

Basically, it is considered desirable to renovate paying attention to the following points in mind.

-Formation of water distribution blocks relative to elevation differences over a certain range
-For that purpose, reorganization of main water distribution pipelines, rearrangement of distribution reservoir (abolition of bypass pipes)
-Replacement of water distribution pipes in the block, installation of stop valves

The large investment is not included in the budget for the NRW reduction measures presented to the 5YSP. Achieving of the Overall Goal of "NRW rate in Kigali City 25%" is heavily dependent on the availability of utilizable own funds in the budget of WASAC and external funding (assistance from development assistance partners). Activities for achieving the Overall Goal should be continued, but it will take substantial time to achieve the goal.

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- Japan International Cooperation Agency (2016) "Detailed Plan Formulation Survey Report for Strengthening Non Revenue Water Countermeasures in Kigali City, Rwanda "
- Japan International Cooperation Agency (2021) "Project for Water Supply Master Plan for City of Kigali, Rwanda"