Water and Sanitation Corporation (WASAC)
Republic of Rwanda

THE PROJECT FOR WATER SUPPLY MASTER PLAN FOR CITY OF KIGALI IN THE REPUBLIC OF RWANDA

FINAL REPORT (Pre-release Version)

VOLUME 1

Executive Summary

October 2021

Japan International Cooperation Agency (JICA)

Nihon Suido Consultants Co., Ltd.
Yachiyo Engineering Co., Ltd.

GE
JR(P)
21-086

EXCHANGE RATE (for Maser Plan Study)

Average value of the telegraphic transfer middle rates at the end of each month between October 2019 and March 2020 published by the National Bank of Rwanda

USD 1 ＝ RWF 923
JPY 1 ＝ RWF 8.48
USD 1 ＝ JPY 108.84

EXCHANGE RATE (for Feasibility Study)

Average value of the telegraphic transfer middle rates at the end of each month between October 2020 and March 2021 published by the National Bank of Rwanda

USD 1 ＝ RWF 973
JPY 1 ＝ RWF 9.23
USD 1 ＝ JPY 105.42

Preface

The Final Report (F/R) of the Water Supply Master Plan for City of Kigali (KWSMP) consists of the following separated volumes, namely:

- Volume 1: Executive Summary
- Volume 2: Kigali Water Supply Master Plan
- Volume 3: Feasibility Study for the Project for Expansion of Karenge Water Supply System
- Volume 4: Feasibility Study for the Project for Construction of Masaka Water Supply System

This report is the “Volume 1: Executive Summary” of the F/R

THE PROJECT FOR WATER SUPPLY MASTER PLAN
FOR
CITY OF KIGALI
FINAL REPORT
Volume 1
Executive Summary

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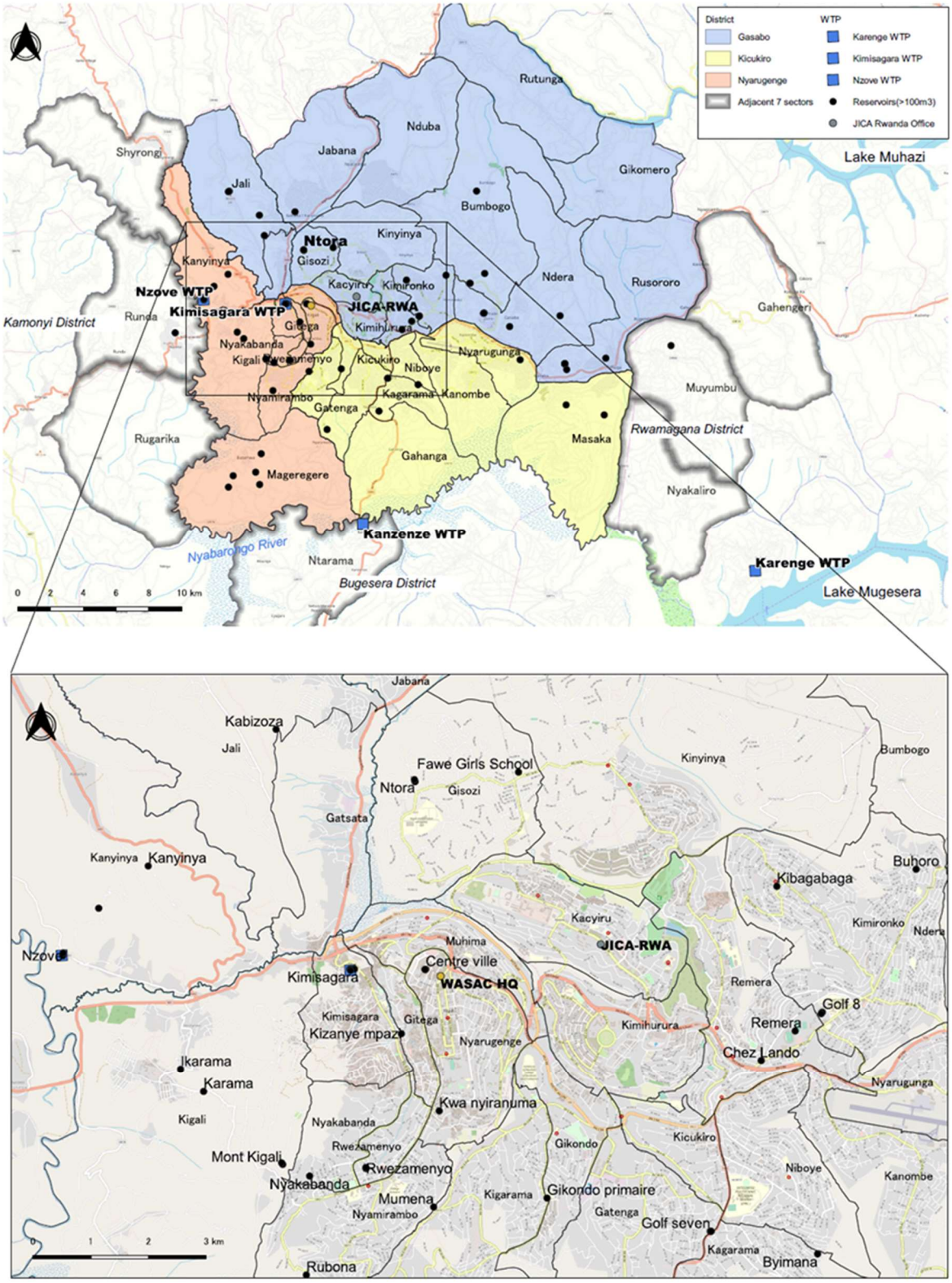
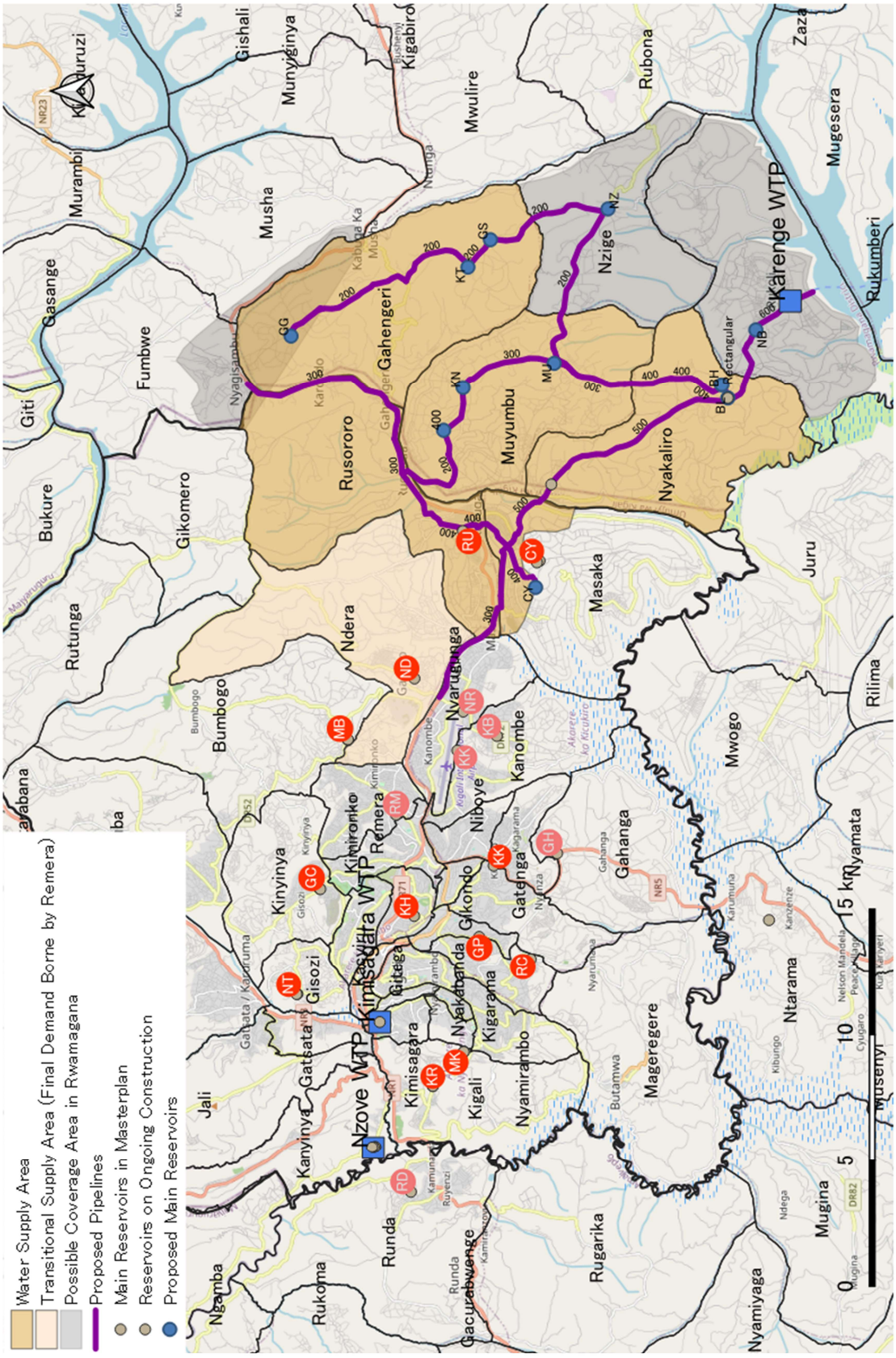
Location Map of Kigali Water Supply Master Plan Study

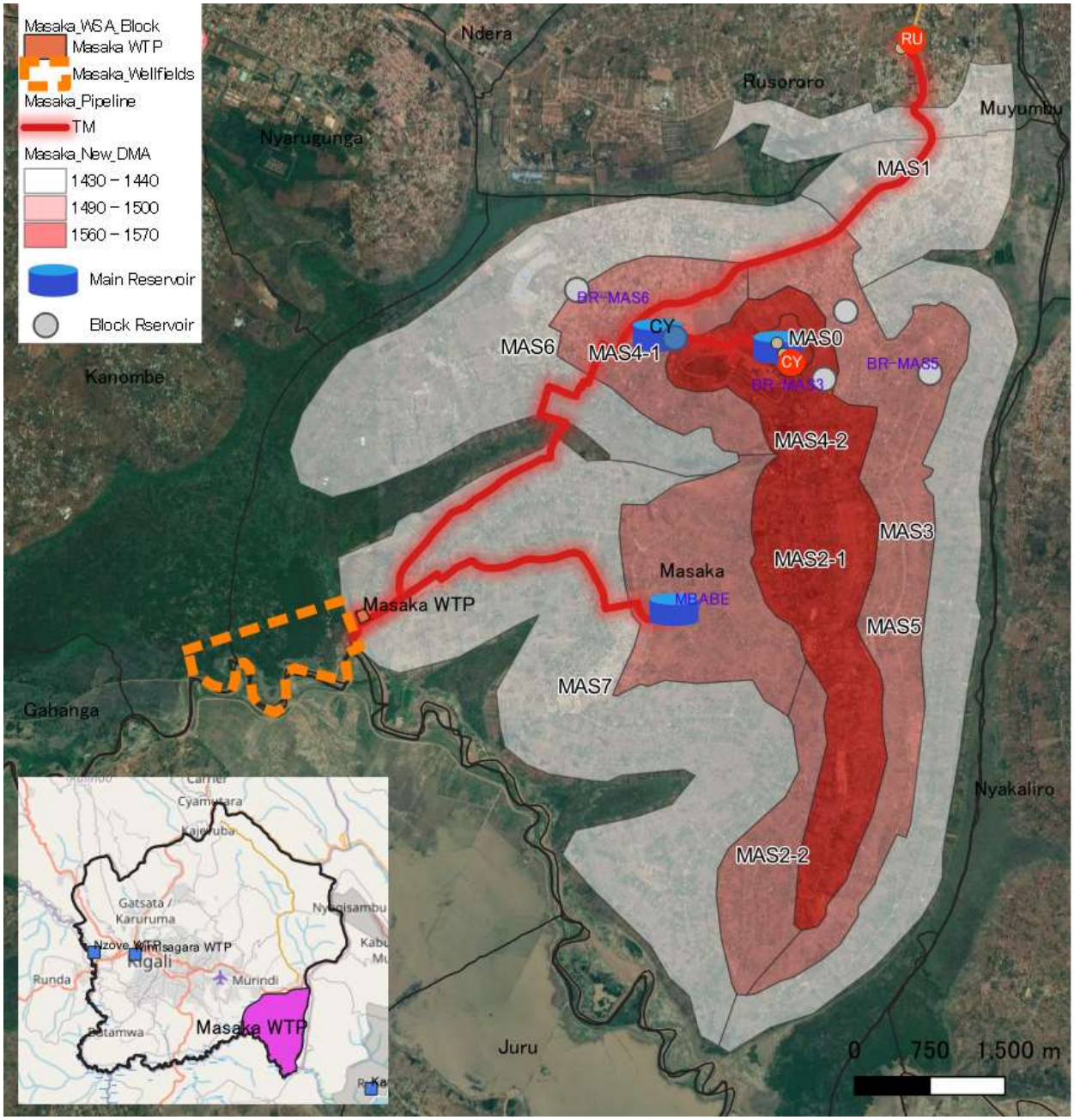


General Map of Kigali City Water Masterplan

Location Map of Karenge F/S



Location Map of Masaka F/S



Abbreviations

AfDB	African Development Bank
B/S	Balance Sheet
C/F	Cash Flow
CoK	City of Kigali
C/P	Counterpart
CW	Clear Water
DAF	Dissolved Air Floatation
DB	Design, Build
DIP	Ductile Iron Pipe
DF/R	Draft Final Report
DMA	District Metered Area
DPCG	Development Partners Coordination Group
EDPRS	Economic Development and Poverty Reduction on Strategy
ESIA	Environmental and Social Impact Assessment
EICV	Fourth Integrated Household Living Conditions Survey
F/R	Final Report
FS	Feasibility Study
FY	Fiscal Year
GDP	Gross Domestic Products
GOR	Government of Rwanda
HDPE	High-Density Polyethylene (Pipe)
IC/R	Inception Report
IFC	International Finance Corporation
IT/R	Interim Report
IWA	International Water Association
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
JST	JICA Study Team
JV	Joint Venture
KPI	Key Performance Indicator
MINALOC	Ministry of Local Government
MINEDUC	Ministry of Education
MININFRA	Ministry of Infrastructure
MINECOFIN	Ministry of Finance and Economic Planning
MoE	Ministry of Environment
MoH	Ministry of Health
MP (M/P)	Master Plan
MUSD	Million United States Dollars
NA	Not Applicable
ND (DN)	Nominal Diameter (Diamètre Nominal)
NGO	Non-Governmental Organization
NISR	National Institute of Statistic of Rwanda
NNYL	Lower Nyabarongo Catchment
NRW	Non-Revenue Water
NST	National Strategy for Transformation
O&M (OM)	Operation and Maintenance
OJT	On-the-Job Training

PBN	Project Brief Note
PBT	Pressure Break Tank
PC	Prestressed Concrete
PCM	Project Cycle Management
PG/R	Progress Report
PHC	Population and Housing Census
P/L	Profit and loss
PPP	Public Private Partnerships
PR	Public Relations
PRV	Pressure Reduce Valves
PS	Permanent Secretary
PVC	Polyvinyl Chloride (Pipe)
QC	Quality Control
RC	Reinforced Concrete
RDB	Rwanda Development Board
RLMUA	Rwanda Land Management and Use Authority
RSB	Rwanda Standards Board
RURA	Rwanda Utilities Regulatory Authority
REMA	Rwanda Environment Management Authority
RW	Raw Water
RWF	Rwanda Franc
RWFA	Rwanda Water and Forestry Authority
SCADA	Supervisory Control and Data Acquisition
SEA	Strategic Environmental Assessment
SEZ	Special Economic Zone
SEZAR	Special Economic Zones Authority of Rwanda
SDGs	Sustainable Development Goals
SGP	Steel Galvanized Pipe
SHM	Stakeholder Meeting
SP	Steel Pipe
TOR	Terms of Reference
UNICEF	United Nation Children Fund
USD	United States Dollar
UWSSD	Urban Water and Sewerage Services Department
WASAC	Water and Sanitation Cooperation
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WRD	Water Resources Development
WTP	Water Treatment Plant
WSA	Water Supply Area

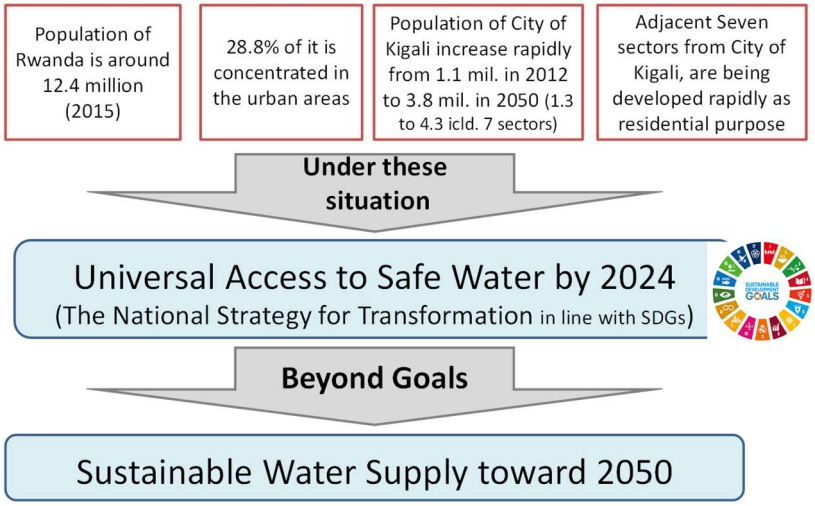
CoK M/P	City of Kigali Master Plan
AfDB M/P	National Water Supply and Sanitation Master Plan by AfDB
KWSMP	Kigali Water Supply Master Plan

Part 1 KIGALI WATER SUPPLY MASTER PLAN

1 INTRODUCTION

Urbanization is the emerging trend in the Republic of Rwanda (hereinafter referred to as "Rwanda") and it has to continue to challenge to increase universal and equitable access to safe and affordable drinking water by 2024. Under these circumstances, it is indispensable for WASAC to have one comprehensive master plan for the improvement of the existing water supply facilities and new facilities in a more efficient and effective manner in order to meet the rapid increase of water demand in the City of Kigali (hereinafter referred to as "CoK"). Therefore, WASAC officially requested JICA to support in the development of the Water Supply Master Plan for the CoK and its seven adjacent sectors (KWSMP).

An image of the Study background is as illustrated in the following **Figure S1.1-1**.



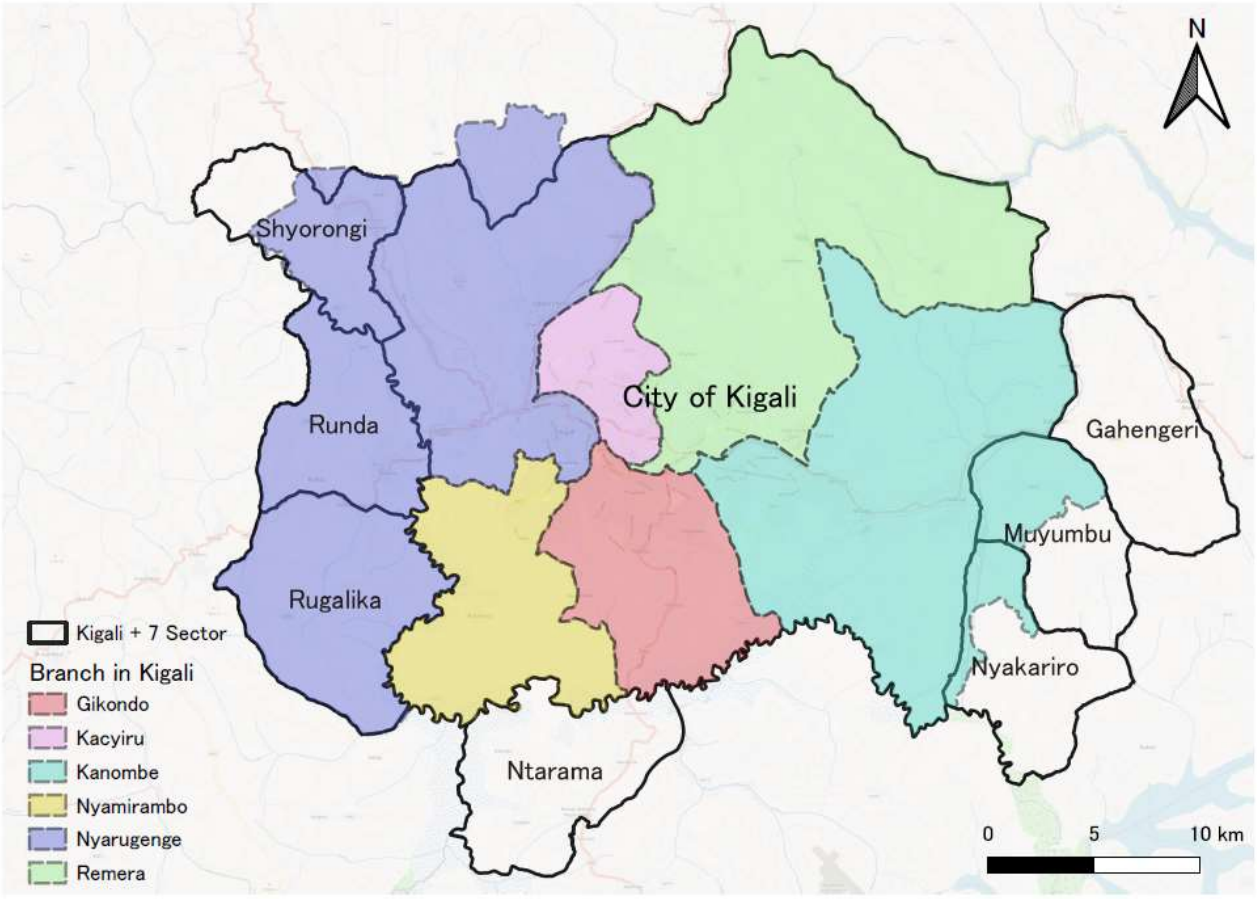
Source: JST

Figure S1.1-1 Background of Necessity of the KWSMP Study

The objectives of the Study are as follows:

1. To develop the Water Supply Master Plan for the CoK and the seven adjacent sectors (KWSMP), which consists of the Master Scenario until 2050 and the 15-Year Investment Plan
2. To conduct a feasibility study on the priority project(s) identified under the KWSMP
3. To pursue technology transfer to the counterpart personnel during the course of the Study.

The Study Area covers the CoK and the sectors of Shyorongi, Runda, Rugarika, Ntarama, Muyumbu, Gahengeri, and Nyakaliro as shown in the following **Figure S1.1-2**.



Source: JST

Figure S1.1-2 Study Area

Expected outputs of this study are as follows;

Output 1: Current conditions of existing water supply facilities and water supply services in the project site are assessed.

Output 2: Water demand in the project site is forecasted, and the water source utilization plan is developed.

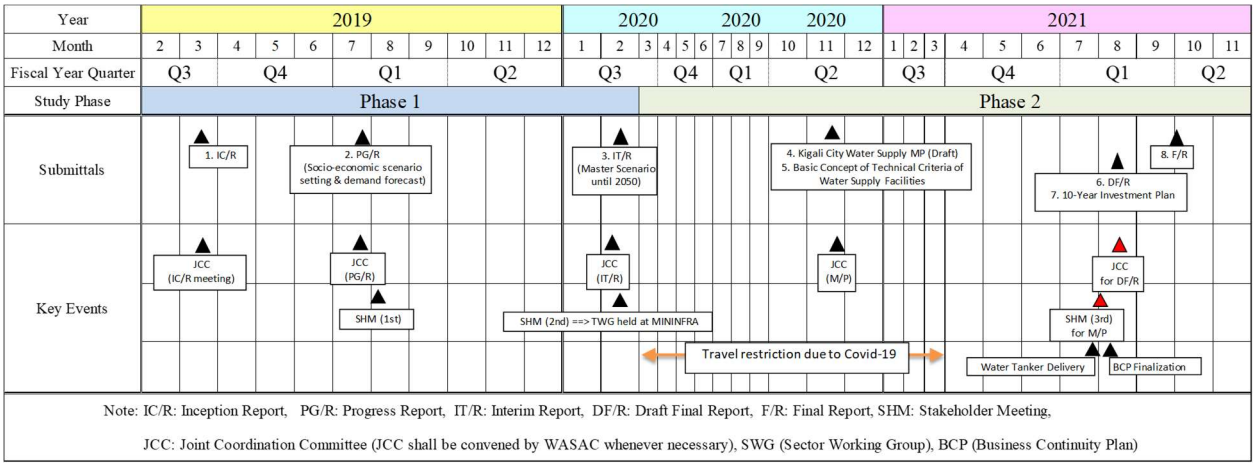
Output 3: KWSMP is developed.

Output 4: Prioritized projects are identified from the 15-Year Investment Plan, and their feasibility studies are conducted.

Output 5: Capacity of WASAC's staff about water supply planning is strengthened.

2 STUDY SCHEDULE

The overall schedule of the Study is as shown in the following **Figure S1.2-1**.



Source: JST

Figure S1.2-1 Study Schedule and Current Time-Basis Location

3 GOVERNMENT AND RELATED DEVELOPMENT PLANS

The notable governing superior plans and/or related policies relevant to this Study are shown in the following **Table S1.3-1**.

Table S1.3-1 Summary of Governing Superior Plans and Related Policies

Plan/Policy	Key Contents (Target Year/Population)	Water Sector
Rwanda Vision 2020 (2012) (including Vision 2050 currently being revised)	• Original vision: prepared in 1998-1999 • Revised vision: prepared in 2012 • Target year: 2020 • 48 indicators (original 47 indicators)	Access to clean water (of the population) • 52% in 2010 • 74.2% in 2012 (current status) • 100% in 2020
National Strategy for transformation and seven (7) Years Government Programme: (NST1)-2017-2024.	• Target year: 2024	7 Years Government Programme: National Strategy for transformation (NST1)-2017-2024.
CoK M/P (2013)	• Target year: 2040 • Population projection: Low scenarios: 3.5 million Medium scenarios: 4.2 million High scenarios: 5.0 million • GDP projection: 12.29-21.28 trillion RWF	• Water demand unit rate: 120 lpcd (urban area) 80 lpcd (rural area) • Non-revenue water (NRW): 30% (2025) 15% (2040) • Projected water demand: 369,000 m^3/d (2025) 622,000 m^3/d (2040)

Plan/Policy	Key Contents (Target Year/Population)	Water Sector
CoK M/P (update 2019)	• Target year: 2050 • Population projection: Low scenarios: 3.2 million Medium scenarios: 3.5 million High scenarios: 3.8 million • GDP projection: 12.3-29.8 trillion RWF	• Water demand unit rate: 120 lpcd (urban area) 80 lpcd (rural area) • Non-revenue water (NRW): Not given • Projected water demand: 573,000 m^3/d (2050, high population growth scenarios are applied and NRW is not included), of which 443,000 m^3/d for domestic (77%) and 130,000 m^3/d for no-domestic (23%).
National Water Supply and Sanitation Master Plans by AfDB (AfDB M/P)	• Target year: 2050 • Population projection: 3.8 million (basically same as high scenarios of CoK M/P)	• Water demand unit rate: 120 lpcd • Non-revenue water (NRW): 15% • Projected water demand (only for domestic): 443,000 m^3/d (NRW is not included) 509,000 m^3/d (NRW is included) • Projected wastewater generation (only for domestic): 420,000 m^3/d (95% of domestic water consumption)
Economic Development and Poverty Reduction Strategy II (EDPRS II), 2013-2018 (2013)	• Target year: 2018 • Average GDP growth: 11.5 % by 2018 • GDP per capita: $1,240 by 2020 • Poverty rate: 30% (2018), 20% (2020)	• Urban households within 200m of an improved water source 86.4% in 2012 (baseline) 100% by 2018
Water and Sanitation Sector Strategic Plan 2013/14 - 2017/18 (2013)	• Target year: 2018 • Develop fully and implement to 100% of the sector's institutional and capacity building framework by 2017/18. • Total budget: RWF 382.3 billion	• Raise rural water supply coverage to 100% by 2017/2018, and implementing public-private partnership (PPP) arrangements • Ensure 100% safe, reliable and affordable urban water supply services by 2017/18
National Water Supply Policy Implementation Strategy (NWSPIS) - December 2016	• Target year: 2020 • Total budget: RWF 337 billion	• % of rural households within 500m of an improved water source: 47.3% in 2015 (baseline, EICV 4) 100% by 2020 • % of urban households within 200m of an improved water source: 60.5% in 2015 (baseline, EICV 4) 100% by 2020 • % non-revenue water (NRW): 35% in 2015 (baseline) 20% by 2020
Integrated Water Management Policy (IWMP)	• Sustainable management of water resources of Rwanda	• Management of water on both demand and supply side and also integrates the other policies on forests, wetland, agriculture and land
Rwanda National Water Resources Master Plan	• Target Year: 2040 • Coverage: Nation-wide	• Water demand unit rate: For Urban: 60/70/80/100 lpcd for 2012/2020/2030/2040 For Rural: 40/60/80/100 for 2012/2020/2030/2040
Development Plan for Special Economic Zone (SEZ)	• Enacted in 2011 which specifies the guidelines for SEZs to operate, the structures and their roles of key players that are regulator, developer and operator.	

Plan/Policy	Key Contents (Target Year/Population)	Water Sector
Climate Change Adaptation	• Following Vision 2020 target	• Impact recognized by climate change were Increase of demand for water supply increase of water temperature (water quality deterioration by algal bloom)

EICV: Integrated Household Living Conditions Survey

4 CONDITION OF EXISTING WATER SUPPLY SYSTEMS

Water Supply Coverage and Supply Area

The water supply coverage in the CoK, including for both piped and non-piped water supply is 85% according to the National Strategy for Transformation (NST1). Meanwhile, the WASAC's coverage is estimated to be 645,000 populations which are around 41% to 49% of the City's total population; the remaining population may be covered by natural springs, shared tap from neighbors or private wells.

Current Water Sources

Rivers, lakes and groundwater (river bed water) that are currently being used as water sources by the WASAC WTPs are summarized as shown in the following table, and the locations of the major sources are presented in the following **Table S1.4-1**.

Table S1.4-1 Water Sources Used by WASAC (for WTP)

WTP	Water Source	Quantity	Quality	Problems/challenges
Nzove 1WTP	 Groundwater (river bed water)	Thirty-one boreholes drilled in 2006. At the moment, 9 boreholes do not work. Current capacity for 22 boreholes is around 25,000 m^3/d.	It is relatively low turbidity compared to the Nyabarongo River. Sometimes high concentrations of ammonia, iron (Fe) and manganese (Mn) are detected.	Maintenance of boreholes
Nzove 2 and New Nzove 1 WTPs	 River (Nyabarongo)	Nyabarongo river can secure a considerable amount of water.	Sometimes the maximum turbidity of the Nyabarongo River was over 10,000 NTU which results in intake stop.	Water Treatment cost is high because of high turbidity. .
Kimisagara WTP	 River (Yanze)	Yanze is a small river and cannot produce much water compared to the Nyabarongo river.	It has better quality than the Nyabarongo River since the environment around the river has been protected.	Presence of sand, mud, stones and gravels at Yanze intake leads to the clogging of raw water transmission pipelines.
Karenge WTP	 Lake (Mugesera)	No specific issues in terms of quantity	Water quality varies depending on the time, but turbidity increases in the rainy season. Eutrophic conditions due to high level of total-nitrogen, total-phosphorus, and	The lake is located in the eastern part of the CoK and is quite far from the town. The Karenge WTP is built near the lake. Algae is always the problem during treatment.

WTP	Water Source	Quantity	Quality	Problems/challenges
			pH.	
Kanzenze WTP		Analysis of 12 pumping test data on Nyabarongo flood plain shows that it is possible to withdraw 1,200 - 1,400 m^3/day per borehole.	Turbidity is lower than that of rivers (<100 NTU), iron, manganese and ammonia are as high as river water. From the pumping test results, the turbidity tends to rise as the pumping time increases.	Although turbidity is lower than that of rivers, water quality is not good compared to deep groundwater because it is river bed water. In the floodplain of the Nyabarongo River there are places where the clay layer is thickly deposited, and there is not a good aquifer.

Source: JST

Water Supply Facilities

Water Treatment Plants in the CoK

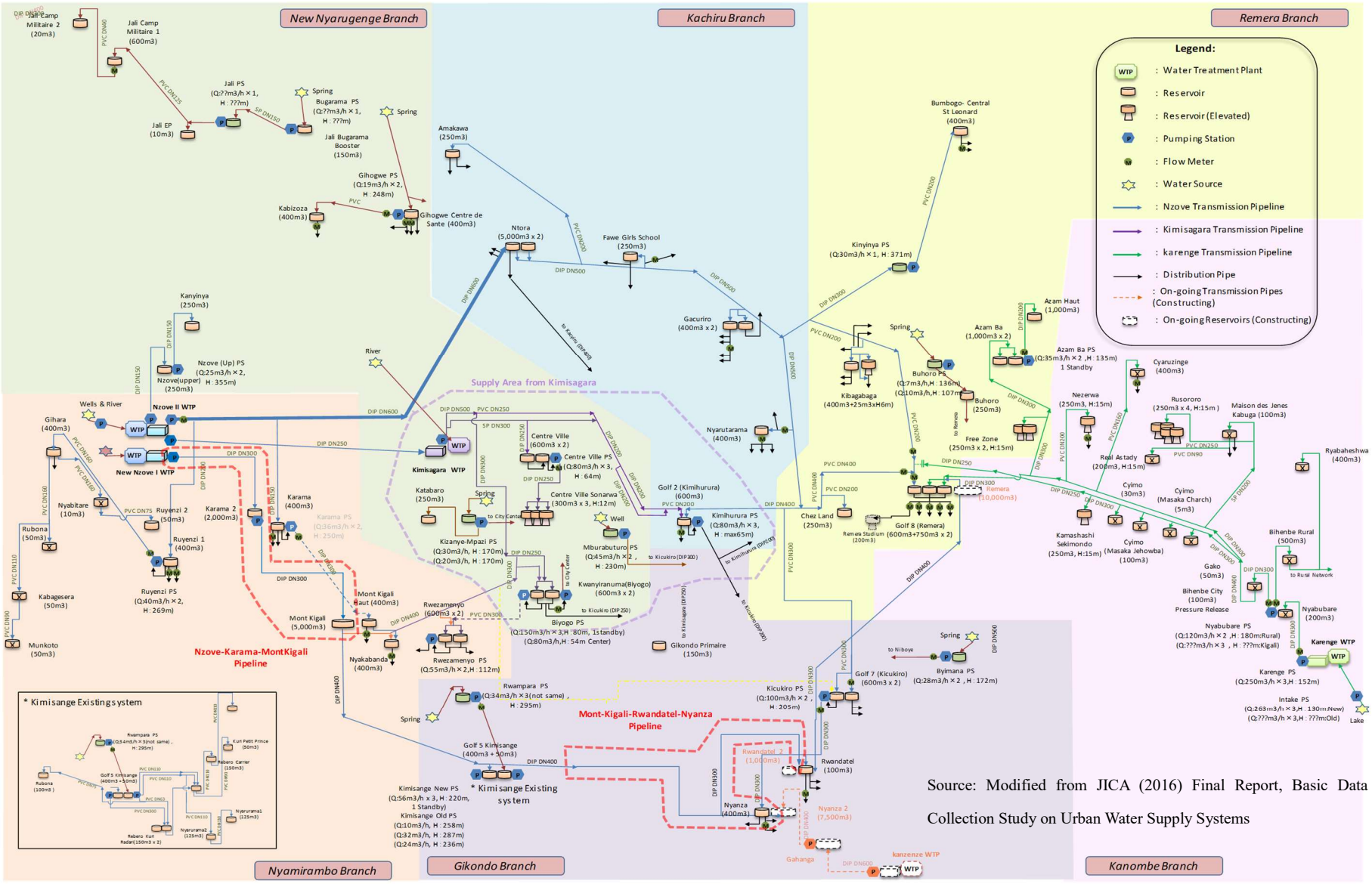
As of June 2019, there are four existing water treatment plants (WTPs) in the CoK, namely the Nzove, the Kimisagara, the Karenge and the Kanzenze. As shown in the following **Table S1.4-2**. The total capacity of these WTPs at current and in future (around 2020) is 142,000 m^3/d and 207,000 m^3/d, respectively.

Table S1.4-2 Summary of the WTPs in the CoK (2019)

WTP		Capacity (m^3/d)	Current Condition	Water Source	Remarks
Nzove	Nzove 1	25,000	Existing	Well (infiltrated water of Nyabarongo River)	The capacity is also reported in some reports 30,000 or 40,000 m^3/d.
	Nzove 2	40,000	Existing	Nyabarongo River	
	New Nzove 1	40,000	Existing	Ditto	Sedimentation tanks with a capacity of 65,000 m^3/d are constructed.
		(25,000)	Future	Ditto	
Kimisagara		22,000	Existing	Yanze River (a tributary of Nyabarongo River)	
Karenge		15,000	Existing	Mugesera Lake	
Kanzenze		(40,000)	Under construction	Well (infiltrated water of Nyabarongo River)	Completed in 2020.
Current Total Capacity		**142,000**			
Future Total Capacity		**207,000**			

Source: WASAC
* WTP: Water Treatment Plant

Existing reservoirs and transmission systems are summarized in the following **Figure S1.4-1**. There are 20 nos. of existing pumping stations apart from the pumps in the Nzove and Karenge WTPs for the water supply system in and adjacent to the CoK.



Source: Modified from JICA (2016) Final Report, Basic Data Collection Study on Urban Water Supply Systems

Source: JST

Figure S1.4-1 Present Status of Existing Water Supply System

Summary of Technical Challenges

The current issues pertaining to the water supply facilities, the transmission and distribution pipelines, and the reservoirs are summarized as follows;

1. There is an enormous gap between water supply capacity and water demand. The demands are high, especially in the eastern to the southern part of the CoK and those areas are seriously in short of water even when compared to the existing water demand.

2. Intermittent water supply is a serious issue for the inclusiveness of water supply not only in the water shortage areas but also in the fringe areas of the pipelines where the pressure is low. The low pressure is because of inappropriate pipe diameter and lacking appropriate zonings, absence of backup route by pipeline loops/networks, inappropriately small diameter of pipes, and frequent leakages from the pipes.

3. The leakage accounts for the majority of NRW, and it often causes serious water supply interruption. At least 20km of pipelines are aged more than 36 years and only 51% of pipelines have data regarding the year of its construction. Combined with the inappropriate arrangement of thrust anchoring and sub-standard pipe materials, many leakages are happening in the primary to secondary distribution mains. The need for expansion cannot be an excuse for inaction of NRW reduction as “expanding water networks without addressing water losses will only lead to a cycle of waste and inefficiency”. Strategic replacement of pipelines is necessary to achieve an NRW target.

4. Lack of pressure management in transmission and distribution systems accelerated the pipe breaks, leakages and wasting energies. High pressure is an intrinsic problem seeing the hilly geographical conditions of the CoK.

5 FINANCIAL SITUATION OF WASAC

Profit and Loss (P/L)

Following **Table S1.5-1** presents the actual P/L from FY 2014/15 up to FY 2019/20 and the revenue estimate of FY 2020/21. The revenue of FY 2019/20 significantly increased due to tariff revision in February 2019. However, the final profit for FY 2019/20 recorded negative due to the substantial depreciation amount of the fixed-assets. The turnover for FY 2020/21 revised budget was expected to increase by around 10% compared with that of FY 2019/20 despite of COVID negative impact.

Table S1.5-1 Profit and Loss Statement (RWF in million)

P/L Accounts		2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21 (for Ref.)	
		Audited	Audited	Audited	Audited	Audited	Non-audited	Revised Budget	Actual/June-April
1. Revenue		11,727.8	15,116.8	15,565.9	15,060.0	18,779.3	21,363.5	23,952.0	18,856.3
2. Cost of Sales		7,635.1	12,671.7	14,372.0	13,964.1	14,702.7	14,941.4	15,573.8	12,086.8
3. Gross Profit =1-2		**4,092.7**	**2,445.1**	**1,193.9**	**1,095.9**	**4,076.6**	**6,422.1**	**8,378.2**	**6,769.5**
4. Other Income		7,373.8	10,989.8	11,016.8	26,737.1	11,920.0	14,418.2		
5. Other expenses	Support to district networks	3,868.9	9,975.6	9,566.9	24,768.5	8,555.3	14,676.0		
	Administrative expenses	5,323.0	3,163.4	3,532.6	7,059.3	6,001.6	6,160.9		
	Total	9,191.9	13,139.0	13,099.5	31,827.8	14,556.9	20,836.9		
6. Operating Profit before depreciation =3+4-5		**2,274.6**	**296.0**	**-888.8**	**-3,994.8**	**1,439.7**	**3.4**	n/a	n/a
7. Depreciation/amortization		3,129.4	3,404.0	3,424.4	3,277.5	3,357.6	2,745.9		
8. Operating Profit =6-7		**-854.8**	**-3,108.0**	**-4,313.2**	**-7,272.3**	**-1,917.9**	**-2,742.5**	n/a	n/a
9. Finacial	Income	848.4	1,205.1	1,217.8	13.1	25.3	5.4		
	Expenses	1,002.7	1,205.1	1,240.9	75.1	577.7	-189.2		
	Profit	-154.3	0.0	-23.1	-62.0	-552.4	194.6		
10. Provision	Write-back	0.0	596.5	0.0	0.0	0.0	0.0		
11. Profit and Loss b/Tax =8+9+10		**-1,009.1**	**-2,511.5**	**-4,336.3**	**-7,334.3**	**-2,470.3**	**-2,547.9**	n/a	n/a
12.Tax	(-) Deffered tax liabilities	-285.9	-459.6	275.1	155.1	281.2	0.0		
13. P/L for the period =11-12		**-723.2**	**-2,051.9**	**-4,611.4**	**-7,489.4**	**-2,751.5**	**-2,547.9**	n/a	n/a

Source: Financial Statements and Budget of WASAC

Balance Sheet (B/S)

Following **Table S1.5-2** presents the B/S of WASAC.

Table S1.5-2 Balance Sheet (Million RWF)

B/S Accounts			2014/15	2015/16	2016/17	2017/18	2018/19	2019/20
			Audited	Audited	Audited	Audited	Audited	Non-audited
Assets	Current	Cash & banks	2,966.9	4,324.5	3,791.2	1,360.5	5,236.2	1,098.7
		Inventory	7,461.1	7,362.2	7,328.8	4,631.5	4,386.1	3,320.7
		Receivables & others	6,834.9	8,764.8	11,028.2	8,392.3	24,121.0	18,458.5
		Total	17,262.9	20,451.5	22,148.2	14,384.3	33,743.3	22,877.9
	Fixed	Property & equipment	47,152.1	50,793.6	52,226.3	52,139.9	52,152.5	49,167.1
		Developmental projects	5,002.3	17,299.5	24,421.3	13,019.9	32,669.9	0
		Intangible assets	512.5	441.3	697.6	726.5	629.3	620.0
		Concession financial assets	16,098.8	21,201.8	22,896.4	22,896.4	50,475.7	22,968.3
		Total	68,765.7	89,736.2	100,241.6	88,782.7	135,927.4	72,755.4
Total of Assets			**86,028.6**	**110,187.7**	**122,389.8**	**103,167.0**	**169,670.7**	**95,633.3**
Liabilities	Current	Payables & others	2,794.3	12,360.2	22,210.9	17,722.4	8,140.8	17,542.8
	Fixed	Deffered tax & income	6,068.5	17,288.2	21,008.1	12,123.5	37,378.4	6,039.0
		10 years' bank loan	0	0	0	0	12,204.9	11,089.7
		AfDB loan disbursement	0	0	0	0	16,924.2	0
		Concession obligation	16,098.8	21,201.8	22,896.4	22,896.4	50,403.7	22,896.4
		Others	0	0	0	545.9	332.5	545.9
		Total	22,167.3	38,490.0	43,904.5	35,565.8	117,243.7	40,571.0
	Total		**24,961.6**	**50,850.2**	**66,115.4**	**53,288.2**	**125,384.5**	**58,113.8**
Equity	Capital		50,000.0	50,000.0	51,621.7	51,621.7	51,621.7	51,621.7
	Reserves	Retainned earnings	-514.3	-2,546.1	-5,563.8	-11,461.3	-16,444.6	-23,216.7
		Re-organization reserves	11,581.3	11,883.6	10,216.5	9,718.4	9,109.1	9,114.6
		Total reserve	11,067.0	9,337.5	4,652.7	-1,742.9	-7,335.5	-14,102.1
	Total		61,067.0	59,337.5	56,274.4	49,878.8	44,286.2	37,519.6
Total of Liabilities and Equity			**86,028.6**	**110,187.7**	**122,389.8**	**103,167.0**	**169,670.7**	**95,633.4**

Source: Financial Statements of WASAC

The characteristics of the B/S are summarized as below:

- Inventory: WASAC has reduced the operational stock every year, particularly chemical stores.
- Receivables and others: mostly from the customers' due amount, which showed a significant increase during the FY 2018/19 despite a decrease of the previous years. The tariff was raised in February 2019 which resulted in the increase of the receivable amount.
- Fixed assets: No significant changes during the last 5 years.
- Long-term borrowings: this is the first drawing from the bank loan, arranged in March 2019 with the Government comfort letter under the following conditions.
- Bank commitment line: 17 billion FRW, loan period: 10 years, interest rate of 15%.
- The ratio of fixed assets to long-term capital average for the last 6 years indicates 92% that secures the financial soundness where the appropriate long-term financing for fixed assets is required.

6 ON-GOING PROJECT

There are five on-going projects pertaining to water supply in the CoK as listed in the following **Table S1.6-1**.

Table S1.6-1 List of On-going Projects

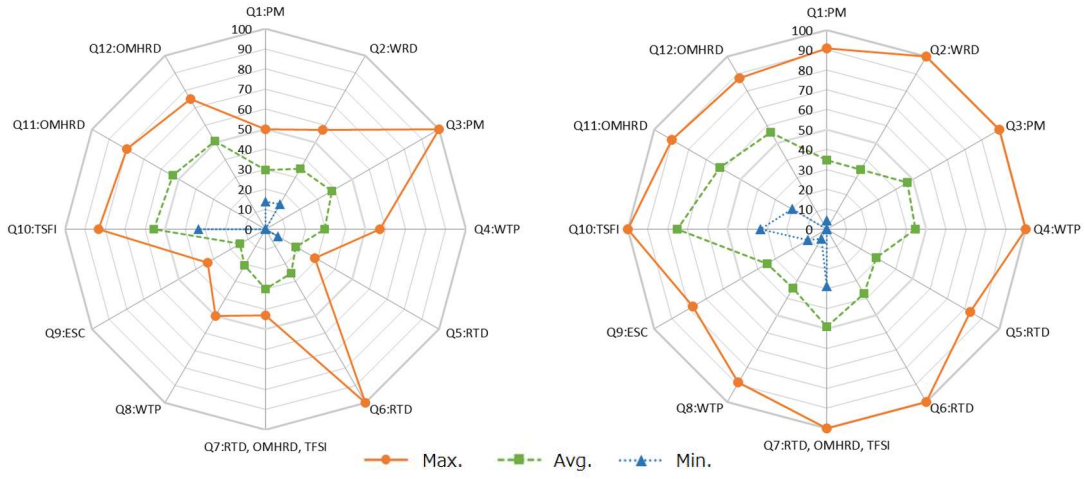
No.	Name of the Project	Investor/Contractor
1	Rwanda Sustainable Water and Sanitation Program (Sub-project: the Design Rehabilitation, Upgrading and Extension of Water Supply Network in the CoK and Peri-urban areas)	AfDB/China Railway
2	New Nzove 1 Project	WASAC/Culligan
3	Kigali Bulk Water Supply Project	Metito (IFC)
4	Nzove-Ntora Transmission Pipe	JICA
5	Project for Strengthening Non-Revenue Water Control in the CoK Water Network	JICA

Source: JST

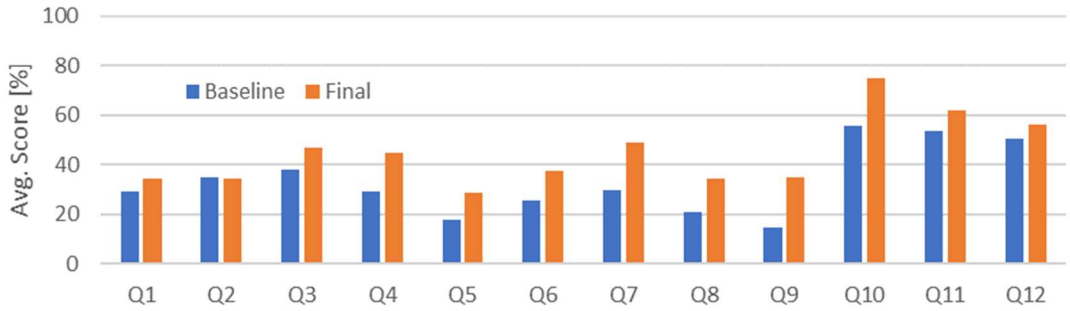
7 CAPACITY DEVELOPMENT

JST conducted first baseline questionnaire survey to the WASAC Staff who are the members of M/P working groups (17 persons) in April 2019 to evaluate their capacity as a progress from the project commencement. The final questionnaire survey is carried out in July 2021 (16 persons) for final evaluation of the capacity development in the entire project.

The comparison of the evaluation results of the baseline and final questionnaire survey is shown in the following **Figure S1.7-1**.



(a) Baseline Questionnaire Survey in August 2019 (b) Final Questionnaire Survey in July 2021



(c) Comparison of the scores between Baseline Questionnaire Survey and Final Questionnaire Survey

Source: JST

Figure S1.7-1 Score of Evaluation

As the scores of the final survey are higher than the one for the previous survey, their knowledge and skill are improved through the collaborate work with JST for M/P formulation.

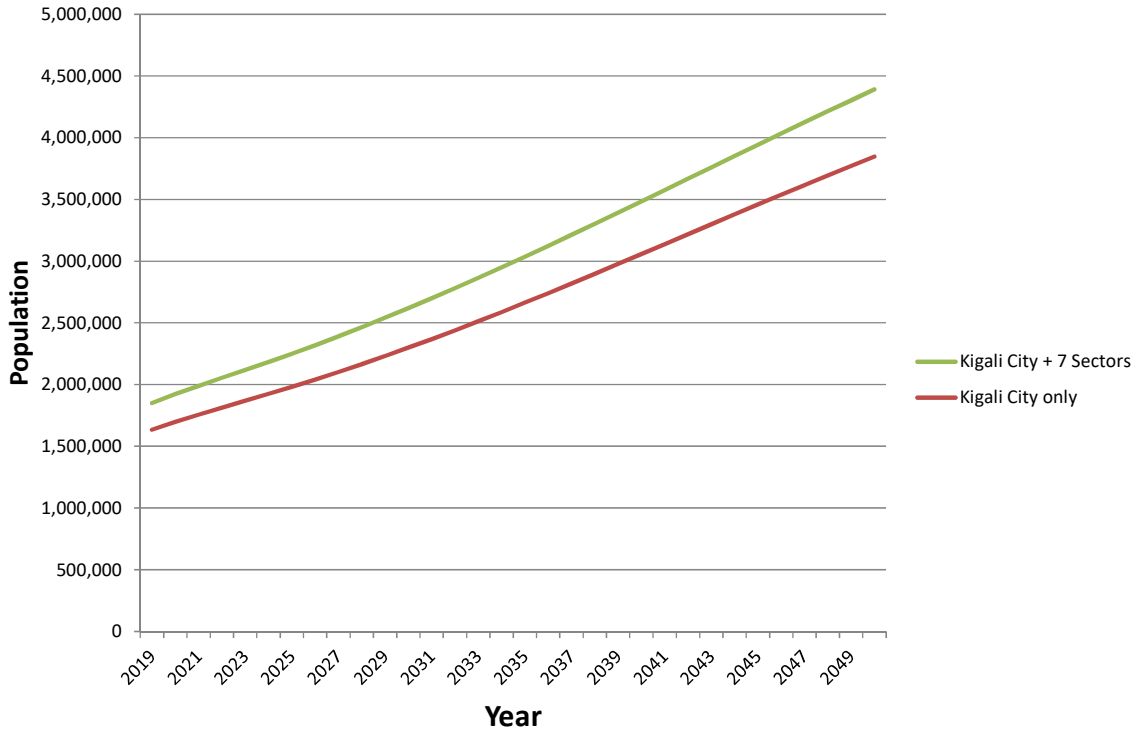
8 FUTURE POPULATION AND WATER DEMAND

Trend of Development for the CoK

Population projection in the CoK is based on the High Growth Scenario of the City Masterplan (2019) (the CoK M/P). The report of the the CoK M/P pointed out that the trend of development and growth in the CoK would be moving towards the eastern and southern parts of the city. In addition, development along major roads would also be expected.

Population

Population in the Study Area is assumed to increase from 1.3 million in 2019 to 4.4 million by 2050 as explained in the following **Figure S1.8-1**.



Source: JST

Figure S1.8-1 Population Projection for the Study Area

Unit Per Capita Consumption Setting

With reference to the relevant governing plans including the CoK M/P and the AfDB M/P, the unit per capita consumption in 2050 is set as follows:

- Urban (for piped water users living in urban areas): 120 lpcd
- Rural (for stand post users living in rural areas): 80 lpcd

Service Coverage Level

The Vision 2050 is under preparation by the government of Rwanda. The MINECOFIN's Minister gave a presentation on the contents of the Vision 2050 in the year 2016. According to this presentation, the Vision 2050 is about ensuring high standards of living for all the Rwandans, including the achievement of universal, sustainable, and reliable access to water (in houses) and sanitation.

Hence, the target of service coverage ratio is set to achieve 100% for individual house connections by 2050.

- 25% of coverage ratio for individual house connection in 2019 increases linearly towards 100% in 2050.
- 16% of the coverage ratio for public tap in 2019 decreases linearly to 0% in 2050.

Consumption of the Non-Domestic Use

For calculation purposes, 20% of net demand is regarded as percentage of non-domestic use {i.e., 20% = non-domestic / (domestic + non-domestic)} for the entire period towards 2050, based on the CoK M/P.

NRW

Based on the 5 Years Strategic Plan for the NRW Reduction of WASAC, the target NRW rate is set as shown in the following **Table S1.8-1**. In this water demand projection, it is regarded that leakage accounts for the majority of the NRW, considering the actual situation in the Study Area.

Table S1.8-1 NRW Ratio Toward 2050

	2019	2025	2030	2035	2040	2045	2050
NRW Ratio	35%	25%	24%	23%	22%	21%	20%

Source: JST

Seasonal Peak Factor

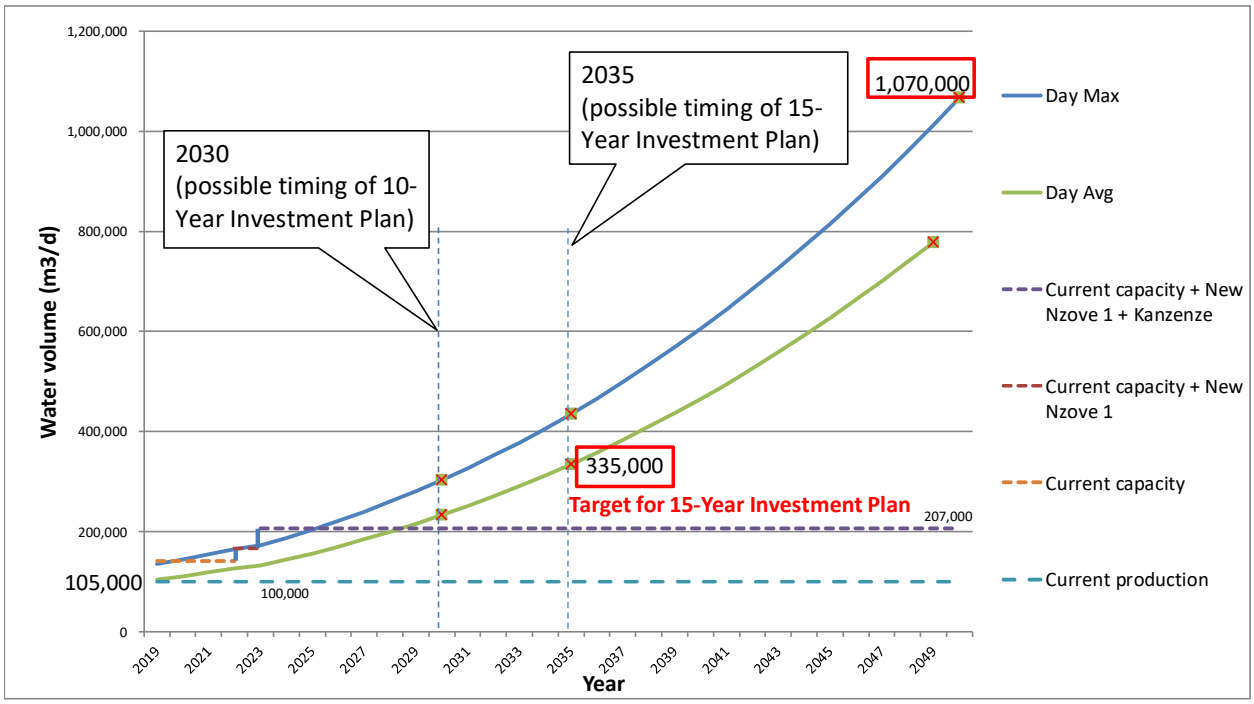
The seasonal peak factor, which is the ratio of maximum demand to average demand (and expressed as the reciprocal of the load factor rate) is used to determine the capacity of production facilities. Based on the O&M record of the WTPs in the Study Area, load factor rate is set as 77% (= seasonal peak factor: 1.3) for estimating the daily maximum demand. Peak factor is assumed to be constant throughout 2050 in this water demand projection.

Projected Water Demand and the Targets

Water demand projection towards 2050 with its milestone targets are presented in the following **Figure S1.8-2**. As a result of the water demand projection, the targets for the facility planning under the Study should follow the following orientation:

- The target water demand in the year 2035 (timing of the 15-Year Investment Plan) shall be the Day Average Demand (approximately 335,000 m^3/d),
- The target water demand in the year 2050 shall be the Day Maximum Demand (approximately 1,070,000 m^3/d).

Thus, the facility planning under the Masterplan is planned with the aim to achieve the above targets.



Source: JST

Figure S1.8-2 Projected Water Demand

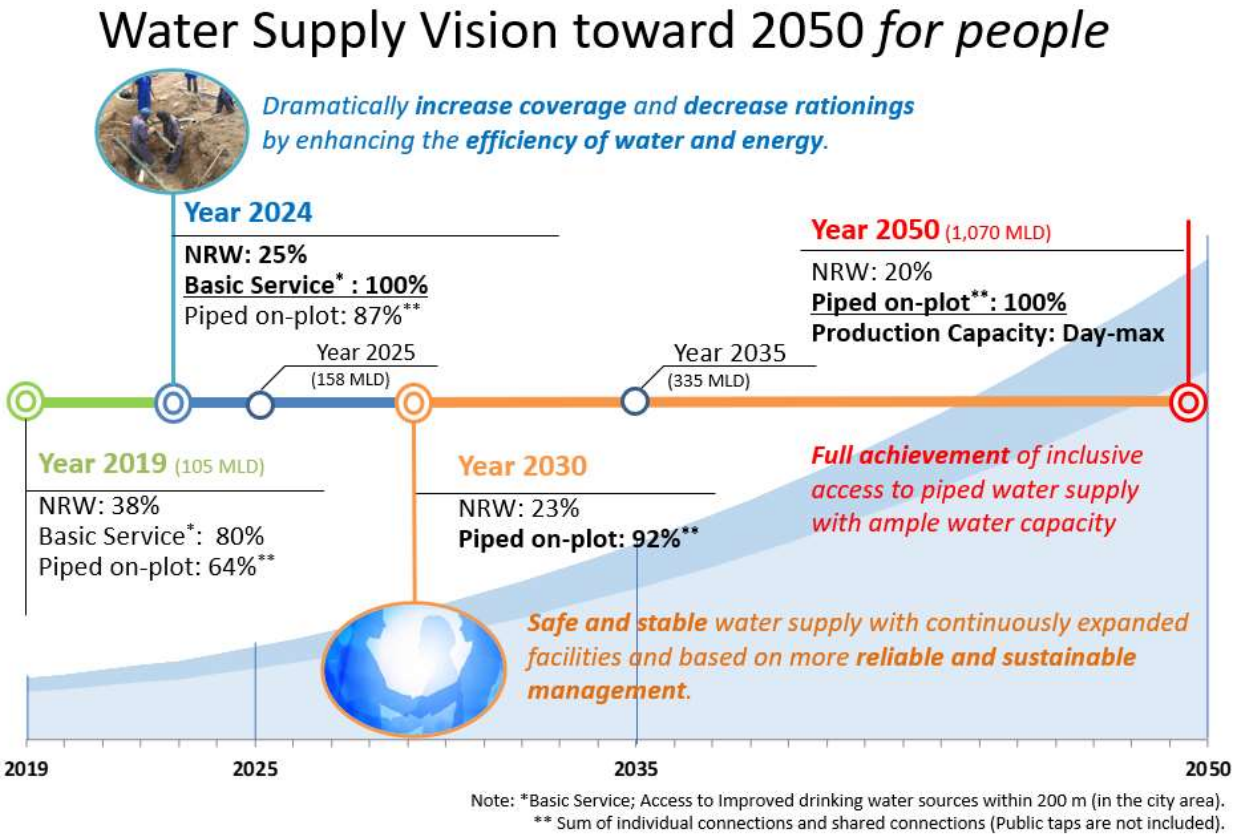
Water Supply Vision

Towards 2050, WASAC needs to focus not only to increase the production capacity but also to improve the efficiency of water supply systems through safe and stable water supply systems with continuous expansion based on more reliable and sustainable management. The vision is in accordance with the One National Strategy for Transformation (NST-1) as the universal access to safe water for urban areas by 2024. Considering the limited financial resources, WASAC needs a progressive approach to achieve universal access to safely managed drinking water services as shown in the following figure. The visions for the benchmark years are as follows (**Figure S1.8-3**);

In 2024: *Dramatically increase coverage and decrease rationings by enhancing the efficiency of water and energy.*

In 2030: *Safe and stable water supply with continuously expanded facilities and based on more reliable and sustainable management.*

In 2050*: Fully achieve inclusive access to piped water supply with ample water capacity.*

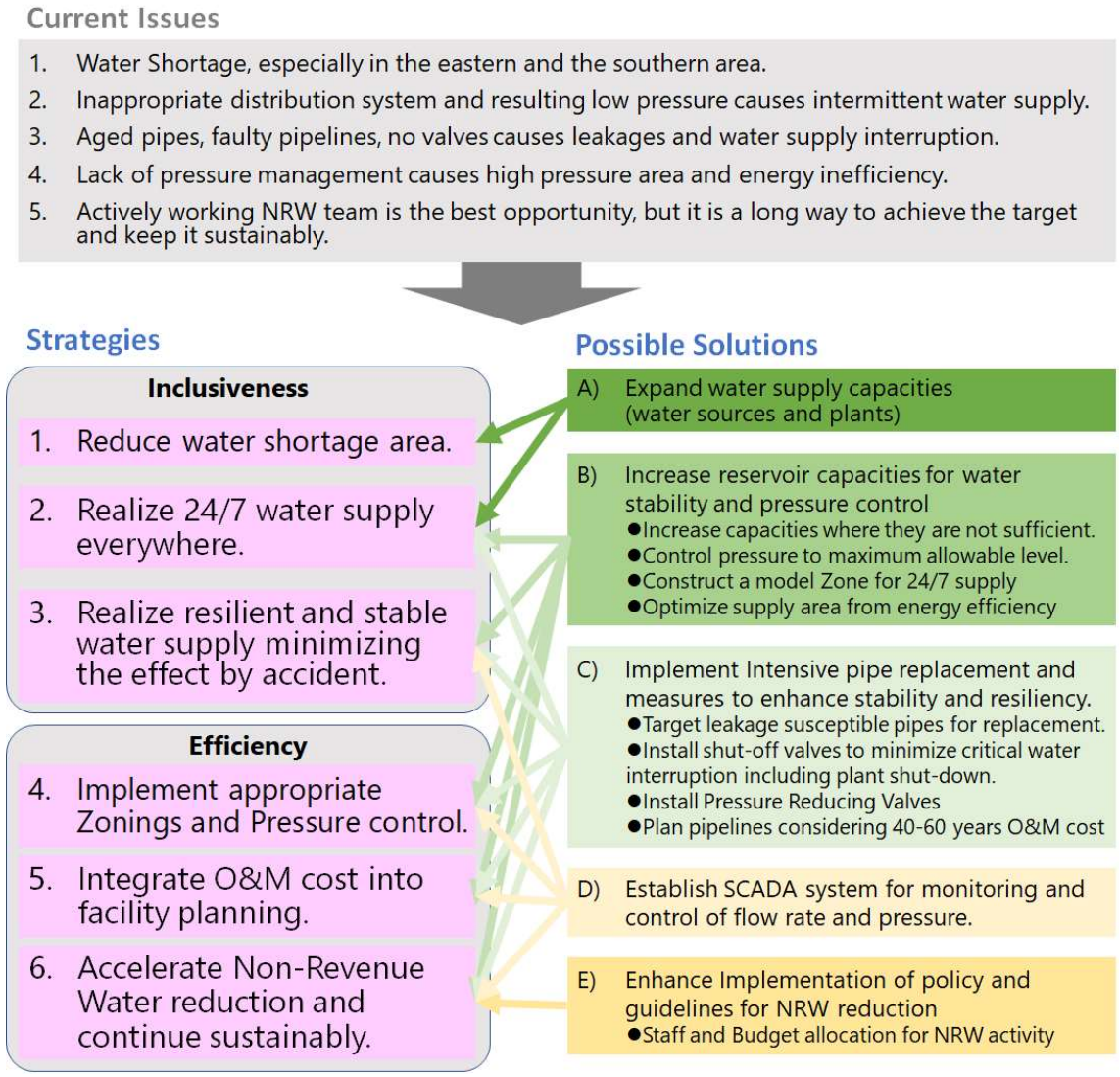


Source: JST

Figure S1.8-3 Visions for Safely Managed Water Services

Strategy for Masterplan

Considering the current issues including, financial situation, ongoing projects, the WASAC's current capacity, and the water demand, the strategy to formulate the KWSMP for the year 2050 has been identified and discussed in the course of the Study based on the analysis of the current conditions that have been attended at the earlier stage of the Study. The strategies and possible solutions are presented in the **Figure S1.8-4**.



Source: JST

Figure S1.8-4 Strategies for Water Supply Facility Development

Organizational Development

In order to make the KWSMP be realized, organizational development for the following aspects should be considered.

- Organizational Enhancement for the Head Office
  - Enhancing the function of Water Resource Management Section
  - Adding new Data Management Section under CEO Office
  - Enhancing O&M of service connection work
  - Enhancing the activity of NRW reduction
  - Capacity Development of Project management and Supervision
  - Strengthening Awareness for Environmental and social considerations and Enhancing Public relation
  - Strengthening management ability of GIS Data
  - Strengthening the Financial & Accounting management
  - Reorganizing Branch Structure
  - Set New Branch at East District of City for an increase of customer connection O&M
- Capacity Development for O&M for Water Treatment Plants (WTPs) including Water quality Assurance and Control (QA/QC)
- Training for Human Resource Development
- Development for Organizational Culture as a New Utility Business Entity

9 WATER RESOURCES DEVELOPMENT PLAN

Present permitted amount of water with 237,350 m^3/day does not meet the future demand of water supply in the Study Area. Therefore, Water Resource Development Plan has been prepared under the Study to identify the extra water sources for future water supply. Estimated additional water sources are shown in the following **Table S1.9-1**.

Table S1.9-1 New Water Sources to be Developed by 2050

Category at Hydrological Cycle	Source	Location	Water Supply m^3/day	Raw Water Intake m^3/day	Amount to be Developed (m^3/day)		Remarks
					2035	2050	
Surface Water	River	Nyabarongo	25,000	25,000	25,000		Intake place is Nzove *
		Nyabarongo or Akagera (by 2035)	100,000	110,000	110,000		Contingency plan**
		Nyabarongo or Akagera (by 2050)	380,000	418,000		418,000	Intake points has not decided yet**
	(Dam)	Nyabarongo, Akanyaru	(200,000)				Sites has not decided yet, need further study**
		Nyabarongo (Butamwa)	(130,000)				Site was recommended by the Nyabarongo II Multi-purpose study***
	Lake	Mugesera	(33,000)	(36,000)			Intake facilities shall be expanded. Not included for water source development
		Mugesera	50,000	55,000		55,000	
Groundwater (sub-surface water) at floodplain)	Boreholes in the river flood plains	Floodplain (Akagera)	80,000	88,000	88,000		Assumed Masaka and Gahanga
		Floodplain (Nyabarongo)	40,000	44,000		44,000	Near Nzove
		Floodplain (Nyabarongo and Akagera)	160,000	176,000		176,000	Rutonde, Kanzenze and Gahanga
Groundwater except floodplain	Borehole and springs	Small scale WSS for remote area	5,000	5,000	5,000		Jali, Rutunga, Gikomero****
		Small scale WSS for remote area	10,000	10,000		10,000	
		Allocated amount(m^3/day)	850,000	931,000	228,000	703,000	

Source: JST,
The F/S for the Nyabarongo II Multipurpose Development Project, conducted by the EDCL (Energy Development Corporation Limited) refers to a plan of the Butamwa Dam that involves abstraction of 1.5 m3/d for the Butamwa WTP. However, the Butamwa WTP is purposely excluded from the Master Scenario 2050 due to its geographical disadvantage for transmission and distribution and concerns over uncertain risk on future water quality. For this reason, this amount is being considered only as a provisional water source under this Water Resource Development Plan.
* Amount based on the hearing from the RWFA (Permitted amount for abstraction).
** Contingency plan in case the water sources from sub-surface water are not capable. The amount shall be transferred to 2050 development if not used.
*** The amounts shown in the "Dam" are included in the amount shown in "Nyabarongo or Akagera (by 2050)" of "River" and deemed as possible sites of "Nyabarongo or Akagera (by 2050)".
*** Location of these area is explained in the Master Scenario of Chapter 7.

10 SOCIO-ECONOMIC SURVEY

Socio-economic Survey has been conducted under the Study to identify customer's potential needs and implementation strategy for improving service level of the water supply service.

As a result of the Socio-economic Survey, followings are recommended:

- The current customers (households in the urban area) have a potential capacity for paying the tariff. Therefore, extra revenue for WASAC can be expected by improving service level (such as 24/7 water supply)

- In urban areas, the improvement of existing water supply services may increase usage since there is a potential demand for water supply. It is considered a relatively easier way to increase income.
- For rural area and low-income sector, development of supporting scheme for connection and water tariff is required
- Water quality survey result shows unprotected water sources were fortunately still acceptable conditions and needs conservation effort
- The rural area has less opportunity to earn income as it requires a bigger investment and households in rural areas have less payment capacity at this moment
- The provision of water supply service at an early stage in rural areas may start with public tap and protected wells and protected spring. It may increase the redundancy of the water supply service
- It is not a good idea to remove public tap since at this moment, even in the urban areas, most of the customer has to fetch water from outside of their premise due to quite frequent water supply failure.

11 STRATEGIC ENVIRONMENT ASSESSMENT (SEA)

Strategic Environmental Assessment (SEA) has been conducted under the Study to achieve the followings:

- To identify and assess potential environmental and social impacts of the Master Scenario used for Master Plan, and priority projects in Master Plan (15 Years Investment Plan)
- To identify potential significant adverse environmental and social impacts of the development projects included in Master Plan and recommend measures for mitigation,
- To develop an alternative plan, scoping of social environmental consideration, baseline survey, and assessment of environmental impact, preparation of mitigation measures and monitoring plans for the Projects.
- Support and prepare a public consultation/meeting plans with the relevant authorities, and stakeholders regarding findings and recommendations.

Followings are major findings of the SEA.

- By developing groundwater as a main source of water treatment plant, there shall be positive and negative environmental impact in each site. However, in each candidate site, it will not cause serious impact on surrounding environment and community.
- Compared with surface water from the Nyabarongo River, utilization of groundwater has advantage on water quality and climate change adaptation measure.
- Even this scenario expecting surface water development in later stage, it is expected to be less impact on environment

- Regulations for ESIA in Rwanda have no much difference with the JICA's guideline 2010 and the World Bank Safe Guard Policy. Difference only lies in procedure regarding information disclosure and public consultation etc. There are several minor differences between them. But they are basically consistent with the JICA's guideline
- This water supply scenario is following Vision 2020, NST1 and series of plans and policies set out by the Rwanda Government. The development following this scenario shall comply to plans and policies of Rwanda's development.

12 MASTER SCENARIO

The "Master Scenario" gives an overall scenario for water supply in the Study Area up to 2050, considering the water resources development plan, and appropriate WTP, transmission and distribution of water system to meet the future water demand. The Master Scenario is the basis of the 15-Year Investment Plan.

Principles

Available water sources to meet the large demand are restricted to the Nyabarongo River basin and Mugesera/Sake Lake and other upcountry water sources. Therefore, the future water supply scenario should be illustrated what the best mixture of those water sources. The technical aspects to be considered for the best mixtures in water transmission, treatment processes, and distribution in order that the scenarios can be evaluated from water *stability*, *flexibility*, *resiliency* and the *life-cycle cost*.

Master Scenario: The year 2025

The Master Scenario in the year 2025 is determined as shown in the following figure. The master scenario simulation is planned based on the projected water demand under NRW 25%.

The policy for the investment toward the year 2025 is as follows;

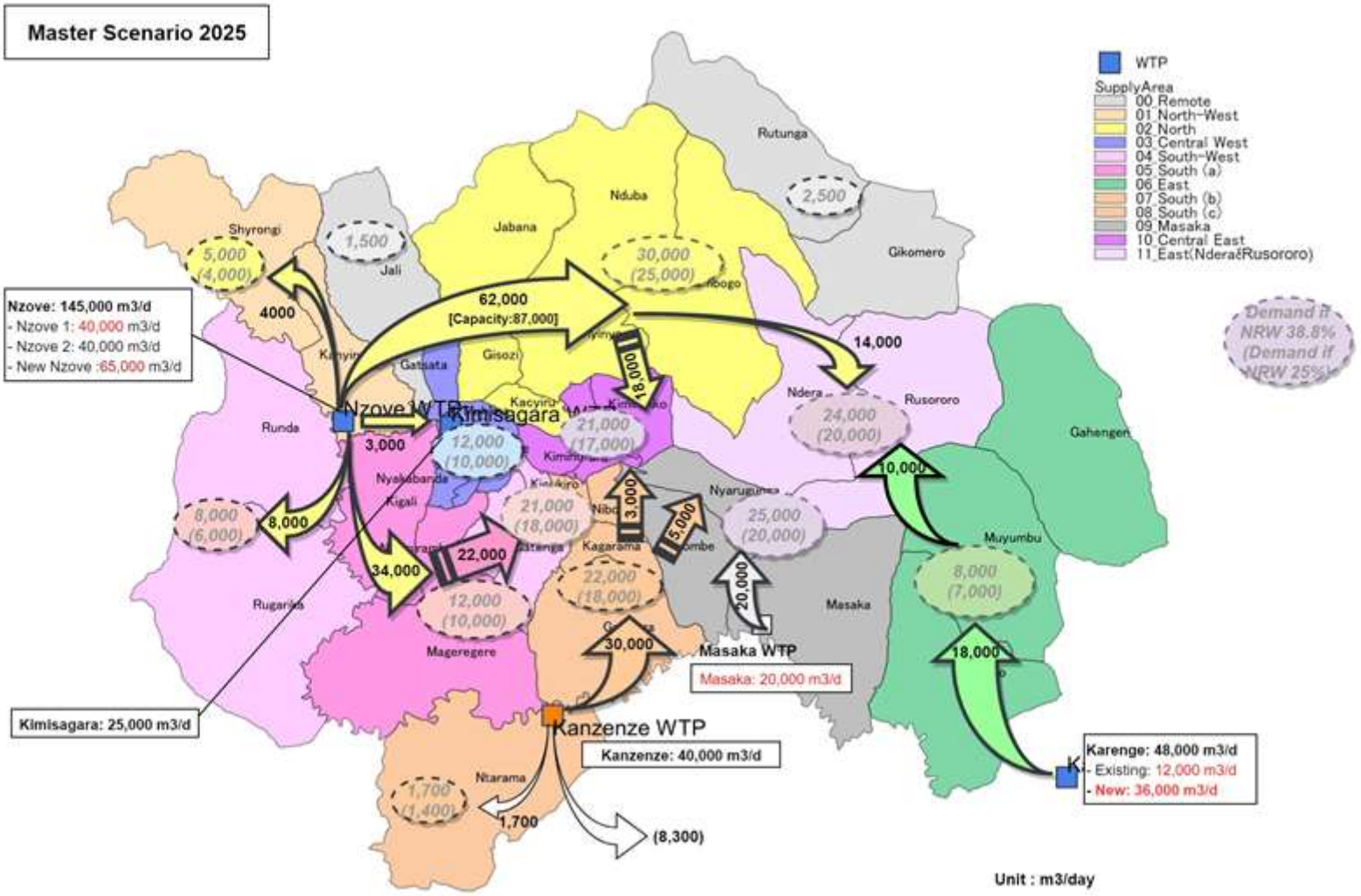
a. Accelerate NRW reduction measures to achieve WASAC's target (25%) progressively
b. Meeting the demand in the east: To construct a new WTP near the high demand area (the Sectors of Masaka, and Karenge) or transmit water from the Remera to the east

The on-going and additional facilities for 2025 is as shown in the following **Table S1.12-1**.

Table S1.12-1 On-going Project and Additional Facilities for 2025

On-going Projects	
Rehabilitation of Nzove 1	+23,000 m^3/day (from 17,000 to 40,000 m^3/day)
Expansion of New Nzove:	+25,000 m^3/day (from 40,000 to 65,000 m^3/day)
Rehabilitation of Karenge WTP	+3,000 m^3/day (from 15,000 to 18,000 m^3/day)
Additional Facilities for 2025: +20,000 m^3/day (Total: 247,000 m^3/day)	
Masaka WTP and forwarding infrastructures	+20,000 m^3/day
NRW Reduction Measures	Phase 1 to 2

Source: JST



Source: JST

Figure S1.12-1 Master Scenario in 2025

Master Scenario: The year 2035

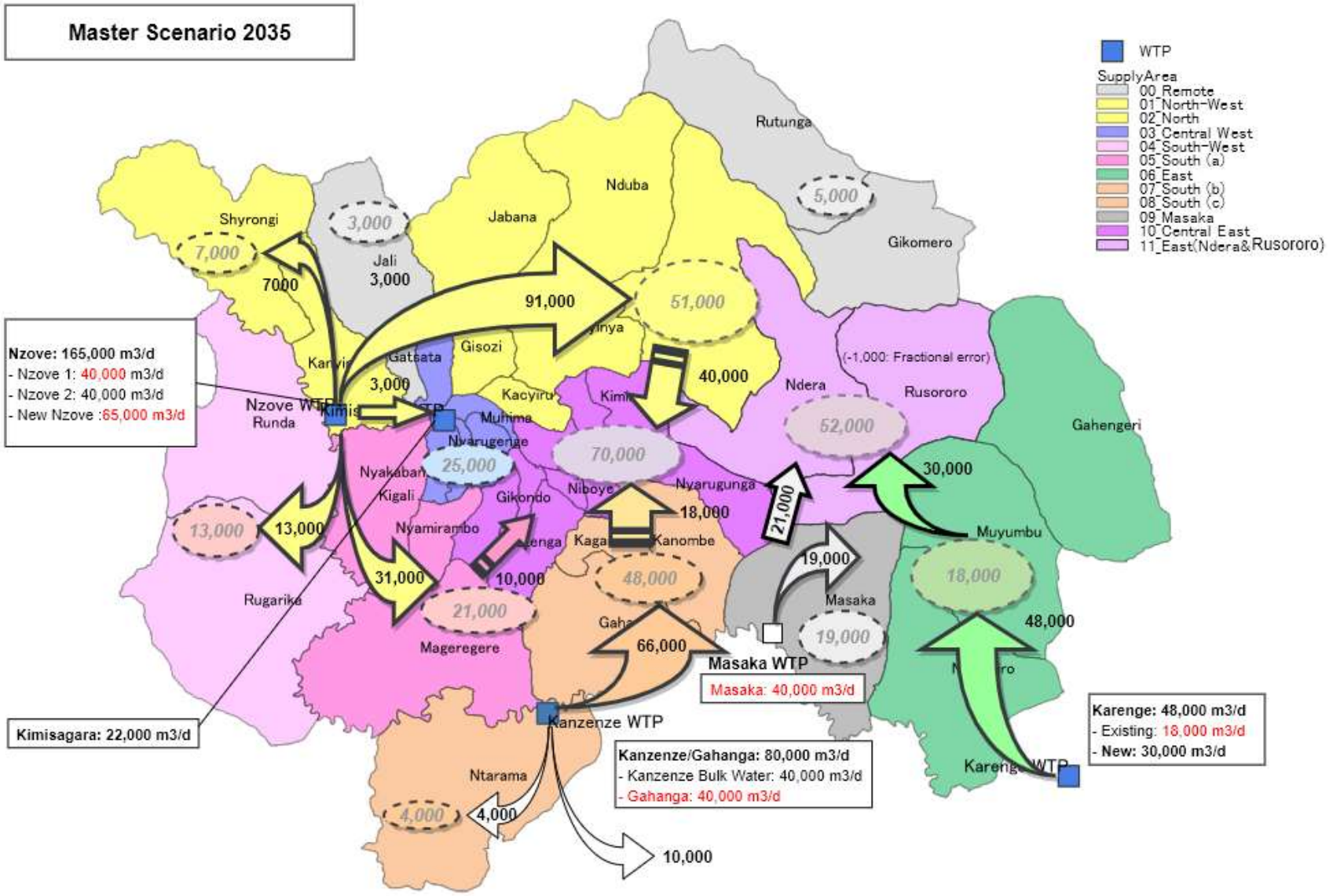
The Master Scenario in the year 2035 is determined as shown in **Figure S1.12-2**.

The additional facilities are as shown in the following **Table S1.12-2**.

Table S1.12-2 Additional Facilities for 2035

Additional Facilities for 2035: +98,000 m^3/day	
Gahanga WTP	+40,000 m^3/day (New)
Masaka WTP	+20,000 m^3/day (Total: 40,000 m^3/day)
Karenge WTP	+36,000 m^3/day (Expansion plus Rehabilitation)
Small Scale WSS	+5,000 m^3/day (For remote areas: Rutunga, Gikomero)
Transmission and Distribution Pipelines for the abovementioned facilities: NRW Project: Phase 3 to 5	

Source: JST



Source: JST

Figure S1.12-2 Master Scenario in 2035

Master Scenario: The year 2050

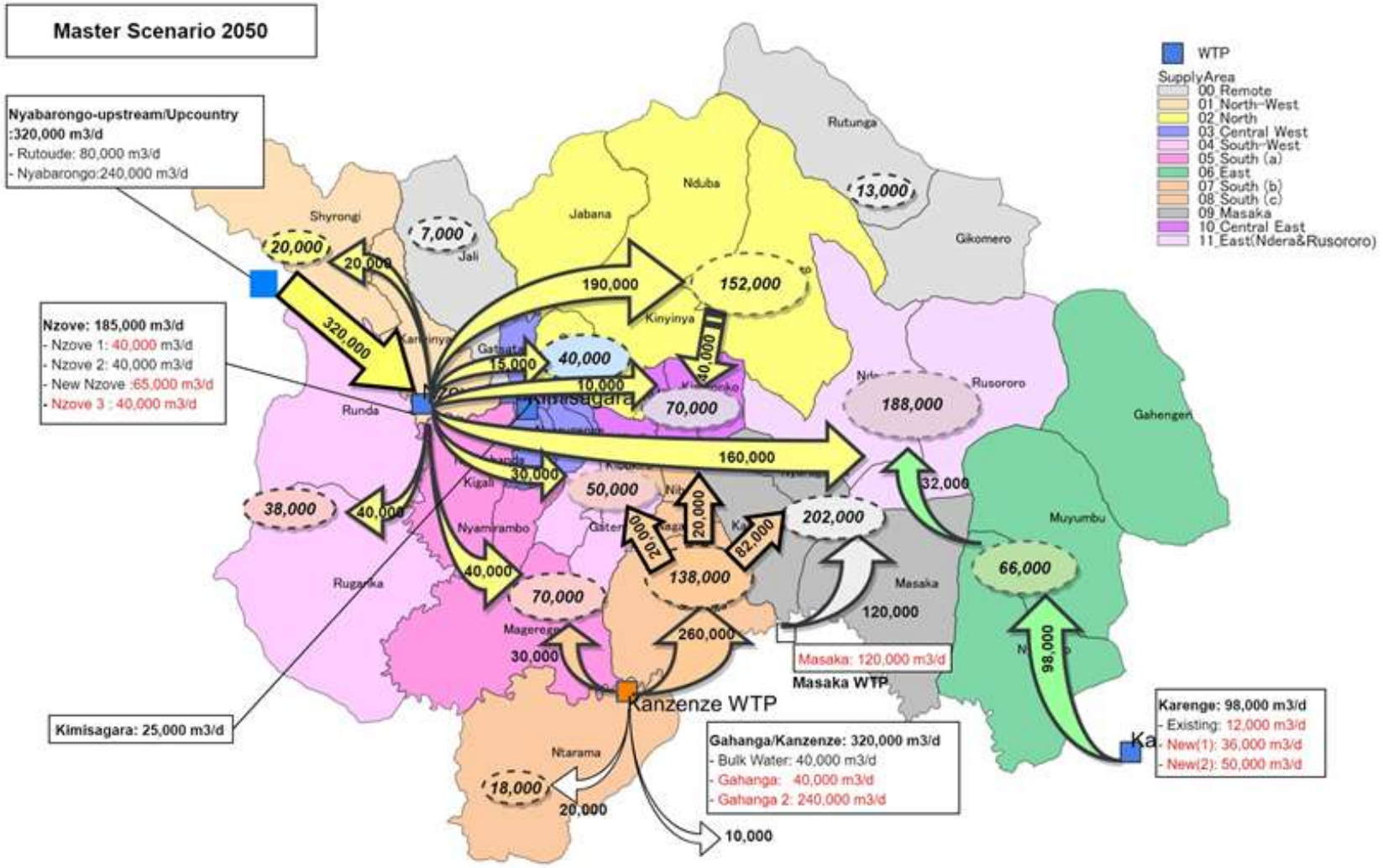
The Master Scenario planning in 2050 is aimed at the determination of the mix of the water source by the given conditions as specified in the CoK Masterplan as show in the following **Figure S1.12-3**.

Additional facilities for the long term are shown in the following **Table S1.12-3**.

Table S1.12-3 Additional Facilities for the Long Term (2050)

Additional Facilities for Long Term (2050) +754,000 m^3/day	
Nzove 3	+40,000 m^3/day (New)
Rutonde	+80,000 m^3/day (New)
Nyabarongo	+240,000 m^3/day (New)
Gahanga2	+240,000 m^3/day (New)
Masaka2	+80,000 m^3/day
Karenge	+50,000 m^3/day
Small Scale WSS	+10,000 m^3/day (For remote areas)
Transmission and Distribution Pipelines for the abovementioned facilities.	

Source: JST

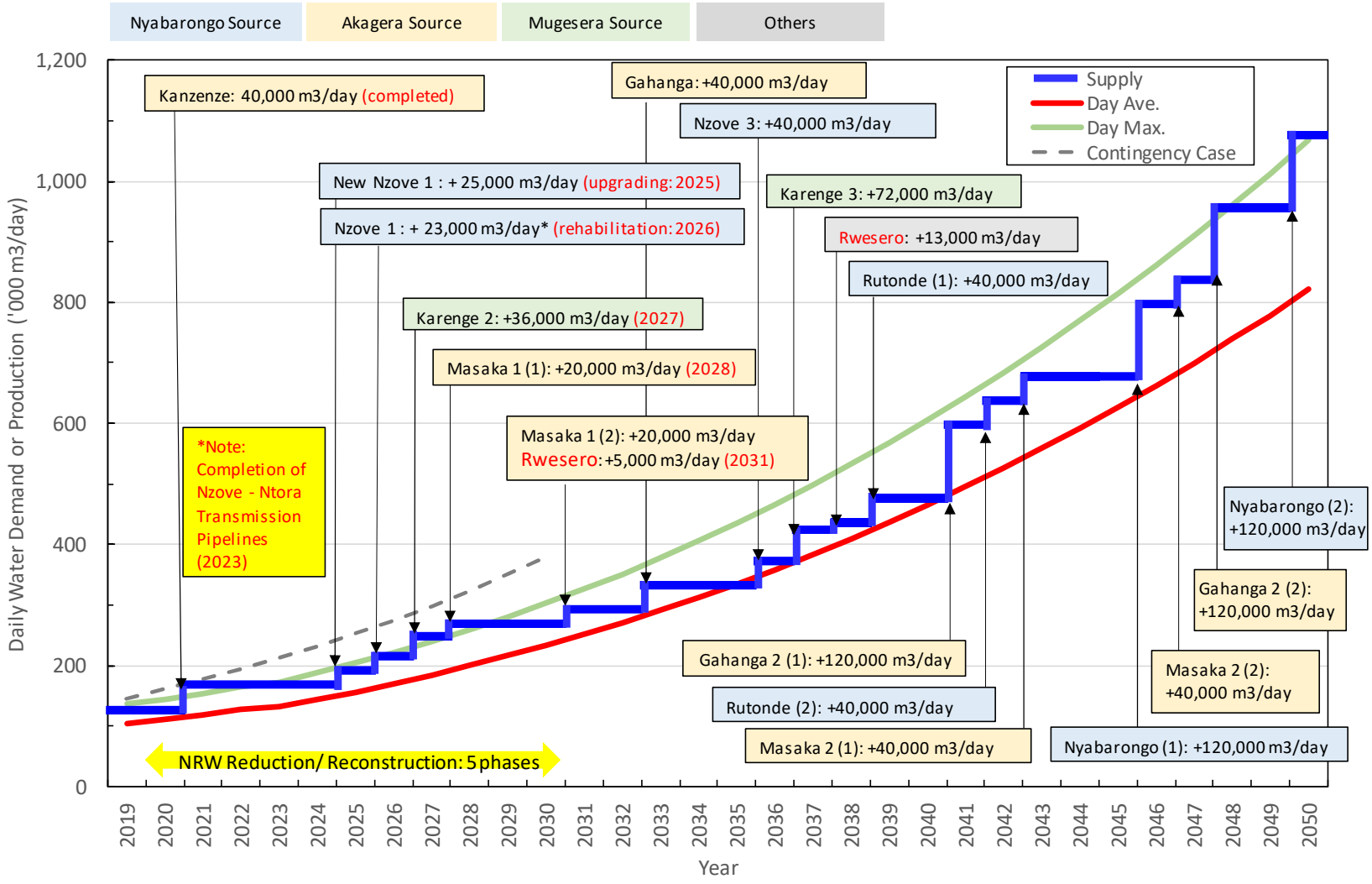


Source: JST

Figure S1.12-3 Master Scenario in 2050

Implementation of the Master Scenario

For road-mapping, the implementation, supply-demand strategy, construction of transmission pipelines, and reconstruction of distribution systems for NRW reduction are elaborated in **Figure S1.12-4**.



Source: JST

Figure S1.12-4 Supply-Demand Balance as the Roadmap for the Master Scenario

Water Production Facilities

The facilities to be constructed towards 2050 are listed in the following **Table S1.12-4**.

Table S1.12-4 Facilities to be constructed towards 2050

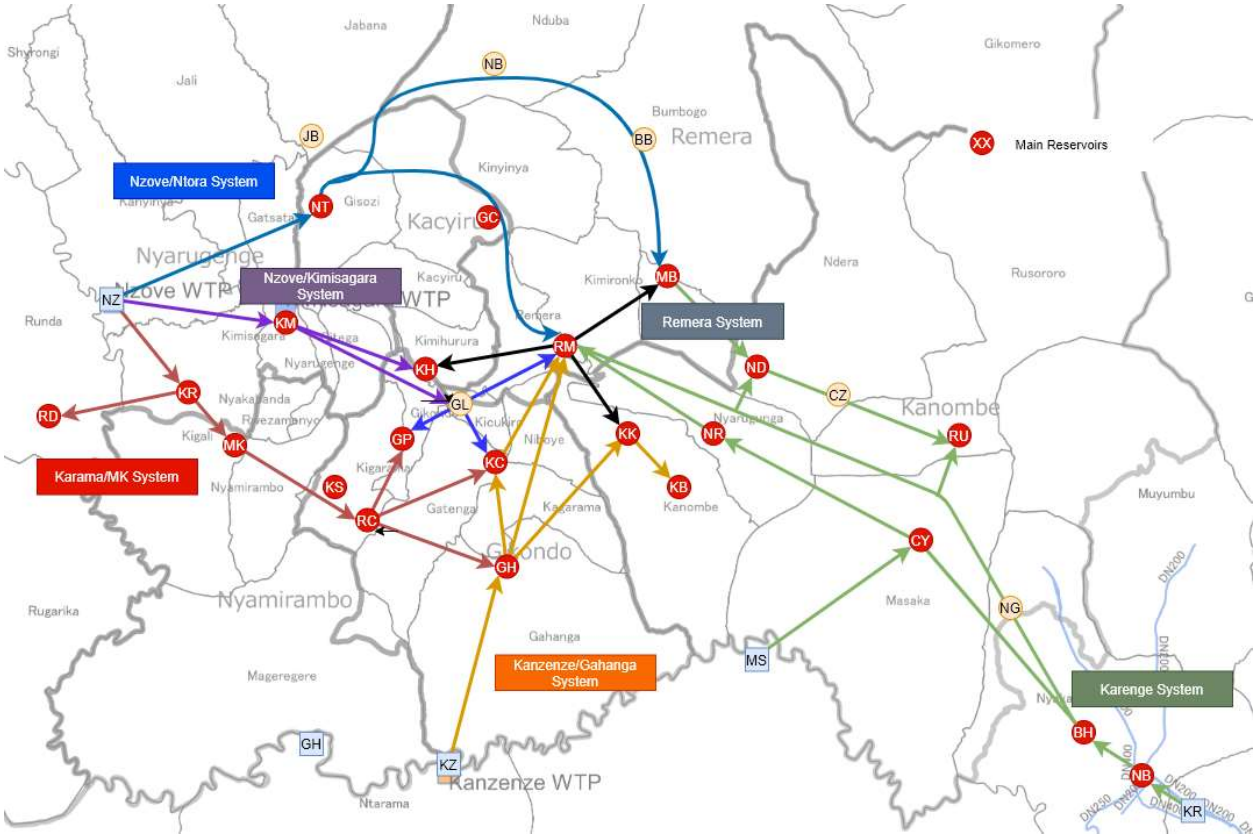
Name of Facilities	Descriptions
Existing Facilities: 162,000 m^3/day[*1]	
On-going Facilities: +65,000 m^3/day (Total: 227,000 m^3/day) [*2]	
Additional Facilities for 2025: +20,000 m^3/day (Total: 247,000 m^3/day) [*3]	
Additional Facilities for 2035: +98,000 m^3/day [*4]	
Gahanga WTP	+40,000 m^3/day (New)
Masaka WTP	+20,000 m^3/day (Total: 40,000 m^3/day)
Karenge WTP	+33,000 m^3/day (Expansion plus Rehabilitation)
Small Scale WSS	+5,000 m^3/day (For remote areas: Rutunga, Gikomero)
Transmission and Distribution Pipelines for the abovementioned facilities	
Additional Facilities for Long Term (2050) +754,000 m^3/day	
Nzove 3	+40,000 m^3/day (New)
Rutonde	+80,000 m^3/day (New)
Nyabarongo	+240,000 m^3/day (New)
Gahanga2	+240,000 m^3/day (New)
Masaka2	+80,000 m^3/day
Karenge	+50,000 m^3/day
Small Scale WSS	+10,000 m^3/day (For remote areas)
Transmission and Distribution Pipelines for the abovementioned facilities	

[*1]: Nzove 120,000 m^3/day, including the rehabilitation, Kimisagara 22,000 m^3/day, Karenge 15,000 m^3/day, and Small-Scale Water Sources 5,000 m^3/day.
[*2]: Kanzenze (Kigali Bulk Water Supply) 40,000 m^3/day, including the demand for Bugesera Airport (10,000m^3/day), which is out of the study area and New Nzove 1 expansion of 25,000 m^3/day.
[*3]: Masaka WTP 20,000 m^3/day

Source: JST

Transmission Pipelines: Grand Design

The transmission pipelines to deliver the clear water from the WTP to the Key Reservoirs are shown in the following **Figure S1.12-5**. All these investments are included in the WTP expansion or the NRW reduction projects, as shown in the following **Table S1.12-5**.



Note: Nzove, NT; Ntora, KM; Kimisagara, KR; Karama, MK; Mont-Kigali, GL; Gikondo-Low (Proposed), GP; Gikondo Premiere, RC; Rebero Carrier, KC; Kicukiro (Golf 7), RM; Remera (Golf 8), GH; Gahanga, KZ; Kanzenze. BH; Bihimbe (from Karenge), MB; Masoro-bas, ND; Ndera, RU; Rusororo, MS; Masaka, NR; Nyarugunga, KK; Kanombe Rwimbogo KB; Kanombe Busanza

Source: JST

Figure S1.12-5 Masterplan for Clear Water Transmission Systems (Ultimate Figure of 2050)

Table S1.12-5 Transmission Routes and Construction Framework

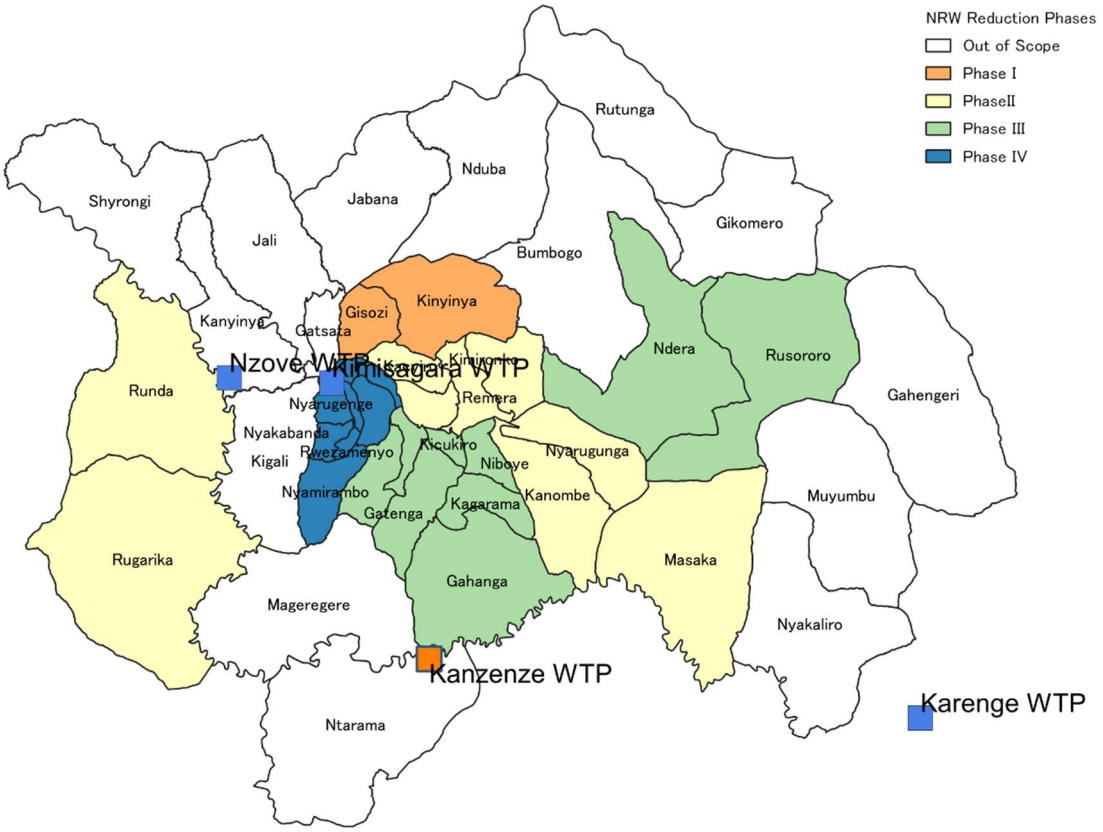
Transmission Scheme	Descriptions	Construction Framework
The Nzove/Ntora	The Nzove WTP (Source: the Nyabarongo) is a single water source. All treated water is transferred to the Ntora Reservoir except the minor transmission to the Mount-Jali, the Kanyinya and the Shyolongi. The line covers the northern area of the entire Kacyiru branch, the Nyarutarama, Remera, and a part of the Kimironko. The branch of the line covers the future north-ring line to the Nduba and the Bumbogo.	On-going Expansion: The North-ring (On-going) and the Ntora-reconstruction (Priority project) Future Expansion: After 2040 along with the Nyabarongo WTP (240,000 m^3/day two phases)

Transmission Scheme	Descriptions	Construction Framework
Karama/MK	The Nzove WTP is a single water source. The water is pumped up to the Mont Kigali (MK) reservoir through the Karama Pumping Station. The major portion of water goes to the Kimisange, the Nyanza, and reaches the Kicukiro. This is a back-up line to supply water to the Rwezamenyo and the CBD, while it is not the mainline due to its low energy efficiency. A part of water goes from the Karama to the Runda and the Rugarika areas and will be the major transmission line after the on-going pipeline expansion.	On-going Expansion: The Karama to the Runda-Rugarika (On-going) Future Expansion: After 2040 along with the Nyabarongo WTP
Nzove/Kimisagara	The primary water source is the Kimisagara WTP (Source: the Yanze) and minor source from the Nzove as on 2020. The major source will be switched to the Nzove after the alternative transmission line (Central Mains) is constructed.	Future Expansion: Towards 2036 for the Nzove 3 and the Rutonde as "the Central Main."
Kanzenze/Gahanga	The new transmission pipelines are constructed from the Kanzenze WTP (Bulk water supply) to the Kicukiro, the Remera, the Kanombe-Kabeza, and the Busanza. The systems will be expanded to the southern part of the lower Gahanga in order to meet the new demand for the gateway city to the new airport.	On-going Expansion: Along the completion of the Kanzenze WTP. Future Expansion: By 2032 along with the Gahanga WTP, After 2040 under the Gahanga 2 and 3 (240,000 m^3/day 2 phases)
Karenge/Masaka	The Old Karenge I and II systems from the Karenge WTP (Source: the Mugesera Lake) to the Remera need expansion and rehabilitation. The northern line (the Karenge II) should be reconstructed with the expansion of the Karenege WTP to supply water to the Upcountry areas (the Nyakaliro, the Muyumbu, and the Gahengeri) and the Rusororo, the Ndera to the Remera. The southern line (the Karenge I) will be reconstructed for and along with the new Masaka Water Sources to feed water to the Masaka, the Nyarugunga, a part of the Rusororo.	Future Expansion: By 202,5the Karenge II along with the Karenge 2 WTP Expansion and by 2036 the Karenge I for the Karenge 3 WTP Expansion.
Remera	The system needs to allocate water from the Remera reservoir to the key reservoirs, namely; the Kicukiro, the Kimihurura, the Kimironko, the Masoro-bas, and the eastern area (the Ndera).	Future Expansion: By 2025 along with the NRW reduction (the Kacyiru/South and the Kicukiro)

Source: JST

Phasing of Rehabilitation for NRW Reduction

The reconstruction of distribution systems is phased in 8 target areas. Setting up of the target areas facilitates the implementation to comprehend the system; each target area contains 100 to 200 km of the existing pipeline (**Figure S1.12-6**).



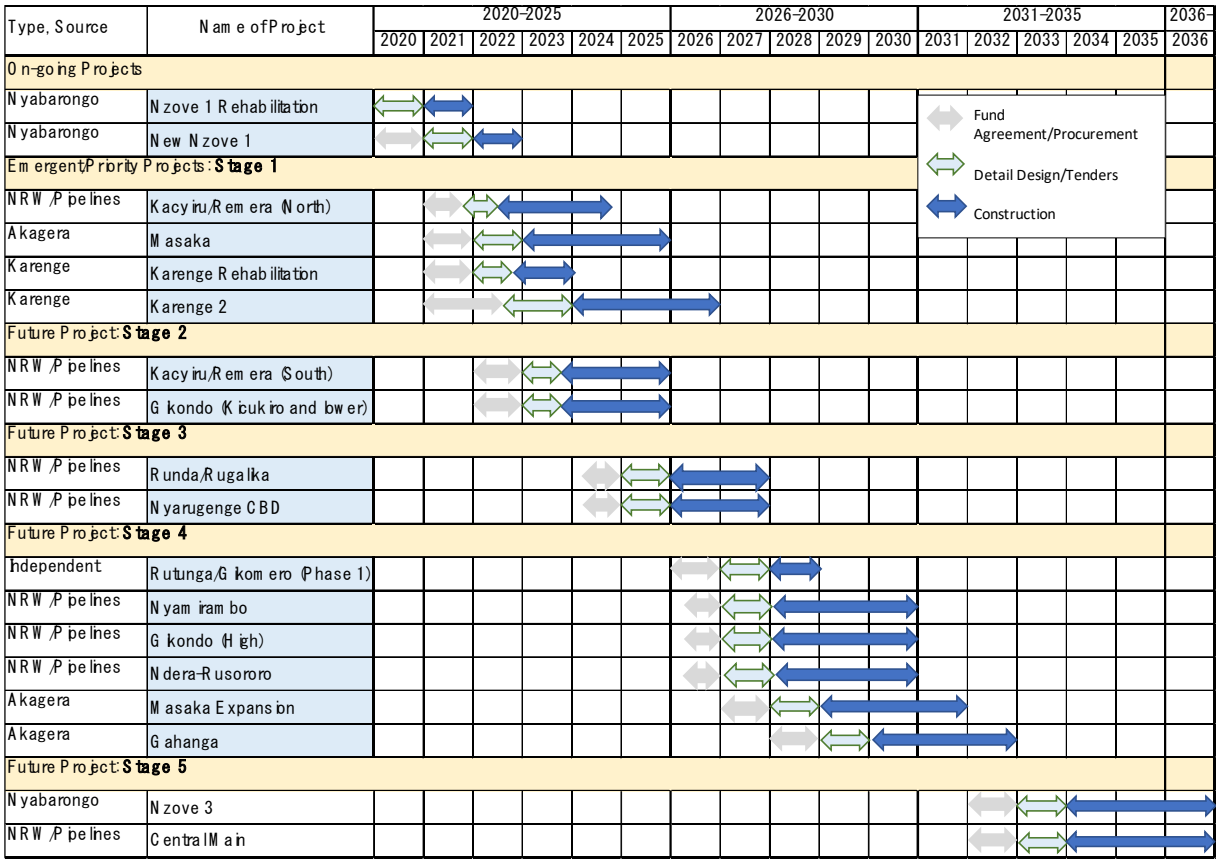
Source: JST

Figure S1.12-6 Schematic of the Phasing of NRW Reduction Project

13 THE 15-YEAR INVESTMENT PLAN

15 year investment plan

The Plan is divided into five (5) stages apart from the On-going projects shown in the following **Figure S1.13-1**.



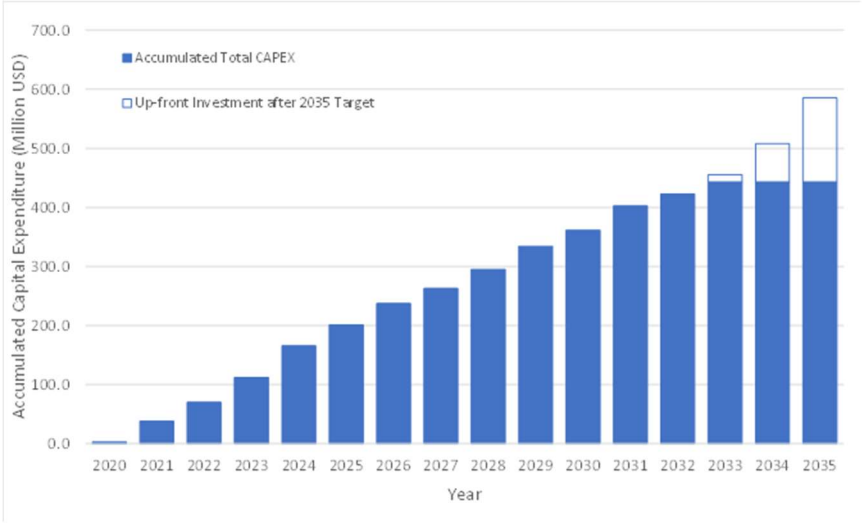
Source: JST

Figure S1.13-1 Implementation Schedule for 15-Year Investment Plan

Investment Plan

(1) Capital Expenditure (Capex)

Estimated annual investment on the 15-Year Investment Plan is 34.3 MUSD/year from the year 2021 to 2035. The capital needs for the 2035 target were estimated to be 443 Million USD (585 Million USD including the up-front investment which should be completed until 2037) as shown in the following **Figure S1.13-2**.

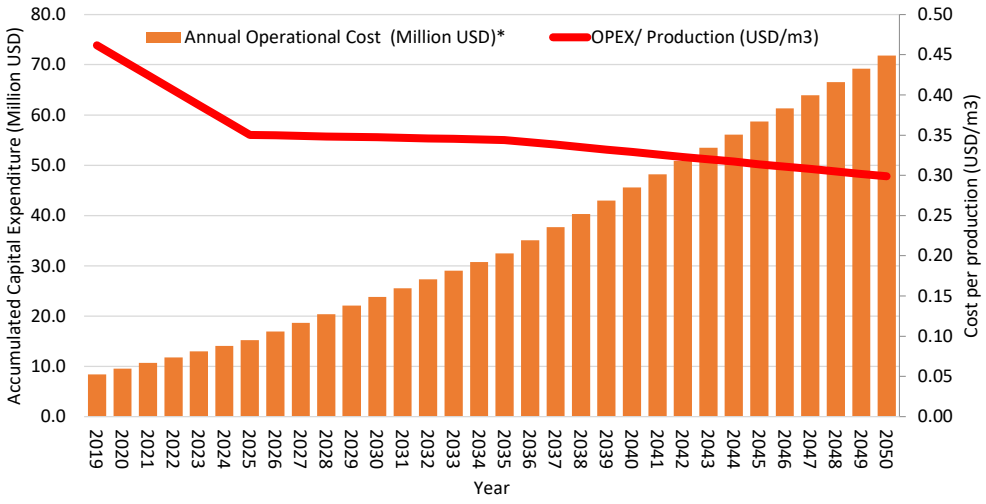


Source: JST

Figure S1.13-2 Accumulated Capital Expenditure for 15-Year Investment Plan

(2) Operational Expenditure (Opex)

The operational cost will significantly decrease along with the NRW reduction up to 2025. The cost is kept low at USD 0.32 /m^3 up to 2035. Further improvement can be materialized on completion of the Central Main after 2035 and can be decreased to low as USD 0.30 / m^3 as shown in the following **Figure S1.13-3**.



Source: JST

Figure S1.13-3 Annual Operational Expenditure towards 2050

Total investment cost by projects is outlined in the following **Table S1.13-1**.

Table S1.13-1 Cost of the 15-Year Investment Plan

This Page is closed due to the confidentiality.

Priority Project

The shortlist of the projects was drafted in accordance with the determination at JCC held on 13th February 2020, as shown in in the following **Table S1.13-2**.

Table S1.13-2 Shortlist and Priority of Development Projects

Priority	ID/ Project Name	Remarks (Possible Financial Sources)
1	**NRW reduction project through pressure control and pipe renewal**	A part of the project will be proposed to Japan's Grant Aid
2	**Construction of Masaka WTP and Clear Water Transmission & Distribution Facilities**	Subject to F/S
3	**Rehabilitation and Expansion of Karenge WTP and Transmission & Distribution Facilities**	Subject to F/S
4	Capacity development for Sustainable Use of Water Resources and Water Supply Facilities	Subject to request for Japanese Grant Aid
-	Kigali Central Transmission Main	WASAC is aware of its necessity. However, due to constraints including budgetary limitation and difficulty in land acquisition, WASAC intends to postpone it in future

Source: JST

14 Economic Evaluation and Financial Consideration on the 15-year Investment Plan

Economic Evaluation

As a result of the economic evaluation for the 15-YIP, the projects are concluded to be economically feasible as the EIRR of the projects exceed 10% of the opportunity cost of capital as described below.

- EIRR : 12. 0%
- NPV : 23,080 million RWF
- B/C : 1.11

Financial Consideration

As a result of the financial evaluation for the 15-YIP, the projects are judged to be financially feasible as the FIRR of the projects exceeds 6.3% of the opportunity of capital as described below.

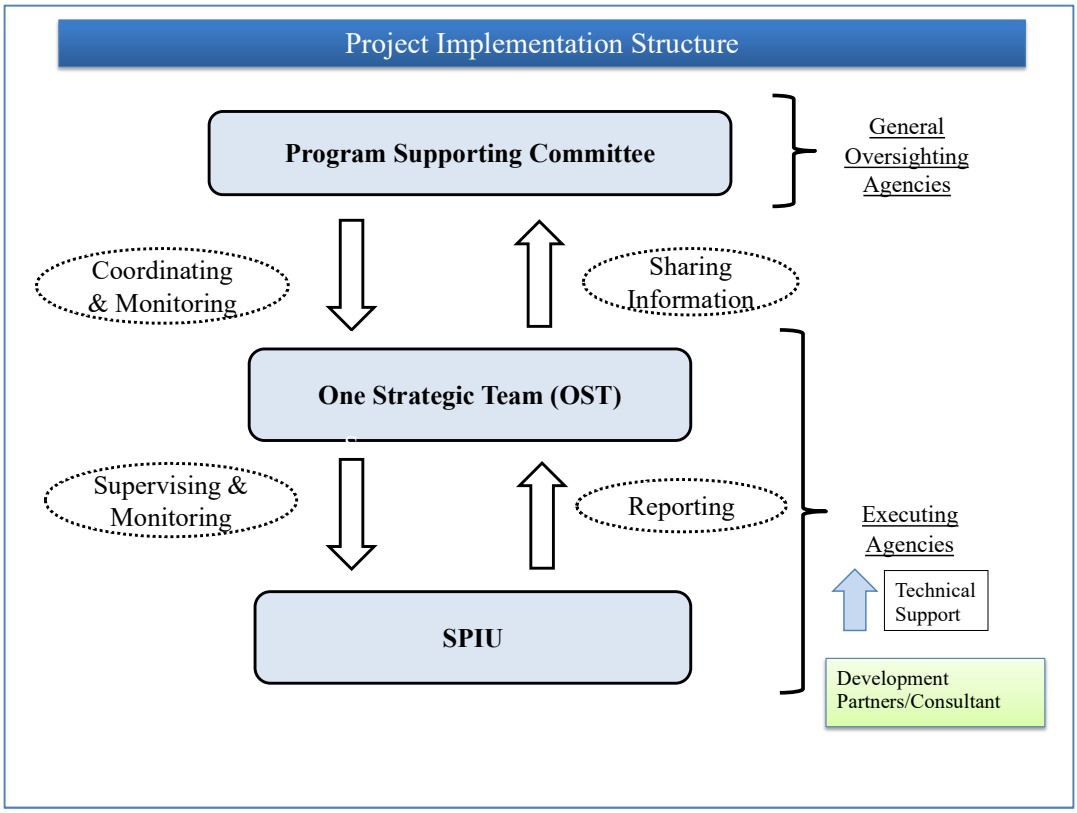
- FIRR : 6.8%
- NPV : 12,520 million RWF
- B/C : 1.04

15 STRATEGY FOR IMPLEMENTATION

Project Implementation Structure

The reliable implementation of the project requires not only the full commitment of all WASAC departments, but also strong cooperation with key government agencies such as ministries and the city of Kigali. Therefore, in addition to the existing department/unit of WASAC, a new Program Supporting Committee and One Strategic Team (OST) will be established.

The overall view of the project implementation system is shown in the following **Figure S1.15-1**.



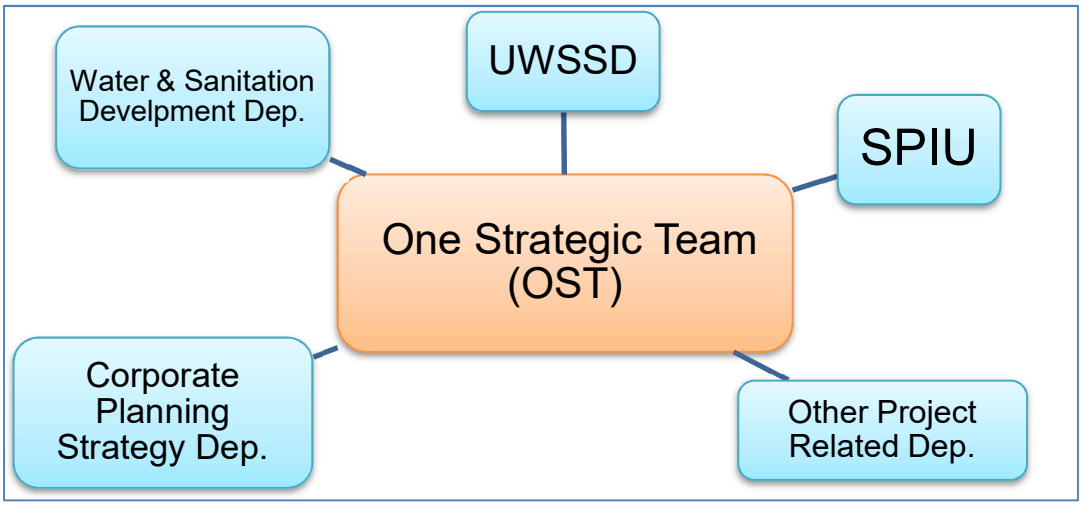
Source: JST

Figure S1.15-1 Project Implementation Structure

Establishing One Strategic Team

OST is formulated as a new unit within WASAC. This team works as a unit with a function to identify cross-organizational issues and examine measure to solve issues and develop strategies for commencement/implementation of the long-term investment projects.

This new team unit is composed by CEO, DCEO, UWSSD, Water & Sanitation Development Dept. SPIU, Corporate Planning & Strategy Dept. and other project related Dept as shown in the following **Figure S1.15-2**.



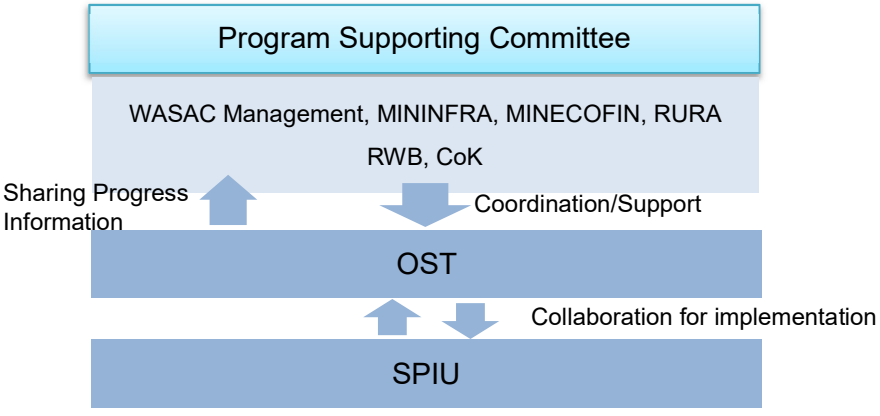
Source: JST

Figure S1.15-2 Formulation of One Strategic Team

Setting up Program Supporting Committee: Coordination with the government ministries and agencies

Coordination with various government ministries such as the MININFRA, the MINECOFIN, the RURA, RWB and the CoK are indispensable for effective implementation of the 15-Year Investment Plan created under the MP.

Therefore, setting up a regular committee consisting of permanent members from WASAC and the related authority including the MININFRA, the MINECOFIN RURA, RWB and the CoK for the MP is important as shown in the following **Figure S1.15-3**.



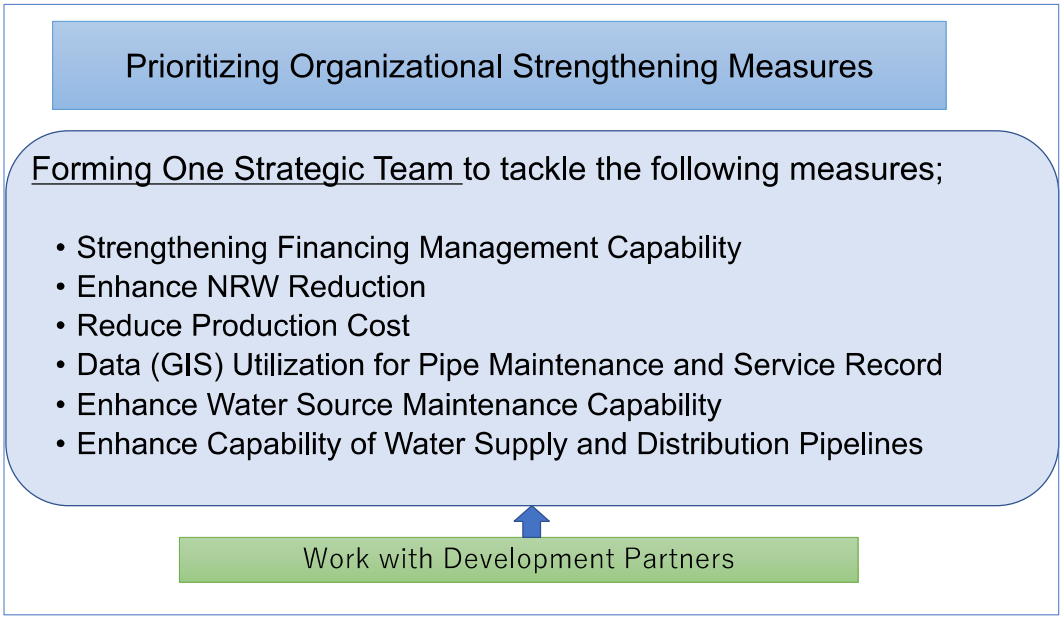
Source: JST

Figure S1.15-3 Formulation of Program Supporting Committee

Prioritizing Organizational Strengthening Measures

The following organizational strengthening measure should be prioritized among organizational issues for

project implementation as is shown in the following **Figure S1.15-4**. A technical cooperation scheme having aid of international development partners can be considered for effective implementation of measures.



Source: JST

Figure S 1.15-4 Prioritizing Organizational Strengthening Measures

16 RECOMMENDATIONS

Key recommendations for the KWSMP are itemized as follows:

1. The establishment of the One Strategic Team (OST) within WASAC and Program Supporting Committee in cooperation with the MININFRA, the RURA and the MINECOFIN are key factors to enhance the implementation and monitoring of the Masterplan. The OST and the Program Supporting Committtee are not only just an implementation unit but also serve as the long-term planning facilities to gain the sustainability of the utility. The 15-Year Investment Plan and KPIs for the monitoring are subject to review and approval by the OST and the Program Supporting Committee.

2. WASAC should implement the improvement measures for strengthening the organizational and institutional aspects including followings.
    - Forming One Strategic Team,
    - Strengthen financial management capabilities,
    - NRW Reduction,
    - Reducing production cost by improving production efficiency,
    - Enhancing Geographic information system (GIS) database construction and utilization,
    - Strengthening Water source maintenance capabilities,

- Strengthening Maintenance capability of water supply and distribution pipelines.

In addition, among the improvement measures itemized in the above, (i) Establishing One Strategic Team for the purpose of attending cross-organizational problems, and (ii) Strengthening financial management capabilities in order to materialize the projects itemized in the KWSMP will be a groundwork of the other activities. In this context, the JST believes that the above (i) and (ii) are the most priority aspects among the improvement measures. **Figure S1.16-1** presents categorization and priority order of organizational strengthening measures

Fields that needs to be strengthened		*Priority*
Category	*Individual aspects to be strengthened*	
Framework for implementation of the "utility turnaround strategy" is established and WASAC is enabled to solve cross-organizational problems.	Establishing One Strategic Team == Establishing a cross-organizational team for the sake of materializing the KWSMP as well as monitoring the progress and status of achievement	A
Financial management capability to implement the M/P is enhanced.	Strengthening financial management capabilities == Preparation of accounting books and financial statements for clear demarcation of assets between the government and WASAC == Development of management accounting systems to monitor production costs and financial performance of all concerned departments	A
Capacity of efficient implementation of NRW reduction is enhanced.	Reduction of NRW == Enhancement of activity to reduce NRW through pressure control and service connection pipes.	B
Water supply facilities are cost-effectively operated.	Reducing production cost (e.g., costs for energy and chemical) by improving production efficiency == Improvement of engineering capacity (e.g., civil/ mechanical /electrical /water quality) for energy efficiency for water production and operation.	B
	GIS database construction and utilization == Creation of GIS database for all areas and utilization of database for maintenance of water distribution pipe network, billing / collection of water charges	B
	Enhancing water source maintenance capabilities == Strengthening monitoring and management capacity for water source (including ground water and surface water)	C
	Enhancing maintenance capability of service connections == Preparation of manuals and standards for improving quality of service connection works and materials	B

Source JST

Figure S1.16-1 Categorization and Priority Order of Organizational Strengthening Measures

International cooperation for capacity building with the development partners is necessary in this regard.

3. WASAC/MININFRA should take an initiative role for the implementation of 15-YIP to expand and reconstruct the infrastructure through the quality investment and distribution block system. The quality investment is necessary in terms of the materials, construction control, and safety measures to achieve the goal for the water supply expansion and efficiency in a long-term perspective.

4. In order for WASAC to tackle the critical issues including NRW reduction and intermittent supply, comprehend the current status, and evaluate the effect of the measures that have been taken, WASAC should consider introducing a smart flow and pressure monitoring system. Smart management and monitoring using digital transformation technologies should be highlighted including the introduction of smart water meters with automatic meter reading techniques and utilization of GIS for the policy determination.

5. WASAC/MININFRA should start a discussion with the concerned organizations including RWB in order to facilitate obtaining water use permissions for the required water resources itemized in the 15-Year Investment Plan as well as the Masterplan.

6. The establishment of water sources monitoring system is needed. Especially, in order to avoid overexploitation of aquifer and identify the influence caused by pumping, water level monitoring boreholes should be constructed in the wellfield and regular monitoring of groundwater level is recommended.

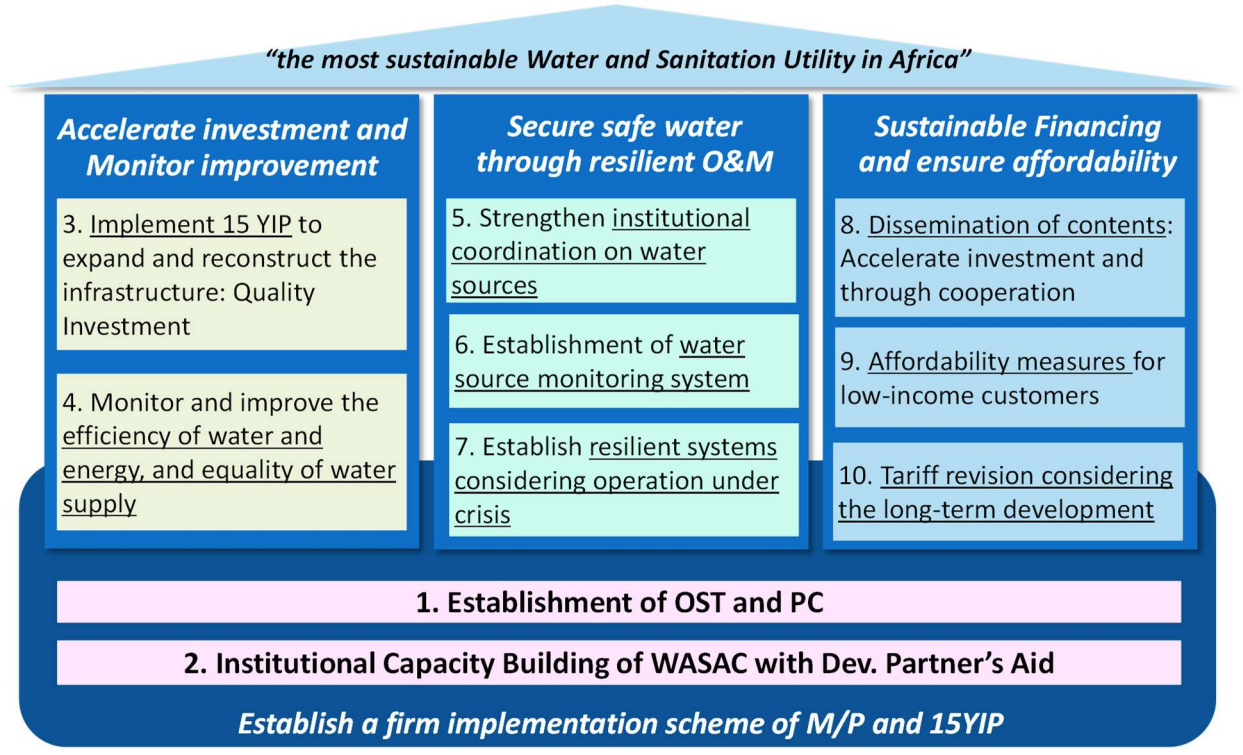
7. In order for WASAC to be prepared for possible future crises (such as a pandemic case likewise Covid-19), WASAC should keep on its effort on developing and improving its financial status so that WASAC can maintain stockpiling essential materials for its O&M (e.g., coagulant and disinfectant used for water treatment). In addition, as proposed in the BCP prepared under the Study, an appropriate inventory management will help WASAC to monitor the status of possession (shortage/ needs) of essential materials.

8. It is recommended that WASAC/MININFRA should widely and actively disseminate the content of the 15-Year Investment Plan to the potential investors including development partners and private investors at the right occasions. In addition to the Sector Working Group that is organized by MININFRA to share the content of the water and sanitation projects with the concerned parties, setting up a platform where concerned parties can exchange such information regularly/continuously could be an option to seek funding sources. Launching and putting such activities on track may be supported by the intervention of the central government and/or technical assistance program by the development partner's aid. In addition, such information should be given to existing private operators as well in order to mitigate the impact on their businesses as a part of social consideration.

9. In order for WASAC to increase the service ratio as planned in the Masterplan, it is necessary to take the low-income groups into WASAC's service as a user. Accordingly, it is recommended that WASAC/MININFRA, RURA, and other authorities including central government organizations and regional government bodies to work on the possible pro-poor measures such as subsidies, loans, self-reliance, job gain, housing, health and so forth support for facilitating low-income groups to be a self-sustainable economic entity.

10. WASAC should discuss with MININFRA and RURA on the revision of the tariff table periodically with an interval of every 3 or 5 years in line with the increase of the number of customers and new facilities, so that WASAC can maintain a stable operational profit, and allocate a fair and equity charge to the satisfaction of its customers, which will contribute to securing funds for appropriate O&M of water supply facilities in the long run.

Figure S1.16-2 illustrates the above key recommendations.



Source: JST

Figure S1.16-2 Key Recommendations

Part 2 FEASIBILITY STUDY FOR THE PROJECT FOR EXPANSION OF KARENGE WATER SUPPLY SYSTEM

1 BACKGROUND AND CURRENT ISSUES

Water supply is an essential service for the people as well as the key national target to meet basic human needs and to achieve economic development. Water and Sanitation Cooperation (WASAC), together with the Government of Rwanda, has made significant efforts to increase water coverage over the past few years and has committed to providing 100% coverage by the year 2024, thereby ensuring universal and equitable access to safe and affordable drinking water for the people aimed at achieving the goals raised by NST-1 along with Sustainable Development Goals (SDGs). The WASAC, in consultation with MININFRA, MINECOFIN and MINEMA, has established a water supply masterplan toward 2050 in order that the water infrastructure will be constructed from the aspect of long-term development in line with the Masterplan of the City of Kigali and adjacent sectors.

Regarding future water demand, water demand in the eastern part of Kigali is dramatically increasing since the trend of development and growth in the City of Kigali would be moving towards the eastern and southern parts of the city, as well as the adjacent sectors in the Rwamagana districts.

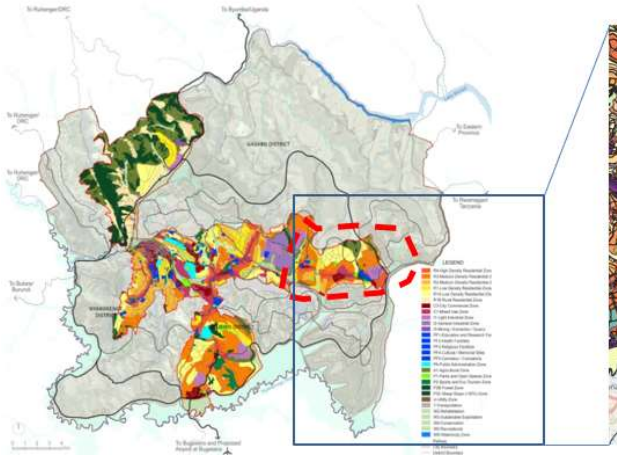


Figure (Left). Emerging Eastern Development Area (Rusororo, Ndera) In the Phase 1 (2019-2024) of the CoK Masterplan (2020)

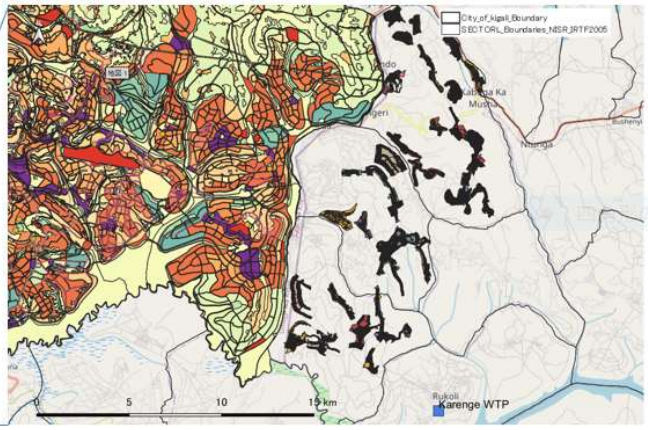
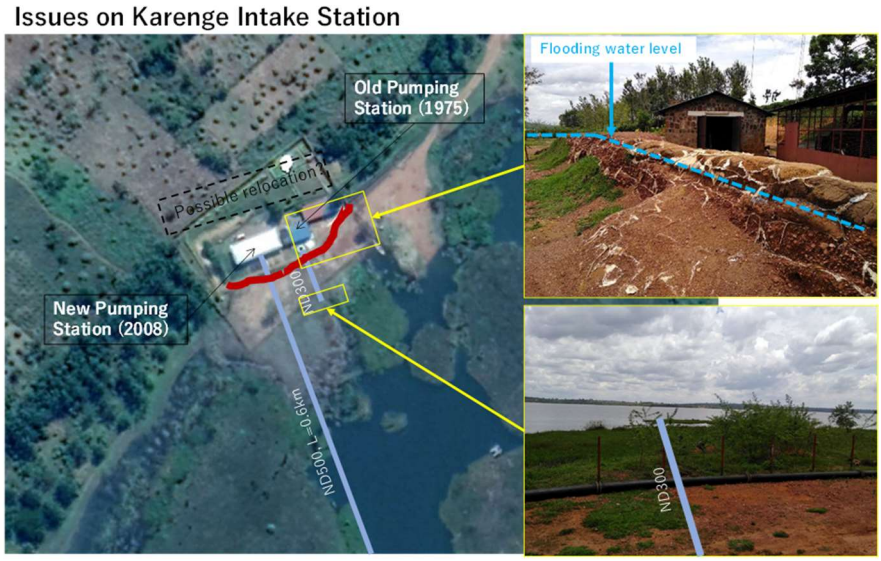


Figure (Right). Sectoral Masterplan of the adjacent sectors (Gahengeri, Muyumbu, Nyakaliro) in Rwamagana

Capacity of existing Karenge WTP to supply water to the study area is limited and is over-loaded (15,000 m^3/day) compared to its design capacity (12,000 m^3/day).

Existing Facilities need a rehabilitation especially for the Raw water pumping station: Flooding is threatening the pumping station operating since its floor level is lower than the high water level of the Mugesera lake in the rainy season. The intake pumps are damaged, overloaded and vulnerable to the flooding risk. An old raw water intake pipe (ND300) is damaged and not working properly.



This Project for Construction of Karenge Water Treatment Plant is one of the most urgent components of the Water Supply Masterplan to serve essential water to the people, especially those living in the growing east in the City of Kigali (CoK) and the Rwamagana District. The Project intends to expand the existing Karenge WTP sourcing water from Lake Mugesera from a capacity of 12,000 m^3/day to 48,000 m^3/day in Phase 1 and will further expand it to 120,000 m^3/day.

Table S2.1-1 Summary of the Expansion Stage and the Plants

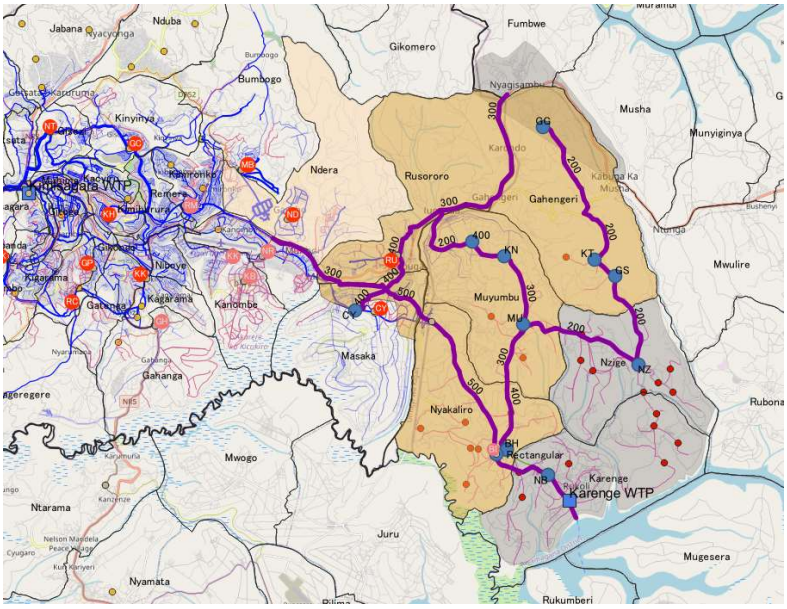
Name	Total Capacity	Remarks
Existing Karenge WTP	12,000 m^3/day	(Currently over-used 15,000 m^3/day in a yearly average supply)
New Karenge WTP (Karenge 2)	Phase 1: 36,000 m^3/day (Total 48,000 m^3/day)	Subject to Preliminary Design and Cost Analysis
	Phase 2: 72,000 m^3/day (Total 120,000 m^3/day)	Conceptualized in the F/S for Future Expansion

Source:JST
Note: "Expanded Karenge WTP" refers to the Existing + New Karenge WTP in this report.

2 DESIGN CONDITIONS

Water Supply Area

Water Supply Area (WSA) is illustrated in **Figure S2.2-1.** WSA of existing Karenge WTP includes Ndera, Rusororo, Kanombe, Nyarugunga, and Masaka sectors in the CoK and some part of Muyumbu and Nyakaliro sectors in the Rwamagana district.

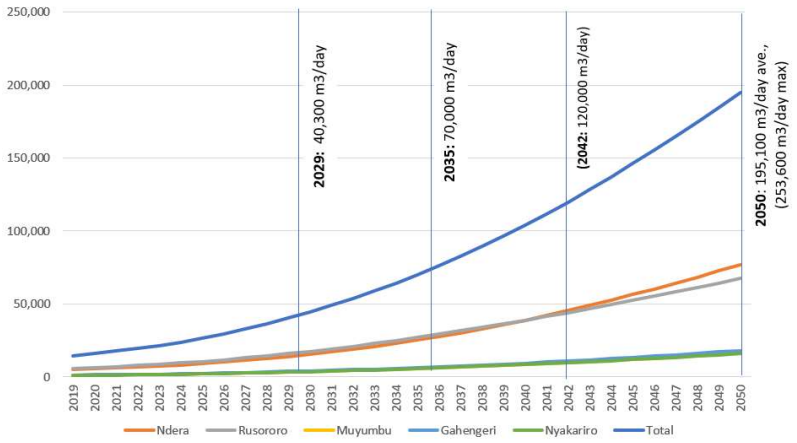


Source:JST

Figure S2.2-1 Water Supply Area (WSA) for the expanded Karenge WTP

Future Water Demand

The projected water demand is as shown in **Figure S2.2-2**. The data and methodology for the water demand projection are in accordance with the KWSMP. The target year 2035 and 2050 is also in line with the KWSMP.



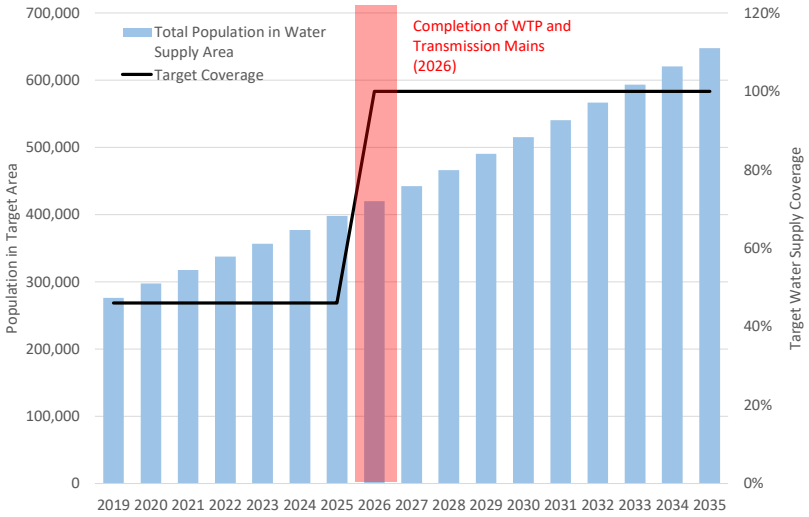
	Year	2020	2025	2026	2029*	2035	2050
a	Total Demand	16,200	26,600	29,600	40,300	70,000	253,600
b	Supply From Ntora-Kanzenze/Remera	0	14,000	14,000	1,800	10,600	0
c	Supply From Masaka	0	0	0	0	21,000	0
d	Supply From Gahanga/Remera	0	0	0	0	0	161,000
e=a-(b+c+d)	Supply from Karenge to Kigali	16,200	12,600	15,600	38,500	38,400	92,600
f	Other Area (Provisional)				9,500	9,500	27,200
g=e+f	Total	16,200	12,600	15,600	48,000	47,900	120,000

Source:JST

Figure S2.2-2 Water Demand Projection for the WSA for expanded Karenge WTP

Future Population and Coverage

Target population and water supply coverage by the Project is as shown in **Figure S2.2-3**. The target year for the completion of the WTPs and major water transmission systems is 2026, and the population in the target area is then 405,000.



Source:JST

Figure S2.2-3 Population Projection and Target Water Supply Coverage by the Project

Water Source

It is recommendable to make the most of existing water permission for the withdrawal from Lake Mugesera is **48,000 m^3/day** due to the lack of scientific evidence on the fact how much water can be withdrawn sustainably.

3 DEVELOPMENT PLAN

Facilities to be Constructed

The facilities to be constructed are summarized in **Table S2.3-1**.

Table S2.3-1 Summary of the Facilities to be Constructed

Water Intake and Water Treatment Plant

Summary of the List of Facilities	
Intake Pumping Stations	
Intake Pipes	ND800, L= 300m Buried/Fixed on the lake bottom with Intake Screen and Connecting well (D=4m)
Intake Pumping Station Building	W=8m, L24m
Intake Pumps	12m^3/min x 115.6m x 340 kw x 3 units +1 standby
Raw Water Transmission Pipeline	DIP ND600, L=1.1km
Miscellaneous	Earthwork, Retaining Wall, Access road (L=100m)
Water Treatment Plant	
Receiving Well	V = 84 m^3, L=10.3m x W=5.0m x H=4.5m
Coagulation-Flocculation Basin	Horizontal-mixed flow, L=18.4m x W=10.6m x H=4.5m
Sedimentation Basin	Baffled wall, Up-flow inclined tube settler L=18.4m x W=18.4m x H=4.5m
Rapid sand filter Basin	Sand Filter 56 m^2 x 6 (t=1.0m, D_{ave}=1.0 mm), L=32.9m x W=24.4m x H=4.5m
Clear Water Reservoirs and Pumping Station	V=3,400 m^3, He=5.0m, L=40.4m x W=25.7m
Clear Water Transmission Pumps	6.66 m^3/min x 214.7m x 345 kW x 5+1 standby with Flywheel
Backwash Tank	V=400 m^3
Sludge Basin	V=200 m^3 x 2 nos.
Drainage Basin	V=250 m^3 x 2 nos.
Sludge Drying Bed	V=500 m^3
Administration Building	Office rooms and Laboratory , Floor Area: 665 m^2

Transmission and Distribution Pipes

Transmission and Distribution Systems	
a-1. Transmission pipelines from Karenge WTP to Kimichanga reservoir	
Transmission Pipelines	DIP, ND700, L=5.7 km
a-2. Transmission pipelines from Kimichanga to Rusororo and Ndera	
Transmission Pipelines	HDPE, ND315, L=2.5 km
	DIP, ND400, L=7.6 km
	DIP, ND500, L=14.5 km Connecting to existing Karenge II pipeline
b. Transmission Pipelines from Rusororo Kabuga to the Rwamagana District	
Transmission Pipelines	HDPE, ND315, L=13.4 km
	DIP, ND400, L=1 km
c. Kimichanga Pumping Station and Transmission to Rwamagana	
Kimichanga Pumping Station (Pumping Station Building and Pumps)	Pumps: 8.3 m3/min x 59.8m x 120 kw x (1unit +1 standby)
Transmission Pipelines	HDPE, ND225, L=23.6 km
	HDPE, ND315, L=8.1 km
	DIP, ND400, L=7.4 km
Booster Pumping Station	BPS1, MU-NZ
	BPS2, NZ-GS
	BPS3, KT-GG
d. Water Distribution Systems	

Source: JST

Land Acquisition Required

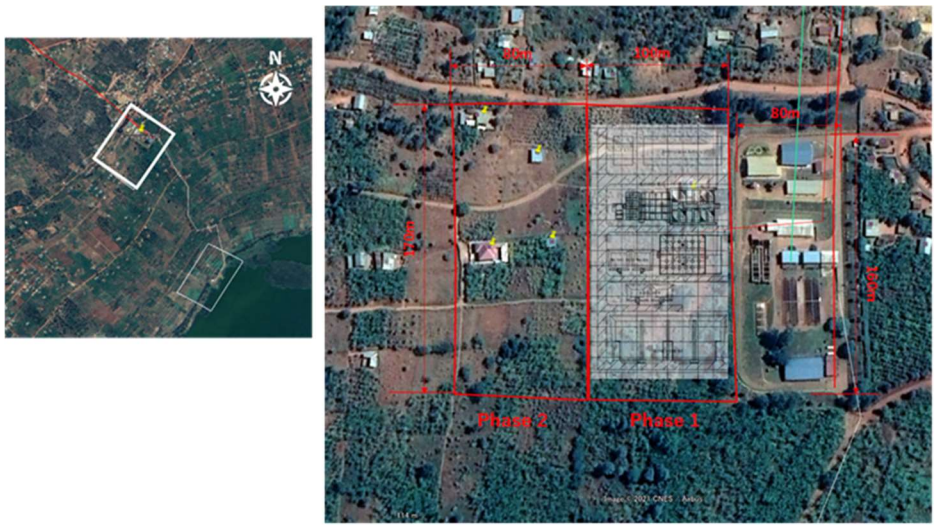
Land acquisition is necessary for the expansion of both the Water Treatment Plant and the Intake.

The required land for the expansion of WTP is listed in **Table S2.3-2** and illustrated in **Figure S2.3-1**. The proposed land for the WTP is located just adjacent to the existing Karenge WTP site. There is only one household for the Phase 1 expansion, and four households for the Phase 2 expansion are anticipated. Note that the land for Phase 2 is not planned to be expropriated until the preparatory phase of the expansion, which is expected to be the year 2039.

Table S2.3-2 Required lands for the Expansion of WTP

Item	Approximate Dimensions	Necessary before	Existing Household
Existing Land	80 m x 160 m (1.28 ha)	-	
Expansion Phase 1	100 m x 170 m (1.7 ha)	July 2022	1
Expansion Phase 2	80 m x 170 m (1.36 ha)	(Year 2039)	4

Source:JST



Source: JST

Figure S2.3-1 Land for the existing Karenge WTP and required land for expansion

The required land for the expansion of the intake at Lake Mugesera is listed in **Table S2.3-3** and illustrated in **Figure S2.3-2**. The proposed land for the Intake is just adjacent to the existing Intake Pumping Station. The land is in a buffer zone of the Lake Mugesera within 50 m and therefore subject to approval by the REMA and related authority.

Table S2.3-3 Required lands for the Expansion of Intake

Item	Approximate Dimensions	Necessary before	Existing Household
Existing Land	55 m x 63 m (1.28 ha)	-	-
Expansion Phase 1	47 m x 31 m (0.14 ha)	July 2022	0
Expansion Phase 2	71 m x 14 to 47 m (0.26 ha)	July 2022	0

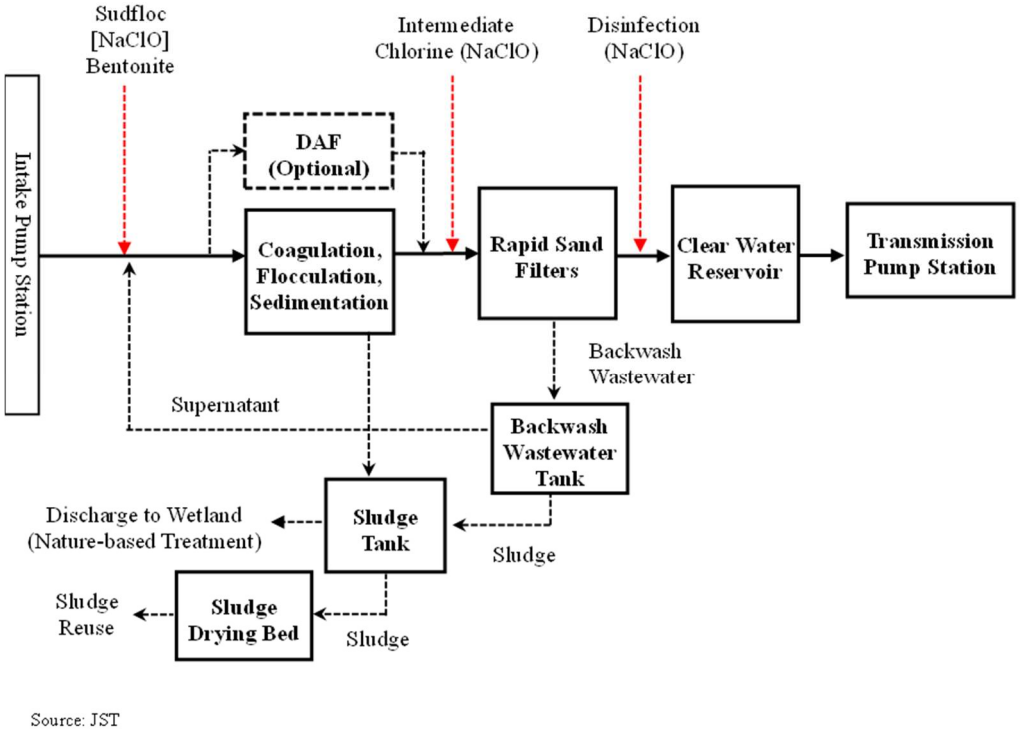
Source: JST

Source: JST

Figure S2.2-1 Area for development at the Intake Expansion in front of Lake Mugesera

Treatment Process

Water quality data of treated water at existing Karenge WTP in 2018 has been collected and studied as shown, which indicated that the treated water quality of the existing Karenge WTP could comply with Rwanda drinking water quality standards by conventional treatment process. Based on careful evaluation as well as the treatment performance of the existing unit treatment process, the best suited treatment process for the WTP for the F/S is proposed and its flow is presented in **Figure S2.3-3**.



Source: JST

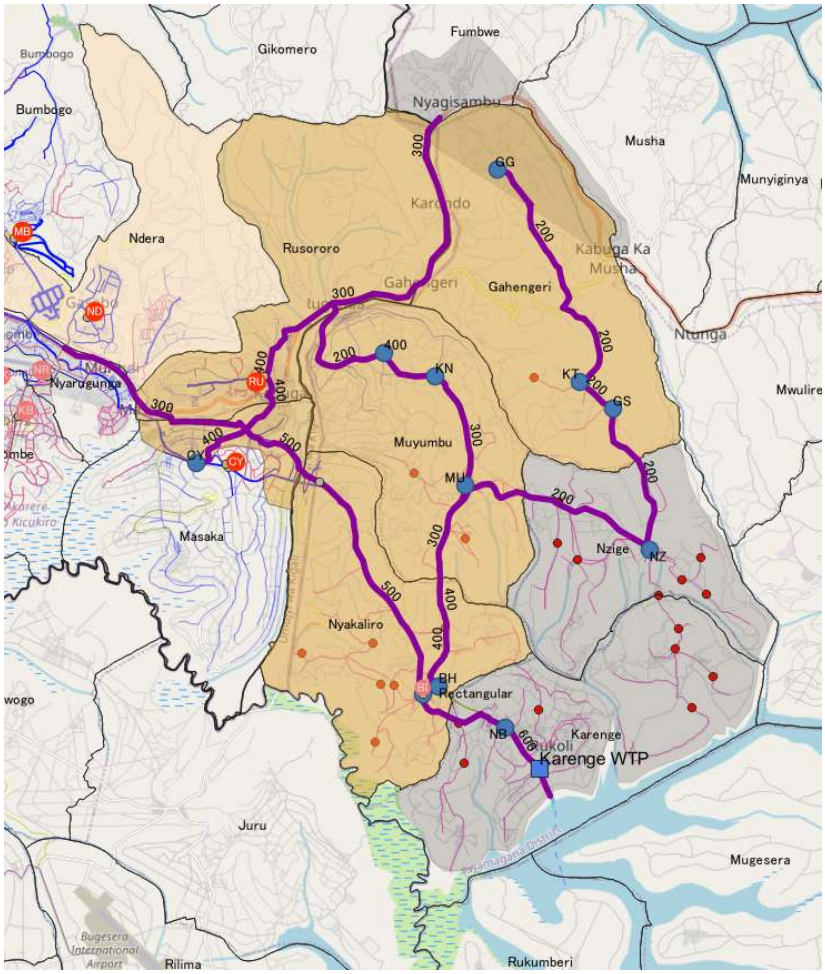
Figure S2.3-3 Proposed Treatment Process

4 WATER TRANSMISSION AND DISTRIBUTION

Water Transmission

The routes and the diameters of the transmission pipelines were determined based on the hydrological models established in this study.

Transmission hydraulics are analyzed in order to verify the necessity of the booster pumps, and to estimate pipe diameters as well as lengths. The lengths are estimated from the GIS and 10 m resolution DEM. Transmission routes and location of nodes for the hydraulic calculation are indicated as in **Figure S2.4-1**.



Source: JST

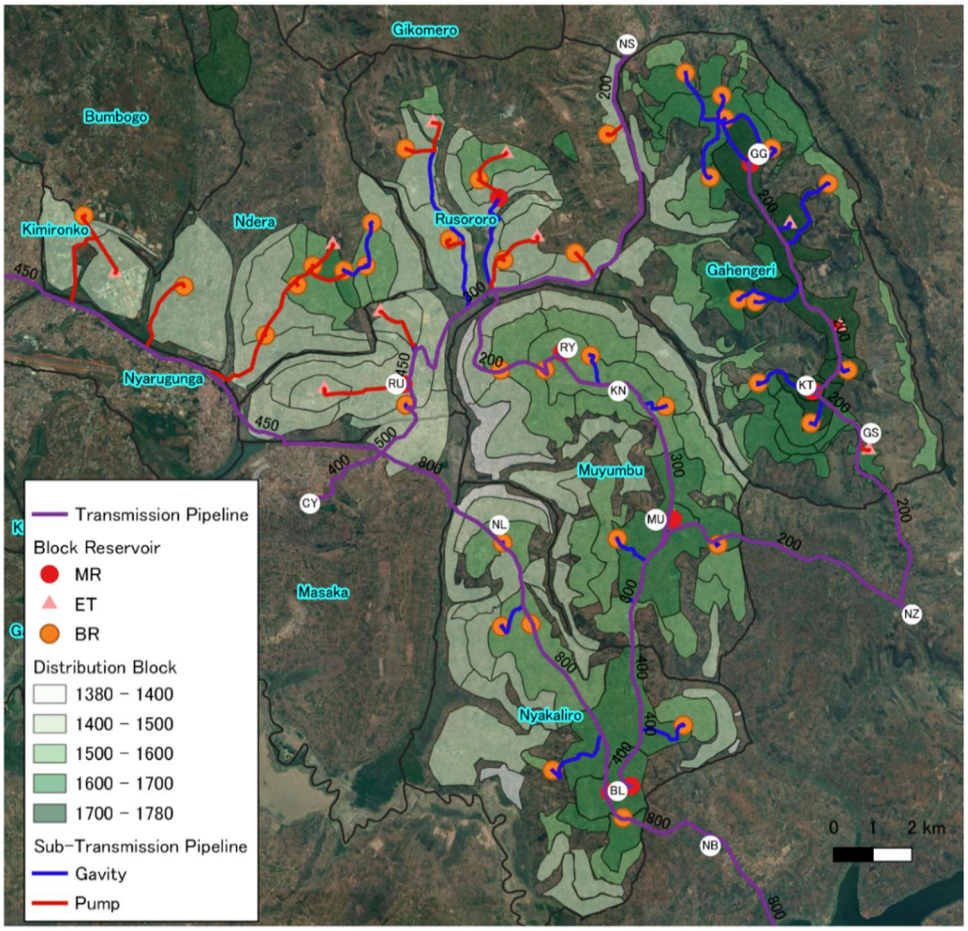
Figure S2.4-1 Water Transmission Models

Water Distribution Blocks

One of the geographic features of the city is large elevation gap, which makes it difficult to implement control water supply pressure adequately. To tackle these issues, we propose to separate the water supply area hydraulically into several distribution blocks (i.e., introducing 'distribution block system'). The key idea of the distribution block system is to create new water distribution pipeline networks or to review the

existing complicated networks under the layer structure.

The whole distribution block system is shown in **Figure S2.4-2**.



Source: JST

Figure S2.4-2 Distribution Block System (Block, Reservoir, Pipelines)

5 IMPLEMENTATION SCHEDULE

The implementation schedule for the Project is illustrated in **Table S2.5-1**. The schedule suggests that the water supply can be inaugurated from the end of the Year 2026 if all procedures go smoothly.

Table S2.5-1 Implementation Schedule for Karenge Expansion Project

This Page is closed due to the confidentiality.

6 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Given the nature, location of the proposed Project, proposed works and the potential impacts associated with the implementation of Project, the consultant can conclude that the nature and extent adverse impacts identified can be avoided, mitigated and eliminated by the implementation of appropriate mitigation measures. In fact, the rehabilitation and extension of the Karenge water treatment Plant and supply system are bound to be executed in a sustainable manner and in compliance with national environmental regulations, JICA environmental and social considerations. However, this requires full implementation of proposed mitigation measures and regular monitoring done per as proposed Environmental Management Plan (EMP).

7 OPERATION AND MAINTENANCE (O&M)

O&M of WTP is to maintain the condition of facilities and equipment so that it can be operated smoothly by performing maintenance and repairs, and replenishing fuel, oils and fats, reagents, etc. Also, it requires patrolling and inspecting the condition of water treatment facilities, discovering abnormal/troubled parts at an early stage, and inspections to maintain a hygienic environment for water treatment facilities and to ensure the safety of workers and visitors.

The number of personnel in WTP will be increased to 54 from the 33 due to an increased workload of water as the volume of water purification is expected 42,000m^3/day at new plant, up from 15,000m^3/day of the existing plant.

8 COST ESTIMATE

Project Cost

The cost for the Project was calculated based on the scope of work as described above (**Table S2.8-1**).

Table S2.8-1 Revised Packaging Plan considering financial arrangement for the Project

This Page is closed due to the confidentiality.

OPEX

The costs required for the operation and maintenance are shown in **Table S2.8-2**.

Table S2.8-1 O&M cost for the Existing and Expanded Karenge WTP

	Energy cost /m^3	Chemical Cost	Maintenance	Salary	Total
	RWF/m^3	RWF/m^3	RWF/m^3	RWF/m^3	RWF/m^3
Existing WTP (from the data in 2019)	269	54	2	21	346
Etimated for Expansion	207	43	2	11	263

Source: JST

9 FINANCIAL AND ECONOMIC EVALUATION

Both financial and economic evaluations are conducted to ascertain the viability of the Project.

Financial Evaluation

Table S2.9-1 shows the results of the financial evaluation. The FIRR of the base case shows 2.2% which is a lower rate than 6.3% of the opportunity cost of capital. However, it is noted that the FIRR will soar to 9.7.% provided that the concessional loans by the development partners are financed.

Table S2.9-1 Results of Financial Evaluation

Case	FIRR	NPV (million RWF)	B/C
Base Case	2.2%	-51,285	0.66
Financing with donor's concessional loan*	9.7%	7,267	1.04

Source: JST

*Assumptions for concessional loan

- Loan amount: Construction and engineering only, exclusive of administration and taxes
- Loan terms and conditions are assumed as follows:
  40 years of loan period including grace period, 10 years' grace period and 0.5% of interest rate per annum

Economic Evaluation

Table S2.9-2 presents the results of the economic evaluation. It shows that the EIRR will exceed 10% of the social discount rate.

Table S2.9-2 Results of Economic Evaluation

Case	EIRR	NPV	B/C
Base Case	10.2%	934 million RWF	1.01

Source: JST

10 CONCLUSIONS

- Emergent needs and social necessity of the expansion of Karenge WTP and forwarding infrastructures were contextualized in light of the social backgrounds, including the current status of development in the study areas and future development plan in the CoK and adjacent sectors in Rwamagana District.

- The target area of the Project mainly focuses on the Rusororo and Ndera sectors in CoK, and Nyakaliro, Muyumbu and Gahengeri sectors in the Rwamagana district, and other emerging demand equivalent to 9,500 m^3/day in the Rwamagana district. The target water supply coverage by the Project is 100% after the completion, including piped water connections and the public tap. The total target population as beneficiaries is approximately 493,500 populations in the year 2030.

- The F/S defined the scope of work, including the intake expansion, WTP, water transmission and distribution systems. The WTP will involve the conventional coagulation-sedimentation and rapid sand filtration system considering the raw water from Lake Mugesera. It requires water transmission pipelines for 83.8 km. The large pipes (up to ND700) should be laid along the existing pipelines of Karenge 2. The pipes from Kimichanga-Bihembe to Muyumbu and Gahengeri are more than 39km but with a smaller diameter (up to ND400).

- The schedule showed that the water supply could be inaugurated from the end of the **Year 2026** if all procedures go smoothly. The schedule should be reviewed in line with the actual process applied to an international development partner's loan conditions and internal procedures for GOR.

- Preliminary Environmental Impact Assessment shows that the impact from the Project was very limited; their resettlement by the plant construction is small (Only one household) with little concern on the environmental pollution.

- Operation and Maintenance, including the personnel, skills and knowledge input, was assessed based on the scale of the future expansion. The new WTP may be utilized as the training center to develop the skills for WTP operation.

- FIRR was estimated as 2.2% and it would be feasible if the concessional loans (Soft loans: 40 years, 10 years' grace period and 0.5% per annum) were applied. EIRR was estimated as 10.3 %, which was over the social discount rate (10%).

- The final packaging plan was revised based on the actual condition of the financial availability provided by WASAC. Note that both Packages 1 and 2 are inseparable and necessary to complete both in parallel to materialize the benefit to the people; the water treatment plant in Package 1 cannot be fully operated before the forwarding infrastructures in Package 2 are completed.

Part 3 FEASIBILITY STUDY FOR THE PROJECT FOR CONSTRUCTION OF MASAKA WATER SUPPLY SYSTEM

1 INTRODUCTION

Water supply is an essential service for the people as well as the key national target to meet basic human needs and to achieve economic development. Water and Sanitation Cooperation (WASAC), together with the Government of Rwanda, has made significant efforts to increase water coverage over the past few years and has committed to providing 100% coverage by the year 2024, thereby ensuring universal and equitable access to safe and affordable drinking water for the people aimed at achieving the goals raised by NST-1 along with Sustainable Development Goals (SDGs). The WASAC, in consultation with MININFRA, MINECOFIN and MINEMA, has established a water supply masterplan toward 2050 in order that the water infrastructure will be constructed from the aspect of long-term development in line with the Masterplan of the City of Kigali (CoK) and adjacent sectors.

Regarding future water demand, water demand in the eastern part of Kigali is dramatically increasing since the trend of development and growth in the CoK would be moving towards the eastern and southern parts of the city, as well as the adjacent sectors in the Rwamagana districts.

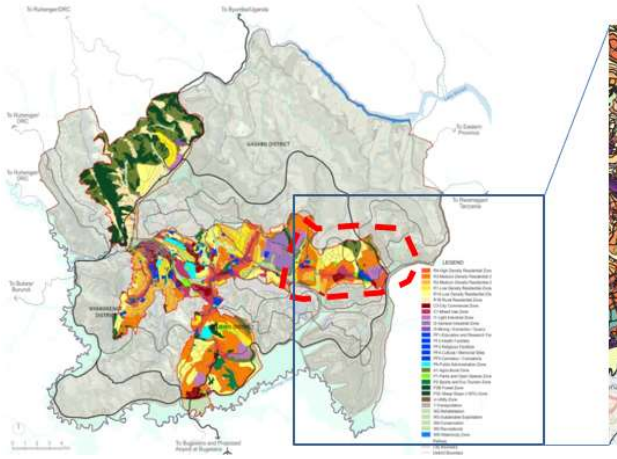


Figure (Left). Emerging Eastern Development Area (Rusororo, Ndera) In the Phase 1 (2019-2024) of the CoK Masterplan (2020)

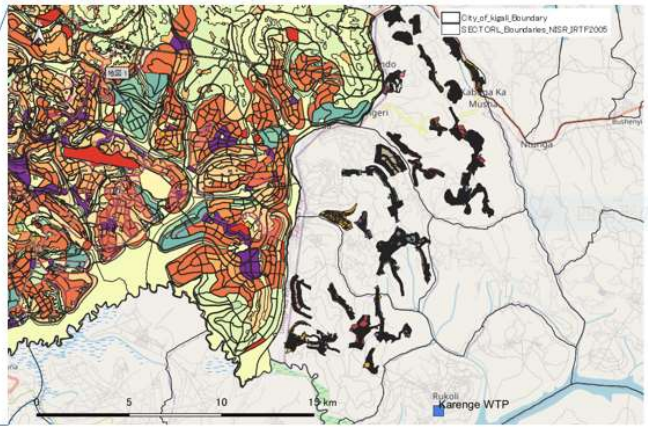


Figure (Right). Sectoral Masterplan of the adjacent sectors (Gahengeri, Muyumbu, Nyakaliro) in Rwamagana

According to the Kigali Master Plan 2050, Masaka and Rusororo sectors are the areas that the earliest development is expected. Currently water supply coverage by the WASAC is quite low in the target area. The estimate covered population by individual connections are 26,000, which consists only 35% of the total population in the Masaka sector (75,000, year 2021)

This Project for Construction of Masaka Water Treatment Plant was selected as a priority project in the Kigali Water Supply Masterplan (KWSMP), as one of the most urgent components of the water supply expansion to serve essential water to the people, especially those living in the growing east in the CoK. The Project intends to construct a new WTP sourcing groundwater along Akagera River with a capacity of 20,000 m^3/day (Phase 1) and 40,000 m^3/day (Phase 2) . The Project is urgent because the water demand is

high and growing rapidly in the service area.

Table S3.1-1 Summary of the Expansion Stage and the Plants

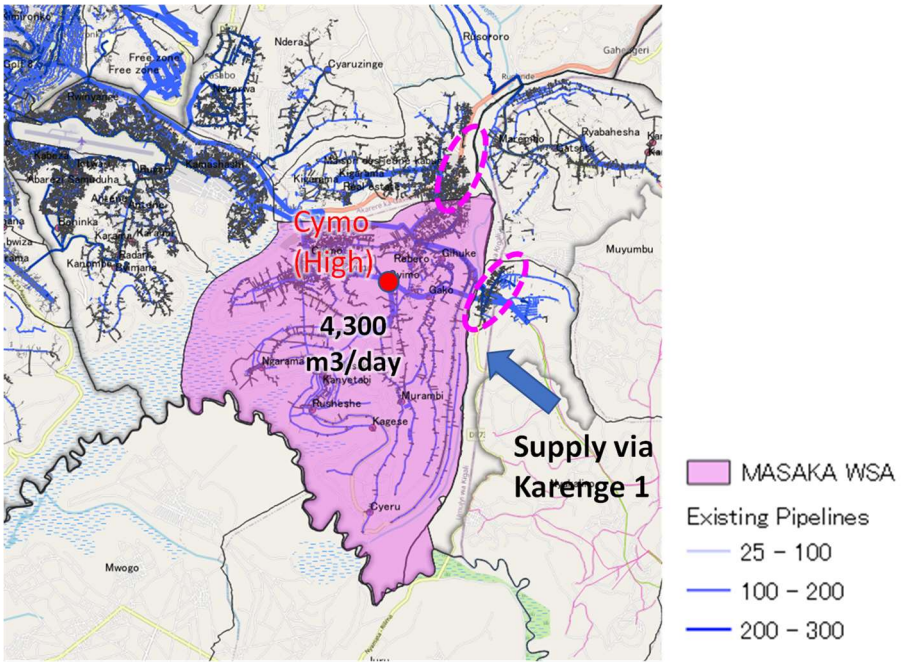
Name	Total Capacity	Remarks
New Masaka Water Treatment Plant	20,000 m^3/day (Phase 1) 20,000 m^3/day (Phase 2*)	Water Sources: Groundwater

* Phase 2: Not included in this study.
Source: JST

2 DESIGN CONDITIONS

Water Supply Area

Water Supply Area (WSA) for new Masaka WTP and the existing water supply systems are illustrated in **Figure S3.2-1**. The area includes entire Masaka sector which is geographically separated from the adjacent sectors. The existing customers in this area are approximately 6,000, from which the water consumption is estimated to be approximately 4,300 m^3/day.

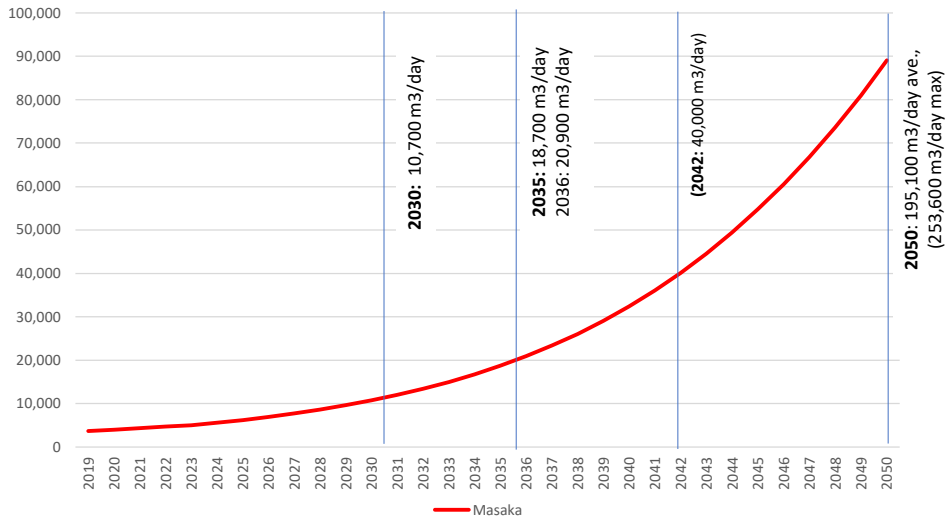


Source: JST

Figure S3.2-1 Water Supply Area of New Masaka WTP and Existing Water Supply

Future Water Demand

The projected water demand in the WSA is shown in **Figure S3.2-2**. The total daily average water demand will reach 10,700 m^3/day in the year 2030, and 18,700 in the year 2035. The demand will then double to 40,000 m^3/day in the year 2042 and will reach 195,100 m^3/day in the year 2050 ultimately.



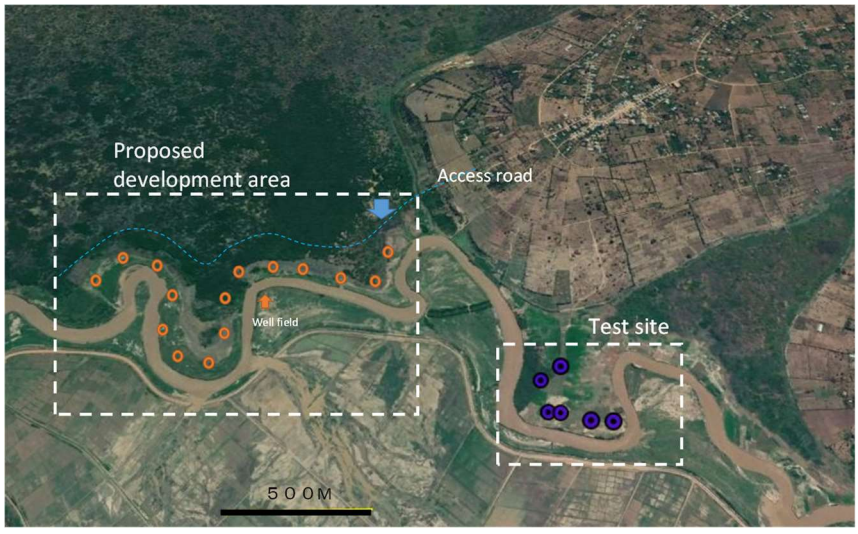
Source: JST

Figure S3.2-2 Water Demand Projection in the WSA (Masaka sector)

3 WATER SOURCES AND INTAKE

It is recommended to use water from boreholes as being done in Kanzenze WTP in order to avoid high turbidity and to avoid the risk of possible contamination of the river water. In order to understand the aquifer property at flood plain of Akagera River around Masaka area, core drilling and water well drilling were carried out.

Based on the results of core drilling and pumping tests, number of new wells for the Masaka WTP will be 15 and respective production capacity is planned as 1,600 m^3/day/borehole. Total well production will be 24,000 m^3/day (15 boreholes x 1,600 m^3/day/borehole).



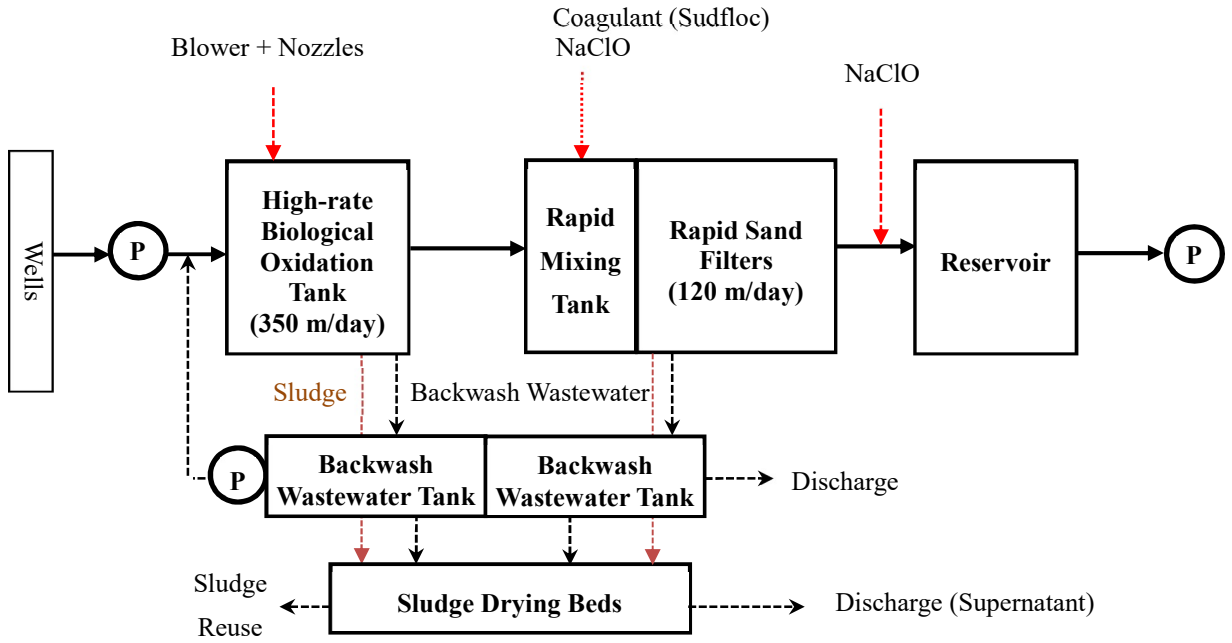
Source: JST

Figure S3.3-1 Proposed Wellfield Site and Test Site

4 CONSTRUCTION OF WTP

Water supply capacity of new WTP in Masaka was determined as 20,000 m^3/day according to the water demand projection as same as the intake water capacity of the wellfields.

Based on comprehensive consideration and the treatment performance in the existing Nzove 1 WTP and Kanzenze WTP where main issues of raw water quality are also turbidity, ammonia, bacteria, iron and manganese, treatment process for the WTP is proposed in **Figure S3.4-1**.



Source: JST

Figure S3.4-1 Proposed Treatment Process

The facilities to be constructed are summarized in **Table S3.4-1**.

Table S3.4-1 Summary of the Facilities to be Constructed

Summary of the List of Facilities	
Intake Well Pumps and Pipelines	
Intake Wells	600 mm to accommodate casing and screen Total number: Maximum 20. Depth of borehole: Maximum 30 m Yield: from 25m^3/h to 80m^3/h 315mm, PVC blank casing and Stainless steel wire wrap screen
Electric Panels Room	Incoming Panel, Switchgears Motor Control Center Panels, Telemetry Panels
Raw Water Transmission Pipeline	ND300-500, L=1,600m ND150, L=3,000m
Miscellaneous	Monitoring and Maintenance equipment and tools
Water Treatment Plant	
High-rate Biological Oxidation Basin	3.0 m^W × 5.6 m^L × 6 Basins (LV=350 m/d)
Rapid Sand Filter Basin	4.0 m^W × 7.2 m^L × 6 Basins (LV=120 m/d)

Summary of the List of Facilities	
Clear Water Reservoirs	10.0 m ^{W} × 17.0 m ^{L} × 5.0 m ^{H} × 2 Tanks
Clear Water Transmission Pumps	a. Masaka-Cyimo middle Clear Water Transmission Pumps: Q 4.9 m^3/min × H 124 m × (3 unit +1 standby) b. Cyimo middle-high Clear Water Transmission Pumps: Q 5.5 m^3/min × H 100 m × (1 unit +1 standby) c. Masaka-Mbabe Clear Water Transmission Pumps: Q 3.7 m^3/min × H 93 m × (1 unit +1 standby)
Backwash Water Tank	6.8 m ^{W} × 10.0 m ^{L} × 3.0 m ^{H} × 2 Tanks
Backwash Wastewater Tank	8.0 m ^{W} × 8.0 m ^{L} × 3.0 m ^{H} × 2 Tanks
Sludge Drying Bed	25.0 m ^{W} × 12.0 m ^{L} × 1.0 m ^{H} × 6 Beds
Administration Building	150 m^2

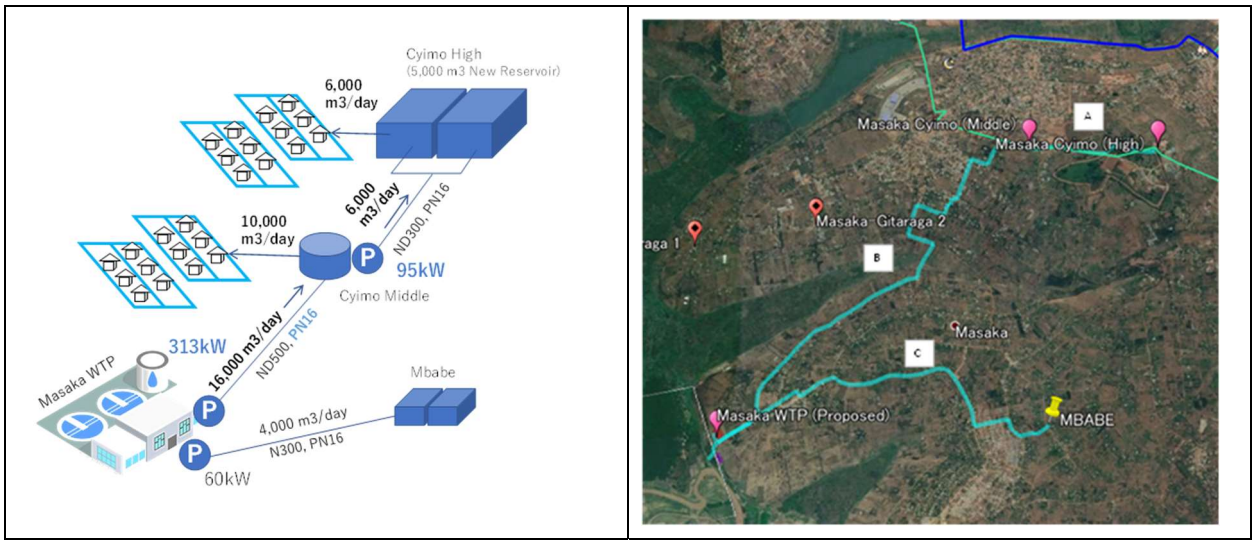
Source: JST

The land acquisition is necessary both for the WTP and the access road for the well fields. Some areas are private owned, some are public lands, being utilized for the agricultural user. Therefore, there is no resettlement expected by the project. The locations for the wellfields are determined according to the shape of the Akagera River and should be determined well pumping test during the construction implementation. On the other hand, the proposed land for the WTP is just a tentative proposal and can be changed flexibly to the vicinity area.

5 WATER TRANSMISSION AND DISTRIBUTION

Water Transmission

The main transmission system for the Masaka WTP is the route to the Cyimo reservoirs. Considering the current and future distribution systems, water demand in the middle-lower elevation areas is high. Considering minimizing energy cost, transmission system which shows figure below (**Figure S3.5-1**) was adopted for this study.

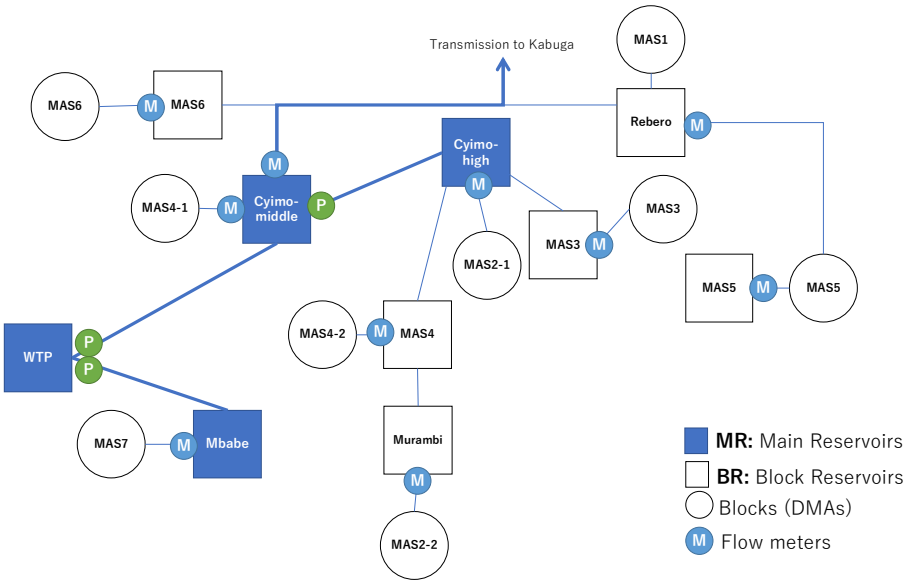


Source: JST

Figure S3.5-1 Adopted Transmission System and its Hydraulics

Water Distribution

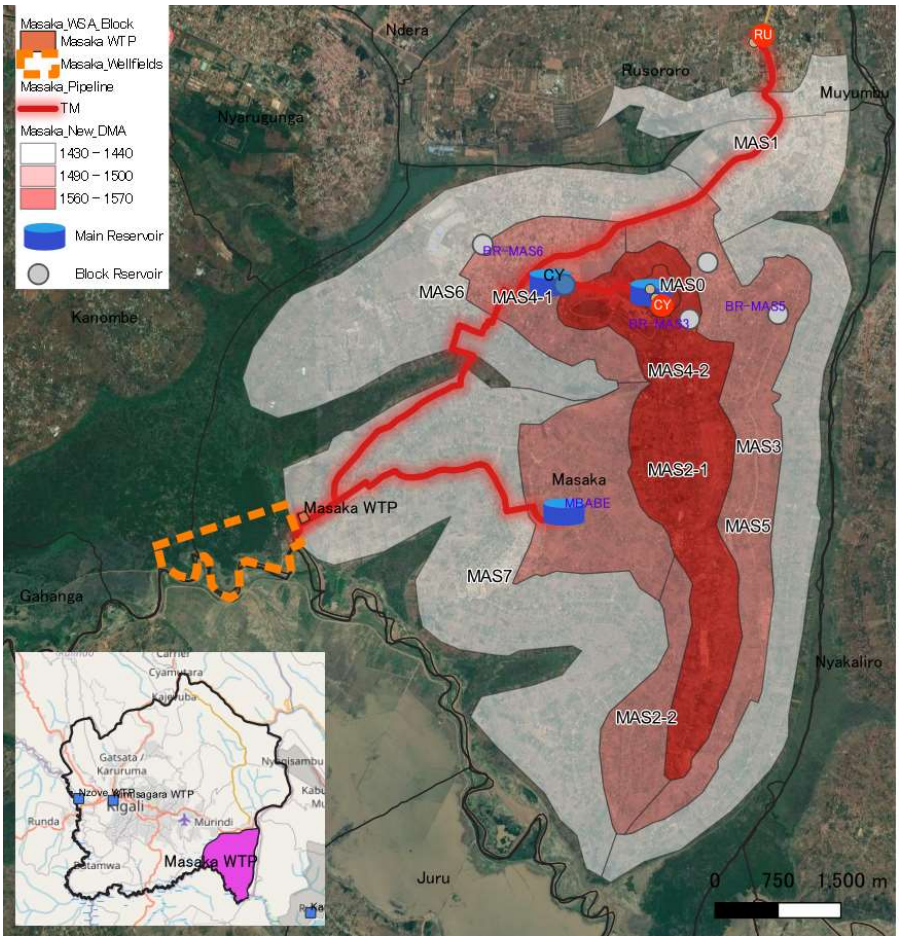
10 distribution blocks are identified in the water supply area. The schematic location of the reservoirs are illustrated in **Figure S3.5-2**.



Source: JST

Figure S3.5-2 Distribution Reservoirs Systems

The Water Supply Area of the Masaka WTP is the entire Masaka sector and some other areas in Rusororo before the target year of 2035 as shown on **Figure S3.5-3**.



Source: JST

Figure S3.5-3 Distribution Systems for Masaka Water Supply Area

6 IMPLEMENTATION SCHEDULE

The implementation schedule for the Project is illustrated in **Table S 3.6-1**. The schedule suggests that the water supply can be inaugurated from the end of the Year 2027 if all procedures go smoothly.

Table S3.6-1 Implementation Schedule for Masaka Construction Project

This Page is closed due to the confidentiality.

7 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

The overall objective of Environmental and Social Impact Assessment (ESIA) for the "Construction of Masaka WTP with its associated Transmission & Distribution Facilities" is to ensure sustainability of proposed project, avoid, minimize and compensate negative impacts and to enhance positive impacts.

Given the nature, location of the proposed project, proposed works and the potential impacts associated with the implementation of project, the consultant can conclude that the nature and extent of adverse impacts identified can be avoided mitigated and eliminated by the implementation of appropriate mitigation measures.

8 OPERATION AND MAINTENANCE (O&M)

O&M of WTP is to maintain the condition of facilities and equipment so that it can be operated smoothly by performing maintenance and repairs, and replenishing fuel, oils and fats, reagents, etc. Also, it requires patrolling and inspecting the condition of water treatment facilities, discovering abnormal/troubled parts at an early stage, and inspections to maintain a hygienic environment for water treatment facilities and to ensure the safety of workers and visitors.

The number of personnel in WTP will be 35 due to the workload of water as the volume of water purification is expected to be 20,000m^3/day at the new plant. Three working shift teams (early morning, day-time and night) are planned.

9 COST ESTIMATE

CAPEX

The cost for the Project was calculated based on the scope of work. The cost is summarized in **Table S3. 9-1**.

Table S3.9-1 Cost Summary of the Masaka WTP Project

This Page is closed due to the confidentiality.

OPEX

Unit O&M Cost (Cost per produced water supply amount) is estimated in **Table S3.9-2**. The electricity for WTP was estimated 0.81 kW/m^3 water produced (**Table S3.9-3**), which is 47% of the existing Karenge System (1.74 kW/m^3) and 54% of the expanded Karenge system (Karenge 2, 1.51 kWh/m^3). As a result, the O&M Cost can be saved up to 200 RWF/m^3, lower than the existing water supply systems.

Table S3.9-2 Estimated Operation Cost for New Masaka WTP

O&M Cost per year

	Energy Cost /m^3	Chemical Cost /m^3	Mainte nance	Salary	Total
	RWF/m^3	RWF/m^3	RWF/m^3	RWF/m^3	RWF/m^3
Expansion	121	36	2	39	198

Source: JST

Table S3.9-3 Estimated Electricity Consumption for the New Masaka WTP

Items	kVA	kW	Unit	Amount, m3/day	kWh/m3	RWF/m3	Total kWh/day
Intake Pumps	11	9.9	20	20,000	0.24	35.33	238
Water Treatment	-	200	-	20,000	0.14	20.71	4,800
From_Masaka_To_Cyimo_Middle		313	1	16,000	0.47	69.81	7,512
From_Cyimo_Middle_To_Cyimo_High		95	1	6,000	0.38	56.50	2,280
From_Masaka_To_Mbabe		59	1	4,000	0.35	52.63	1,416

Source: JST

10 FINANCIAL AND ECONOMIC EVALUATION

Both financial and economic evaluation are conducted to ascertain the viability of the project.

Financial Evaluation

Table S3.10-1 shows the results of the financial evaluation. The FIRR of the base case shows 4.9% which

is lower than 6.3% of the opportunity cost of capital. However, it is noted that the FIRR will soar to 17.8% if donor's concessional loan is financed based on the assumptions below. In this context, the project will achieve well over the financially feasible level of 6.3%.

Table S3.10-1 Results of Financial Evaluation

Case	FIRR	NPV	B/C
Base Case	4.9%	-7,802million RWF	0.88
Financing with donor's concessional loan*	17.8%	16,066 million RWF	1.22

Source: JST

*Assumptions for concessional loan

- Loan amount: Construction and engineering only, exclusive of administration and taxes
- Loan terms and conditions are assumed as follows:
  40 years of loan period including grace period, 10 years of grace period, and 0.5% of interest rate per annum.

Economic Evaluation

Table S3.10-2 presents the results of the economic evaluation. It shows that the EIRR will sufficiently exceed 10% of the opportunity cost of capital. Accordingly, the project is judged to be economically viable.

Table S3.10-2 Results of Economic Evaluation

Item	EIRR	NPV	B/C
Base Case	15.6%	151.743 million RWF	1.41

Source: JST

11 CONCLUSION

- Emergent needs and necessity to construct Masaka WTP and forwarding infrastructures were contextualized in light of the social backgrounds and the current status of development in the study areas and future development plan in the CoK.

- The target area of the Project mainly focuses on the Masaka sector equivalent to 20,000 m^3/day in the year 2035. The target water supply coverage by the Project is 100% after the completion, including piped water connections and the public tap. The total target population as beneficiaries is approximately 169,000 populations in the year 2035, which means an additional 143,000 will gain access to water by the project.

- The F/S defined the scope of work, including the intake expansion, WTP, water transmission and distribution systems. The WTP assumed high-rate filtration to treat iron & manganese, coagulation and rapid sand filtration system considering the raw water from the well fields in the marshland along the

Akagera River.

- The schedule showed that the water supply could be inaugurated from the end of the year 2026 if all procedures go smoothly. The schedule should be reviewed in line with the actual process applied to an international development partner's loan conditions and internal procedures for GOR.

- Preliminary Environmental Impact Assessment shows that the impact from the Project was very limited; there is no resettlement by the plant construction is expected with little concern on the environmental pollution.

- Operation and Maintenance, including the personnel, skills and knowledge input, was assessed based on the scale of the future expansion. The new WTP may be utilized as the training center to develop the skills for WTP operation.

- FIRR was estimated as 4.9% and it would be feasible if the concessional loans (Soft loans: 40 years, 10 years' grace period and 0.5% per annum) were applied. EIRR was estimated as 15.6 %, which was significantly higher than the social discount rate (10%), thus the project was proved economically viable.