Republic of Malawi
Blantyre Water Board (BWB)

DATA COLLECTION SURVEY ON URBAN WATER SUPPLY IN BLANTYRE CITY IN REPUBLIC OF MALAWI

FINAL REPORT

FEBURARY 2022

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.
YOKOHAMA WATER CO., LTD.

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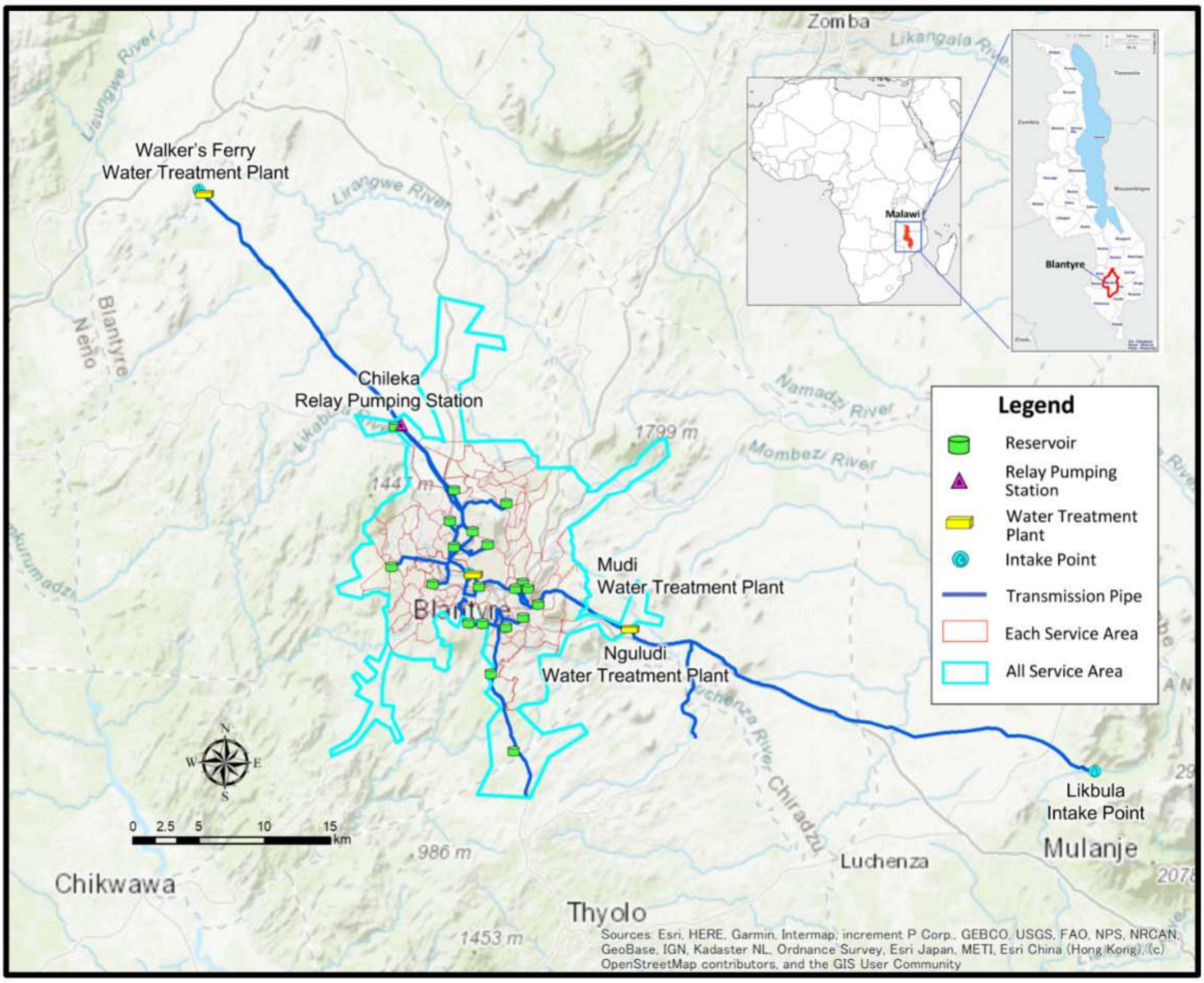
Exchange Rate applied in this Report

As of December 2021

USD 1.00 = JPY 113.603
Malawian Kwacha (MWK) 1.00 = JPY0.14117
USD 1.00 = MWK 804.725

(Source: JICA Official Website)

Location Map



List of Abbreviation

Abbreviation	Description
AC	Asbestos Cement
AfWA	African Water Association
B/C	Cost Benefit Ratio
BEA	Blantyre Environmental Affairs
BWB	Blantyre Water Board
CEO	Chief Executive Officer
CI	Cast Iron
CRWB	Central Region Water Board
CS	Carbon Steel Pipe
DEA	Department of Environment Affairs
DMA	District Metered Area
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EMA	Environment Management Act
EPANET	The United States Environmental Protection Agency's Network
EU	European Union
ESAWAS	Eastern and Southern Africa Water and Sanitation
EWASCO	Embu Water and Sanitation Company
FDH	First Discount House
GI	Galvanized Iron Pipe
GIS	Geographic Information Systems
GWOPA	Global Water Operators' Partnerships Alliance
HDPE	High Density Polyethylene
HRD	Human Resource Development
IASB	International Accounting Standards Board
ICT	Information and Communication Technology
IDA	International Development Association
IFRSs	International Financial Reporting Standards
IMIS	Integrated Management Information System
IWA	International Water Association
JICA	Japan International Cooperation Agency
JST	JICA Survey Team
KPI	Key Performance Indicator
LCD	Liter per Capita per Day
LiSCaP	The Project for Strengthening the Capacity of Non-Revenue Water Reduction for Lilongwe Water Board
LWB	Lilongwe Water Board
MFNR	Ministry of Forestry and Natural Resources
MWK	Malawian Kwacha
NBM	National Bank of Malawi
NGO	Non-Government Organization
NRW	Non-Revenue Water
NRWB	Northern Region Water Board
O&M	Operation & Maintenance
PVC	Polyvinyl Chloride
SCADA	Supervisory Control And Data Acquisition
SRWB	South Region Water Board
ST	Steel Pipe
SWOT	Strength, Weakness, Opportunity and Threat

Abbreviation	Description
TCE	Technical Committee on the Environment
TVET	Technical and Vocational Education and Training
UN	United Nation
UNICEF	United Nations International Children's Emergency Fund
USD	U.S. Dollar
VEI	Vitens Evides International
VfM	Value for Money
WASAC	Water and Sanitation Corporation
WASAMA	Water Services Association of Malawi
WOP	Water Operation Partnership
WHO	World Health Organization
WTP	Water Treatment Plant
YWWB	Yokohama Waterworks Bureau

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CHAPTER 1 : Outline of the Survey

1-1 Background and Objective

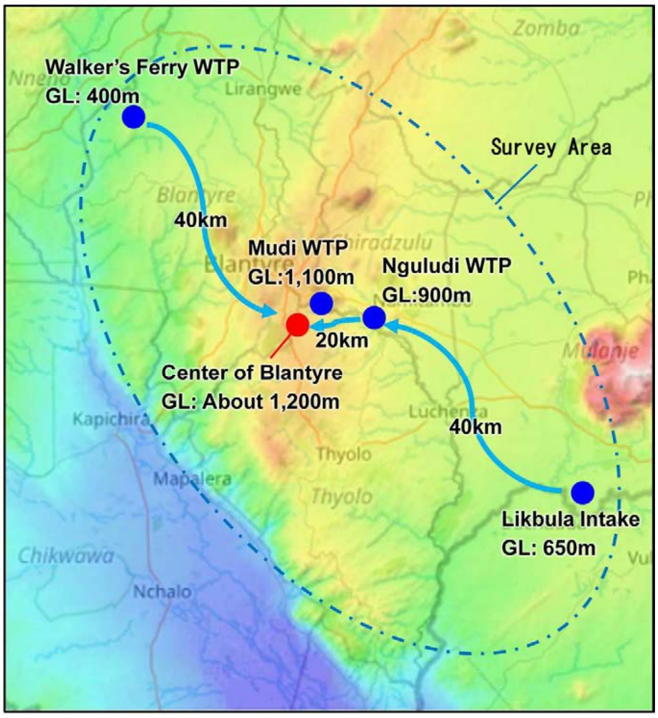
1-1-1 Background

The service coverage ratio in the rural area in Republic of Malawi (hereinafter referred to as "Malawi") is approximately 65%[1] as of 2017, while that in the urban area is approximately 85%[2]. The population in the urban area is remarkably increasing at approximately 3% per year (World Bank, 2016). In future, it is anticipated that the water demand in Malawi will increase continuously.

Under this circumstances, Malawi Government advocated the water resource development which is applicable for the climate change, a catchment prevention and the improvement in water supply in urban and rural areas as strategic field in the Malawi Growth & Development Strategy (2017-2022) III (MGDSIII). In addition, Malawi focuses on a service coverage ratio to be 100% in the urban areas in the Vision 2063 formulated in 2021, while pointed out high production costs in water supply and energy sectors due to low reliability.

The population of Blantyre city as of 2021 is about 0.84 million[3]. According to the United Nation (hereinafter referred to as "UN") "World Population Prospects 2019", the population growth rate in the past 10 years was less than 3 % per annum, while the growth rate from 2021 to 2035 is predicted to be between 3 % and 4.5 %. This will bring the population of Blantyre city to about 0.96 million in 2030.

In 2020, the actual water consumption of Blantyre city was estimated at 44,000 m^3/day[4], while the actual quantity of water supply was about 95,000 m^3/day. Non-Revenue Water (hereinafter referred to as "NRW") in 2020 equates to about 54 %[5]. In addition, as shown in Figure 1-1.1, since about 85% of the required water is transferred from Walker's Ferry Water Treatment Plant (hereinafter referred to as "WTP") which is located about 40 km away from Blantyre city at an actual head of about 800 m, Blantyre Water Board (hereinafter referred to as "BWB") has been facing high energy costs.



Source: topographic-map.com

Figure 1-1.1 Location Maps of the Water Supply Facilities in Blantyre City

On the other hand, Mudi Dam which is located close to the center of Blantyre city has problems with the built-up of sediments at the bottom of the dam resulting in the decrease in the intake capacity and water production from the dam, and Mudi WTP has deteriorated.

Therefore, the Blantyre city's water supply urgent challenges are to increase the water supply quantity, eliminate leakage, reduce the electricity costs and increase effective storage capacity of Mudi Dam. In the future, it is necessary to support on BWB's financial soundness through coping with the countermeasures.

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1 WHO/UNICEF
2 WHO/UNICEF
3 2018 Population Census in Malawi
4 Based on the data obtained from the billing section of BWB. This consumption does not include that of the customers who has not installed water meters, etc.
5 Based on the data obtained from the billing section of BWB.

1-1-2 Objective

The objective of the Data Collection Survey for Urban Water Supply in Blantyre in Republic of Malawi (hereinafter referred to as “the Survey”) is to identify and prioritize the challenges and needs faced in the urban water supply sector of Blantyre city, and to consider future cooperation approaches by Japan International Cooperation Agency (hereinafter referred to as “JICA”).

The other objective is to establish a successful support model in Malawi and to examine the possible scaling up of the support model in other cities in Malawi and the Sub-Saharan Africa region. The support models are composed of the JICA's technical cooperation for Lilongwe Water Board (hereinafter referred to as “LWB”), the development projects of water sources through their potential analysis and expansion projects of the WTPs in the future.

1-2 Outline of the Survey and Survey Approaches

1-2-1 Outline of the Survey

The JST examines issues on the water supply service in Blantyre city and organizes the development challenges and their priorities to ensure the appropriate cooperation approaches to BWB. In addition, in terms of scaling-up output of the existing technical cooperation, the JST examines the possibilities on regional collaboration by water utilities in sub-Sahara. Figure 1-2.1 shows the outline of the Survey.

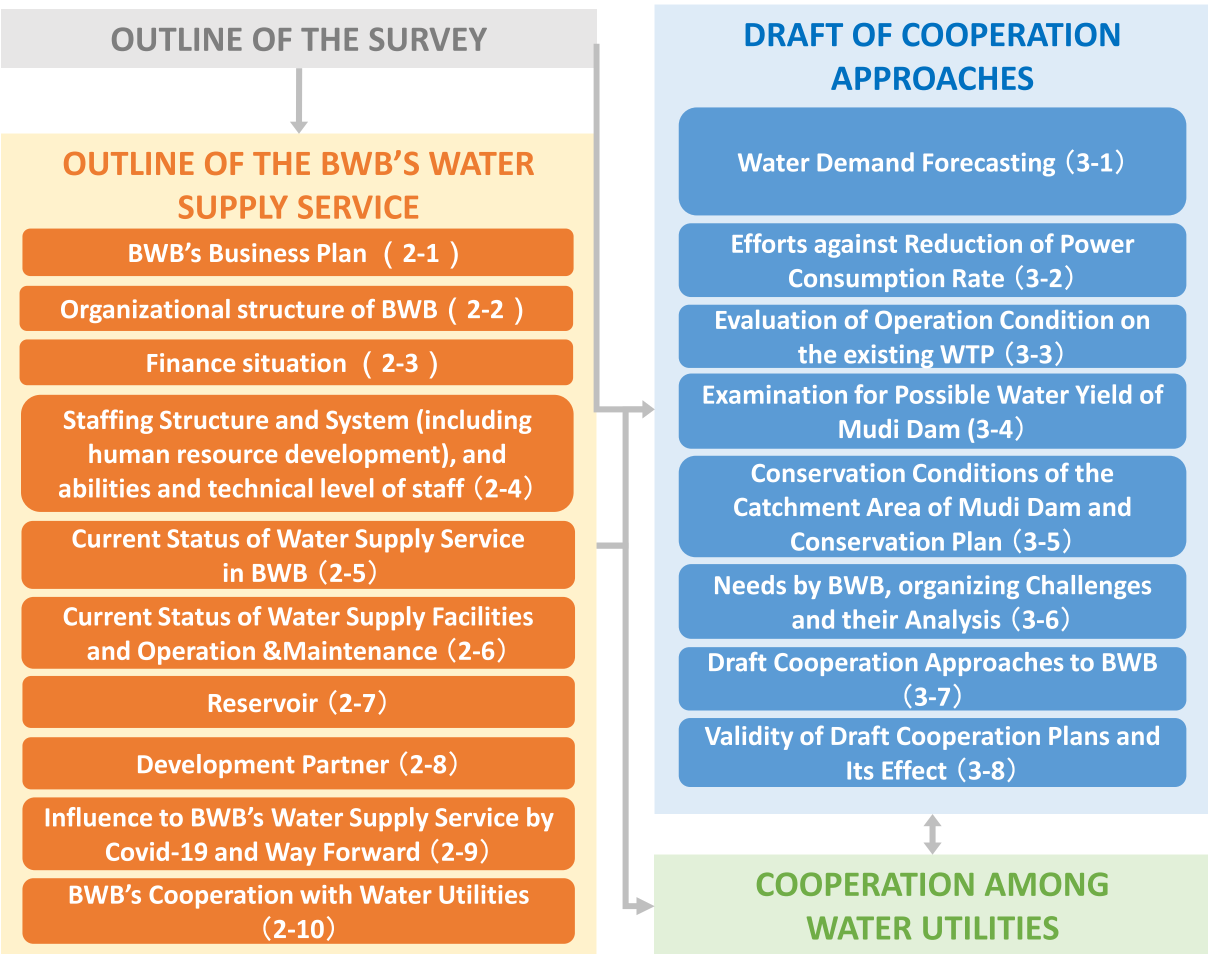


Figure 1-2.1 Outline of the Survey

1-2-2 Survey Areas

The survey area covers the entire Blantyre city including surrounding areas as shown in Figure 1-1.1

1-2-3 Survey Approaches

The JST conducts the Survey through the following six approaches:

(1) Examination of Cooperation Approaches to meet the Water Consumption in 2030

The JST examines the cooperation approaches on infrastructure development projects targeting 2030, through forecasting the water demand and learning the water supply & demand balance.

(2) Examination of Cooperation Approaches on Efficiency of the Water Supply Service and the Financial Soundness

One of the most important challenges that BWB has been facing is to improve the financial conditions. The JST examines cooperation approaches on an infrastructure development and the improvement in the water supply management and focus on the financial soundness. In particular, since electricity costs required for the pumps, etc. at Walker's Ferry WTP makes up about 85% of the total electricity costs required for all the pumps, the JST examines how to reduce the electricity costs at Walker's Ferry WTP.

(3) Examination of Cooperation Approaches on Improvement in Operation & Maintenance (hereinafter referred to as "O&M") System of Water Supply

In order to promote the water supply service efficiency and strengthen the capacity development of BWB as well as improve the BWB's financial condition, the JST examines cooperation approaches on the improvement in BWB's O&M capacity.

(4) Promotion of utilizing and strengthening the JICA Network

The JST considers the framework for utilizing know-how of the water utilities which were strengthened through the past projects.

(5) Compilation of Cooperation Plans focusing on the Cluster of "Water Supply Business Growth Support-Urban Water Supply"

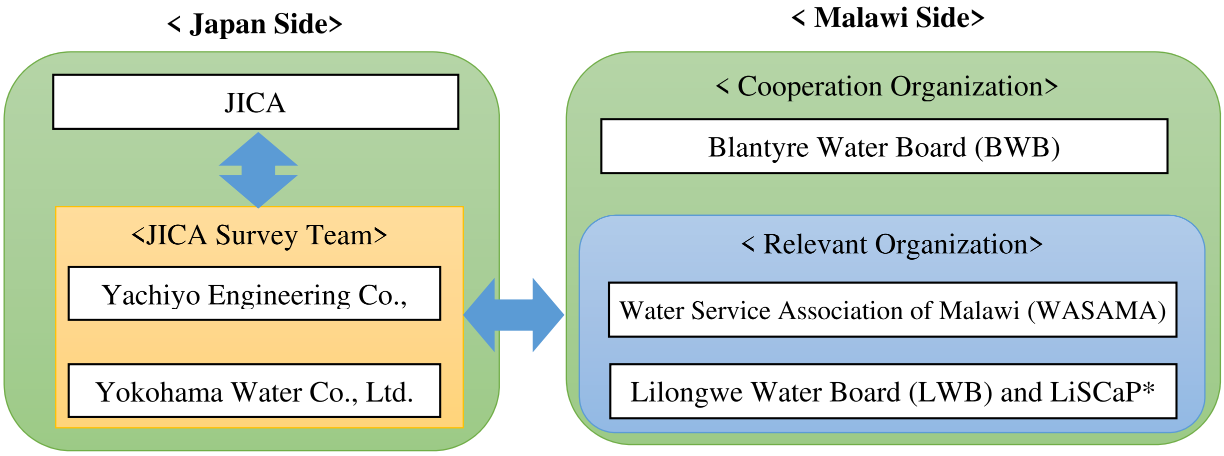
In order to improve the business environment of BWB, the JST organizes cooperation plans, considering not only cooperation approaches for individual projects but also the knowledge gained through the previous projects of the other water utilities as well as assistances of development partners.

(6) Innovation and Utilization of Digital Transformation (DX)

The JST examines cooperation approaches with the applicability and effectiveness of Information and Communication Technology (hereinafter referred to as "ICT") utilization such as a management platform, an asset management, an infrastructure management system, a knowledge management.

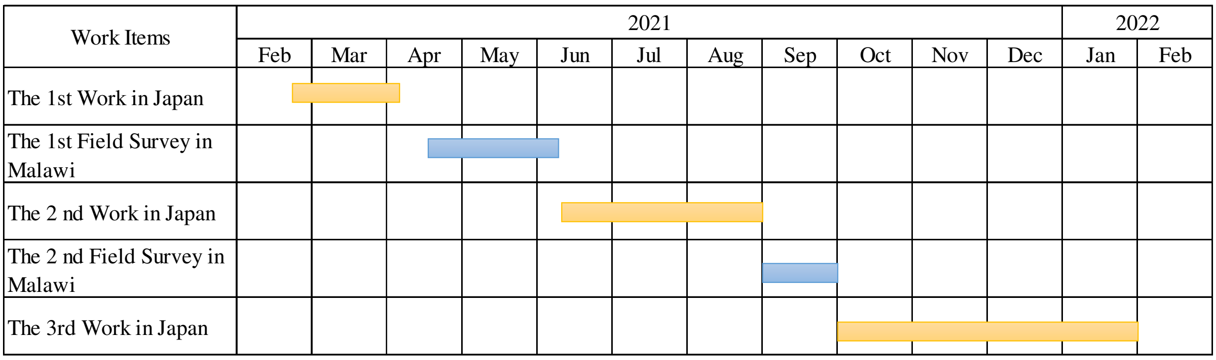
1-3 Framework and Schedule of the Survey

Figure 1-3.1 and Figure 1-3.2 shows the framework of the Survey and its schedule respectively.



Source: The JST

Figure 1-3.1 Framework of the Survey



Source: The JST

Figure 1-3.2 Schedule of the Survey

CHAPTER 2 : Outline of the BWB's Water Supply Service

2-1 BWB's Business Plan

BWB has the "BWB STRATEGIC PLAN 2020-2025" as a Business plan. "Planning, Monitoring and Evaluation Division" in BWB is in charge of developing and managing this plan. The term of this plan is five years. The current plan is the "BWB STRATEGIC PLAN 2020-2025", the achievement status of the previous plan is analyzed at the beginning of this plan, and unachieved goals are carried over to the current plan.

The "Strategic focus areas", "Strategies under each perspective" and "Key performance indicators" which are addressed during the planning period by year are given in the plan. Table 2-1.1 shows a "Strategic focus areas" and "Strategies under each perspective". Table 2-1.2 and Table 2-1.3 shows the goals of "Strategic focus areas" and "Key performance indicators" respectively.

Feasible strategies are stated in "BWB STRATEGIC PLAN 2020-2025" based on that BWB analyzed the internal and external environments of the organization through SWOT analysis.

Table 2-1.1 Strategic focus areas in "BWB STRATEGIC PLAN 2020-2025"

STRATEGIC FOCUS AREAS	STRATEGIES UNDER EACH PERSPECTIVE	STRATEGIES
Infrastructure Growth and Business Continuity	Non-Revenue Water Reduction	• Formulate NRW Master Plan • Implement NRW Plan • Forecast water demand for supply areas • Replace and recalibrate faulty and under-registering meters • Conduct meter accuracy tests • Consider the regrouping meters to specific points in low income areas • Consider the subcontracting of reticulation management for other areas to private operators
	Alternative Energy Sources Development	•Conduct feasibility study, design and construct an independent power generation plant • Negotiate and implement a special tariff on electricity • Purchase bulk power from EGENCO • Improve pump efficiency
	Water Production	• Construct intake facilities on Shire River, water treatment plant, pumping stations, pipelines and reservoirs; • Implement measures to sustain water production of Likhubula WTP; • Explore other water sources (Boreholes).
	Development of Infrastructure	• Rehabilitate and replace pumping equipment (Nyambadwe, Ndirande and Sanjika Pumping Stations including Mudi WTP); • Design rehabilitation works for improvement in capacities of Mudi and Hynde Dams; • Rehabilitate reservoirs (Zomba Road, Chigumula, Kameza, Soche, Bangwe, and Ndirande UNICEF); • Rehabilitate pipelines (Chiradzulu, Mapanga, Mpemba, Matindi and Milare); • Extend distribution networks (Malowa, Njuli, Chatha, Lunzu, Matindi, Chileka, Mpemba, Nancholi, Green Corner, Manyowe, South Lunzu Area 10, South Lunzu Area 12, Manje, Namiyango, Chikunda and Bvumbwe); • Replace old transmission mains from Walker's Ferry to Nyambadwe; • Upgrade water quality laboratory equipment; • Refurbish meter workshops and procure meter testing equipment; • Refurbish and extend Zone offices (Kabula and Soche); • Construct new offices (administration block, Limbe Zone and Salima filter media collection site); • Rehabilitate and upgrade the sewerage systems; • Formulate and review Board's Master Plan; • Construct a data center; • Examine alternative source of power.
	Data Management	• Procure and install Integrated Management Information System (IMIS); • Procure and Install Hydraulic Modelling Software (Info Works); • Procure operational softwares (AutoCAD, Microsoft Projects and ArcGIS); • Design and install SCADA/Telemetry system; • Develop and implement comprehensive asset management system; • Strengthen the capacity for quality assurance; • Develop, implement, document and record management system.
	Risk Management	• Develop an enterprise risk management framework; • Formulate and implement business continuity and a disaster recovery plan; • Enhance security for IT infrastructure; • Formulate a water safety plan;

STRATEGIC FOCUS AREAS	STRATEGIES UNDER EACH PERSPECTIVE	STRATEGIES
		• Implement Quality Management Systems for ISO accreditation.
Financial Growth and Sustainability	Revenue Growth	• Increase customers; • Encourage stakeholders to end proliferation of illegal boreholes and water operators; • Encourage relevant stakeholders to implement a cost reflective tariff; • Consider and implement options for income diversification (Bottled Water); • Consider the implementation of Automatic Metering Infrastructure.
	Improve Revenue Collection	• Adhere to debt collection policy strictly; • Work in collaboration with a credit bureau to enhance collection from debtors; • Resolve all the customer bill queries in accordance with the customer service charter level standards; • Develop and implement customer incentive programmes; • Encourage customers to avoid outstanding arrears; • Install flow limiters in the premises of customers to understand affordability.
	Value for Money Investments	• Review the Strategic Investment Plan; • Accelerate to materialize major infrastructure projects by financing investment; • Research and implement smart technologies in sectors such as energy efficient, water production and a chemical usage.
	Improve Profitability	• Restrain operational expenditure under the approved budget; • Promote value for money in procurement; • Reduce unplanned expenditures.
	Improve Cash Flow Management	• Develop and adhere to monthly cash budget; • Adhere to revenue collections as budgeted; • Improve supply chain management.
	Improve financial position	• Initiate the restructuring of loans; • Encourage the shareholder for the capitalization of loans into equity; • Implement the cost reflective tariff; • Enhance project proposal preparation to access grants for project financing.
	Compliance and Governance	• Strengthen monitoring mechanism of operations; • Ensure compliance to Board's policy and procedures; • Promote a review of Waterworks Act and Bylaws to incorporate punitive measures along with the business environment challenges; • Ensure compliance to all statutory obligations; • Undertake targeted Value for Money (VfM) Audits.
	ICT Solutions	• Develop in house applications to improve efficiency and service delivery effectiveness; • Implement smart storage computing - Migrating of non-core IT data to cloud; • Optimize IT network connectivity to ensure uptime of up to 99%; • Enhance two-way information flow by expanding real-time technologies to pass information instantly to and from field staff and customers; • Expand use of online technology to serve and engage various stakeholders; • Strengthen relationship with stakeholders by using digital technologies, while improving efficiency and connectivity with customers and BWB's staff by using mobile technologies; • Adopt digital technologies to enhance stakeholder engagement; • Harness the Power of Business Intelligence and predictive analytics.
Customer and Stakeholder	Customer Satisfaction	• Develop and implement communication strategy; • Conduct customer surveys and implement recommendations;

STRATEGIC FOCUS AREAS	STRATEGIES UNDER EACH PERSPECTIVE	STRATEGIES
Satisfaction		• Develop and implement Corporate Social Responsibility Programmes; • Manage and update an interactive website; • Develop and implement marketing strategy to improve visibility of the Board; • Improve 24/7 faults maintenance response; • Formulate and implement community outreach and education plan; • Redefine and restructure the call centre function; • Adhere to Customer Service Charter level standards.
	Stakeholder Engagement	• Develop and implement innovative Stakeholder involvement and liaison programmes; • Implement and monitor innovative ideas from stakeholder engagement.
	Staff Satisfaction	• Review and implement improved staff welfare schemes; • Conduct staff satisfaction surveys.
	Environmental Protection	• Enhance stakeholder involvement and participation in environmental protection initiatives; • Adopt appropriate technologies for protection of catchment areas; • Formulate and implement environmental protection and sustainability plans; • Develop and implement a policy for chemical and waste discharge.
Capacity Development and Productivity	Skills Development	• Formulate and implement a 5-Yr strategic human resource development plan; • Develop and effectively implement annual training plans; • Recruit staff periodically.
	Research and Development	• Develop a Robust Research and Development Framework; • Conduct action research on identified priority areas.
	Business Re-engineering	• Establish a framework for business process re-engineering; • Promote knowledge sharing culture.
	Staff Productivity	• Develop and implement tailor made/ in house behavioral change programs (Mind Set change initiatives, supervision, teamwork, reporting and communication); • Enhance performance management system; • Develop human capital through appropriate benchmarking; • Promote compliance of embracing core values of the Board; • Develop and implement health and safety programs • Review job descriptions to align to organization's needs

Source: Prepared by the JST based on "BWB STRATEGIC PLAN 2020-2025" obtained from BWB

Table 2-1.2 Goals of Strategic Focus Areas in "BWB STRATEGIC PLAN 2020-2025"

i. Improve the reliability of water supply service.	ii. Improve production, operations and data management.
iii. Increase customers from 60,000 to 100,000 connections.	iv. viii Improve customer satisfaction.
v. Reduce NRW from 53%* to 30%.	vi. ix Ensure compliance to good governance principles and practices.
vii. Reduce electricity costs through development of alternative power sources.	viii. Promote corporate branding.
ix. Improve finance.	x. Improve staff productivity.
xi. Restructure and improve facility management.	

Source: Prepared by the JST based on "BWB STRATEGIC PLAN 2020-2025" obtained from BWB
Note:
*54% in the track record as of 2020

Table 2-1.3 Key Performance Indicators in "BWB STRATEGIC PLAN 2020-2025"

Performance Indicator	Unit	Baseline	2021	2022	2023	2024	2025
Service Coverage	%	86	88	90	92	94	95
Water Production	m^3/day	96,000	100,000	110,000	120,000	120,000	167,000
Water Sold	m^3/month	1,300,000	1,531,111	1,602,325	1,862,161	2,153,124	2,296,666
NRW	%	53	45	43	37	32	30
Collection efficiency (Government)	%	30	40	45	50	60	65
Collection efficiency (Private)	%	75	80	83	86	88	90
Days for arrears (Government)	Days	617	462	410	369	307	283
Days for arrears (Private)	Days	84	79	76	73	71	69
Developing distance of pipelines	km/year	45	50	55	60	65	70
New water connections per year	No.	5,000	8,000	8,000	8,000	8,000	8,000
Number of customers	No.	58,000	66,000	74,000	82,000	90,000	100,000
Ratio of water samples applying for Malawi standards (residual chlorine test)	%	100	100	100	100	100	100
Required days to connect new water connections	Connections days	45	28	28	21	21	21
Response time to New Water connection applications	Days	7	7	7	7	7	7
Response time to customer queries	Hours	72	24	24	24	24	24
Continuity of water supply	Hours	22	23	23	24	24	24
Customer satisfaction rating	%	35	45	55	65	75	80
Return on capital employed	%	-11	-9	-7	-3	-1	0.5
Creditors days	Days	330	290	220	180	140	120

Performance Indicator	Unit	Baseline	2021	2022	2023	2024	2025
Current ratio	:	0.3	0.5	0.7	0.8	0.9	1.0
Quick ratio	:	0.35	0.46	0.67	0.82	0.96	1.00
Staff per 1,000 connections	:	12	10	8	6	6	5
Job satisfaction level	%	67	69	71	73	75	77

Source: Prepared by the JST based on "BWB STRATEGIC PLAN 2020-2025" obtained from BWB

In addition to the above, Table 2-1.4 shows the infrastructure development projects under consideration by BWB. The financial resources for the implementation of the projects of No.3 to No.6 in the table were not identified during the Survey.

Table 2-1.4 Infrastructure construction projects under consideration by BWB

No.	Project	Outline	Background / purpose	Period	Project cost	Notes
1	New Water Source on Shire River and Associated Infrastructure	**Phase 1:** **Contract-1:** Intake (299,000 m^3/day: 100%), desilting basin (100%), Conveyance Pipelines (4.1km: 100%) **Contract-2:** ● WTP (75,000 m^3/day: 50%), Transmission Pumps (50%), Transmission Pipelines (27 km x 1,200 mm: 100%) **Phase 2:** Transmission Pipelines between the Chileka Relay Pumping Station and each Service Reservoir	Construct a water intake facility, a WTP, and transmission facility to meet increase in water demand.	Phase 1: Jun. 2020/6 - Aug. 2023 Phase 2: To be determined	USD 165,000,000	● USD 78,000,000 (Approximately 47%) out of the total project cost will be financed by Exim India in bilateral cooperation between Malawi and India. ● USD 49,000,000 out of the above amounts will be loaned by Exim India. ● USD29,000,000 out of the USD78,000,000 will be granted by India. ● The remaining amounts out of USD165,000,000 has not been committed yet by development partners, etc.
2	Development of a Total of 57 Mega Watt Grid Connected Solar PV-Power Plant for BWB	Phase 1 ● Construct a 45MW solar power generation facility at Walker's Ferry WTP and a 12MW solar power generation facility at Nguludi WTP Phase 2 ● Construct a 29MW solar power generation facility at Chileka pumping station.	Construct the solar power generation facility for reducing the electricity costs.	Phase 1: Jun. 2020/6 - Feb. 2023 Phase 2: To be determined	USD 112,000,000	● USD 72,000,000 (about 64%) of the total project cost will be financed by Exim India in bilateral cooperation between Malawi and India. ● USD 45,000,000 out of the above amounts will be loaned by Exim India. ● USD27,000,000 out

No.	Project	Outline	Background / purpose	Period	Project cost	Notes
						of the USD72,000,000 will be granted by India. ● The remaining amounts out of USD112,000,000 has not been committed yet by development partners, etc.
3	Prefeasibility study and detailed design for renovation of Mudi dam	● Conduct the feasibility of increasing dam capacity including designs and cost estimate for Mudi Dam	Conduct the feasibility of increasing the storage capacity of Mudi Dam by dredging and raising and excavating.	1 June to 30 December2021	MWK 1,500,000,000	● No potential funder has been identified yet.
4	Design and Development of New Water Source from Mombezi and Makuwa Rivers	● Construct a multi-purpose dam on Mombezi River in Chiradzulu with a capacity of 71.6 million m^3/day (with intakes on Mombezi and Makuwa rivers) ● Develop a WTP producing 115,000 m^3/day, pipelines of 100 km (250 to 900 mm in diameter, three new reservoirs with a total capacity of 52,200 m^3 and three new pumping stations to pump water to Blantyre	Develop water source, construct intake, WTPs and transmission facilities to contribute to the reduction of electricity costs and to meet increase in water demand.	1 October 2020 to 1 January 2026	MWK 142,131,639,687 USD 190,780,724	● No potential funder has been identified yet.
5	NRW reduction through pipe network rehabilitation	● Replace pipelines of 460 km pipes (including pipe materials, excavation, backfilling and road re-instatements) ● Replace transmission and distribution system, valves and fire hydrants ● Construct and rehabilitate	Replace asbestos cement pipes (AC) which were laid over 50 years ago to withstand water pressure fluctuation for the purpose of elimination of water loss.	30 July 2020 to 30 July 2023	MWK 16,762,500,000 USD 22,500,000	● No potential funder has been identified yet.

No.	Project	Outline	Background / purpose	Period	Project cost	Notes
		1000 valve chambers				
6	Improvement in water supply efficiency through Distribution Network Modelling and Power Reduction Studies	● Develop a hydraulic model for BWB's water supply system. ● Study the measures that power consumption can be reduced.	Reduce energy costs which make up over 60% of the total revenue and NRW of over 50% which is equivalent for losses of MWK 22 billion annually.	1 June 2021 to 1 June 2022	MWK 2,500,000,000 USD 3,355,705	● No potential funder has been identified yet.

Source: Prepared by the JST based on data obtained from BWB

2-2 Organizational Structure of BWB

2-2-1 The Water Supply Administration System in Malawi

In Malawi, the Ministry of Agriculture, Irrigation and Water Development which had been responsible for the water supply services was renamed the Ministry of Forestry and Natural Resources on July 8, 2020, as the new government was inaugurated. The Ministry has three departments: the Department of Forestry, the Department of Fisheries, and the Department of Water Resources, which supervise the urban water supply.

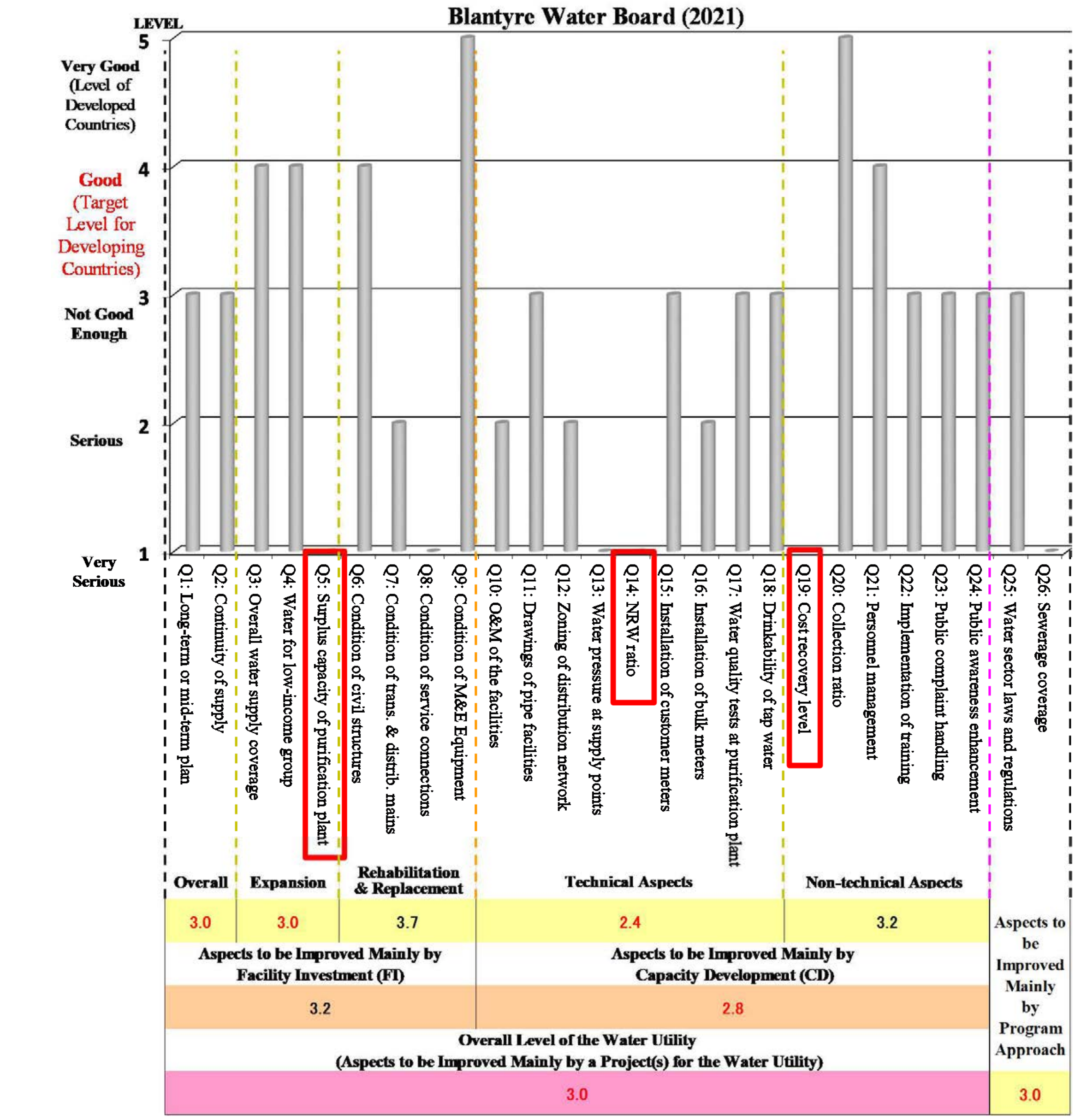
The Water Works Act of 1995 established public water corporations as semi-official organizations in each region (Northern, Central and Southern regions). In addition, the water sectors were established at city level in only two major cities: Blantyre and the capital Lilongwe. Water divisions, which had been established as departments that were part of city hall, etc., were set up as a water board.

The Water Works Act Law stipulates that the water boards are responsible for sewerage and public health services as well as water supply. However, as there are no relevant laws nor regulations for the implementation of this act, local governments are essentially responsible for sewerage services throughout Malawi at the present time. In Blantyre, the sewage services are under the jurisdiction of the health department of Blantyre City Hall, and the cost of sewage works is covered with municipal taxes.

2-2-2 Organizational Capacity Assessment

The JST conducted a basic information survey on BWB by using the BWB STRATEGIC PLAN 2020-2025 and “the Handbook for Capacity Assessment of the Urban Water Supply Sector and Water Supply Companies in Developing Countries” in order to learn their capacity at organizational level. The evaluation results for each item are shown in Figure 2-2.1.

From the results of this evaluation, it can be determined that there are problems in three particular items: "Q5 Water purification reserve capacity", "Q14 NRW ratio" and "Q19 Operating income and expenditure ratio". Meanwhile, since there is no current information from the results of interviews on water pressure in "Q8 Status of water supply pipes" and "Q13 Customer meters", these have been set as N/A.



Source: The JST

Figure 2-2.1 Organizational Capacity Assessment

2-2-3 Organizational Structure

The current organizational structure was reviewed by BWB in 2019, however the organizational structure has not yet been completed. Implementation will be fully completed by 2025, which is the final year of BWB STRATEGIC PLAN 2020-2025.

In BWB, job positions are composed of 12 grades from BWB1: a Chief Executive Officer (hereinafter referred to as “CEO”), to BWB12: simple laborers. Figure 2-2.2 shows the overall organizational structure of BWB (up to the divisional level).

The board of directors (which consists of 10 members) are not present continuously in BWB, and the CEO, represent as a top grade of the organization. In addition to the four departments: Finance, Technical Services, Human Resource & Administration, and Distribution and Commerce, which are managed by a grade of Directors, the four divisions: ICT Division, Planning, Monitoring & Evaluation Division, Procurement Division, and Internal Audit Division, are under a direct control of the CEO.

The office term of the CEO and the Directors is three years, and staff below a grade of managers are full-time employees in no fixed term employment.

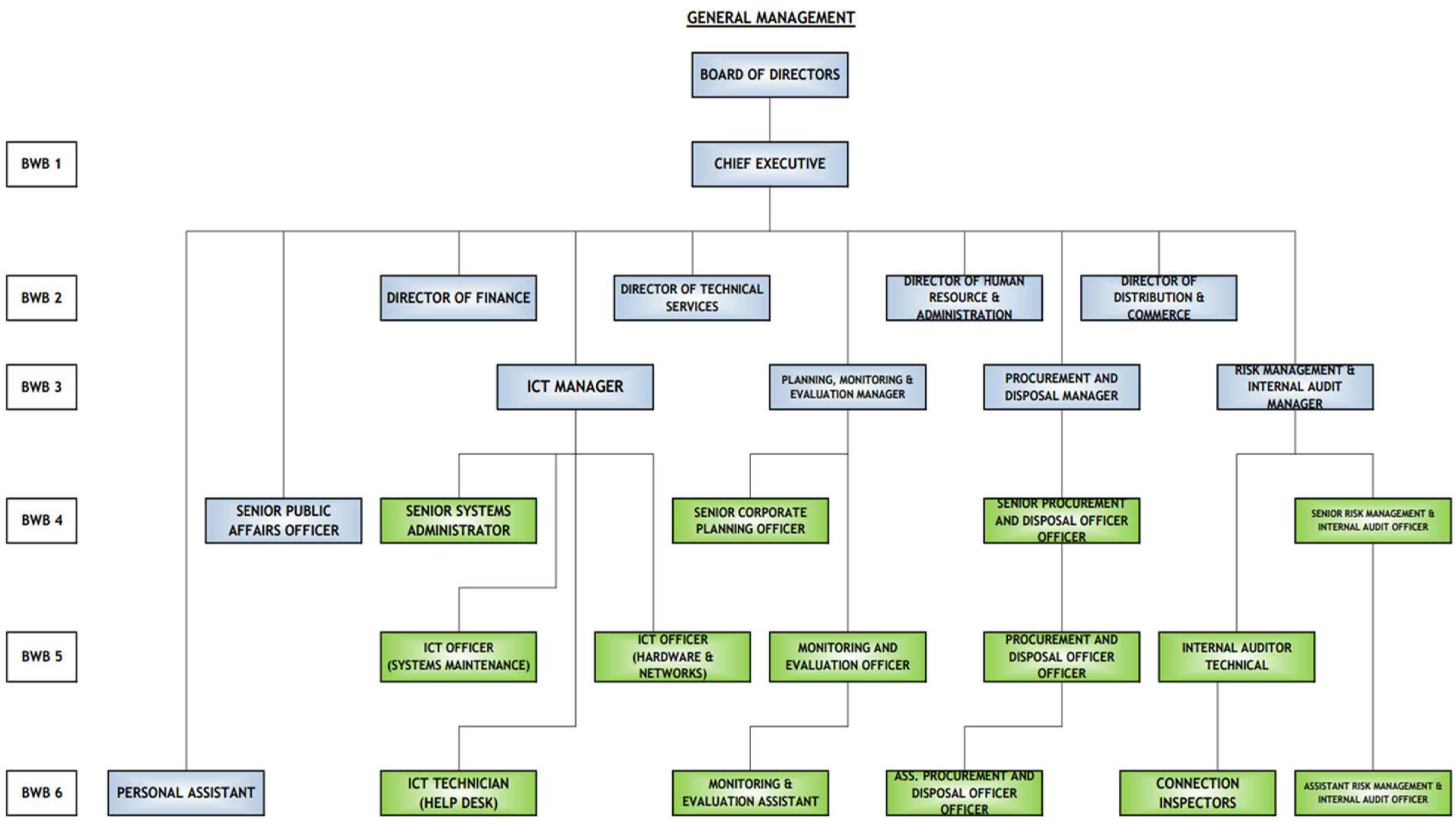


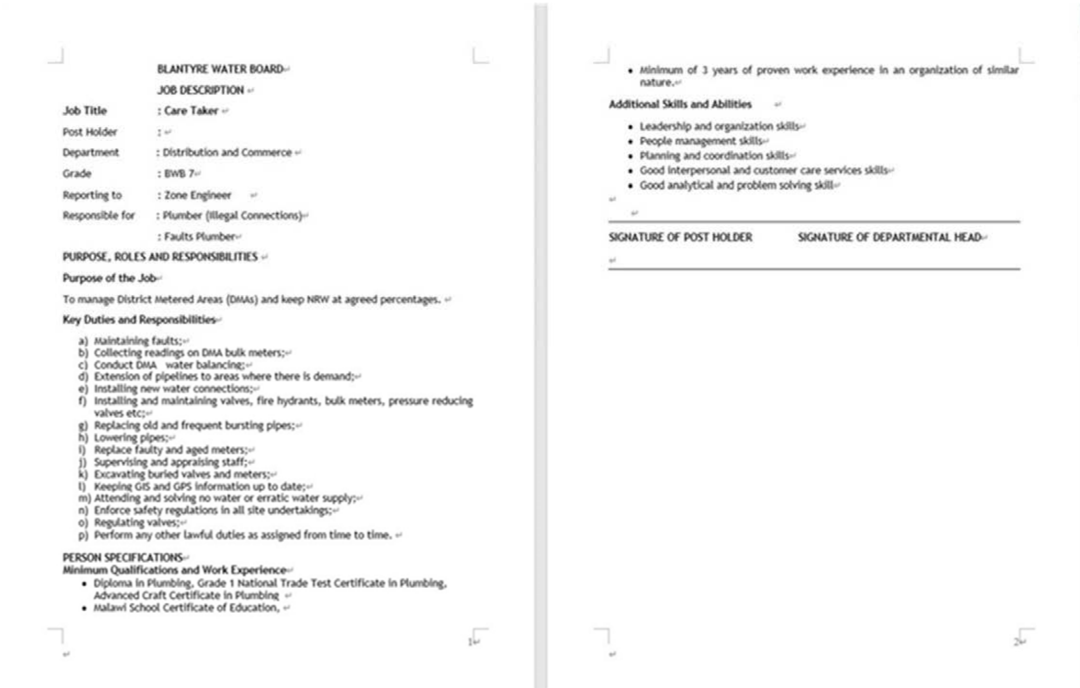
Figure 2-2.2 Overall Organizational Structure

2-2-4 Job Description

The job description was reshuffled in 2019 along with the reorganization of BWB. Figure 2-2.3 shows an example of the current job description.

Direction system in BWB was not clear in the past days, but currently, the following contents of job description are indicated:

- Job title;
- Department;
- Job position in detail;
- Qualifications required for job position;
- Direction system among directors, managers and subordinates.



BLANTYRE WATER BOARD
JOB DESCRIPTION

Job Title : Care Taker
Post Holder :
Department : Distribution and Commerce
Grade : BWB 7
Reporting to : Zone Engineer
Responsible for : Plumber (Illegal Connections)
: Faults Plumber

PURPOSE, ROLES AND RESPONSIBILITIES

Purpose of the Job

To manage District Metered Areas (DMAs) and keep NRW at agreed percentages.

Key Duties and Responsibilities

a) Maintaining faults;
b) Collecting readings on DMA bulk meters;
c) Conduct DMA water balancing;
d) Extension of pipelines to areas where there is demand;
e) Installing new water connections;
f) Installing and maintaining valves, fire hydrants, bulk meters, pressure reducing valves etc;
g) Replacing old and frequent bursting pipes;
h) Lowering pipes;
i) Replace faulty and aged meters;
j) Supervising and appraising staff;
k) Excavating buried valves and meters;
l) Keeping GIS and GPS information up to date;
m) Attending and solving no water or erratic water supply;
n) Enforce safety regulations in all site undertakings;
o) Regulating valves;
p) Perform any other lawful duties as assigned from time to time.

PERSON SPECIFICATIONS
Minimum Qualifications and Work Experience
- Diploma in Plumbing, Grade 1 National Trade Test Certificate in Plumbing, Advanced Craft Certificate in Plumbing
- Malawi School Certificate of Education,

1

- Minimum of 3 years of proven work experience in an organization of similar nature.

Additional Skills and Abilities
- Leadership and organization skills
- People management skills
- Planning and coordination skills
- Good interpersonal and customer care services skills
- Good analytical and problem solving skill

SIGNATURE OF POST HOLDER SIGNATURE OF DEPARTMENTAL HEAD

2

Source: BWB

Figure 2-2.3 Job Description

2-3 Finance Situation

The financial status of BWB was assessed through the financial statements that were collected during the Survey. The BWB's financial statements were prepared in accordance with the International Financial Reporting Standards (IFRS) set by the International Accounting Standards Board (IASB). Table 2-3.1 shows a list where the composition of financial statements in BWB and Japanese accounting standards correspond to each other. Through the review and comparison of each of the financial statements, it is concluded that although the names used by the different organizations slightly differ, their components, contents and functions are not significantly different.

Table 2-3.1 Correspondence between Financial Statements in BWB and Japanese Accounting Standards

BWB financial statements	Financial statements by Japanese accounting standards
Statement of comprehensive income	Balance Sheet
Statement of comprehensive income	Statement of comprehensive income (Profit and loss statement)
Statement of changes in equity	Statement of Changes in Net Assets
Statement of cash flows	Statement of cash flows
Notes to the financial statements	Notes

Source: The JST

Based on the corresponding financial statements listed above, the JST analyzed the financial status of BWB in terms of the following items.

(1) Profit and Loss;
(2) Financial position of assets and liabilities;
(3) Solvency;
(4) Status of water sales revenue and cost structure;
(5) Long term borrowings.

The relationships between the items listed above and BWB financial statements are tabulated in Table 2-3.2. For each of the BWB financial statements listed in the table, the JST examined the position where BWB is with regards to each of the items. This supports a better understanding of the current situations and performance of BWB in its overall operation.

Table 2-3.2 List of Items and BWB's Financial Statements

No	Description of section / Item	BWB's financial statements
(1)	2.3.1 Profit and Loss	Statement of comprehensive income
(2)	2.3.2 Financial Status of Assets and Liabilities	Statement of financial position
(3)	2.3.3 Solvency	Statement of financial position Statement of cash flows
(4)	2.3.4 Status of Water Sales Revenue and Cost Structure	Statement of comprehensive income Notes to the financial statements
(5)	2.3.5 Long Term Borrowings	Statement of financial position Notes to the financial statements

Source: The JST

2-3-1 Profit and Loss

Table 2-3.3 summarizes the BWB's profit and loss (C) statement and water sales revenue (D) from FY2015 to 2020. In Malawi, the fiscal year-end is at the end of June which means that the FY 2018 commences from 1st July 2017 to 30th June 2018.

Table 2-3.3 Changes in Profit and Loss and Water Sales Revenue (FY 2015 to 2020)

Unit: 1,000 MWK

Item/Fiscal year	2015	2016	2017	2018	2019	2020
Total income A	8,649,755	9,630,573	13,017,961	15,714,730	18,997,891	16,877,822
Total costs B	▲9,543,535	▲13,120,621	▲21,703,156	▲18,094,158	▲20,875,903	▲26,134,605
Profit and loss (▲) C=A+B	▲893,780	▲3,490,048	▲8,685,195	▲2,379,428	▲1,878,012	▲9,256,783
Water sales revenue D	7,677,224	8,863,166	12,134,700	14,844,521	17,260,916	16,138,867
Ratio of loss to water sales C/D x (-1)	11.6%	39.4%	71.6%	16.0%	10.9%	57.4%

Source: Prepared by the JST based on financial statements obtained from BWB

The considerations for the profit and loss statement are as follows:

- For each year from FY 2015 to 2020, the total cost (B) exceeded the total income (A). Therefore, the profit and loss (C) statement for each year resulted in a loss.
- The JST calculated the ratio of loss to water sales (C/D x (-1)), and the result was 57.4% in case of FY 2020. This means that it would take a 57.4% increase in water tariff, if BWB wished to eliminate the loss (C).

2-3-2 Financial Status of Assets and Liabilities

Table 2-3.4 summarizes the BWB's assets (A), liabilities (B) and accumulated losses from FY2015 to FY2020. The table shows that the accumulated losses statement for BWB has been steadily increase over the years since 2015 to date due to the cumulative amounts of accumulated losses.

Table 2-3.4 Changes in Assets, Liabilities, and Accumulated Losses (FY 2015 to 2020)

Unit: MWK 1,000

Item/Fiscal year	2015	2016	2017	2018	2019	2020
Assets A	27,525,031	30,549,890	36,716,562	40,457,375	53,409,470	58,167,450
Liabilities B	22,364,533	27,368,173	39,035,493	45,176,799	60,006,906	74,021,669
A-B	5,160,498	3,181,717	▲2,318,931	▲4,719,424	▲6,597,436	▲15,854,219
Accumulated losses	▲1,891,997	▲3,848,921	▲12,576,786	▲14,947,648	▲16,823,552	▲26,080,335

Source: Prepared by the JST based on financial statements obtained from BWB

The considerations for the assets and liabilities statement are as follows:

(1) BWB already accumulated losses in FY 2011 and MWK 1.89 billion in FY 2015. The situation of accumulated losses has not changed by the end of FY2020. In FY 2013, the accumulated losses in BWB were eliminated, but recurred in FY 2014 due to loss (total income < total cost).

(2) In FY 2017, the BWB's liabilities (B) is higher than its assets (A) value, that is "A-B < 0", going-on even in FY 2020.

2-3-3 Solvency

Table 2-3.5 summarizes the yearly current ratio (A/B) which is derived by dividing the current asset (A) values with the current liabilities (B) from FY 2015 to FY 2020, respectively. This table includes cash and cash equivalents at the end of each year. This item is one of the statement of cash flows from FY 2015 to FY 2020.

Table 2-3.5 Changes in Current Ratio (FY 2015 to 2018)

Unit: MWK 1,000

Item/Fiscal year	2015	2016	2017	2018	2019	2020
Current assets A	3,433,452	3,266,183	4,565,429	7,599,767	7,370,334	8,430,526
Current liabilities B	4,143,212	9,399,053	18,195,593	20,438,874	21,580,278	32,892,033
Current ratio A/B	82.9%	34.8%	25.1%	37.2%	34.2%	25.6%
Cash and cash equivalents at end of year	472,009	▲845,530	▲1,101,572	▲480,269	▲858,664	▲621,200

Source: Prepared by the JST based on financial statements obtained from BWB

The considerations for the solvency statement are as follows:

- The Current ratio (A/B) is a management analysis indicator for short-term solvency. This indicator is generally required to be greater than 100%. However, the ratio in BWB is very low at 25.6%, in the case for FY 2020.
- The balance of cash and cash equivalents is the balance of cash on hand and in the banks plus any overdraft, which showed a negative statement in BWB at the end of the FY 2020.
- From the above considerations, the JST gauges the BWB financial condition to be extremely poor compared with normal ones. The two factors to arrive at this conclusion are the fact that the current ratio (A/B) is lower than 100% and secondly, the quantities of cash and the cash equivalents are negative at the end of year.

2-3-4 Status of Water Sales Revenue and Cost Structure

As shown in Table 2-3.3, the water sales revenue has been increasing since 2015, except for 2020, while, the expenses have also been increasing, resulting in a deficit every year.

Table 2-3.6 shows the list of water tariff in BWB which was approved by the Government of Malawi through the amended Waterworks Act on 30th July 2018. The water tariff in BWB increased by 5% for domestic customers and 10% for other customers from 1st August 2018. The effect of that increase in water sales revenue is expected from FY 2019.

The structure of the water tariff in BWB is summarized below, referencing the contents of Table 2-3.6.

- All water usages except kiosks have a basic rate and basic water volume.
- In cases where the basic water volumes used does not exceed, all the users are charged basic rates only.
- In cases where the basic water volumes used exceed, all the users are charged not only the basic rate

but also tariff for every volume that exceed the basic water volume.

- The structure of tariff according to the volume is designed such that the greater the volume of water used, the higher the charges. This is similar to many water supply operations in Japan.
- The unit price of the kiosks' usage is uniform.
- There are two ways to pay tariff: one is post-payment and the other is pre-payment by purchasing a prepaid card. Tariff of MWK120 is added to the basic tariff of post-payment in case of pre-payment.

Table 2-3.6 Water Tariff in BWB (Post-payment, From 1st Aug 2018)

Unit: MWK

Purpose	Basic rate	Basic water volume (m^3)	Fee according to the volume (per m^3)			
			0-5 m^3	6-10 m^3	10-40 m^3	40 m^3-
Domestic purpose	2,305.42	5	-	490.00	580.00	640.00
Institutions	10,397.11	10	-	-	1,180.00	1,240.00
Commercial purpose	13,618.37	10	-	-	1,500.00	1,650.00
Industrial purpose	19,093.98	10	-	-	2,170.00	2,390.00
Kiosks	-	-	225.00			

Source: Prepared by the JST based on financial statements obtained from BWB

Table 2-3.7 shows the status of water sales revenue collection (A) from 2015 to 2020. The uncollectible amount (B) from FY 2015 to 2020 is approximately MWK 200 to 500 million each year. The ratio of the total uncollectible amounts to the total water sales revenue (B/A) from FY 2015 to 2020 was 2.6% which can be used as a reference figure, although the actual ratio varies by year.

Table 2-3.7 Status of Water Sales Revenue Collection (FY 2015 to 2020)

Unit: MWK 1,000

Item/Fiscal Year	2015	2016	2017	2018	2019	2020	Total
Water sales revenue A	7,677,224	8,863,166	12,134,700	14,844,521	17,260,916	16,138,867	76,919,394
Uncollectible amount B	195,783	530,379	323,301	304,140	287,942	353,368	1,994,913
Ratio of uncollectible amount B/A	-	-	-	-	-	-	2.6%

Source: Prepared by the JST based on financial statements obtained from BWB

BWB has worked to increase the total water supply through enhancement of Walker's Ferry WTP and construction of Nguludi WTP, and since 2018, the water supply quantity has been increasing year by year (if water supply quantity as of 2018 is set as 100%, it increased by 108.5% in 2019 and 121.8% in 2020) (see Table 2-3.8). The number of customers is also on an increasing tendency from a baseline of 100% in 2018 increasing by 103.1% in 2019 and 115.3% in 2020 respectively. While the water demand in urban areas is increasing as mentioned above, the water sales volume has fallen as of 2020 after a slight increase as of 2019 (water sales volume as of 2018 is set as 100%, increasing by 103.0% in 2019, decreasing by 96.7% in 2020).

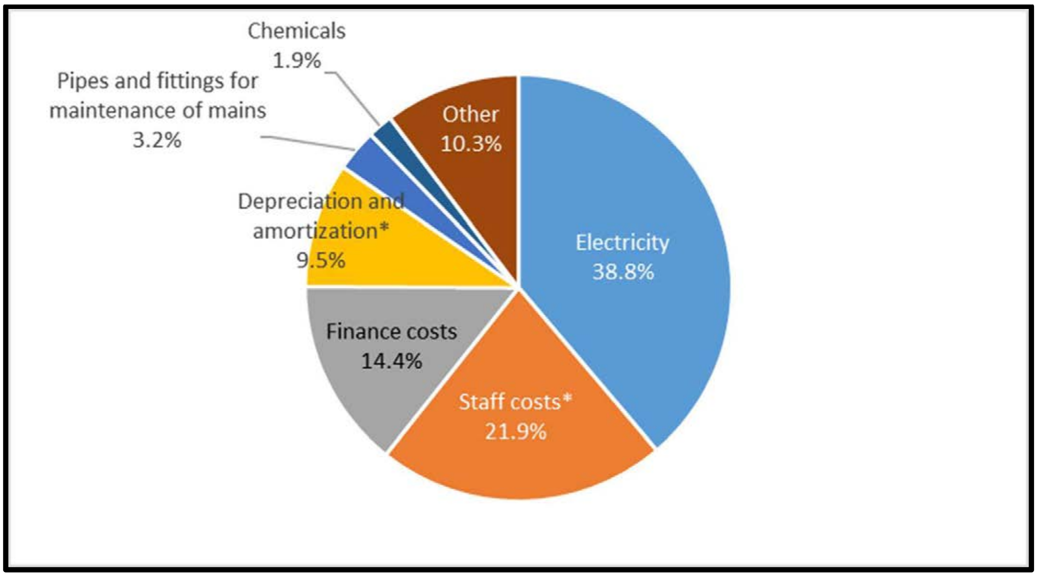
It is not a natural phenomenon for the growing water utilities to have increase in production and customers, but falling sales volume, the cause of the problem need to be determined and verified by BWB. In addition, daily per-capita water consumption in pre-paid meters is 80 Liter per Capita per Day (hereinafter referred to as "LCD") as of 2020, while 90 LCD as of 2018. The causes of decrease in 2020 needs to be verified.

Table 2-3.8 Tendency in Production, Customer Base and Sales Volume

Item	2018	2019	2020
Supplied water volume	100 %	108.5 %	121.8 %
Number of customers	100 %	103.1 %	115.3 %
Sales volume	100 %	103.0 %	96.7 %
Pre-paid customer LCD value	90	89	80

Note: The percentage values in the table are relative to 100% in 2018.
Source: Prepared by the JST based on materials provided by BWB

The BWB's cost structure for FY 2020 is illustrated in Figure 2-3.1. “Personnel costs” and “Depreciation” in this figure contains the total cost of sales, selling expenses, and administrative expenses.



Source: Prepared by the JST based on financial statements obtained from BWB

Figure 2-3.1 Cost Structure in BWB (FY 2020)

The evaluation of the status of the water sales revenue and the cost structure are as follows:

(1) The cost structure in FY2020:

- “Electricity costs”, “Personnel costs”, “Financial costs” and “Depreciation and amortization” account for more than 70% of the total costs in BWB
- “Electricity costs” accounts for more than 30% of the total cost which means to secure profits for BWB, so it is necessary to decrease “Electricity costs”.

(2) Personnel costs account for the second largest share at about 20% of the total after electricity costs. The structure ratio of the personnel cost in LWB is 23.5% in FY2016, which is lower than that in BWB.

On the other hand, Table 2-3.9 shows the personnel costs of BWB and LWB in terms of "Personnel costs per m^3 of water supply”. The indicator of personnel costs per m^3 for BWB is 82.65MWK/m^3 in FY 2016 and that for LWB is 67.38MWK/m^3 in the same fiscal year. Personnel costs per m^3 of BWB is higher than that of LWB. Therefore, BWB will be able to reduce expenditure through an efficient water supply management.

Table 2-3.9 Personnel Costs per m^3 of Water Supply (FY 2016)

Water board	Quantity of Water Supply A	Personnel Costs (Unit: K MWK) B	B/A
BWB	30,300 m^3	2,504,328	82.65 MWK/m^3
LWB	33,732 m^3	2,272,825	67.38 MWK/m^3

Source: Prepared by the JST based on data obtained from BWB

2-3-5 Long-term Borrowings

Table 2-3.10 summarizes the state of long-term borrowings by BWB. Loans that comes through the government of Malawi are recorded as long-term borrowings. The Malawi government adds a certain premium to the interest rate to prevent the foreign exchange risk that will be incurred when the Malawi government receives the loan, when re-lending to BWB.

Table 2-3.10 Situation of Long-term Borrowings through the Government of Malawi

Items \ Financier	International Development Association (IDA)	European Investment Bank (EIB)	Exim Bank of India	Total
The start of borrowing	Nov 2011	Dec 2009	Mar 2018	–
The start of repayment	Jan 2021	Feb 2015	Mar 2023	–
The period of borrowing	35 years	20 years	20 years	–
Frequency of repayments	Twice a year	Twice a year	Twice a year	–
Annual interest rates	10%	12%	1.5%	–
Balance at the end of FY2018 (Unit: K MWK)	10,201,452	6,138,314	3,532,799	19,872,565

Source: Prepared by the JST based on financial statements obtained from BWB

The state of the long-term borrowings by BWB are described below:

- BWB has not made any repayment on their loans and interests (described in Table 2-3.10) though the dates to start the repayments to IDA and EIB were effective as of Jan 2021 and Feb 2015, respectively.
- Table 2-3.11 shows the changes in the loan balance at the end of each year from 2015 to 2020. The loan balance (A+B-C+D) is calculated as the sum of the loan balance at the start of each fiscal year (A) which is brought over from the end of the previous year, additional borrowings (B), Repayments (C) and Balance of accrued interest (D). Table 2-3.11 shows that the loans balance increased annually from FY 2015 to 2020. This situation laid the background for the discussion in section "2-3-3", which BWB cannot make loans and interests repayments due to BWB problematic financial state (effectively insolvent).

Table 2-3.11 Changes in Balance at the End of Year of Long-term Borrowings

Unit: 1,000 MWK

Item/Fiscal Year	2015	2016	2017	2018	2019	2020
Balance at the first of fiscal year A	6,249,709	10,699,133	13,634,868	14,754,682	19,872,565	32,529,295
Additional borrowing B	3,520,771	1,815,921	-	3,532,806	10,739,650	3,922,578
Repayment C	-	-	-	-	-	-
Provision for balance of accrued interest D	928,653	1,119,814	1,119,814	1,585,077	1,917,080	2,120,396
Balance at the end of fiscal year A+B-C+D	10,699,133	13,634,868	14,754,682	19,872,565	32,529,295	38,572,269

Source: Prepared by the JST based on financial statements obtained from BWB

- BWB had made attempts to improve its financial situation which would enable it to repay the long-term borrowing. For instance, BWB have drawn up several proposals with the intention to secure funding from different donors which should contribute to the increase in BWB's income through the management of these proposal projects. One of such projects was funded through a loan from Exim Bank of India which should contribute to improvement in BWB income sources.
- Apart from the above loans, BWB borrowed long-term loans from commercial banks such as First Discount House (FDH) Bank since FY2017 as shown in Table 2-3.12. These loans were taken for the purchase of prepaid meters, and have been repaid.

Table 2-3.12 Long-term Borrowings from City Banks

Unit: MWK 1,000

Bank	Borrowing Amounts (Unit: K MWK)	The Start of Borrowing	The Start of Repayment	The Period of Borrowing	Annual Interest Rates	Balance as of 30 Jun. 2020 (Unit: K MWK)
FDH	700,000	10 May. 2017	17 May. 2020	3 years	20%	-
FDH	3,556,664	27 May. 2019	31 May. 2025	6 years	20%	3,198,204
FMB	700,000	11 Sep. 2018	11 Sep. 2022	4 years	20%	336,574
NBM	1,900,000	7 May. 2019	7 May. 2027	8 years	18%	1,764,531
NBM	3,040,623	4 Dec. 2019	4 Dec. 2027	8 years	15%	3,040,623

Source: Prepared by the JST based on data obtained from BWB

Table 2-3.13 shows the conditions and interest rates for obtaining short-term loans from commercial banks in Malawi.

Table 2-3.13 Conditions for obtaining a short-term loan from a commercial bank in Malawi (As of Sep. 2021)

Item	Contents
The period of a loan	Three to five years. The period of seven years is negotiable for blue-chip companies.
The use of funds	Use of funds is clarified before financing.
Financial conditions	Bank statements in the past six months is required before financing. Other assessments are made by the banks.
Collateral and guarantee	All banks require land property as collateral.
Annual interest rates	All banks use a reference rate from Reserve Bank of Malawi, 12.2%. On top of this they add their own rate (premium), to make effective rate. For example; 1.NBM: 10.1%, so effective rate is 22.3% 2.FDH: 11%, so effective rate is 23.2%（If company brings cash as collateral, the premium is 6%, and effective rate therefore is 18.2%）

Source: Prepared by the JST based on interviews with local banks

2-3-6 Considerations based on Survey Results

Table 2-3.14 summarizes the changes in profit and loss, long-term borrowings, and equity in BWB from FY 2015 to 2020 based on the results of the survey.

Table 2-3.14 Changes Profit and Loss, Long-term Borrowings, and Equity (FY 2015 to 2018)

Unit: 1,000 MWK

Item/Fiscal Year	2015	2016	2017	2018	2019	2020
Profit/▲loss	▲893,780	▲3,490,048	▲8,685,195	▲2,379,428	▲1,878,012	▲9,256,783
Balance at the end of fiscal year of long- term borrowings (Total of balance in Table 2-3.11 & Table 2-3.12)	10,699,133	13,634,868	15,454,682	20,401,386	38,885,109	46,912,202
Equity (▲insolvent)	5,160,498	3,181,717	▲2,318,931	▲4,719,424	▲6,597,436	▲15,854,219

Source: Prepared by the JST based on financial statements obtained from BWB

Note: Balance at the end of fiscal year of long- term borrowings (FY2020) includes the balance of borrowings (MWK 700,000 k in FY2017, MWK 528,821 k in FY2018, MWK 6,355,814 k in FY2019, MWK 8,339,933 k in FY2020)

The considerations on the profit and loss, long-term borrowings, and equity statement are as follows.

- BWB has not covered the costs with water sales revenue, posting losses every year. Therefore, BWB has not been able to secure the funds that needs to repay the principal and interest on its loans, facing increase in the balance of the loans year by year and insolvency from FY 2017.
- To secure profits in BWB, the effective means is to increase revenue or decreased costs by reducing NRW. Therefore, to improve the profit and loss, there are three representative measure as listed below.

- Water source development in areas adjacent to the water supply service areas: Improvement in raw water transmission efficiency → Reduction of annual O&M costs
- Reduce NRW: Effective usage of water production → Reduction of selling expenses
- Renewal of pump facilities: Improvement in pump efficiency → Reduction of annual O&M costs
- Improvement in water supply service: Improve the efficiency of management → Reduction of annual O&M costs

● In order to cover costs through water sales revenue, it is necessary to reduce electricity costs, which accounts for a large proportion (about 30%) of BWB's expenditure.

For example, in FY 2018, BWB reported a loss of approximately MWK 2.8 billion before tax. If the electricity costs had been reduced by approximately MWK 1.4 billion per year as described in section 3-2, BWB would have been able to improve profits and losses in that year.

● The improvement in financial situation of BWB is needed to reduce the outstanding long-term borrowings through the reduction of water supply cost based on the above method.

2-3-7 Current Financial Situation and Measures to improve It

The following are the results of interviews with the BWB's management staff and the finance department staff regarding the current financial situation and measures to improve it. They are concerned about the current financial situation, but at this point they are only considering measures to address it.

(1) Increase Water Tariff

1) BWB raised water tariff every year from 2015 to 2018, but not in 2019 and 2020. That is reason why the relevant Ministry did not approve the increase in water tariff. In November 2021, the increase in the water tariff was approved by the government and BWB raised the water tariff by 65%.

2) BWB is troubled by the fact that water sales revenue is declining even though the customer is steadily increasing.

(2) Reduce the Costs

1) BWB believes that the most important way to reduce costs is to steadily implement NRW reduction. It is particularly concerned with commercial losses.

2-4 Staffing Structure and Human Resource System (including human resource development), and abilities and technical level of staff

2-4-1 Staffing Structure

In FY 2020, the number of BWB's staff were 719 persons (see Table 2-4.1).

Table 2-4.1 BWB Roles and Number of Employees

Department	Planned
CEO	1
SENIOR PUBLIC AFFAIRS OFFICER	1
PERSONAL ASSISTANT	1
Legal Counsel	1
ICT DIVISION	6
PROCUREMENT DIVISION	6
PLANNING , MONITORING AND EVALUATION DIVISION	6
INTERNAL AUDIT DIVISION	8
FINANCE DEPARTMENT	30
HUMAN RESOURCE AND ADMINISTRATION DEPARTMENT	89
TECHNICAL SERVICES DEPARTMENT	309
DISTRIBUTION AND COMMERCE DEPARTMENT	261
Total	**719**

Source: BWB New Establishment Warrant

When the JST had interviews with each department, it was observed that some of staff were insufficient. In addition, it was confirmed that staff were temporarily assigned to the busy departments. It seems that staff are being actively recruited, as BWB had interviews with new employee even during the Survey.

The water supply zones are divided into three: LIMBE (72 employees), SOCHE (71 employees), and KABULA (71 employees) zone office, each of which provides customer services for their regions.

The zone offices have a wide range of work responsibilities, including "management of different types of District Metered Area (hereinafter referred to as "DMA")," "water leakage repairs," "small-scale pipeline replacement," "water meter replacement," and "new connections" in the technical field, and "meter readings and price decisions," "billing," and "stopping water supplies due to arrears" in the administrative field.

2-4-2 Human Resources Development Department, Human Resources Development Plan, OJT, Off-JT, and Training Programs

(1) Human Resources Development Department

The Human Resources & Administration Department (89 employees) is in charge of works related to human resources.

As described in 2-2-3, there is hierarchy of employees based on a division of duties divided into 12 grades. The employees are evaluated twice a year (interim and end of year), and there is a reward system of MKW 50,000 which was established for highly evaluated employees. In principle, employees should not be "transferred to other departments" (apart from transfers between workplaces for doing the same work) and there should not be "personnel reshuffles to other positions", and employees should basically continue doing the same work.

BWB selects eligible persons among BWB's present staff to fill vacant positions. At the same time, the selected persons have an opportunity to be promoted to a higher grade, if they satisfy certain conditions. There is also a regular pay raise system, and there are annual pay raises of 5-10%.

It can be said that in this way BWB has created a system to give employees incentives, which are required for raising motivation.

(2) Human Resources Development Plan

The Human Resource Management Division of BWB is in charge of the human resources development plan. BWB formulated the HUMAN RESOURCE STRATEGIC PLAN 2021 - 2025 in January, 2021. This is the first time that BWB formulated such a human resource development plan. The roles of each department, the required employee profile, and annual achievements, etc. are defined as the purpose of achieving the goal of "Providing potable water through a committed and productive workforce".

(3) OJT, Off-JT and Training Programs

Based on the above-mentioned strategic plan, BWB formulated the training plans every fiscal year and has conducted various types of training (OFF-JT). However, BWB has been forced to cancel the training because of budget constraints. Unplanned training is given if requested by the local employees.

In regard to the training plans for newly hired employees, nothing has been prepared. They only receive an orientation, and subsequent trainings depending on their workplace.

The interviews with each department revealed that no operational manuals have been developed and no effective trainings have been provided for local employees. The concept of OJT has been understood at a management level but not at a field level.

2-4-3 Abilities and Technical Level of Staff

The JST had interviews on the existence of manuals and training progress under each department. The interview results are shown below:

(1) Water Treatment Plant (WTP) Operation

There is an operational manual at Walker's Ferry WTP, but trainings in accordance with the manual have not been given. On the other hand, there are neither operational manuals nor trainings at Mudi WTP and Nguludi WTP. Table 2-4.2 presents the current status of manuals and trainings at each WTP.

Plant operator training organized by Water Services Association of Malawi (hereinafter referred to as "WASAMA") is held once every two years as training on water purification (classroom only). The experienced employees of the Water Boards is in charge of lectures and prepare their materials. Several employees from BWB participates the course each time, and 10 employees are scheduled to take the course this year (20 day training period).

Table 2-4.2 Operation Status of the WTPs

Items	Walker's Ferry	Mudi	Nguludi
Operation manual	Yes	No	No
Operation training	No	No	No
Note: Trainees learn the basics of WTP operation through the plant operator training by WASAMA.			

(2) Water Transmission and Distribution pipe and Facility / Equipment Replacement

BWB recognizes that there are problems in construction management. BWB prepared the Construction Management Manual in 2018 in collaboration with a short-term volunteer from Yokohama Waterworks Bureau (hereinafter referred to as "YWWB). However, construction management manual has not been used at the level of field staff who have unknown it. Construction management depends on the ability of the person in charge of each site.

Training orientated towards plumbers is provided, but it isn't enough. Construction drawings are managed by the DRAWING OFFICE, and new construction work is managed in a way that allows both paper drawings and electronic data to be referred to. However, the drawings prepared in the past exist as only paper media but many of them have been lost. Currently BWB have worked on digitizing the existing paper data.

(3) Measures against NRW

Adequate number of staff is not assigned to the NRW countermeasures section in terms of the number of planned personnel (10 out of the planned 27 staff). The details of their activities are as follows:

1) Identifying water leak volume based on flow measurements between the facilities;
2) Detecting water leakage from water supply pipes;
3) Water balance analysis;
4) Learning NRW in the BWB's service areas;
5) Water distribution analysis for each DMA reported by the zone offices;
6) Site reconnaissance based on the results of meter readings from the zone offices (meter difference tests, checking illegal connections).

However, a manual of the above activities has not been prepared.

This section works on water meter inaccuracy test, testing and on-site inspections of suspected illegal connections without specific manuals in cooperation with the zone offices. There is a need to prepare a manual that includes a division of responsibilities between the NRW Countermeasure Section and zone offices.

(4) DMA Management

The caretaker plumbers manage operation including meter reading of bulk meters in DMAs, the preparation of water balance sheets for DMAs, the management of valves, handling of defective water flow, and updating GIS data in each DMA, but BWB does not have specific DMA management manuals, just relying on the abilities of the caretaker plumbers.

The BWB's Strategic Plan 2020-2025 states that the bulk meters have been installed in each DMA, but from interviews with different zone offices it was confirmed that there are meter shortages and failures, and accurate water flow rate measurements are not made. In regard to water pressure management, all the data loggers owned by BWB have broken down, nor is there a water pressure management manual, and as such systematic water pressure measurement is not carried out. According to the aforementioned interview, BWB has to borrow the devices from the Northern Region Water Board (hereinafter referred to as “NRWB”), when water pressure has needed to be measured.

In addition to the various works mentioned above, it is necessary to develop management manuals for all the DMA, including hydraulic control and residual chlorine management, and conduct their trainings.

(5) Water Leakage Repairs and Small-size Pipeline Upgrades

The caretaker plumber who is in charge of each DMA is responsible for water leakage repairs, replacing small pipes, and replacing water meters. There are four caretaker plumbers in each zone office in addition to assistant caretaker plumbers, which reduces the work load so that a staff can be responsible for five to seven DMAs.

The Construction Management Manual is required for water leakage repairs and small pipeline replacement. However, it has not been used for the works, which have resulted in depending on the abilities of the caretaker plumber. In regard to water leakage repair, BWB needs to take actions flexibly in the sites, but does not work appropriately, like BWB reuse the existing materials.

(6) New Connections

Based on the organizational restructuring in 2019, the rules for the applications of service connections were reviewed. As a result of that, applicants have been forced to purchase materials of service connections and bear costs of the excavation of laying pipes, etc. The applicants are supposed to present the receipt for the procurement of the material to BWB and adjust the construction date.

BWB is responsible for the branching from water distribution pipelines, piping of water service pipelines, and installation of water meters. Once piping is completed, the customers have to backfill by themselves. After the construction work is completed and water passes through pipelines, the rights of the property regarding the water supply pipelines are transferred to BWB.

In regard to materials procured by applicants, there has to be adequate material inspection by BWB prior to installation from the viewpoint of quality control, and staff education for this is also needed.

According to BWB's customer service charter, the timeframe for water supply application to connection is defined as “within 28 days of payment”. One plumber enables to connect service pipelines for 10 households daily and two plumbers work on service connections in each zone office. That is, service connections can be connected for 400 households (10 households x 2 plumbers x 20 days/month) monthly. Even though weather condition is considered, it seems that plumbers in the zone offices are deployed appropriately. However, the work schedule has not been followed. There are various reasons such as delays in water meter and material procurement, 3,000 backlog applications in each zone office.

The above information is based on the interviews. Moreover, although the rules were altered, manuals associated with this alteration have not been prepared. As is the case with other operations, it depends on the ability of the person in charge.

(7) Meter Readings, Settlements and Disconnection of Water Supply for Arrears

Each zone office has one billing officer who is responsible for handling settlements and under the officer, and there are three to four technicians responsible for work supervising meter readings and disconnection of water supply in case of arrears. The number of staff required for meter readers and disconnection drivers in each zone office are 24 persons, but actually depending on number of customers in each zone office. The monthly numbes of workload in meter readings is 900-1,000 households per staff.

Meter reading is supposed to be done within 10 days (including weekends and holidays) from the 27th of the previous month, and the meter reading and disconnection technician who receives daily meter readings from the meter readers, checks these readings as well as requests reinvestigations, if there are any abnormal values. Final confirmation is completed by the billing officer in each zone office, and billing data for the month in question is confirmed by the 15^{th}. Response to requests for paper-based billing made by companies, etc. is completed by the 17^{th}. Disconnection of water supply for arrears is taken from the middle to the end of the month following the completion of meter readings. The meter reader and disconnection driver also performs these work tasks. Table 2-4.3 lists the staffing allocation for each zone office.

Table 2-4.3 Zone Size and Staff Allocation by Zones

Items	LIMBE	SOCHE	KABULA
Number of customers*	23,523	14,227	26,134
Number of DMA	44	34	53
Caretaker Plumber	7 (Planned 4)	5 (Planned 4)	9 (Planned 4)
Plumber (New Connections)	2	1 (Planned 2)	2
Billing Officer	1	1	1
Meter Reading and Disconnection Technician	4 (5,880)**	3 (Planned 4) (4,742)**	4 (6,533)**
Meter Reader and Disconnection Driver	26 (Planned 24) (904)**	16 (Planned 24) (889)**	27 (Planned 24) (967)**
Number of applications (applications per Month)	300/Month (Average by interview)	172/Month (Results for August)	272/Month (Results for July)
Number of backlog applications	Approximately 3,000 households / Each zone office		

Note:
*Number of registered customers as of May 2021. As the number of customers used in the table does not include customers with no water meters, it doesn't necessarily match the total number of customers.
** ( ) is the number of households per employee.
Source: Prepared by JST based on interviews with BWB

A manual for meter readings or disconnection of arrears has not been formulated, but "Policy and Procedure Statements" is equivalent to the manual. The date that "Policy and Procedure Statements" was formulated is as old as July 2014, and it was observed that the contents are closer to the allocation of duties rather than a manual.

BWB operates two pricing systems for settlements at the same time. One is the postpaid meter (EDAMS) and the other is the prepaid meter (RAPIS). Both the billing officer and the meter reading and disconnection technician require relevant skills to operate these two systems correctly. However, there are no manuals for the operation of either system.

2-4-4 Study into Staffing Structure and System (Human Resource Development), and Abilities and Technical Level of Staff

The abilities and technical level of BWB staff are considered below.

(1) Water Treatment Plant (WTP) Operation/Dam Water Source Management

The existing WTPs have deteriorated and they do not have sufficient capacity to be operated properly. To cope with this problem, BWB has been making imaginative and creative efforts at the existing facilities, but they are in a situation where excessive operations are forced upon the water treatment process, for example with carry-over in the sedimentation basins and the formation of mud balls in the filtration ponds.

Therefore, in addition to facility upgrades for appropriate water treatment processes, it is necessary to train personnel in water treatment technology and implement an appropriate water treatment management.

There are currently no engineers who specialize in dam management in regard to dam water sources.

BWB has identified the shape and volume of sediment, but not done observations on reservoir water levels and inflow, which are needed for reservoir operation plans, and the data for considering reservoir plans such as at this time is insufficient. The dam was constructed in 1955, and currently the water intake tower is both aging and in need of improvement. Therefore, the organizational capacity for dam management is poor.

(2) Water Transmission & Distribution Pipe and Facilities/Equipment Replacement

Pipe line rehabilitation work is ordered as contract work, however, as a construction management manual is not utilized, the supervisor does not have sufficient leadership skills for dealing with contractors. It is deemed necessary to improve the technical skills of staff members through the preparation of a useful manual.

With regard to facility/equipment rehabilitation, it was confirmed in this survey that the proposals and reports from development partners had not been studied in detail within BWB. For example, there was no one in charge who could clearly answer questions from the JST on matters such as the selection of pumps, the selection of pipe diameters, and plans concerning solar power generation. If left as it is now, BWB will be forced to procure various things without question as per the plan prepared by each development partner, and the management will only become more difficult by incurring unnecessary debts. It is necessary for the staff of BWB to strengthen the ability to judge plans and proposals with their own eyes rather than blindly accepting them, and to have the ability to discuss the necessity of proposals for BWB. To achieve this, they need to improve the quality of their work as engineers.

(3) Measures against NRW

The NRW section utilizes the automatic calculation software of Liemberger & Partners GmbH for the water balance analysis, however the accuracy concerning what has been inputted for each item is not guaranteed. Accurate water balance analysis is possible by understanding the software and improving the accuracy of inputted items. The flowmeters installed at Walker's Ferry WTP, Chileka relay pump station and Mudi WTP are the diversion of the ultrasonic flowmeters already owned by BWB, however they do not meet installation conditions (upstream side 10D and downstream side 5D) and have to be verified with regard to measurement accuracy. It can be commended that BWB has the attitude of not procuring expensive electromagnetic flowmeters, and it makes effective use of the equipment BWB has, but it is not the situation where it is possible to say that the level of technology is sufficient.

The countermeasures against illegal connections in cooperation with each zone office can be commended.

(4) DMA Management

All DMAs set by zone offices cannot ensure hydraulic isolation. The reasons for this, such as the failure of the bulk meters (which don't meet DMA requirements) and it has not been possible to manage water pressure, are understandable, but it must be said that the skills for managing DMA are insufficient.

(5) Water Leakage Repairs and Small-size Pipeline Upgrades /New Service Connections

The technical staff members at zone offices carry out work, for example "repairing water leaks" and "new service connections," with insufficient tools and materials, but it is difficult to appraise these staff members as having "high technical capabilities" as there are cases where incorrect construction methods are used. However, the wisdom and ingenuity that can be found at each office can be commended. Since employees are generally diligent, it is believed that improvements can be made by providing them with training in regard to correct construction works and by giving them sufficient tools and materials.

(6) Meter Readings, Settlements and Disconnection of Water Supply for Arrears

Staff involved in water tariff work, including meter readers and payment supervisors, are not conscious about problems in the processes of meter reading and payments. The current situation is one in which just the billing process is overly executed, and staff are satisfied with that "only the tariff recovery rate is high". The cause of this was also brought into sharp relief in workshops organized by volunteer staff from YWWB in 2017 and 2018 where it was found that "there are no manuals" and that "training is insufficient." It is believed that it is urgent to establish a system in which there are highly accurate meter readings/payments/billing operations through preparation of meter reading and payment manuals and by improving training.

(7) The need for operational manuals and training systems to improve technical skills

It was confirmed through the Survey that, while a human resource development plan had been formulated, a manual for each work had not been prepared and the training system had been inadequate. New employees learn their work by following experienced employees doing their work, since there is not any systematic training.

This method of learning leads to a risk that what experienced employees are doing could be accepted as "right", which has the hidden danger of incorrect knowledge being acquired by inexperienced employees.

In addition, if employees gain and accumulate tacit knowledge rather than formal knowledge, this leads to a risk of the loss of technical skills that should have been inherited before experienced employees retire, etc., meaning that converting this tacit knowledge to formal knowledge is an urgent challenge.

For having a countermeasure against this, there is a need to establish a human resources development system that has a series of cycles: the formulation of a range of operation manuals, passing down technical skills through training, and achievement evaluation by means of capacity assessment of employees.

2-5 Current Status of Water Supply Service in BWB

2-5-1 Water Production and Water Consumption

(1) Water Production

The JST compiled the water productions from 2003 to 2020 by the WTPs as shown in Table 2-5.1. The combined design capacity is 133,000 m^3/day, while average water productions totaled to about 89,000 m^3/day in the past five years. Due to drawdown of water levels in the dam and river, the rate of actual water production is about 67 % of the design capacity. The actual water productions in Mudi WTP and Nguludi WTP in particular are remarkably low at about 34% and 37% of the design capacity respectively.

Table 2-5.1 Water Production in each WTP

Year	Water Production Volume (Million m^3)				Daily Water Production (m^3/day)			
	Walker's Ferry	Mudi	Nguludi	Total	Walker's Ferry (Design Cap.: 96,000)	Mudi (Design Cap.: 17,000)	Nguludi (Design Cap.: 20,000)	Total (Design Cap.: 133,000)
2003	30.61	3.25	-	33.86	83,863	8,904	-	92,767
2004	26.52	2.25	-	28.77	72,658	6,164	-	78,822
2005	27.03	3.57	-	30.60	74,055	9,781	-	83,836
2006	26.90	2.09	-	28.99	73,699	5,726	-	79,425
2007	25.48	3.90	-	29.38	69,808	10,685	-	80,493
2008	26.64	2.00	-	28.64	72,986	5,479	-	78,466
2009	27.47	2.40	-	29.87	75,260	6,575	-	81,836
2010	28.07	1.97	-	30.04	76,904	5,397	-	82,301
2011	28.68	2.23	-	30.91	78,575	6,110	-	84,685
2012	28.24	2.42	-	30.66	77,370	6,630	-	84,000
2013	25.30	2.90	-	28.20	69,315	7,945	-	77,260
2014	21.33	2.37	-	23.70	58,438	6,493	-	64,932
2015	20.60	1.60	-	22.20	56,438	4,384	-	60,822
2016	28.18	2.12	-	30.30	77,205	5,808	-	83,014
2017	26.30	1.40	-	27.70	72,055	3,836	-	75,890
2018	26.50	2.10	-	28.60	72,603	5,753	-	78,356
2019	-	-	-	33.50	77,012*	6,295**	-	85,085
2020	-	-	-	33.50	80,904*	7,142**	7,422***	95,468
Average Water Production in the Past Five Years (m^3/day) (2016 and 2020)					75,956 (85.2%)	5,767 (6.5%)	7,422 (8.3%)	**89,145 (100%)**
Rate of Actual Water Production (Average between 2016 and 2020) to Design Capacity (%)					79.1	**33.9**	**37.1**	**67.0**

Source: The Annual Report of BWB and Operation Data of Nguludi WTP

Note:

* Since water production data of Walker's Ferry WTP in 2019 and 2020 were not compiled in BWB, they were calculated deducting the water production of Mudi WTP and that of Nguludi WTP from the total water production.

** The data was provided by Mudi WTP

*** 7,422 m^3/day is the data for a few months. For reference, about 10,500 m^3/day is produced in 2021.

(2) Water Consumption

Table 2-5.2 shows the water production and the water consumption from 2018 to 2020. The water consumption is about 43,700 m^3/day in 2020 but the water consumption does not include that of the customers (about 15,000 customers) whose service pipelines have been disconnected due to cases where there are arrears or where water meters have not been installed. The actual water consumption is estimated to be about 10,000 m^3/day (70 - 80 LCD x 15,000 households x 8 person / households) in maximum higher than the water consumption data shown in Table 2-5.2, considering the actual number of customers as of 2021.

Table 2-5.2 Water Production and Water Consumption

No.	Items		2018	2019	2020
1)	Water Production (m^3/day)	-	78,356	85,085	95,468
2)	Water Consumption based on Raw Data (m^3/day)	-	45,429	41,563	**43,678**
3)	NRW (m^3/day)	1) – 2)	32,927	43,522	51,790
4)	NRW Ratio (%)	(1) – 2)) / 1) x 100	42.0	51.2	54.2

Source: Prepared by the JST based on The Annual Report of BWB, Operation Data of Ngludi WTP and the billing data provided by the billing section

2-5-2 Dam Water Source and Raw Water Yield

Table 2-5.3 indicates the monthly raw water intake quantity at Mudi Dam from 2018 to 2020 obtained from BWB. The range of daily water intake varies from approximately 8,800 m^3/day to approximately 4,700 m^3/day.

Table 2-5.3 Monthly and Daily Average Raw Water Yield at Mudi Dam

Month/Year	2018	2019	2020	Total (m^3)	Monthly Average (m^3/month)	Daily Average (m^3/day)
Jan.	111,915	98,552	225,669	436,136	145,379	4,690
Feb.	154,582	67,316	245,218	467,116	155,705	5,502
Mar.	255,074	167,824	273,178	696,076	232,025	7,485
Apr.	240,496	261,129	251,870	753,495	251,165	8,372
May	259,684	270,126	11,592	541,402	180,467	5,822
Jun.	268,955	214,704	N.A.	483,659	241,830	8,061
Jul.	241,199	239,945	N.A.	481,144	240,572	8,019
Aug.	262,680	244,873	N.A.	507,553	253,777	8,186
Sep.	251,155	261,843	N.A.	512,998	256,499	8,550
Oct.	171,659	263,052	305,960	740,671	246,890	7,964
Nov.	180,923	226,482	387,322	794,727	264,909	8,830
Dec.	130,939	162,833	513,583	807,355	269,118	8,681
				Annual Total	2,738,336	90,162

Source: BWB

The JST separated out the raw water yield from Table 2-5.3 into rainy and dry season as shown in Table 2-5.4. It shows that there is not much difference in raw water yield between rainy and dry season.

Table 2-5.4 Range of Water Intake by Seasons

Season	Raw Water Intake Quantity (m^3/day)	Remarks
Rainy Season	8,830 - 4,690	From November to April
Dry Season	8,550 - 5,820	From May to October

Source: Prepared by the JST based on financial statements obtained from BWB

2-5-3 Service Areas

Table 2-5.5 shows a list of service reservoirs and summarized the service areas by for each of the service reservoir in Blantyre city. Figure 2-5.1 shows the service areas and their supply hours.

Table 2-5.5 List of Service Reservoirs in Blantyre City

No.	Name	Purpose	Storage Capacity (m^3)	Distribution Area
1	Walker's Ferry	Clear water tank	5,120	
2	Chileka	Clear water tank	4,551	
3	Chileka village / Airport	Reservoir	146+370	Lunzu
4	Kameza	Reservoir	5,000	Chileka, Lunzu, Ngumbe, Kameza, NGUMBE, Matindi
5	South Lunzu	Reservoir	5,749	Machinjiri, South Lunzu
6	Nyambadwe	Reservoir	13,500	Ginnery Corner, Kampala Manase, Mandala, Manyowe, Mount Pleasant, Nancholi & Baluti area, Naperi, New Naperi, Old Naperi, Soche East, Sunnyside, Zingwangwa , Zingwangwa Newlines, Blantyre Central, Chemusa, Chilomoni, Kabula Hill, Namiwawa, Nyambadwe High Pressure, Nyambadwe Low Pressure Zingwangwa, Sigerege, Mbayani
7	Ndirande	Reservoir	14,162	Ginnery Corner, Makata Industrial Estate, Njamba, Nkolokosa, Ndirande Newlines, Ndirande THA, Ndilande-Malaysia
8	Chirimba	Reservoir	2,250	Chapima Heights, Chirimba Industrial Area, Chirimba THA, Chilimba, Kameza, Likhubula, NGUMBE
9	Mt. Pleaant	Reservoir	2,500	Chikwawa Rd, Manase, Mpemba, Nancholi & Baluti area, Ntonda
10	Sanjika	Reservoir	600	Presidential Palace
11	Unicef	Reservoir	500	Ndirande Unplanned
12	Sochi (Chimwankhunda)	Reservoir	5,000	Chimwankhunda, Chimwankunda Newlines, Green Corner, Manja, Naotcha, Njamba, Nkolokosa, Ntonda, Angello Goveya, Chigumula, Chiwembe, Kanjedza, Manje, Soche Misesa
13	Mudi	Clear water tank	2,379	
14	Chichiri	Reservoir	4,958	Central Area, Limbe Central, Maoni, Maselema, Mudi Estate, Nkolokoti
15	Kanjedza	Reservoir	9,092	Chimwankhunda, Chilobwe, Chimwankunda Newlines, Manja, Njamba, Nkolokosa, Angello Goveya, Bangwe, BCA HILLS, Chigumula, Chinyonga, Chiwembe, Kanjedza, Limbe Central, Manje, Ngludi, Soche Misesa
16	Bangwe Clinic	Reservoir	305	Bangwe
17	B.C.A	Reservoir	252	BCA HILLS
18	Chigumula	Reservoir	5,000	Bvumbwe, Chigumula
19	Zomba road	Reservoir	9,000	Chichiri, Khama, Limbe Central, Maselema, Mudi Estate, Namiyango, Nkolokoti
20	Upper mpingwe	Reservoir	743	Mpingwe
21	Lower mpingwe	Reservoir	900	Chiradzulu, Kachere, Mapanga,
22	Mpingwe	Reservoir	5,000	
23	Mguludi	Clear water tank	240	
	Total		97,317	

Source: Prepared by the JST based on financial statements obtained from BWB

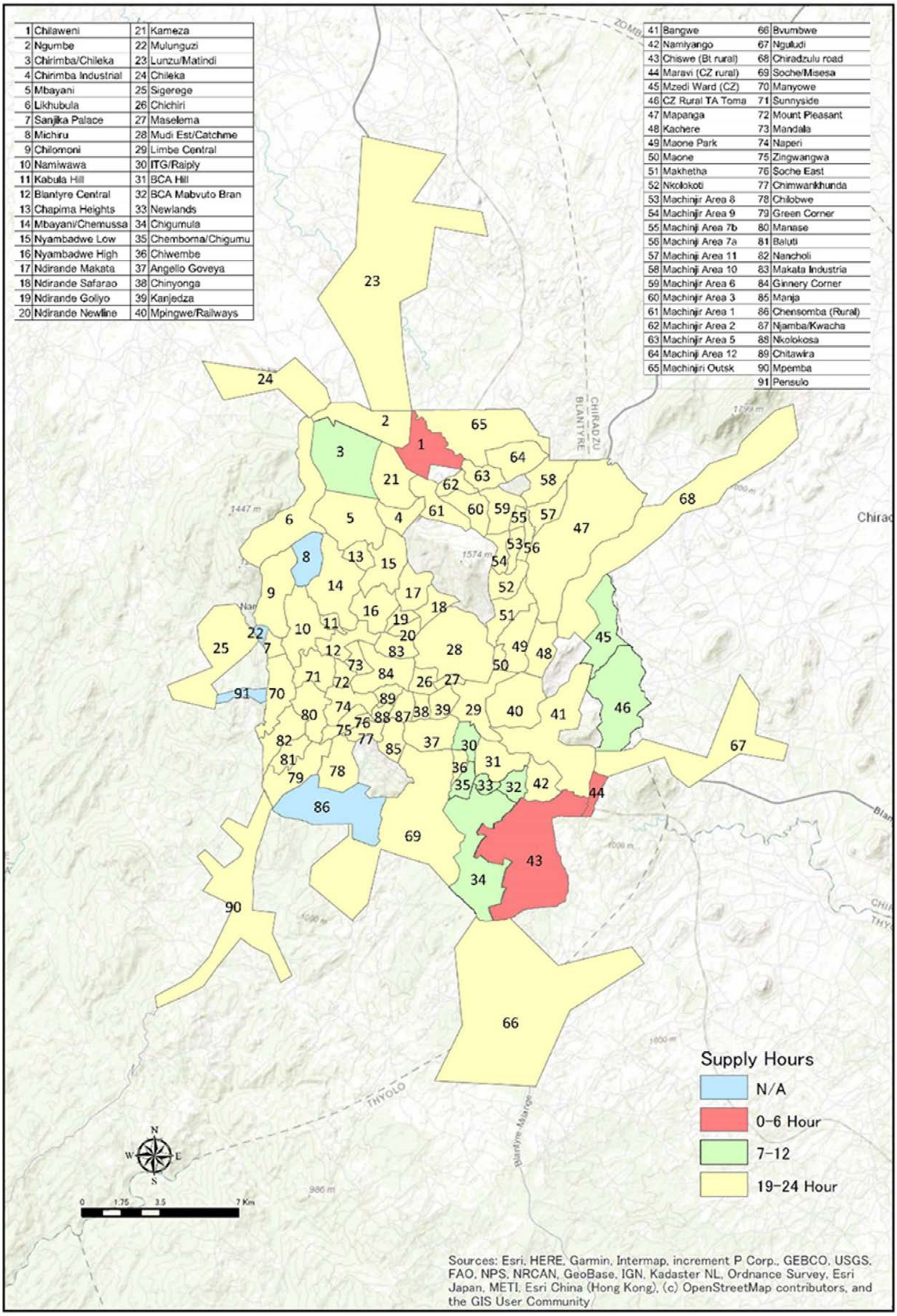
2-5-4 Supply Hours

The BWB's service areas consist of 91 areas. Supply hour data for the four areas are currently not available. Water is supplied for at least 19 hours daily in the 76 areas which make up about 83.5% of the total areas serviced by BWB as shown in Table 2-5.6. Figure 2-5.1 also shows the distribution of water rationing in the BWB's service areas. The service areas where BWB is responsible for water supply, consists of urban and suburb. The areas like 11 service areas where water supply hours is short belong to suburb. The JST speculated that inappropriate water pressure and leakage control cause short supply hours. However, BWB needs a furthermore survey to identify the exact causes.

Table 2-5.6 Supply Hours by Zones

Zone	Number of Areas	Supply Hours				
		0-6	7-12	13-18	19-24	N/A
Soche Zone	22	0	0	0	20	2
Kabula Zone	25	1	1	0	21	2
Limbe Zone	44	2	7	0	35	0
Total	91	3	8	0	76	4
	100.0 %	3.3 %	8.8%	0.0 %	83.5%	4.4%

Source: BWB



Source: Prepared by JST based on the result of interview with BWB

Figure 2-5.1 Service Area Map in BWB Management Area

2-5-5 Customer Service

BWB has been tackling the enhancement of customer service functions by utilizing ICT. The initiatives have been underway to improve convenience for customers, for example, making it easy for customers to inquire bills through the BWB's homepage, to pay water tariff by mobile phone and to submit new water supply applications via the website.

Facebook is actively used for public relations, in addition to posts with information about construction work, water outages, and disconnection of water supply for arrears on the website.

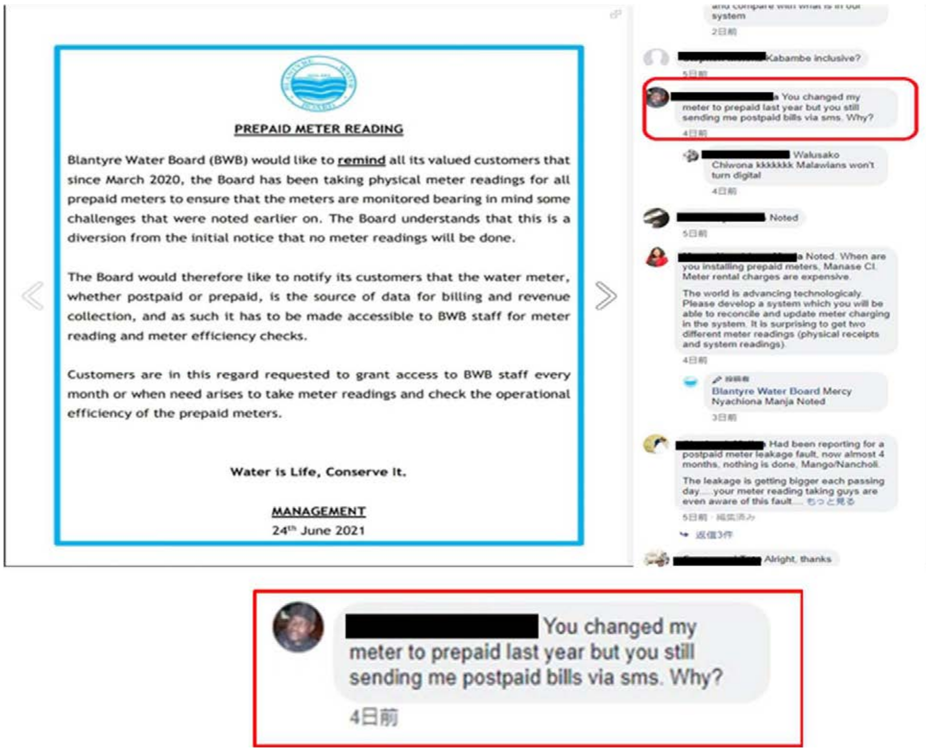
BWB has attempted to make services more convenient for customers by increasing the number of tariff payment locations and by setting up the prepaid meter token purchase locations for 24 business hours. A toll-free call center was established in 2019, and its ability to handle inquiries has been strengthened.

BWB published the customer service charter, and is striving to improve customer satisfaction. The BWB Strategic Plan 2020-2025 states that in 2020, the baseline year, customer satisfaction was 35%, and the company's objective is to reach 80% by 2025, the final year of the plan.

2-5-6 Linking of Pricing Systems

The interviews with each department during the second survey revealed that the EDAMS pricing system for postpaid meters and the RAPIS pricing system for prepaid meters are not linked with each other. System linkage is indispensable for BWB, when there are multiple pricing systems deployed.

In fact, in June 2021, when BWB posted a cooperation request on Facebook for prepaid meter customers to allow the reader to enter their premises and to read water meters, a customer responded that "I switched to a prepaid meter last year, but I am still receiving postpaid meter bills" (double billing). System integration would have prevented the mistake of invoices issued for the same customer from both systems. The relevant information at that time is shown in Figure 2-5.2.



Source: BWB Facebook

Figure 2-5.2 Double Billing Complaints from Customers

2-5-7 Implementation Status of NRW Measures

BWB confirmed the current status of NRW in terms of the following points:

(1) Definition of NRW;
(2) Categories of NRW;
(3) Current evaluation of NRW;
(4) Progress of NRW reduction.

(1) Definition of NRW

Table 2-5.7 shows the water balance sheet (average in 2020) of BWB based on the definition of International Water Association (hereinafter referred to as "IWA"). In general, NRW is composed of "Unbilled Authorized Consumption", "Apparent Losses (Commercial Loss)", and "Real Losses (Physical Loss)". Through the Survey, the JST confirmed that NRW in the BWB' water supply service is based on the IWA's definition. However, the basis of physical and commercial loss is not clarified.

Table 2-5.7 Water Balance Sheet of BWB based on the IWA Definition

System Input 91,775 m3/day Error Margin [+/-]: 5.0%	Authorized Consumption 43,099 m3/day Error Margin [+/-]: 0.1%	Billed Authorized Consumption 42,771 m3/day	Billed Metered Consumption 42,771 m3/day	Revenue Water 42,771 m3/day
			Billed Unmetered Consumption 0 m3/day	
		Unbilled Authorized Consumption 329 m3/day Error Margin [+/-]: 8.3%	Unbilled Metered Consumption 55 m3/day	Non-Revenue Water 49,004 m3/day Error Margin [+/-]: 9.4%
			Unbilled Unmetered Consumption 274 m3/day Error Margin [+/-]: 10.0%	
	Water Losses 48,676 m3/day Error Margin [+/-]: 9.4%	Commercial Losses 32,361 m3/day Error Margin [+/-]: 13.5%	Unauthorized Consumption 1,573 m3/day Error Margin [+/-]: 14.2%	
			Customer Meter Inaccuracies and Data Handling Errors 30,788 m3/day Error Margin [+/-]: 14.2%	
		Physical Losses 16,315 m3/day Error Margin [+/-]: 38.9%		

Source: Prepared by BWB

(2) Categories of NRW

According to the categories such as "1) Physical losses" and "2) Commercial losses", current status of NRW in Blantyre city were summarized below.

1) **Physical Losses**

Table 2-5.8 shows the outline of typical physical losses.

Table 2-5.8 Outline of Typical Physical Losses in BWB

Physical Loss	Characteristics
Existence of deteriorated pipes, especially Asbestos (hereinafter referred to as "AC") pipes	● There are many deteriorated pipes in Blantyre City, although BWB does not accumulated pipeline's specific data, such as pipe installation year and repair records and so on.
Existence of high-pressurized pipelines	● There are undulating land in Blantyre City.
Inadequate construction of distribution and service pipelines, etc.	● There are defects in construction quality. ● There is no budget to repair pipelines.

Source: The JST

a. Existence of aged Pipes, especially AC Pipes

AC pipelines make up about 46% of the total distribution networks in the BWB's water supply system. Unfortunately, specific data, such as the year of pipes installation and repair records were not well organized in BWB. Through an interview with BWB, the JST confirmed that almost all deteriorated distribution pipes in BWB' service areas have exceeded their effective duration.

b. Existence of High-pressurized Pipelines

Picture-1 in Table 2-5.9 shows the conditions of undulating land in Blantyre City. The topography in Blantyre city has elevation ranging between 1,000 m to 1,200 m.

Picture-2 shows Mpingwe service reservoir and the surrounding areas. The service reservoir was constructed in 2019 at the elevation of approximately 1,200m. The water distribution from Mpingwe service reservoir have been suspended because the pipelines were frequently damaged by the highly-pressurized water supplied from the highly elevated service reservoir.

Table 2-5.9 Topographical Feature of Blantyre City (Example)

Picture-1	Picture-2
Example of undulating land 	View at Mpingwe Service Reservoir 

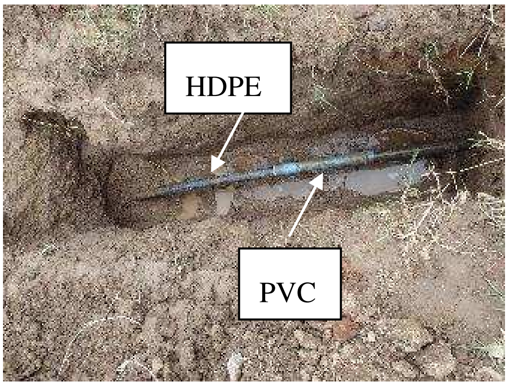
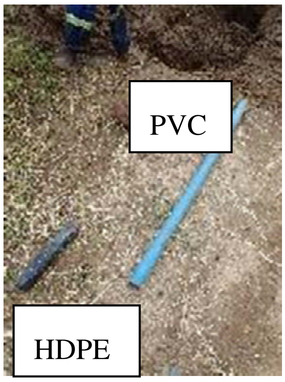
Source: The JST

c. Inadequate Construction of Distribution and Service Pipelines, etc.

Table 2-5.10 shows examples of substandard construction methods identified by the JST through site reconnaissance. The JST confirmed that BWB does not have a budget necessary for pipe repairs and routine pipe rehabilitation work. BWB therefore had to improvise with whatever means possible whenever the need arises to repair burst pipes such as using a piece of pipe in place of a joint fitting as shown in the photograph in Table 2-5.10. This approach of fixing leakages actually creates more leakages instead of minimizing them.

It was also observed that a lot of water supply pipes are placed at shallow depths and or exposed on the surface at numerous locations including road surfaces. These pipes are highly prone to damage by passing vehicles on the road and other means therefore has very short service life.

Table 2-5.10 Issues to be solved for Construction Methods

Construction Methods	Contents
Deformed pipe connection by socket processing on site	Example of deformed pipes: The following pictures show the connection with HDPE and PVC pipe. In case where there are not enough construction materials, or alternative materials would be required. ● Pipe strength will not be ensured, and leakage risk will be remaining ● Connection with meters and deforming pipes increase the risk of leakage  
Water supply pipes laid in shallow depth	Water supply pipes laid in shallow depth and or exposed was observed. ● Pipe will be damaged due to many vehicles, and leakage will occur. 

Source: The JST

2) Commercial Losses

Table 2-5.11 summarizes the outline of typical commercial losses in BWB.

Table 2-5.11 Outline of Typical Commercial Losses in BWB

Commercial Loss	Features
Illegal connections	Vandalism: Facilities broken by taking water Illegal connection: Connecting by-pass pipes to get water illegally
Metering errors	Less quality, deterioration and inadequate calibration of water meters

Source: The JST

a. Illegal Connection

Table 2-5.12 shows the issues of illegal connections faced by BWB that needs solving. BWB is severely challenged by ongoing vandalism to its service infrastructure such as water meters and illegal connections by a large number of customers and water users. This is due to a number of factors including but not limited to weak daily management capacity by BWB and people’s attitude to intentionally steal water. BWB needs to take swift action to educate water users on this issue.

Table 2-5.12 Issues to be solved for Illegal Connections

Illegal Connection	Contents
Vandalism	Function of water management will be stopped due to destruction of several kinds of valves.

Illegal Connection	Contents
Illegal connections by large customers	A part of large customers such as private factories and public schools, etc. are connected to water supply pipe illegally. For example, water meters were installed by house owners to conceal an illegal connection prior to the BWB's inspection. 

Source: The JST

b. Metering Errors

Table 2-5.13 summarizes the issues relating to metering defects that needs to be solved. The Survey has concluded that faulty meters is predominantly due to insufficient maintenance work performed by BWB on its meters.

Table 2-5.13 Issues on Metering Defects

Types of Meters	Characteristics
Battery consumption	There are the difference between the discharge volume measured by digital meter and by analogue meter because of battery runout of digital meters. Digital meter Mechanical meter 
Decline in meter accuracy	Flow rate measured by water meters is seriously different from that measured by accurate mechanical counters. 

Source: The JST

c. Incorrect Meter Readings

According to a report from the 2017 baseline survey of the Chembe DMA carried out by a volunteer from YWWB, the average water use in one district increased from 8 m^3 to 10 m^3 per month when the volunteer accompanied the meter readers for all readings in one district of the DMA (increase in revenue water by 25%).

Moreover, there were cases in which the amount of billed water for certain month was 100-200 m^3, which was extraordinarily larger than the amount of billed water for other month. BWB inspected the meters, but no abnormalities were found. It is implied that the accuracy of meter readings is not guaranteed, since the meter readings may be read arbitrarily.

In the Chembe district, the NRW ratio was 69.3% as of October 2017, but it declined by 49.1% in the following month as of November 2017. This is because meter reading errors were corrected and pipelines were repaired. Since the staff in charge of the meter reading has a duty to report water leakage in upstream of water meters, implementation of accurate water meter readings led to an improvement in the NRW ratio by 20%[6].

d. **Incorrect meter guarantee**

The staff in charge of billing settlements investigate water meters again, if water meter reading data is abnormal based on reports from the water meter readers. However, as described in "c. incorrect meter readings", as long as the accuracy of water meter reading is not guaranteed, it is difficult to ensure the accuracy of settlements.

According to BWB, if water meter readers cannot enter premises of customers having “Gate lock” in expensive residential areas, the average bill amounts for the past three months is charged (which is automatically calculated by the billing system). However, flat bills estimated by the billing system are charged for customers that water meter readers cannot read water meters for a long time. These customers continue to pay flat bills without any water meter readings, but BWB has not examined the measures for eliminating the above flat bill situation.

Revenue water shown in the water balance sheet is the data input in the billing system. Accurate water meter reading makes guarantee of accuracy of water balance analysis. Accurate water meter reading, accurate billing settlements and accurate billing are key elements to collect water tariff. As far as the JST surveyed current situation of the water meter reading and billing department, the management of three elements has not been satisfied.

(3) Current Evaluation of NRW

1) Equipment required for NRW Reduction

Table 2-5.14 shows the list of equipment required to perform NRW reduction activities that are currently in BWB possession. This was also reported by YWWB in 2016. The JST observed through the field activities that BWB’s NRW reduction team which was only recently established in 2021 has limited experience in the use of leak detectors and the other instruments.

Table 2-5.14 List of Equipment required for NRW Reduction Activities

Equipment Type	Specification	No.
Ultrasonic portable flow meter	Filexim F601	2
Pressure meter	Existence of some specifications	17
Noise reduction leakage detector	FUJI TECOM DNR-18	3
Leakage detector	FUJI TECOM LD-7	3
Steel pipe detector	GUTERMANN DETECTION DS82	2
Leak sound listening stick/bar	BWB Directly operation	4

Source: Prepared by the JST based on the data obtained from YWWB report in 2016

2) Evaluation of NRW on Transmission Pipes

Table 2-5.15 shows water flow rate transferred through the transmission pipelines from Walker’s Ferry WTP (No.1), the Chileka relay pumping station (No.2) and the service reservoirs (No.3 No.4, No.6 and No.7). The water flow rates were measured using the water flowmeters installed at the outlet of Walker’s Ferry WTP and the Chileka relay pumping station. Based on the analysis of the monthly water flow rate, the JST confirmed that the NRW ratio was estimated at about 2.0 % as tabulated in Table 2-5.15.

[6] Source: "Activity Report” prepared by YWWB in 2017

Table 2-5.15 Actual Flow Rate in the Transmission Pipe (Walker's Ferry – Chileka)

Section of Transmission	No.1 -No.2	No.2 - No.6/No.7	No.2 – No.4	No.2 – No.3			
Places / Month	Walker's Ferry WTP:A (m^3/month)	Chileka pumping station (m^3/month)				NRW	
		Main pipe	Kameza Booster	Chileka Village	Total: B (m^3/month)	Balance: A-B (m^3/month)	Ratio (%)
Feb 2021	2,460,034	2,206,758	230,479	8,350	2,445,586	14,448	0.6
Mar 2021	2,621,760	2,329,455	230,228	10,864	2,570,547	51,213	2.0
Apr 2021	2,443,521	2,186,282	223,518	11,565	2,421,365	22,156	0.9

Source: Prepared by the JST based on data obtained from BWB

(4) Progress of NRW Reduction

1) Establishment of NRW Reduction Team

BWB established the NRW reduction team in 2021 who has been carrying out the following activities.

a. Tendency of NRW Ratio

Table 2-5.16 shows the tendency of NRW ratio from FY2018 to FY2021. The average NRW ratio in FY 2020 was about 54%. Since FY 2020, the NRW ratio has increased. This is because BWB has been able to measure the flow rate more accurately using a flow meter at Walker's Ferry WTP since the end of FY 2019.

Table 2-5.16 Tendency of NRW Ratio

Month	FY 2018 (Jul 2017 – Jun 2018)	FY 2019 (Jul 2018 – Jun 2019)	FY 2020 (Jul 2019 – Jun 2020)	FY 2021 (Jul 2020 – Jun 2021)
July	48%	39%	54%	54%
August	43%	39%	51%	53%
September	34%	33%	48%	51%
October	33%	32%	57%	49%
November	34%	32%	46%	51%
December	43%	33%	51%	57%
January	39%	40%	53%	57%
February	34%	36%	58%	55%
March	42%	39%	57%	56%
April	41%	41%	55%	N.A
May	39%	39%	59%	N.A
June	38%	39%	54%	N.A
Average	**39%**	**37%**	**54%**	**54%**

Source: Prepared by the JST based on the data obtained from BWB

b. NRW Reduction in Daily Routine Works

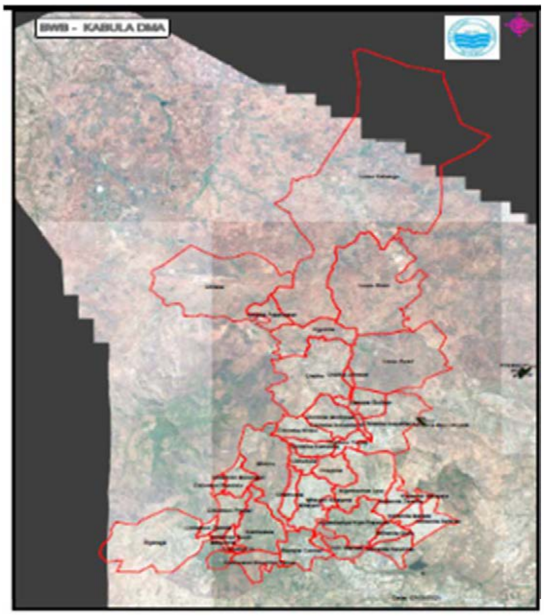
BWB has been attempting to implement the following activities to reduce the NRW as part of their daily routine works. However, due to inadequate human resources and budgets, there is no notable impact on reducing the overall NRW.

- Activities to resolve surface leakage from aging pipes and pipe jointing points
- Water meter replacement and inspection of illegal connection based on reports by citizens

c. NRW Reduction by creating DMA

BWB is in the process of creating DMAs in the water supply service areas with 131 DMAs being the immediate target as shown in Figure 2-5.3. Table 2-5.17 shows example (Data on June 2021 at Soche zone office) of NRW volume and its rate in each DMA, and it is implemented to check the inflow and outflow water flow rate. After completion of DMA's creation, BWB can select DMAs to be prioritized to measure NRW but cannot analyze each commercial and physical loss, based on IWA water balance sheet described in Table 2-5.7.

Regarding section "2)" and "3)" described below, NRW reduction activities have not been sufficiently implemented by BWB, but it is important to take measures to reduce NRW in the long-term.



Source: BWB

Figure 2-5.3 DMA creation by BWB

Table 2-5.17 Example of NRW and its Volume

No	Name of DMA	Date of 1st bulk meter Reading	Date second bulk meter reading	1st Reading	2nd Reading	DMA Input (m^3)	Consumption from individual meter reading (m^3)	NRW (%)
1	Mpemba	7-Jun-21	6-Jul-21	600,661	625,309	24,648	22,204	2,444 (10%)
2	Njamba	7-Jun-21	6-Jul-21	523,134	528,825	5,691	4,930	762 (13%)
3	Green Corner	7-Jun-21	6-Jul-21	146,544	153,333	6,789	5,873	916 (13%)
4	Manja Apostolic	7-Jun-21	6-Jul-21	59,638	76,766	17,128	14,172	2,956 (17%)
5	Sunnyside	7-Jun-21	6-Jul-21	580,678	637,641	56,962	44,997	11,966 (21%)
6	Chichiri	7-Jun-21	6-Jul-21	1,147,686	1,243,324	95,638	74,378	21,260 (22%)
7	MalingaMoyo	7-Jun-21	6-Jul-21	62,724	68,347	5,623	4,365	1,258 (22%)

Source: BWB

2) Distribution Pipe Rehabilitation Plan in BWB

The Infrastructure Planning, and Design and Construction Division are responsible for the rehabilitation of the water supply facilities. However, the divisions have not prepared the BWB's annual construction plan including the whole projects in BWB.

Table 2-5.18 shows the management status of piping materials in the construction sites. Picture-1 shows the management status of necessary materials such as pipes and valves as an example and Picture-2 shows a reuse method of deteriorated AC pipes (When PVC pipes were installed, AC pipe were reused as a protective material to prevent the PVC pipes from exposure).

Table 2-5.18 Management Status of Pipe Materials (Examples)

Picture-1	Picture-2
Pipe materials management in BWB 	Utilization of AC pipes 

Source: The JST

On the other hands, Table 2-5.19 shows the outline of the proposed project related to NRW reduction of BWB. Total length of the deteriorated AC pipes with diameter of at least 75 mm to be replaced is about 460 km (About 80% of total AC pipe length). The total costs were estimated at MWK 16.76 billion (= USD22.5 million).

Table 2-5.19 Proposed Project related to NRW Reduction in BWB

Items	Contents
Ministry	Ministry of Agriculture, Irrigation and Water Development
Name of Project:	NRW reduction through pipe network rehabilitation
Physical Description of the Project:	Target: Replacement of 460 km- AC pipes Construction/ Replacement of 1000 valves and their chambers
Target Area	Blantyre City
Estimated Capital Cost of the Project:	MWK 16,762,500,000 (USD22.5 million)

Source: Prepared by the JST based on the data obtained from BWB

Unit cost which is used for quantity survey on distribution pipelines in Malawi is approximately MWK 25,000/m in average. Considering this unit cost, the JST recognized that the project which is mainly composed of the following works can be carried out in the budget of MWK16.76 billion reasonably.

- Excavation, backfilling, road pavement;
- Removal of the existing pipes;
- Replacement with PVC pipes (460 km).

Therefore, the construction cost for the project was estimated at MWK 11.5 billion (=Unit cost MWK 25,000/m x 460 km), which is lower than original budget of MWK 16.76 billion. However, the annual progress of pipe laying in BWB was about 50-60 km/year in the past. Therefore, it is important to make adequate construction plan.

3) Long-term Education and Enlightenment for NRW Reduction

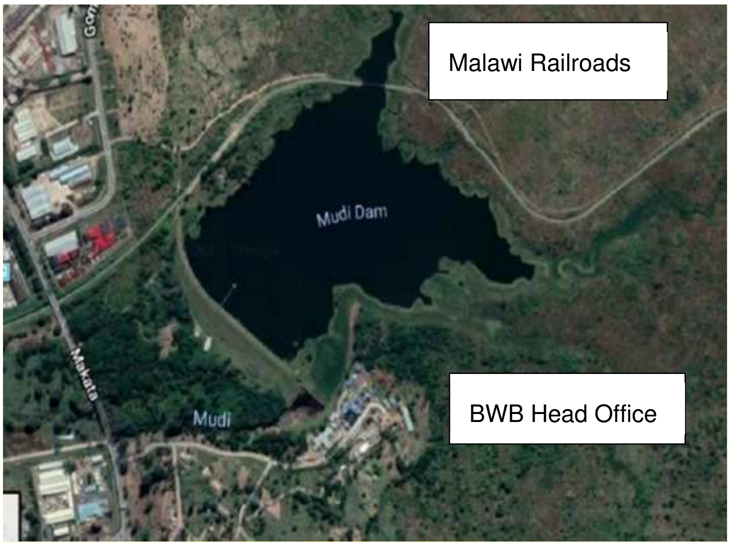
In order to reduce NRW in a short-term period, it is important to conduct daily monitoring and impose strict penalties for illegal connections. At the same time, it is desirable that BWB should realize to take a long-term education and or enlightenment such as the development of awareness brochure and awareness meeting to make users understand the importance of NRW reduction.

2-6 Current Status of Water Supply Facilities and Operation &Maintenance (O&M)

2-6-1 Water Sources (Mudi Dam)

(1) Mudi Dam

Mudi Dam's structure is a rock filled type with a catchment area of 8.9 km^2, height of 15 m, and an effective reservoir capacity of 1.5 million m^3 (when completed in 1955). The plan view of Mudi Dam is shown in Figure 2-6.1.



Source : Google

Figure 2-6.1 Dam Body and Reservoir of Mudi Dam

Detailed information on reservoir of Mudi Dam is shown below.

Table 2-6.1 Detailed Information on Reservoir of Mudi Dam

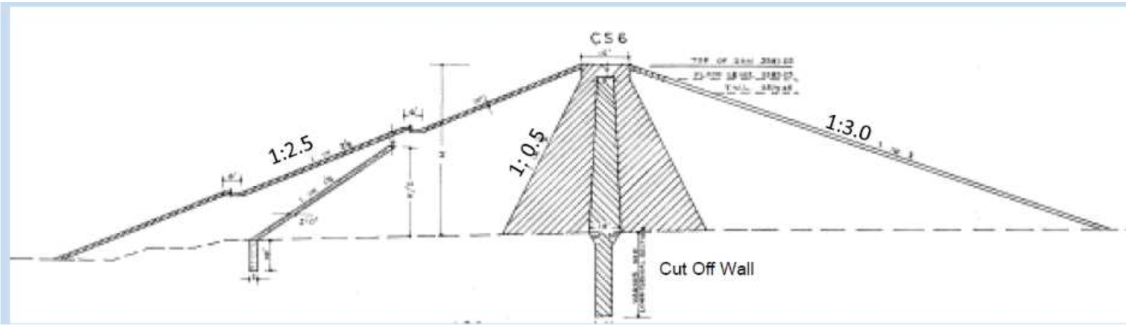
Item	Data	Remarks
Catchment Area	8.9 km^2	
Dam Height	15.0 m	
Effective Storage Capacity	1,500,000 m^3	1955 (Completion year of dam works)
Reservoir Area	25 ha	1,092 m
Top Water Level (TWL)	1,092.95 m	TWL: Top Water Level
Minimum Level for Water Intake	1,080.0 m	Minimum draw off level
Maximum Depth of Reservoir	15.3 m	
Top Level of Spillway	1,090.96 m	

Source: BWB

The key drawings including the dam plan, the typical cross section and cross section along the dam axis are shown in Figure 2-6.2 to Figure 2-6.4.

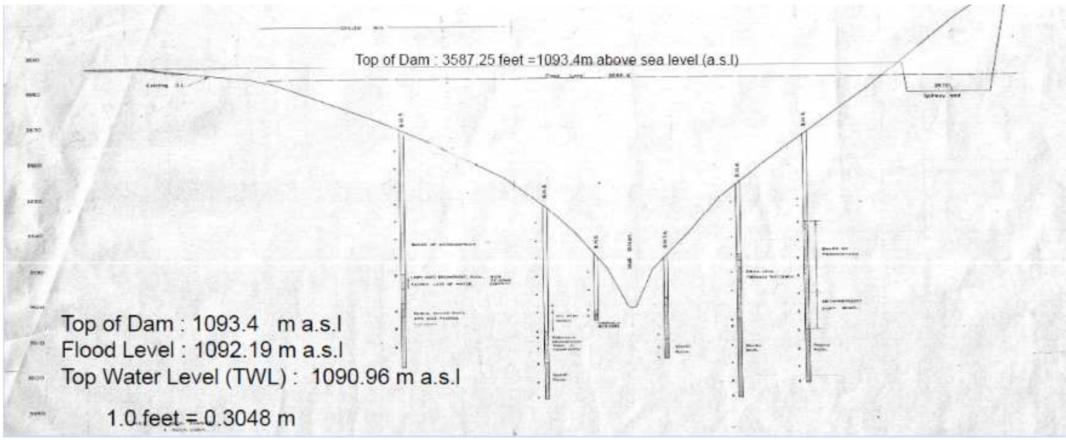
Source: BWB

Figure 2-6.2 Plan of Dam Body and Reservoir in Mudi Dam



Source: BWB

Figure 2-6.3 Typical Cross Section of Dam Body Maximum Cross Section



Source: BWB

Figure 2-6.4 Cross Section along the Dam Axis of Dam Body

According to the Technical Standards for Maintenance of River and Sabo[7] Facilities (Dam Edition) revised by the Ministry of Land, Infrastructure, Transport and Tourism, dam facilities should consist of dam bodies, spillways, and foundations. Specific facilities and equipment associated with dams include the following:

1) Civil engineering structures (dam body, reservoir, and spillways);
2) Mechanical equipment such as outlet works and water intake;
3) Telecommunication equipment such as power supply and communication equipment;
4) Slopes around the reservoir;
5) Monitoring/measurement equipment; and
6) Other maintenance equipment.

Combination of these equipment fulfill the necessary functions to effectively operate any dam facilities. However, out of these equipment, “3) Telecommunication equipment”, “5) Monitoring/measurement equipment”, and “6) other management equipment” have not been installed in Mudi Dam. According to the above classification, the current status and maintenance conditions of Mudi Dam are as follows:

Table 2-6.2 Current Conditions and Maintenance Conditions at Mudi Dam

Facility	Current Conditions	Maintenance Conditions	Remarks
1. Dam body “1)”	Subsidence and water leakage on the embankment were not observed.	Visual inspection has been conducted.	The dam was completed in 1955.
2. Reservoir “1)”	Cumulative sediment volume has increased by about 20% since 1955.	Sediment volume has been monitored through periodical hydrographic	

7 Sediment Disasters Prevention

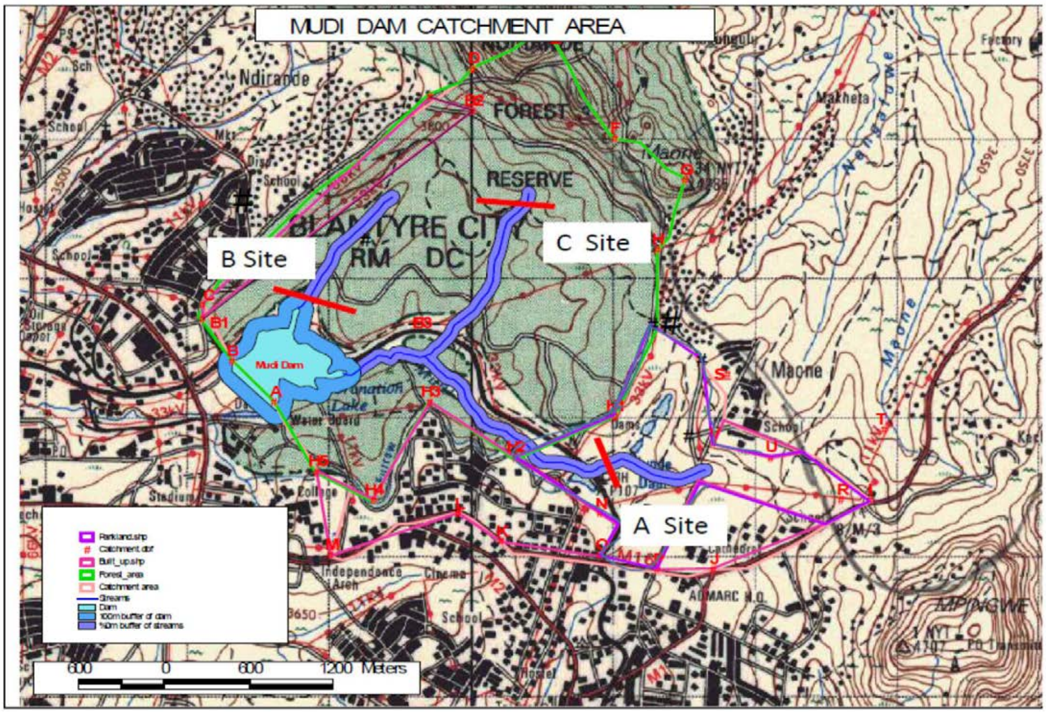
		survey	
3. Spillway “1)”	There are no spillway subsidence and gate damages.	Visual inspection has been conducted.	Water level control Gates were installed in 2001.
4. Intake facility “2)”	In the intake tower, since sedimentation is in progress, raw water can only be taken from the upper inlet out of three stage inlets which are composed of an upper, a middle and a lower inlet.	Regular inspections are being carried out, but countermeasures to remove the sediments have not been taken by BWB.	Rehabilitation plan was examined in 2008.
5. Slopes in the reservoir “4)”	More than 60 years has passed since completion of the reservoir, but the slopes in the reservoir has been stable.	Visual inspection has been conducted.	
6. Catchment	All development activities and housing construction are prohibited to conserve the catchment area.	Regular monitoring of catchment and tree planting have been conducted.	

Source: The JST

The challenge that BWB has with Mudi Dam is the decrease in the of raw water yield due to an insufficient storage capacity and the clogging of the bottom section of the intake tower. The insufficient storage capacity is caused by the accumulation of sediments and less rainfall. The dam infrastructure on the other hand is intact, there are no problems such as subsidence of the dam body and leakage of water at the downstream slope.

(2) Water Quality at Mudi Dam

The JST conducted a rapid water quality test by using the portable water quality meters and the simplified water analysis instrument, that is, “Pack Test”. Water samples were collected from the intake tower of Mudi WTP and also from the three points as shown in Figure 2-6.5. The rapid water quality test results are shown in Table 2-6.3.



Source: The JST and BWB GIS Section

Figure 2-6.5 Sampling Point at Mudi Dam (A, B, C)

Table 2-6.3 Rapid Water Quality Test Results at Mudi Dam

Sampling Date (2021)		Unit	12-May, 2021	1-Jun, 2021	13-May, 2021		7-Sep, 2021	
Water Quality Parameters			Intake Point	Intake Point	Site A	Site B	Site C	Intake Point
Portable Water Quality Meters	Temperature	°C	19.0	19.0	21.0	22.0	20.0	21.0
	pH		8.9	8.4	7.0	7.2	7.4	-
	Electrical Conductivity	µS/cm	174	170	129	156	197	-
	Turbidity	NTU	8.89	5.26	51.3	11.6	15.4	-
Simplified Water Analysis Instrument	Biochemical Oxygen Demand	mg/L	0-20	0-20	20-40	20-40	0-20	0-20
	Total Nitrogen*	mg/L	0.0	0.0	0.0	0.0	0.0	0.0-0.5
	Phosphate Ion	mg/L	0.2 or less	0.5-1.0	0.2-0.5	0.2 or less	0.2 or less	0.2-0.5
	Ferrous Ion	mg/L	0.2 or less	0.2 or less	0.2-0.5	0.2 or less	0.2 or less	0.2-0.5
	Manganese Ion	mg/L	0.2 or less	0.5 or less	0.5 or less	0.5 or less	0.5 or less	0.5 or less
	Chemical Oxygen Demand	mg/L	-	-	-	-	-	8.0 or more

Source: The JST

* Total Nitrogen : The sum of "NO_3^--N", "NO_2^--N" and "NH_4^+-N".

As far as the number of samples was taken at the end of a rainy season, it was observed that low turbidity was detected at the intake and ferrous iron and manganese were not almost detected from Site A to Site C. In addition, since the concentration of total nitrogen and phosphate ion was low in Mudi Dam, it is considered that water quality might have not been affected by agricultural activities and human waste.

Turbidity in Site A exceeded 50 NTU, because mud might be included in the water sampled in the site which is like a wetland. As shown in Table 2-6.3, BOD concentration in all the sampling sites exceeded the environmental standard. The JST analyzed BOD but concluded that the results were just for reference purpose due to the following reasons:

- Sampling points were a wetland, and
- A detection limit of BOD Pack Test is 0-20 mg/L

In September, 2021, the JST analyzed the water quality at the Mudi intake point as the data of dry season. Water quality in a rainy season is not different from that in a dry season significantly in all parameters.

In addition, since Mudi Dam is a stagnant water body, a COD concentration was measured using a low-range water analysis instrument with a detection limit 0- 8.0 mg/L. As a result, the COD showed a maximum value of 8.0 mg/L or more, but this concentration is applied for the Japanese environmental conservation standards for lake and it was observed that water quality of raw water source had been safe at Mudi Dam.

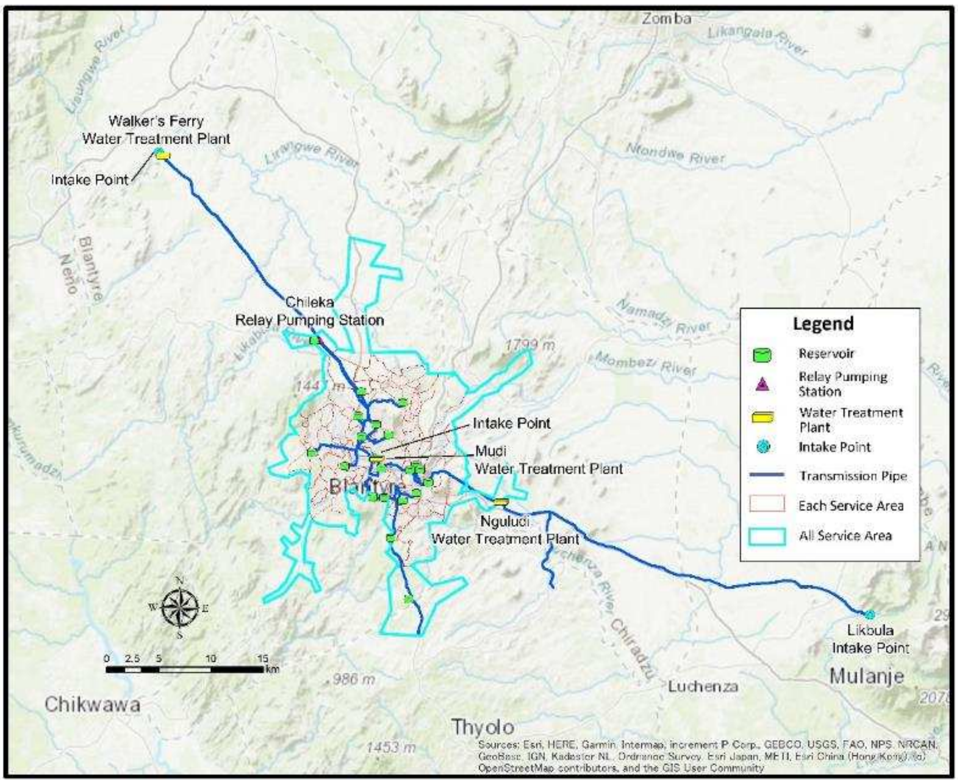
2-6-2 WTPs

(1) WTPs in Blantyre City

BWB established the water supply utility of Blantyre City in 1929. There are three principal water treatment facilities at present namely Mudi WTP, Walker's Ferry WTP and Ngulудi WTP as shown in Figure 2-6.6. Mudi WTP and Mudi Dam which are located in the center of Blantyre City, was constructed in 1955, and Mudi WTP was improved in 1979. Its treatment process is a rapid sand filtration system.

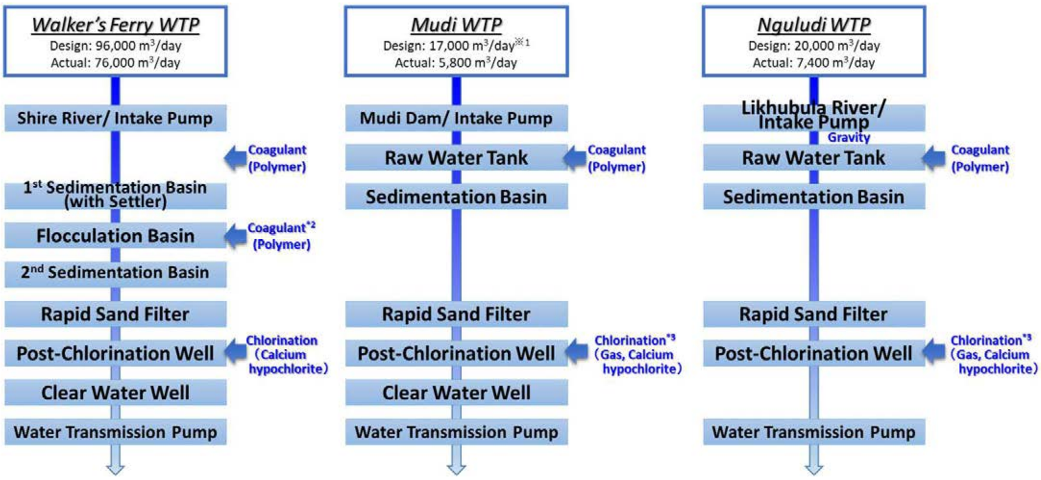
Walker's Ferry WTP which is located approximately 40 km northwest of Mudi WTP, was constructed in 1963 which receives raw water from Shire River. Its treatment process also utilizes rapid filtration system.

Nguludi WTP which is located approximately 20 km southeast from Mudi WTP and was constructed in 2019. The intake facility is located approximately 40 km southeast of Nguludi WTP and is sourcing raw water from Likhubula River is conveyed to Nguludi WTP by gravity. Its treatment process is also a rapid sand filtration system. The treated water is transferred to Blantyre City by transmission pumps from Nguludi WTP. The treatment process diagrams of each WTP are shown in Figure 2-6.7.



Source: Prepared by the JST based on the GIS database obtained from BWB

Figure 2-6.6 Location Map of Water Treatment Facilities in Blantyre City



Source: Prepared by the JST based on result of the field survey

Notes:

1: BWB doesn't have any copies of the design documents and drawings of Mudi WTP as the facility was constructed in 1955. BWB guesstimate the design capacity of Mudi WTP as 45,000 m^3/day because it was written on a plaque at the intake pump station that the maximum operation of the pumps is 45,600 m^3/day as shown in Figure 2-6.8. However, based on the survey results by the JST, the water treatment capacity of Mudi is about 17,000 m^3/day. Decrease in water source potential of Mudi Dam has been caused by sedimentation of silt and exclusion of the catchment areas where water quality deteriorated due to agricultural activities. Capacity evaluation of the existing WTP is described in Section 3-3.

2: The water may be dosed with either Calcium Hypochlorite or chlorination gas in the case of high turbid raw water, if necessary,

3: Calcium hypochlorite is used for treating water in the case where Chlorination Gas is out of stock.

Figure 2-6.7 Treatment Flows of Water Treatment Facility

Source: The JST
Notes: [left] Intake Pumps, [right] Operation Board of Intake Pump Station

Figure 2-6.8 Intake Pump Station and Operation Board

(2) Water Transmission and Distribution to Blantyre City

Water supply from Mudi Dam (located in the center of Blantyre City) would be most efficient and economical-wise in terms of energy use. However, in actual case, Walker's Ferry WTP and Nguludi WTP are utilized since Mudi Dam does not have the required capacity and Mudi WTP deteriorates. BWB therefore had to bear high-operation costs just to supply water to its users when utilizing Walker's Ferry WTPs. Walker's Ferry WTP is located 40 km away from the center of Blantyre city and water from this WTP had to be pumped up to the city center which sits 800 m higher elevation than the above Walker's Ferry WTP.

In addition, the operation costs to supply water produced at Nguludi WTP which has a capacity of 20,000 m^3/day is cheaper than that of Walker's Ferry WTP. However, at present (May 2021), the actual water production at Nguludi WTP is less than 10,000 m^3/day which is half of the design capacity. This is due to a drawdown of water level at the water intake facility in the end of the rainy season. It is unlikely that Nguludi WTP will be extended to become an alternative WTPs.

(3) O&M in Mudi WTP

1) Operating System

The WTPs have the following staffing levels:

- Walker's Ferry WTP (77 staff including 20 in the HR section);
- Chileka Pumping Station (43 staff);
- Mudi WTP (88 staff including 5 staff in the central monitoring room and 40 staff working in small pumping stations and wells);
- Nguludi WTP (17 staff).

The operation control system differs according to the WTP and the pumping station. Walker's Ferry WTP is operated in three shifts, while Mudi and Nguludi WTP in two shifts, according to the annual plan shift table. The working hours per week are set at a maximum of 40 hours under local labor laws, and are adjusted within shifts so as not to exceed these hours. All operations are managed directly by full-time staff but not outsourced. The operation records for each WTP are reported to the headquarters in the form of weekly reports. Table 2-6.4 shows the staffing levels at the WTPs.

Table 2-6.4 WTP Staffing Levels

WTPs / Items	Walker's Ferry	Mudi	Nguludi
Number of staff	77	88	17
Group system	4 groups of 5 persons	4 groups of 4-5 persons	4 groups of 3 persons
Work shift	8 - 16, 16 - 24, 24 - 8 3 shifts	7 - 16, 16 - 7 2 shifts	7 - 16, 16 - 7 2 shifts

Items \ WTPs	Walker's Ferry	Mudi	Nguludi
Operation record	Yes	Yes	Yes
Operation planning manager	Production and Supply Manage	Supply Officer	Supply Officer
Water quality manager	Water Quality Laboratory Technician	Same as left	Same as left
Drug control manager	Water Quality Laboratory Technician	Same as left	Same as left

Source: Prepared by the JST based on the interviews with BWB

A draft of the operation plan is formulated by the managers of each water treatment plant and approved by the technical services director. A water quality laboratory technician in the Water Quality & Environmental Management Section is in charge of the management of water quality and chemicals.

2) Water Quality Management

The water quality and environmental management section is responsible for water quality management. The section consists of (1) a senior quality and environmental officer (one staff); (2) a water quality officer (one staff); (3) an environmental officer (one staff but currently vacant); (4) water quality laboratory technicians (two staff); (5) a laboratory attendant (one staff).

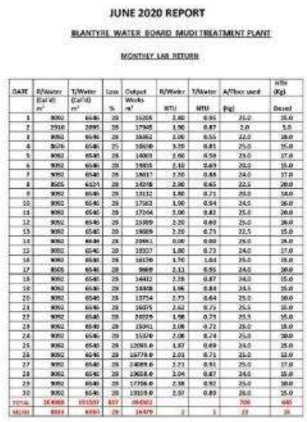
Water quality is analyzed by the laboratory in each WTP during BWB business hours only, but not conducted in night time. Table 2-6.5 shows the current status of water quality management in each WTP.

Table 2-6.5 Water Quality Analysis at Mudi WTP

Water Quality Test Parameters		Water temperature, pH, Color, Residual chlorine (only treated water), Turbidity
Water Sampling Staff		Laboratory Attendant (one staff)
Sampling Points		Raw water (at receiving well), after sedimentation basin, after rapid sand filter (two points.), treated water (at water transmission pumps)
Frequency	Walker's Ferry WTP	Week Day: Every one hour during 8:00-16:30 (Except 12:00-13:00) Holiday: Twice during the morning, Twice in the afternoon
	Mudi WTP	Week Day: Every one hour during 8:00-16:30 (Except 12:00-13:00) Holiday: Twice during 8:00-12:00, Distributed water is analyzed during 13:00-16:30
	Nguludi WTP	Week Day: Every one hour during 8:00-16:30 (Except 12:00-13:00) Holiday: Twice during the morning, Twice in the afternoon

Source: The JST

The water quality & environmental management section records the water quality results in the record books, tabulating the daily average data, submitting to the headquarters at the end of the month as a water quality monthly report as shown in Figure 2-6.9.



JUNE 2020 REPORT

BLANTYRE WATER BOARD MUDI TREATMENT PLANT

MONTHLY LAB RETURN

Notes: [left] Water Quality Analysis at Laboratory, [Center] Record Book for Water Quality, [right] Monthly Report to HQs

Figure 2-6.9 Record Book and Monthly Report

In Mudi WTP, water quality analysis is conducted not only in the WTPs but also in the water distribution network every day. Water quality analysis parameters and sampling points are shown in Table 2-6.6. BWB will manage the designated water sampling points by using GIS in near future.

Table 2-6.6 Water Quality Analysis in the Water Distribution Networks

Water Quality Analysis Parameters	pH, Turbidity, Color, Residual chlorine (only treated water), *E.coli* and *Coliform*
Water Sampling Staff	Water quality laboratory technician (two staff)
Sampling Points (36 points)	Chadzunda, Mpemba, Green Corner, Nancholi, Manase, Sunnyside, Sanjika State House, Sigerege, Chilomoni, QECH, Chichiri, Namiwawa, Blantyre Central, Mt. Pleasant, Mudi Estate, Limbe Central, BCA, Midima, Newlands, Chigumula, Bvumbwe, Nguludi, Chikunda, Bangwe, Namiyango, Makhetha, Nkolokoti, South Lunzu, Chilimba, Kameza, Ngumbe, Ngumbe, Lunzu, Chileka, Mbayani
Frequency	Water quality analysis are conducted on the same day regardless weekdays or holidays. The water quality analysis in the distribution networks is conducted at least 12 points per day and completed in a week.

Source: The JST

Based on the Malawi national water standards and the WHO water quality guideline, BWB conducts a monthly water quality analysis for 21 parameters. The sampling target facilities and the parameters for the monthly water quality analysis are shown in Table 2-6.7.

Table 2-6.7 Monthly Water Quality Analysis in the BWB's Major Facilities

Water Quality Analysis Parameters	pH, Turbidity, EC, SS, TDS, Carbonate, Bicarbonate, Total Alkalinity, Total Hardness, Chloride, sulfate, Nitrate, Phosphate, Calcium, Magnesium, Silica, Manganese, Iron, Sodium, Potassium, Fluoride, Chromium, Lead
Sampling Points	Walker's Ferry WTP, Mudi WTP, Nguludi WTP (raw and treated water), Bvumbwe Boreholes, Lunzu Boreholes
Frequency	The Water Quality and Environmental Management Section takes water sampling in the middle of every month, analyzing all the samples at the BWB laboratory by the end of the month, submitting the analysis results as a water analysis report to the director of technical services by the 5th of the following month.

Source: The JST

BWB conducts a surface water pollution monitoring once every four months at Shire River, and its source (Lake Malawi) which are the water source of Walker's Ferry WTP.

Table 2-6.8 Surface Water Pollution Monitoring

Water quality Analysis Parameters	Algae, Phosphate, Nitrate
Water Sampling Staff	Lab Technicians, Water Quality Officer
Sampling Points	Nkhata-Bay, Tukombo, Nkhotakota Boma, Senga-Bay, Chipoka, Monkey-Bay, Mangochi, Liwonde, Zalewa
Frequency	Once every four months (e.g. March, June, September, December) The analysis is conducted in the BWB laboratory and results submitted as a water analysis report to the director of Technical Services by the 10th of the following month.

Source: The JST

The JST conducted a basic water quality analysis three times during the 1st field survey to verify the results that BWB analyzed. The results that BWB analyzed and the results that the JST collected at the same time at the same locations and analyzed, indicated a similar tendency as shown in Table 2-6.9. The JST also conducted a basic water quality analysis in Walker's Ferry WTP. The results indicated a similar tendency as well. The JST didn't analyze the treated water quality for Nguludi WTP due to time constraints.

Table 2-6.9 Comparison of Water Quality Analysis (As of 10AM, June 1st 2011)

Sampling Point	Raw Water (Receiving Well)	After Sedimentation Basin	After Rapid Sand Filter-1	After Rapid Sand Filter-2	Treated Water
Turbidity (BWB)	7.41	6.00	1.31	0.99	0.64
Turbidity (JST)	5.26	8.39	8.63	1.58	0.39
pH (BWB)	7.17	7.14	7.10	7.10	7.44
pH (JST)	8.4	7.7	7.6	7.5	7.8

Source: BWB and the JST

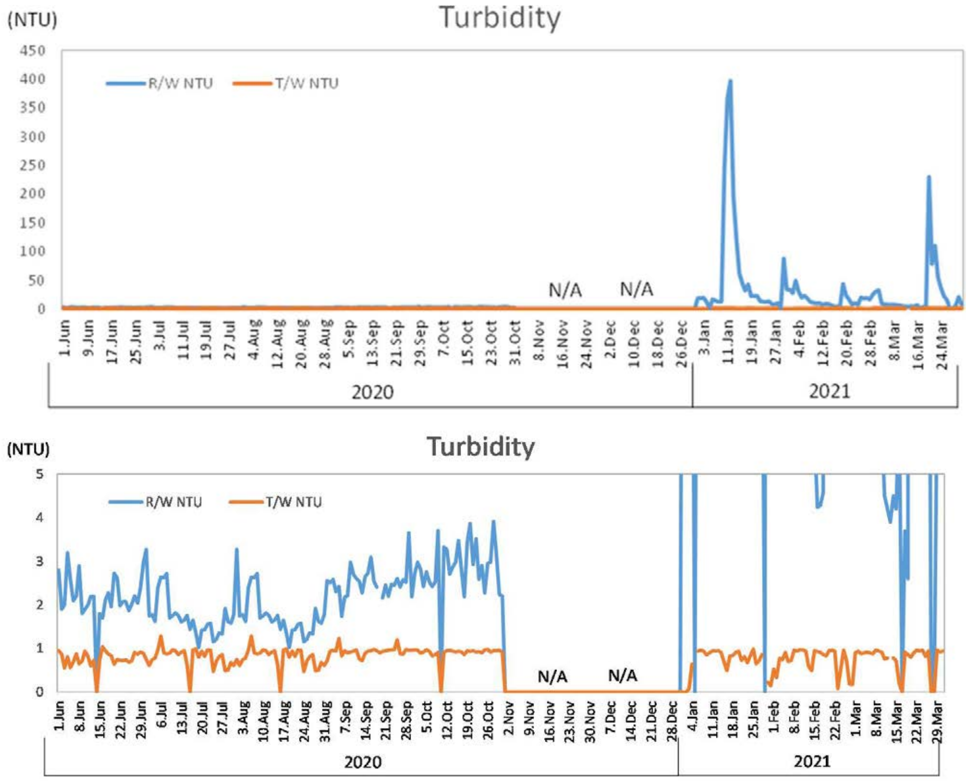
Figure 2-6.10 illustrates the variation in turbidity from June 2020 to March 2021 (10 months) except for November and December 2021 which the data is not available. The average turbidity of the treated water during this period was 0.82 NTU, which aligns with the Malawi national water standards adopted by BWB of less than 1 NTU. However, turbidity exceeding the standard value (maximum 1.29 NTU) was observed on five days out of the above period of 275 days.

According to the interview with BWB, in case that raw water turbidity is high during the rainy season, the Mudi WTP is operated at a reduced intake pump speed, and if significant carryover is observed, the WTP operation is stopped. The standard value of raw water turbidity for deciding to stop operation has not been set.

Turbidity of the raw water during dry season had minimal fluctuation with an average turbidity level of 2 NTU. On the other hand, turbidity of the raw water during rainy season fluctuates significantly with the average turbidity of 37 NTU (maximum 397 NTU).

In order to decrease turbidity, it is necessary to add coagulant into the mixing basins. Performing a Jar test is necessary to determine a dosing rate of coagulant if required. This test must be conducted promptly in case of rapid fluctuations in turbidity of raw water.

BWB has not conducted jar tests since May 19th, 2020. However, it did 18 times (approximately once per week) from November 2020 to February 2021 during the rainy season.



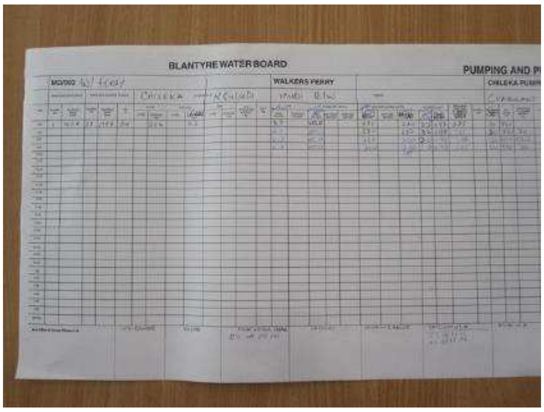
Source: Prepared by the JST based on BWB's Water Quality Records

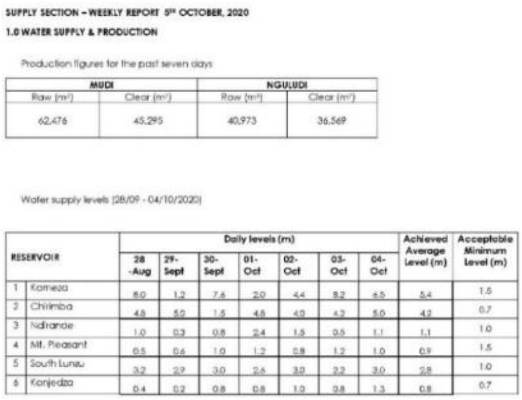
Notes: [Upper] Turbidity Records from June 2020 to March 2021, [Lower] Same as UP (Expanded Y-Axis)

Figure 2-6.10 Variation in Turbidity

3) Operation

BWB manages not only 24-hour operation of Mudi WTP but also entire operation of the water transmission and the distribution system in Blantyre city. Records of a flow rate of WTPs, transmission and distribution system are recorded daily in a log book and submitted to the BWB headquarters as a weekly report as shown in Figure 2-6.11. Data from the other WTPs and pump stations are verbally reported through a radio.





SUPPLY SECTION – WEEKLY REPORT 5th OCTOBER, 2020

1.0 WATER SUPPLY & PRODUCTION

Production figures for the past seven days

MUDI		NGULUDI	
Raw (m³)	Clear (m³)	Raw (m³)	Clear (m³)
62,476	45,295	40,973	36,569

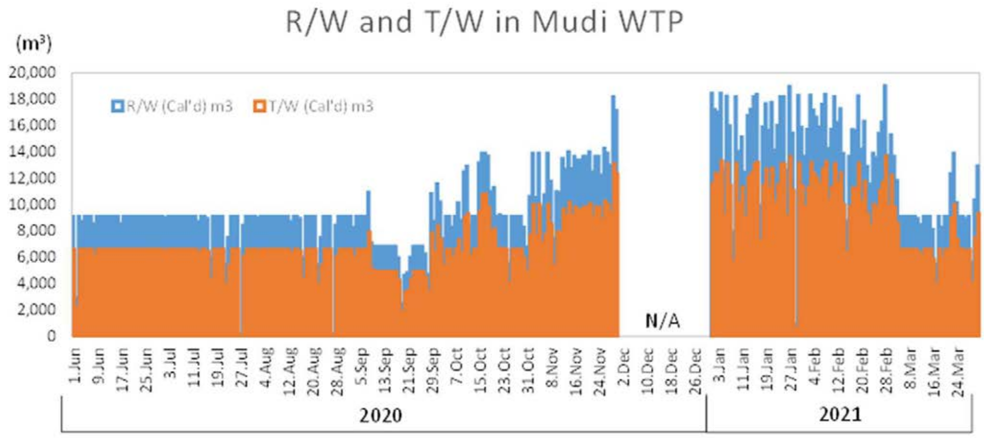
Water supply levels (28/09 - 04/10/2020)

RESERVOIR		Daily levels (m)							Achieved Average Level (m)	Acceptable Minimum Level (m)
		28 -Aug	29-Sept	30-Sept	01-Oct	02-Oct	03-Oct	04-Oct		
1	Kameza	8.0	1.2	7.6	2.0	4.4	8.2	6.5	5.4	1.5
2	Chirimba	4.8	5.0	1.5	4.8	4.0	4.2	5.0	4.2	0.7
3	Ndirande	1.0	0.3	0.8	2.4	1.5	0.5	1.1	1.1	1.0
4	Mt. Pleasant	0.5	0.6	1.0	1.2	0.8	1.2	1.0	0.9	1.5
5	South Lunzu	3.2	2.9	3.0	2.6	3.0	2.2	3.0	2.8	1.0
6	Konjedza	0.4	0.2	0.8	0.8	1.0	0.8	1.3	0.8	0.7

Notes: [left] Operation Record Book, [right] Weekly Report for HQs

Figure 2-6.11 Record Book and Weekly Report

Flow rates of the raw water at Mudi Dam and the treated water at Mudi WTP from June 2020 to March 2021 with the exception of December 2021 data is shown in Figure 2-6.12. During the dry season (June 2020 to October 2020), the average flow rate of the raw water was 8,600 m3/day and the treated water was 6,200 m3/day, while during the rainy season (November 2020 to March 2021), the average flow rate of the raw water was 13,400 m3/day and the treated water was 9,600 m3/day. The average flow rate of the raw water and treated water during the entire period were 11,000 m3/day and 7,900 m3/day, respectively, indicating that the difference between the raw water and treated water flow rate was about 28%, resulting in a large amount of water loss.



Source: Prepared by the JST based on BWB's Operation Records

Figure 2-6.12 Variation in Raw Water and Treated Water Flow

Data on water quality and operation in Mudi WTP was recorded in handwriting. Then, only necessary data for reports to the headquarters was organized, but data required for formulating rehabilitation plans is not.

4) Maintenance

As a daily inspection, water levels of the service reservoirs and injection volume of chemical are recorded every hour. In some of the service reservoirs, a telemetry monitoring system using a solar power generation has been introduced, but it has not been fully utilized because the power supply is not stable.

BWB conducts leak detection and inspection of valve operation panel every month in order to conserve the WTPs, and has the monthly electricity and chemical costs recorded by the water supply officer.

2-6-3 Water Transmission and Distribution Facilities

Table 2-6.10 contains information on the existing transmission pipes including the material type and the total length in the networks. The steel pipes (ST) make up about 73% of the total length of the transmission pipelines. Other pipe information such as construction year and records of repair on each of the pipelines was not properly recorded by BWB. However, the JST was able to confirm that the transmission pipes between Walker's Ferry WTP and Chilek a relay pumping station were laid in 1963. Most of the transmission pipelines in Blantyre city deteriorate.

Table 2-6.10 Existing Transmission Pipes

Pipe Materials	Length (m)	Ratio (%)
Asbestos Cement (AC)	11,197	10.0
Cast Iron (CI)	17,097	15.4
Carbon Steel Pipe (CS)	2	0.0
Galvanized Iron Pipe (GI)	700	0.6
Polyvinyl chloride (PVC)	1,211	1.1
Steel Pipe (ST)	81,382	72.9
Total	111,589	100

Source: BWB

Figure 2-6.13 Deteriorated AC pipes

Table 2-6.11 contains information on the existing distribution pipes. AC pipes make up about 46% of the total length of the distribution pipelines. Similarly with transmission pipes, specific data including the construction year and record of repair on each of the pipelines are not properly organized. Based on discussion with BWB, the JST recognized that almost all distribution pipelines are in a deteriorative state in the BWB' water service area (see Figure 2-6.13).

Table 2-6.11 Outline of Installation Distribution Pipes

Materials	Length (m)	Ratio (%)
Asbestos Cement (AC)	564,256	46.3
Cast Iron (CI)	4,199	0.3
Carbon Steel Pipe (CS)	98	0.0
Galvanized Iron Pipe (GI)	203,951	16.7
High Density Polyethylene (HDPE)	177.960	14.6
Polyvinyl chloride (PVC)	265,183	21.8
Steel Pipe (ST)	265	0.1
Others	2,539	0.2
Total	1,218,451	100

Source: BWB

2-6-4 Water Service Pipelines

There are two types of water meters: postpaid (conventional) water meter and prepaid water meter. Table 2-6.12 shows number of customers by water meter type as of 2020. The customers in postpaid make up about 67% of total customers.

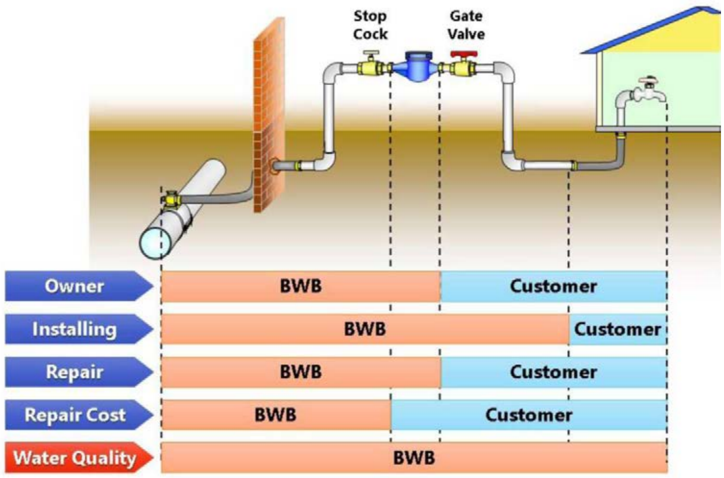
Table 2-6.12 Number of Customers by Water Meter Type (Year 2020)

Water Use	Type of Customers	Postpaid	Prepaid	Total
Domestic	House connections	35,263	17,866	53,129
	Kiosks	461	242	703
	Sub-total	35,724	18,108	53,832
		66.4%	33.6%	100.0%
Non-Domestic	Institution	678	298	976
	Commerce	1,182	316	1,498
	Industry	105	7	112
	Sub-total	1,965	621	2,586
		76.0%	24.0%	100.0%
Total		37,689	18,729	56,418
		66.8%	33.2%	100.0%

Source: BWB

BWB has a policy of scaling-up prepaid meters throughout Blantyre city due to concerns that the ratio of water tariff collection is much lower in postpaid meters. However, the price (USD240) of the prepaid meter used by BWB is six fold higher than that (USD 40) of postpaid meter. In addition, there are fears that an excessive reliance on prepaid meters is one of the reasons for an increase in illegal connections due to less inspection. At present, a policy to undertake meter readings for prepaid meter customers has been announced, and it is believed that illegal connections can be suppressed.

Figure 2-6.14 shows conceptual diagram of water service pipelines and O&M responsibility between BWB and customers.



Source: "Construction Management Manual & Standard Operating Procedures"

Figure 2-6.14 O&M Responsibility of Service Pipelines between BWB and Customers

1) Each water service pipeline is fitted with a stop cock and a gate valve where BWB and the customer manages them respectively.

2) It has been observed that much of the leakage occurs around water service pipelines.

2-6-5 Hydraulic Analysis

The JST conducted the hydraulic analysis focused on the BWB water supply service in following processes, based on the water demand data in 2020 and 2030.

(1) Setting of Basic Conditions (Based on Data in 2020)

Table 2-6.13 and Figure 2-6.15 shows the basic conditions and the schematic drawing for hydraulic analysis respectively. Based on Figure 2-6.15, the JST prepared a hydraulic analysis model using "EPANET Ver. 2.2" as shown in Figure 2-6.16.

The JST used the planned data obtained from BWB and the actual data checked through site reconnaissance for analysis as shown in Table 2-6.14, Table 2-6.15 and Table 2-6.16. However, the remarks in hydraulic analysis model and pumping stations are as follows:

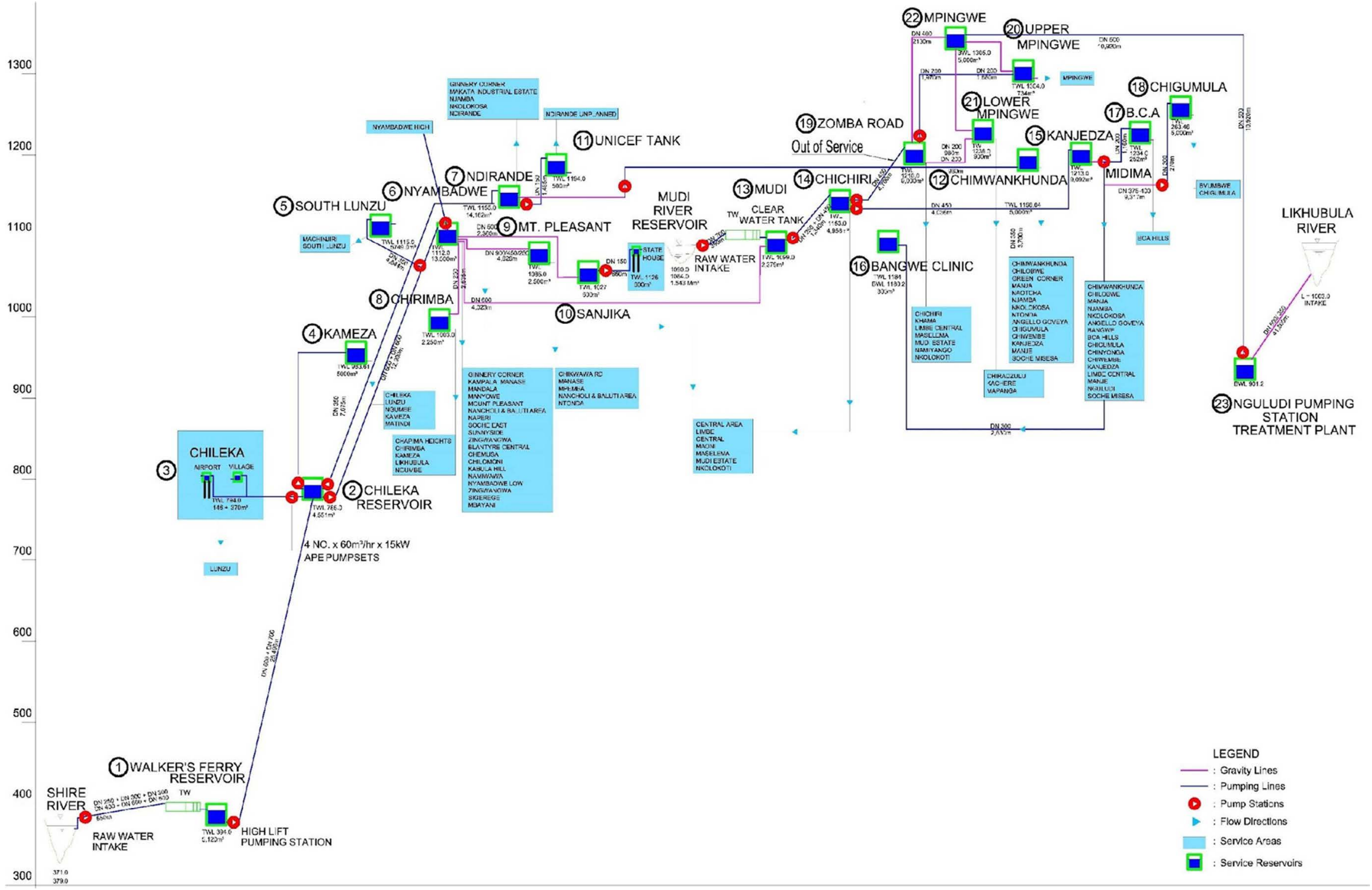
1) Water transmission pipe between No. 14 Chichiri and No. 19 Zomba road (See Figure 2-6.16): the water transmission is operated in case of only water scarcity, after construction of Nguludi WTP in 2019. Therefore, the hydraulic analysis does not include these pipelines.

2) Pumping stations (See Table 2-6.15): the JST analyzed networks based on the actual numbers of pumps operating, since some of pumps have not been operated due to budget constraint and insufficient spare parts.

Table 2-6.13 Basis Conditions for Hydraulic Analysis (Planned data of the existing facilities)

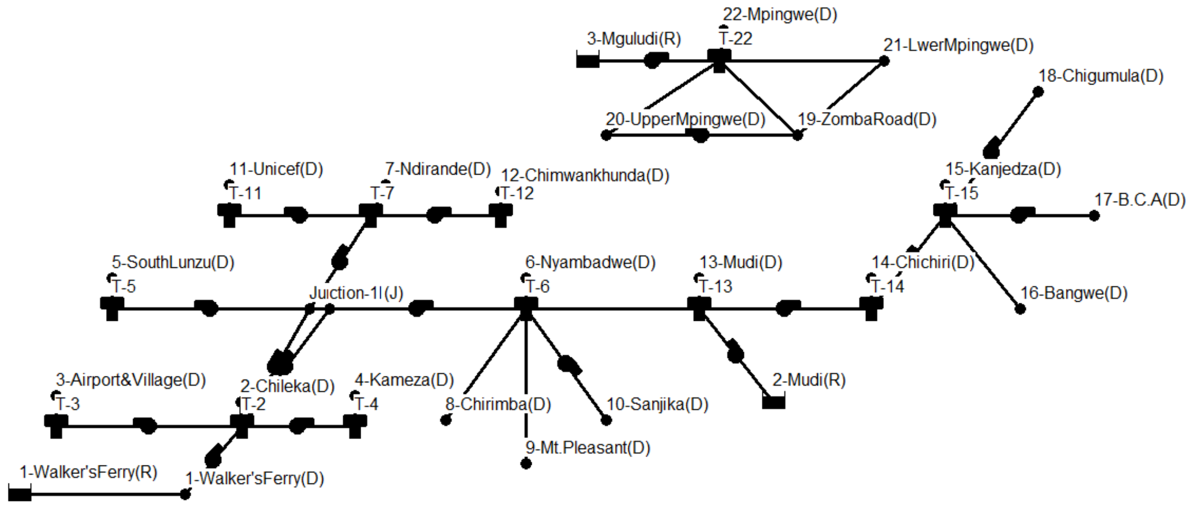
<table>
<tr><th>Items</th><th>Contents</th></tr>
<tr><td>Calculation Area</td><td>Schematic drawing in BWB Management area (see Figure 2-6.15)</td></tr>
<tr><td>Calculation Soft</td><td>EPANET Ver. 2.2</td></tr>
<tr><td>Calculation Method</td><td>Hazen- William’s equation: $I=10.666C^{-1.85}D^{-4.87}Q^{1.85}$</td></tr>
<tr><td>Velocity coefficient</td><td>C = 100 (Consideration by the JST)</td></tr>
<tr><td>Planned Data
Actual Data</td><td>Following table shows planned and actual data in each facility
<table>
<tr><th></th><th>Planned Data</th><th>Actual Data</th></tr>
<tr><td>Hydraulic analysis model</td><td>Difference from actual data</td><td>Figure 2-6.16</td></tr>
<tr><td>Service reservoirs and clear water tanks</td><td>Table 2-6.14</td><td></td></tr>
<tr><td>Pumping stations*</td><td>Difference from actual data</td><td>Table 2-6.15</td></tr>
<tr><td>Water transmission Pipes</td><td>Table 2-6.16</td><td></td></tr>
</table>
* Pumping station: 24 hours/day operation</td></tr>
<tr><td>Water Demand as of 2020</td><td>● The daily average water demand: 95,000 m^3/day (Daily Max.: 114,000 m^3/day).
● Water demand is allocated by the number of customers in each service area.</td></tr>
</table>

Source: The JST



Source: Prepared by the JST based on the data obtained from BWB

Figure 2-6.15 Schematic Drawing in BWB Management Area



Source: The JST (EPANET)
Note: Water transmission pipe No.2 Chileka - Junction is section of two pipes. One transmission pipe is junction of No. 5 and No.7, and the other is pumping No.6 separately

Figure 2-6.16 Hydraulic Calculation Model (Actual Condition)

Table 2-6.14 Basic Data of the Service Reservoirs (Planed Condition)

No.	Name	Types of Tanks	H.W.L (m)	L.W.L (m)	Storage Capacity (m^3)
1	Walker's Ferry	Clear water tank	394.0	390.4	5,120
2	Chileka	Ditto	785.0	780.0	4,551
3	Chileka village / Airport	Service reservoir	794.0	Not obtained	146+370
4	Kameza	Ditto	963.6	955.7	5,000
5	South Lunzu	Ditto	1,115.0	1,111.5	5,749
6	Nyambadwe	Ditto	1,112.0	1,106.7	13,500
7	Ndirande	Ditto	1,155.0	1,149.4	14,162
8	Chirimba	Ditto	1,003.0	998.0	2,250
9	Mt. Pleasant	Ditto	1,085.0	1,080.0	2,500
10	Sanjika	Ditto	1,126.0	1,122.8	600
11	Unicef	Ditto	1,194.0	1,190.4	500
12	Chimwankhunda	Ditto	1,198.0	1,190.6	5,000
13	Mudi	Clear water tank	1,099.0	1,095.5	2,379
14	Chichiri	Service reservoir	1,153.0	1,146.0	4,958
15	Kanjedza	Ditto	1,213.0	1,206.0	9,092
16	Bangwe Clinic	Ditto	1,184.0	1,180.0	305
17	B.C.A	Ditto	1,234.0	1,229.5	252
18	Chigumula	Ditto	1,263.0	1,255.6	5,000
19	Zomba road	Ditto	1,210.0	1,204.0	9,000
20	Upper mpingwe	Ditto	1,304.0	1,299.0	743
21	Lower mpingwe	Ditto	1,236.0	1,231.2	900
22	Mpingwe	Ditto	1,313.0	1,305.0	5,000
23	Nguludi	Clear water tank	903.7	901.2	240
	Total				97,317

Source: Prepared by the JST based on the data obtained from BWB

Table 2-6.15 Basic Data of the Pumping Stations (Actual Condition)

No	Pumping Station	Transmission Pipeline Routes	No. of Units in Operation (No. of Installation)	Power (kW)	Capacity (m^3/hr)	Head (m)
1	Walker's Ferry (Clear water tank)	1. Walker's Ferry -> 2. Chileka	5 (8)	1,825	750	550
2	Chileka	2. Chileka -> 3. Village / Airport	1 (4)	150	60	40
		2. Chileka -> 6. Nyambadwe	4 (8)	1,650	750	590
		2. Chileka -> 5. South Lunzu 2. Chileka -> 7. Ndirande	1 (1)	1,000	450	600
4	Kameza	2. Chileka -> 4. Kameza	2 (5)	185	245	230
6	Nyambadwe (Booster Pump)	6. Nyambadwe -> High pressure	1 (4)	78	900	51
7	Ndirande	7. Ndirande -> 11. Unicef	1 (3)	18.5	45	90
		7. Ndirande -> 12. Chimwankhunda	1 (3)	110	241	90
10	Sanjika (Booster Pump)	10. Sanjika -> State House	1 (3)	30	60	100
13	Mudi (Clear water tank)	13. Mudi -> 14. Chichiri	2 (4)	250	664	66
14	Chichiri	14. Chichiri -> 15. Kanjedza	3 (4)	133	438	102
		14. Chichiri -> 19. Zomba road	0	250	428	93
16 17	Midima (Booster Pump)	15. Kanjedza -> 17. B.C.A	1 (4)	55	239	68
18	Chigumula (Booster Pump)	Booster pump -> 18. Chigumula	1 (3)	110	241	90
19	Zomba road	19. Zomba road -> 20. Upper mpingwe	1 (3)	55	190	112
			1 (3)	40	190	112

Source: Prepared by the JST based on the data obtained from BWB
Note: Nos. of the routes that there is no a pumping station, are not included in the table.

Table 2-6.16 Basic Data of the Transmission Pipes (Planed Condition)

No	Transmission pipeline routes	Methods	Materials	Diameter (mm)	Length (m)
1 – 2	Walker's Ferry –> Chileka	Pump	Steel Pipes	600 700	25,496
2 – 3	Chileka –> Village / Airport	Pump	AC GI	AC-250mm GI-100mm GI-75mm	AC-838m GI-667m GI-204m
2 – 4	Chileka –> Kameza	Pump	Steel Pipes	350	7,675
2 – 5	Junction of South Lunzu –> South Lunzu	Pump	Ditto	350	4,844
2 – 6	Chileka –> Junction of South Lunzu Junction of South Lunzu –> Nyambadwe	Pump	Ditto	600 600	12,900 3,594
2 – 7	Junction of South Lunzu –> Ndirande	Pump	Ditto	600	2,095
6 – 8	Nyambadwe – Chirimba	Gravity	Ditto	350	2,535
6 – 9	Nyambadwe –> Mt.Pleasant	Gravity	Ditto	900 450 250	4,626
6 – 10	Nyambadwe –> Sanjika (Booster Pump)	Pump	Ditto	150	650
6 – 13	Nyambadwe –> Mudi (Clear water tank)	Gravity	Ditto	600	4,023
7 – 11	Ndirande –> Unicef	Pump	Ditto	150	1,485
7 – 12	Ndirande –> Chimwankhunda	Pump	Ditto	350	3,700
13 – 14	Mudi (Clear water tank) –> Chichiri	Pump	Ditto	250 450	1,340

No	Transmission pipeline routes	Methods	Materials	Diameter (mm)	Length (m)
14 – 15	Chichiri –> Kanjedza	Pump	Ditto	450	4,036
14 – 19	Chichiri –> Zomba road	Pump	Ditto	450	4,700
15 – 16	Kanjedza –> B.C.A (Booster Pump)	Gravity	Ditto	200	1,160
15 – 17	Kanjedza –> Bangwe (Booster Pump)	Pump	uPVC	200	1,924
15 – 18	Kanjedza –> Chigumula (Booster Pump)	Pump	Steel Pipes	375-400	9,317
19 – 20	Zomba road –> Upper mpingwe	Pump	Ditto	200	1,880
19 – 21	Zomba road –> Lower mpingwe	Gravity	Ditto	200	980
19 – 22	Mpingwe – Zomba road	Gravity	Ditto	400	2,130
20 – 22	Mpingwe – Upper mpingwe	Gravity	Ditto	200	1,970
21 – 22	Mpingwe – Lower mpingwe	Gravity	Ditto	200	980
22 – 23	Mguludi pumping station –> Mpingwe	Pump	Ditto	500	10,920

Source: Prepared by the JST based on the data obtained from BWB

(2) Results of Hydraulic Analysis (Based on Data in 2020)

Table 2-6.17 shows the conditions required for hydraulic analysis, while Table 2.6-18 and Table 2.6-19 show the results of hydraulic analysis by a node and a link respectively. Dynamic level and effective water pressure in each node and flow rate, velocity and unit headless in each link were figured out through the hydraulic analysis.

Table 2-6.17 Conditions of Hydraulic Analysis

Nodes and Links	Items	Conditions
Nodes • Water demand points from service reservoirs	Low Water Level at service reservoir	Planned Low Water level
	Daily average water demand (m^3/day)	Actual water production as of 2020 (see Table 2-6.18)
	Daily max. water demand (m^3/day)	Daily average water demand x 1.2 (Peak factor)
Links • Transmission pipe	Length (m)	Based on data of BWB (See. Table 2-6.16)
	Diameter (mm)	Based on data of BWB (See. Table 2-6.16)
	Roughness	C: 100, considered by the JST

Source: The JST

Table 2-6.18 Results of Hydraulic Analysis - Nodes

Network Table – Nodes*	Elevation (m)	Daily Average Water Demand (m^3/day)	Daily Max. Water Demand (m^3/day)	Dynamic Level (m)	Effective Water pressure (m)
	A	B	C= B x 1.2	D	E = D-A
Junc 1-Walker'sFerry(D)	390	0	0	545.4	155.4
Junc 2-Chileka(D)	780	0	0	790.0	10.0
Junc 3-Airport&Village(D)	794	952	1,142	804.8	10.8
Junc 4-Kameza(D)	956	7,652	9,182	959.5	3.5
Junc 5-SouthLunzu(D)	1,112	12,142	14,570	1,193.4	81.4
Junc 6-Nyambadwe(D)	1,107	23,653	28,384	1,207.9	100.9
Junc 7-Ndirande(D)	1,149	7,087	8,504	1,251.5	102.5
Junc 8-Chirimba(D)	998	9,375	11,250	1,081.3	83.3
Junc 9-Mt.Pleasant(D)	1,080	5,897	7,076	1,097.0	17.0
Junc 10-Sanjika(D)	1,123	27	32	1,203.7	80.7
Junc 11-Unicef(D)	1,190	414	497	1,233.1	43.1
Junc 12-Chimwankhunda(D)	1,191	6,411	7,693	1,260.7	69.7
Junc 13-Mudi(D)	1,096	0	0	1,100.4	4.4
Junc 14-Chichiri(D)	1,146	2,751	3,301	1,149.4	3.4
Junc 15-Kanjedza(D)	1,206	10,255	12,306	1,221.4	15.4

Network Table – Nodes*	Elevation (m)	Daily Average Water Demand (m^3/day)	Daily Max. Water Demand (m^3/day)	Dynamic Level (m)	Effective Water pressure (m)
	A	B	C= B x 1.2	D	E = D-A
Junc 16-Bangwe(D)	1,180	1,739	2,087	1,195.6	15.6
Junc 17-B.C.A(D)	1,230	485	582	1,269.0	39.0
Junc 18-Chigumula(D)	1,256	1,282	1,538	1,287.6	31.6
Junc 19-ZombaRoad(D)	1,204	3,003	3,604	1,297.9	93.9
Junc 20-UpperMpingwe(D)	1,299	935	1,122	1,307.7	8.7
Junc 21-LwerMpingwe(D)	1,231	1,047	1,256	1,262.2	31.2
Junc 22-Mpingwe(D)	1,305	0	0	1,318.3	13.3
Junc Junction-1(J)	1,050	0	0	1,260.0	210.0
Resvr 1-Walker'sFerry(R)	420		-101,700	420.0	0.0
Resvr 2-Mudi(R)	1,250		-6,300	1,250.0	0.0
Resvr 3- Nguludi (R)	901		-6,000	901.0	0.0

Source: The JST (EPANET)

Note: See Figure 2-6.16 Hydraulic calculation model

Table 2-6.19 Results of Hydraulic Analysis - Links

Network Table – Links*	Section	Length (m)	Diameter (mm)	Roughness	Flow Rate (m^3/day)	Velocity (m/s)	Unit Head Loss (m/km)
1(R)-1(D)	Walker's Ferry WTP -> Reservoir	100	600	100	101,719	2.16	29.4
6 (D)-8 (D)	Nyambadwe – Chirimba	2,535	350	100	11,174	3.26	20.4
6 (D)-9 (D)	Nyambadwe –> Mt.Pleasant	4,626	450	100	7,077	1.19	4.7
6 (D)-13 (D)	Nyambadwe –> Mudi	4,023	600	100	13,515	0.88	3.3
15(D)-16(D)	Kanjedza –> B.C.A	1,160	200	100	2,087	1.51	6.4
19(D)-21(D)	Zomba road –> Lower mpingwe	980	200	100	3,603	1.62	14.8
19(D)-22(D)	Mpingwe –> Zomba road	2,130	400	100	3,603	3.71	1.1
20(D)-22(D)	Mpingwe –> Upper mpingwe	1,970	200	100	1,122	0.33	0.1
21(D)-22(D)	Mpingwe –> Lower mpingwe	980	200	100	5,981	3.07	37.8
1(D)-2(D)	Pump 1-Walker'sFerry(P)	25,496	850	100	101,719	2.16	29.4
2(D)-3(D)	Pump 2-Chileka(P1)	667	100	100	1,142	10.64	35.2
2(D)-1(J)	Pump 2-Chileka(P2-1)	12,900	780	100	91,395	2.32	102.2
1(J)-5(D)	Pump 2-Chileka(P2-2)	4,844	350	100	14,570	2.75	63.6
1(J)-7(D)	Pump 2-Chileka(P2-3)	2,095	600	100	16,642	5.11	2.5
1(J)-6(D)	Pump 2-Chileka(P2-4)	3,594	600	100	60,183	4.59	47.1
2(D)-4(D)	Pump 2-Chileka(P3)	7,675	350	100	9,182	1.16	42.9
7(D)-12(D)	Pump 7-Ndirande(P)	3,700	350	100	7,641	2.38	14.7
6 (D)-10 (D)	Pump 10-Sanjika (P)	650	150	100	33	3.48	0.0
7(D)-11(D)	Pump 11-Unicef(P)	1,485	150	100	497	1.63	2.3
2(R)-13(D)	Pump 13-Mudi(P1)	1,340	450	100	6,300	0.46	0.1
13(D)-14(D)	Pump 13-Mudi(P2)	1,340	450	100	19,815	1.72	9.1
14(D)-15(D)	Pump 14-Chichiri(P2)	4,036	450	100	16,513	1.65	19.6
15(D)-17(D)	Pump 17-B.C.A (P)	1,924	200	100	582	1.59	1.0
15(D)-18(D)	Pump 18-Chigumula(P)	9,317	375	100	1,538	0.91	1.4
19(D)-20(D)	Pump 19-ZombaRoad(P)	1,880	200	100	1,122	0.84	3.3
3(R)-22(D)	Pump 3-Nguludi(P)	10,920	500	100	5,981	0.72	4.9

Source: The JST (EPANET)

Note: See Figure 2-6.16

(3) Consideration on Transmission System (Based on Data in 2020)

It was observed that there were high pressures (about 1.0 Mpa) at some nodes between No. 6 Nyambadwe and No. 8 Chirimba; and No. 22 Mpingwe and No. 19 Zomba Road by gravity in the transmission routes. Actually, the transmission pipelines between No. 22 Mpingwe and 19 Zomba Road service reservoir have not been functioned because of high pressure.

(4) Hydraulic Analysis considering Water Demand in 2030

Table 2-6.20, Table 2-6.21 and Table 2-6.22 contains the following information respectively: "basis conditions for water demand in 2030"; "water demand in 2030 by each Reservoir"; and "result of effective water pressure in hydraulic calculation".

Table 2-6.20 Basis Conditions for Water Demand

Items	Contents
Conditions of hydraulic calculation	See Table 2-6.17
Daily max. water demand in 2030*	Case 1: 114,000 m^3/day, Track record in 2020 Case 2: 185,000 m^3/day & Leakage ratio: 12% (see Table 3-1.9) Case 3: 175,000 m^3/day & Leakage ratio: 7.5% (see Table 3-1.9)

Source: The JST
* See Section 3-1-1 (Water demand)

Table 2-6.21 Water Demand by Service Reservoirs

No	Reservoir or Clear Water Tank	Storage Capacity (m^3/day)	Case 1 (m^3/day)	Case 2 (m^3/day)	Case 3 (m^3/day)
1	Walker's Ferry	5,120	0	0	0
2	Chileka	4,551	0	0	0
3	Chileka village / Airport	146+370	1,142	1,853	1,753
4	Kameza	5,000	9,182	14,901	14,095
5	South Lunzu	5,749	14,570	23,645	22,367
6	Nyambadwe	13,500	28,384	46,062	43,572
7	Ndirande	14,162	8,504	13,800	13,054
8	Chirimba	2,250	11,174	18,133	17,152
9	Mt. Pleaant	2,500	7,077	11,485	10,864
10	Sanjika	600	32	52	49
11	Unicef	500	497	807	763
12	Chimwankhunda	5,000	7,641	12,401	11,730
13	Mudi (Clear water tank)	2,379	0	0	0
14	Chichiri	4,958	3,302	5,358	5,068
15	Kanjedza	9,092	12,306	19,971	18,891
16	Bangwe Clinic	305	2,087	3,387	3,204
17	B.C.A	252	582	944	893
18	Chigumula	5,000	1,538	2,496	2,361
19	Zomba road	9,000	3,603	5,847	5,531
20	Upper mpingwe	743	1,122	1,822	1,723
21	Lower mpingwe	900	1,256	2,039	1,928
22	Mpingwe	5,000	0	0	0
23	Mguludi	240	0	0	0
	Total	97,317	114,000	185,000	175,000

Source: The JST

According to the results of hydraulic calculation in Table 2-6.22, the effective water pressure in Case-2 & Case-3 is lower pressure than that in Case-1, and negative pressure occurred in some of reservoirs. Therefore, the capacity of the water transmission pipelines should be amplified, and specific measures are described in section "3-2".

Table 2-6.22 Results of Effective Water Pressure in Hydraulic Calculation

No	Reservoir or Clear Water Tank	Effective Water Pressure (m)		
		Case 1	Case 2	Case 3
1	Walker's Ferry (Clear W. T.)	145.4	155.4	155.4
2	Chileka (Clear W. T.)	10.0	-200.7	-165.9
3	Chileka village/Airp't	10.8	-40.1	-31.7
4	Kameza	3.5	-58.7	-48.4
5	South Lunzu	81.4	-158.8	-119.1
6	Nyambadwe	100.9	-115.5	-79.8

No	Reservoir or Clear Water Tank	Effective Water Pressure (m)		
		Case 1	Case 2	Case 3
7	Ndirande	102.5	-49.3	-24.2
8	Chirimba	83.3	53.8	58.7
9	Mt. Pleaant	17.0	10.2	11.3
10	Sanjika	80.7	80.7	80.7
11	Unicef	43.1	39.7	40.2
12	Chimwankhunda	69.7	48.3	51.9
13	Mudi (Clear W. T.)	4.4	-0.5	0.3
14	Chichiri	3.4	-9.9	-7.7
15	Kanjedza	15.4	7.1	9.8
16	Bangwe Clinic	15.6	6.4	7.9
17	B.C.A	39.0	37.6	37.8
18	Chigumula	31.6	29.7	30.0
19	Zomba road	93.9	92.3	92.6
20	Upper mpingwe	8.7	4.0	4.7
21	Lower mpingwe	31.2	-23.7	-14.6
22	Mpingwe	13.3	6.3	7.5

Source: The JST

(5) WTPs that transfer Water to each Service Reservoir and Clear Water Tank

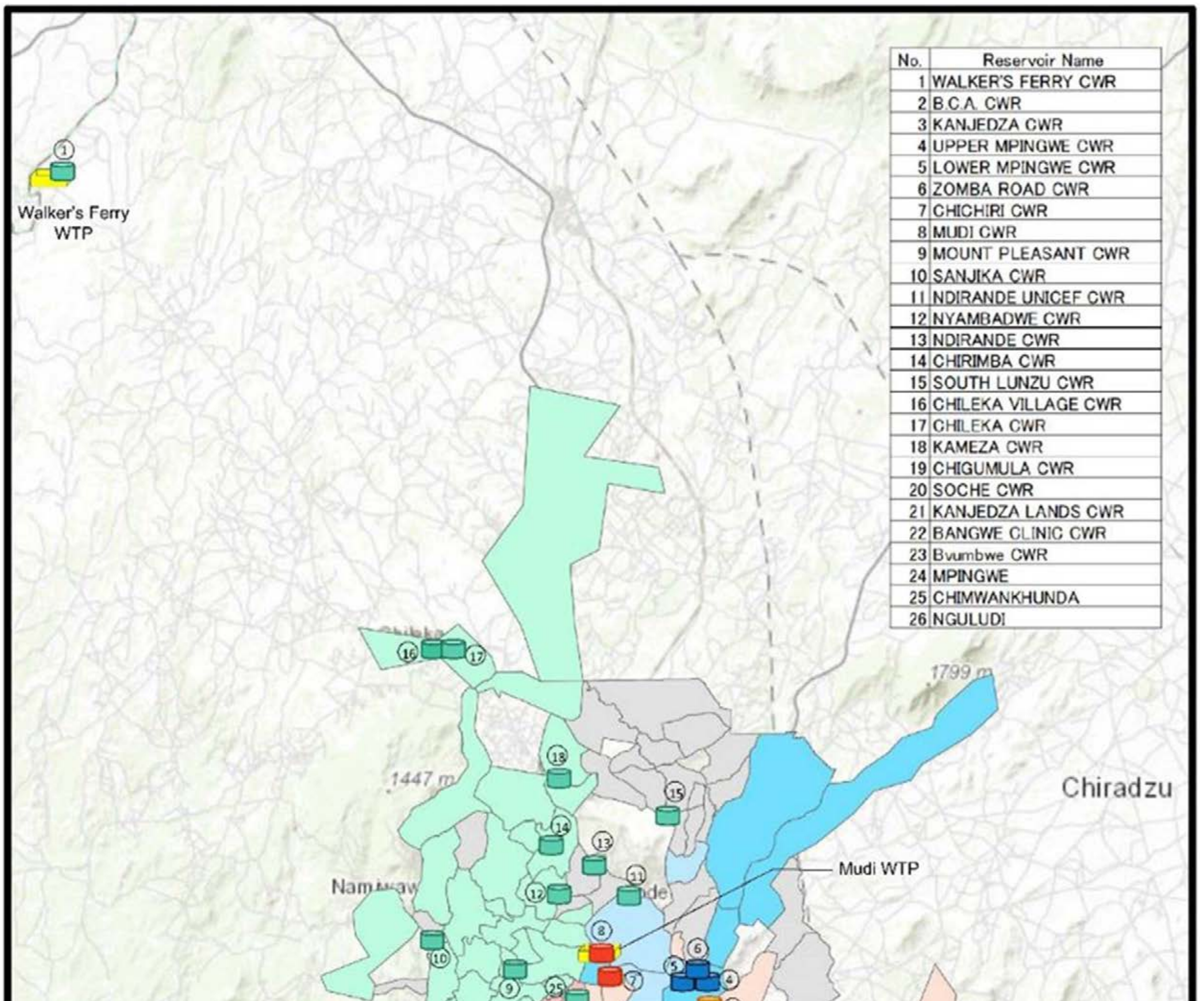
Table 2-6.23 shows the list of the WTPs, and clear water tanks and service reservoirs that receive the treated water from the WTPs. Their locations and the coverage area are illustrated in Figure 2-6.17.

Originally, the service reservoirs from No.14 to No.21 were supposed to receive water from Mudi WTP. Since Nguludi WTP was constructed funded by India in 2019, the service reservoirs of No.19, No.20 and No.21 have been able to receive water from Nguludi WTP. However, the service reservoirs from 14 to No.18 have still received water (Assumed Daily Max. Demand: 25,800 m^3/day as of 2020) from both Walker's Ferry WTP and Mudi WTP, because of insufficient water production of approximately only 5,700 m^3/day at Mudi WTP. Therefore, one of challenges is to increase water production at Mudi WTP as much as possible, while reducing water production at Walker's Ferry WTP in order to reduce electricity costs at Walk's Ferry WTP whose power consumption rate is remarkably high.

Table 2-6.23 WTPs and the Service Reservoirs & Clean Water Tanks covered with the WTPs

No	Name	Types of Tank	Water Treatment Plant
1	Walker's Ferry	Clear water tank	Walker's Ferry
2	Chileka	Clear water tank	Walker's Ferry
3	Chileka village / Airport	Service reservoir	Walker's Ferry
4	Kameza	Service reservoir	Walker's Ferry
5	South Lunzu	Service reservoir	Walker's Ferry
6	Nyambadwe	Service reservoir	Walker's Ferry
7	Ndirande	Service reservoir	Walker's Ferry
8	Chirimba	Service reservoir	Walker's Ferry
9	Mt. Pleaant	Service reservoir	Walker's Ferry
10	Sanjika	Service reservoir	Walker's Ferry
11	Unicef	Service reservoir	Walker's Ferry
12	Chimwankhunda	Service reservoir	Walker's Ferry
13	Mudi	Clear water tank	Walker's Ferry and Mudi
14	Chichiri	Service reservoir	Walker's Ferry and Mudi
15	Kanjedza	Service reservoir	Walker's Ferry and Mudi
16	Bangwe Clinic	Service reservoir	Walker's Ferry and Mudi
17	B.C.A	Service reservoir	Walker's Ferry and Mudi
18	Chigumula	Service reservoir	Walker's Ferry and Mudi
19	Zomba road	Service reservoir	Nguludi (<- Mudi)
20	Upper mpingwe	Service reservoir	Nguludi (<- Mudi)
21	Lower mpingwe	Service reservoir	Nguludi (<- Mudi)
22	Mpingwe	Service reservoir	Nguludi
23	Nguludi	Clear water tank	Nguludi

Source: The JST



Source: The JST

Figure 2-6.17 WTPs and Coverage Areas

(6) Consideration on the Transmission Routes based on Water Demand in 2030

In order to improve the efficiency of water transmission system, the JST examined the water transmission routes and pumping operation. There are two options of the water transmission routes through the rehabilitation of Mudi WTP as follows:

Option 1: Present Routes

- No.13 Mudi WTP (by pumping-up) (30,418 m^3/day) -> No. 14 Chichiri (by pumping-up) (5,068 m^3/day) -> No. 15 Kanjedza (18,891 m^3/day) & No.16-No.18 (6,459 m^3/day)

Option 2: Revised Routes

- No.13 Mudi WTP (by gravity) (28,065 m^3/day)-> No. 10 Sanjika (49 m^3/day) & No.9 Mt. Pleasant (10,864 m^3/day)& No.8 Chirimba (Partially, 17,152 m^3/day)
- No. 6 Nyambadwe (by pumping-up) (30,418 m^3/day) -> No.14 Chichiri (5,068 m^3/day) & No. 15 Kanjedza (18,891 m^3/day) & No.16- No.18 (6,459 m^3/day)

Table 2-6.24 Two Transmission Routes from Mudi WTP

From (Service Reservoirs)	Option 1		Option 2		Balance (“Option 2” – “Option 1”)
	To (Service Reservoirs)	Water Flow Rate* (m^3/day)	To (Service Reservoirs)	Water Flow Rate* (m^3/day)	
No.6 Nyanbadwe			No.14 Chichiri & No.15 Kanjedza	30,418	30,418
No. 13Mudi	No.14 Chichiri	30,418		0	-30,418
No.14 Chichiri	No.15 Kanjedza	25,349		0	-25,349
No.15 Kanjedza	No.16-18	6,459	No.16-18	6,459	0
Total		**62,226**		**36,877**	**-25,349**

Source: The JST
Note:
* Based on Case 3 (safe side for a benefit analysis) shown in Table 2-6.21

Table 2-6.24 shows the comparison of water flow rates pumped-up of two options. The water flow rates to be pumped-up of Option 2 is 25,349 m^3/day lower than that of Option 1. Therefore, BWB will be able to reduce electricity costs, if the transmission route is revised.

2-7 Reservoir

Assuming storing water for about 12 hours of daily max water demand referring to the Japanese design guidelines, the storage capacity of No.4 Kameza, No.5 South Lunzu, No. 6 Nambadwe No.8 Chirinba and No. 9 Mt. Pleasant is insufficient in 2030 (see Table 2-6.21). The expansion in capacity of these service reservoir should be considered when rehabilitating service reservoirs.

2-8 Development Partners

There are no activities by development partners in water sector in Blantyre city apart from the Indian Government.

BWB has two large scale projects: “New Water Source on Shire River and Associated Infrastructure” and “Development of a Total of 57 Mega Watt Grid Connected Solar PV-Power Plant for Blantyre Water Board”. As shown in Table 2-8.1 and Table 2-8.2, USD78 million out of USD165 million in the former project and USD72 million out of USD112 million in the latter project were committed by Indian Government through bilateral cooperation. Out of the committed amounts, USD 56.2 million will be disbursed as grant aid, while USD93.8 million as loan. BWB will pay back the loan to the Indian Government together with an interest of 1.5% per year through the Ministry of Finance of Malawi Government.

As of May 2021, the former project (Project Period: Jun. 2020 - Aug. 2023) has yet to reach the procurement stage, while the latter project (Project Period: Jun. 2020 - Feb. 2023) have gone through the procurement phase. The EXIM is also one of the firm making the short-list to provide consulting services to the latter project.

Table 2-8.1 New Water Source on Shire River and Associated Infrastructure

Project	Main Specification	Cost			Scheme	Commitment
Phase-1 Jun. 2020 - Aug. 2023	**<u>Contract-1:</u>** Intake (299,000 m^3/day: 100%), desilting basin (100%), Conveyance Pipelines (4.1km: 100%) **<u>Contract-2:</u>** WTP (75,000 m^3/day: 50%), Transmission Pumps (50%), Transmission Pipelines (27 km x 1,200 mm: 100%)	USD165 Million	USD78 Million (47%)	USD48.8 Million	Loan	Committed by Indian Government
				USD29.2 Million	Grant	
Phase-2	Transmission Pipelines between the Chileka Relay Pumping Station and each Service Reservoir		USD87Million (53%)	-	-	No development partners committed

Source: BWB

Table 2-8.2 Development of a Total of 57 Mega Watt Grid Connected Solar PV-Power Plant for BWB

Project	Main Specification	Cost			Scheme	Commitment
Phase-1 Jun. 2020 - Feb. 2023	Nguldi 11.4 MW Walker's Ferry 42 MW <u>Phase 1</u> Construct a 45MW solar power generation facility at Walker's Ferry WTP and a 12MW solar power generation facility at Nguludi WTP	USD112 Million	USD72 Million (64%)	USD45.0 Million	Loan	Committed by Indian Government
				USD27.0 Million	Grant	
Phase-2	Phase 2 Construct a 29MW solar power generation facility at Chileka pumping station.		USD40Million (36%)	-	-	No development partners committed

Source: BWB

2-9 Influence to BWB's Water Supply Service by Covid-19 and Way Forward

According to the result of an interview with BWB, the Covid-19 pandemic has negatively impacted BWB through the following aspects:

- Since customers are hesitant to go to banks or the customer service counters to pay their water bills in fear of contracting the virus, the financial status of BWB has been progressively affected.
- The flow of operation of BWB has been affected as staff had to work in shifts irregularly. This has also created unnecessary high workload for the BWB's staff.
- The BWB's meter readers have been refused entry into premises by some house owners, resulting in that water meter readings make it extremely difficult to perform their task properly.
- Staff meetings in BWB have been minimized to reduce infection risks.

In connection with the above issues, BWB established a covid-19 committee which oversees all the issues related to BWB in 2020. The covid-19 committee has been proactive to ensure that the staff are protected from the pandemic and also making sure that the BWB's staff get vaccinated.

BWB have also actively followed the Government policy of ensure that BWB's office are disinfected at least every two weeks. To achieve this, BWB delivered covid-19 prevention equipment including handwashing facilities and hand sanitizer to almost all the BWB stations and offices to prevent the spreading of the covid-19 virus.

2-10 BWB's Cooperation with Water Utilities

BWB's cooperation started with support for GIS from Vitens Evides International (hereinafter referred to as "VEI") funded by EU and European Investment Bank from 2009 to 2011. Since that time, BWB has been developing and maintaining GIS independently.

Domestically in Malawi, BWB has a cooperative relationship with water boards anchored by WASAMA, to which BWB belongs as a key corporate member, and contributes to domestic cooperation through participation in The Project for Strengthening the Capacity of Non-Revenue Water Reduction for Lilongwe Water Board (hereinafter referred to as "LiSCaP")'s knowledge co-creation. Regionally in Sub-Saharan Africa, BWB has established a knowledge sharing relationship with water utilities in Rwanda and Kenya with support of JICA, while using the EU/UN-Habitat programme to form a partnership with a water utility in South Africa, and is trying to expand it further. In addition, beginning with JICA volunteer scheme, BWB has been supported continuously by YWWB.

BWB's cooperation with water utilities is described in detail in Chapter 4.

CHAPTER 3 : Draft of Cooperation Approaches

3-1 Necessity of Rehabilitation of the existing Water Treatment Plant and Water Source Development

3-1-1 Water Demand Forecasting

(1) Design Criteria

The JST has set design criteria for key factors such as service coverage, daily per-capita water consumption, NRW ratio, etc. to estimate the water demand in 2030. These design criteria are deduced based on several discussions with BWB, the 2018 population census and the analysis of the existing reports. Table 3-1.1 shows the summary of the design criteria.

Table 3-1.1 Summary of Design Criteria

No.	Item	Data	Basis
1	Target Year	2030	
2	Service Coverage in Urban	95.3%	Based on a transition in the track record of the past three years
3	Daily per-capita Water Consumption (Domestic for House Connections)	100 LCD	Based on the track record in 2018-2020
4	Daily per-capita Water Consumption (Domestic for Kiosks)	25 LCD	Based on the result of the interview with Water User Associations (hereinafter referred to as "WUAs") in terms of number of households which rely on one kiosk
5	Rate of Non-domestic Use to the Total Water Consumption	40%	Based on the track record in 2018-2020
6	NRW Ratio	High: 40% Medium: 30% Low: 25%	Set three scenarios considering the baseline of NRW ratio in 2020
7	Leakage Ratio	High: 12% Medium: 9.0% Low: 7.5%	30% of NRW ratio
8	Daily Max. Factor	1.20	Based on Detailed Designs for Water Intake on Shire River, Water Treatment Works, Pump Stations, Pipelines and Reservoirs in 2015

Source: Prepared by the JST based on various sources provided by BWB

1) Service Coverage

The BWB's billing data does not include the data for customers whose service pipelines have been disconnected due to arrears or other factors and water meters that have not been installed. Therefore, actual service coverage ratio would have been higher than the service coverage ratio stipulated in 2018 and 2020 as shown in Table 3-1.2. The JST utilized the actual service coverage ratio (the latest data in accurate) for April 2021 available from the BWB's billing section as the baseline for estimating the service coverage ratio in 2025 and 2030. The service coverage in urban Blantyre city is 74.6% in April 2021. The service population and service coverage were calculated based on average household size of eight persons and 230 persons using one kiosk.

The JST also calculated an increasing rate of service coverage based on the number of customers in 2018 and 2020 and applied that to set the future service coverage. As a result, the service coverage is estimated at 83.2% and 95.3% in 2025 and 2030 respectively (see Table 3-1.2).

Table 3-1.2 Estimating Service Coverage until 2030

Unit: %

2018	2020	Increasing Rate per year between 2018 and 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
67.0	70.7	2.76	74.6	76.7	78.8	81.0	**83.2**	85.5	87.8	90.3	92.8	**95.3**

Source: The JST

Note: Service population in 2021 includes users in "Connected without meter" and "Disconnected with meter", while that in 2018 and 2020 dose not. Therefore, the service coverage in 2021 as a baseline was applied for estimating future service coverage.

2) Daily per-capita Water Consumption of Domestic Use

a. House Connections

As shown in Table 3-1.3, daily per-capita water consumption for domestic use in house connections is 66 to 77 LCD on average from 2018 to 2020. However, daily per-capita water consumption in house connections with prepaid meters is 80 to 90 LCD, higher than those with postpaid meters. In the Survey, the JST applied 100 LCD, a figure used by BWB to estimate future domestic water consumption in house connections.

Table 3-1.3 Track Record of Number of Customers and Domestic Water Consumption by Type of Water Meters

Items			2018	2019	2020
Customers	Postpaid	House Connections	41,392	37,472	35,263
		Kiosks	592	550	461
	Prepaid	House Connections	4,676	10,070	17,866
		Kiosks	137	157	242
	House Connections		46,068	47,542	53,129
	Kiosks		729	708	702
	Total		46,797	48,250	53,831
Service Population	Postpaid	House Connections	331,136	299,776	282,104
		Kiosks	136,064	126,558	105,953
	Prepaid	House Connections	37,408	80,560	142,928
		Kiosks	31,491	36,187	55,564
	House Connections		368,544	380,336	425,032
	Kiosks		167,555	162,744	161,518
	Total		536,099	543,080	586,550
Domestic Water Consumption (m^3/day)	Postpaid	House Connections	20,799	15,910	14,679
		Kiosks	1,703	1,382	1,245
	Prepaid	House Connections	3,364	7,158	11,419
		Kiosks	273	313	423
	House Connections		24,163	23,068	26,098
	Kiosks		1,976	1,695	1,668
	Total		26,139	24,763	27,767
Daily per-capita Water Consumption (LCD)	Postpaid	House Connections	63	53	52
		Kiosks	13	11	12
	Prepaid	House Connections	**90**	**89**	**80**
		Kiosks	9	9	8
	Average in House Connections		**77**	**71**	**66**
	Average in Kiosks		**11**	**10**	**10**

Source: Prepared by the JST based on the billing data obtained from the billing Section of BWB

b. Kiosks

Daily per-capita water consumption for domestic use in kiosks is 10 to 11 LCD on average from 2018 to 2020 (see Table 3-1.3). According to Water Resource Management Guideline, daily per-capita water consumption in kiosks is sated at 40 to 50 LCD, but BWB analyzed that people using kiosks rely on other sources such as wells due to the shortage of water in the BWB's water supply service therefore 25 LCD is applied for the future water consumption in principle.

The JST interviewed staff of WUAs who is responsible for the nine kiosks. It was revealed that on a daily basis, an average of 28 households use one kiosk. Assuming a household size is eight persons, about 224 persons use one kiosk (see Table 3-1.4). That is rounded up to approximately 230 persons per kiosk. The JST applied 230 persons per kiosk in its calculation for the current status of daily per-capita water consumption in kiosks shown in Table 3-1.3. This table supports that 25 LCD as daily per-capita water consumption can be applied for water demand forecasting.

Table 3-1.4 Number of Households using Kiosks and Water Consumption in Blantyre City

No.	Kiosk	Avg. Sales/day (MK)	Avg. Water Consumption per Kiosk (L/day)	Avg. No. of Households per Kiosk	Avg. Service Population per Kiosk (person)	Daily per-capita Water Consumption (LCD)
		a.	b. = a. / MWK25 x 20 L	c.	d. = c. x 8 persons	e. = b. / d.
1	Che Isa	10,000	8,000	50	400	20
2	Nkolokoti	5,000	4,000	30	240	17
3	Madulila	9,000	7,200	40	320	23
4	Hafford	6,000	4,800	20	160	30
5	Sikelo	3,000	2,400	15	120	20
6	Lamula	4,000	3,200	20	160	20
7	Mwase	6,000	4,800	20	160	30
8	Che Mussa	3,000	2,400	15	120	20
9	Kabula Development	6,000	4,800	40	320	15
Average		5,778	4,622	**28**	**224**	21

Source: The JST

Note: The average water tariff of a 20 L bucket in all these Kiosks is MK25.

3) Rate of Non-Domestic Use to Total Water Consumption

Non-domestic water users are comprised of institutional, commercial and industrial consumptions in the BWB's water supply service area. Table 3-1.5 shows non-domestic water consumption by meter type from 2018 to 2020. The non-domestic water consumption makes up 36.4% to 42.5% of the total water consumption between 2018 and 2020. Therefore, 40% was applied for the total future non-domestic water demand between 2018 and 2020. Each proportion in institutional, commercial and industrial use for 2020 was applied for each use in the future non-domestic water demand.

Table 3-1.5 Non-Domestic Water Consumption

Items	Category		2018	2019	2020
Number of Customers	Postpaid	Institution	975	733	678
		Commerce	1,590	1,189	1,182
		Industry	90	79	105
	Prepaid	Institution	85	251	298
		Commerce	86	279	316
		Industry	1	5	7
	Institution		1,059	984	977
	Commerce		1,677	1,469	1,498
	Industry		91	84	112
	Total		2,827	2,537	2,587
Non-Domestic Water Consumption (m^3/day)	Postpaid	Institution	11,453	9,704	8,279
		Commerce	3,958	3,017	2,706
		Industry	3,533	2,650	3,639
	Prepaid	Institution	232	1,028	829
		Commerce	112	374	451
		Industry	2	27	7
	Institution		11,685	10,732	9,108

Items	Category	2018	2019	2020
	Commerce	4,070	3,391	3,157
	Industry	3,534	2,677	3,646
	Total	**19,290**	**16,800**	**15,911**
Rate of Non-domestic Water Consumption to Total Water Consumption (%)		**42.5**	**40.4**	**36.4**
Total Water Consumption (m^3/day)		**45,429**	**41,563**	**43,678**

Source: Prepared by the JST based on the billing data obtained from the billing Section of BWB

4) NRW Ratio

Table 3-1.6 shows NRW ratio in the BWB's water supply service between July 2017 and Mar 2021. Since July 2019, NRW ratio has increased due to the utilization of flow meters a more accurate means to measure flow rates. Before July 2019, the flow rates were only estimated by staff based on pump operation hours and the flow rate in the pump specifications. It is vital that future NRW ratio is set out so that relevant plans of specific activities for NRW reduction and corresponding financial plans can be considered or designed. At present, no projects of NRW reduction have been committed to and the framework of the new NRW section of BWB has not been ready.

The JST has set three scenarios of NRW ratio including high (40%), medium (30%) and low (25%) levels in 2030 to forecast future water demand, from the baseline of NRW ratio at 54 % in 2020. The NRW ratio from 2021 to 2030, is predicted to decrease from the baseline figure in 2020 (54%) to a range of figures shown in Table 3-1.7 through the implementation of NRW reduction measures based on the scenarios below.

Table 3-1.6 NRW Ratio

Month	Production (x 1000 m³) per billing cycle					Sales Volumes (x 1000 m³)					Non Revenue Water (x 1000 m³)					Non Revenue Water as a %				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
Jan.	-	2,334	2,591	2,562	2,965	-	1,332	1,564	1,208	1,274	-	1,002	1,028	1,354	1,692	-	42.9	39.7	52.9	57.0
Feb	-	2,134	2,340	2,749	2,863	-	1,323	1,487	1,156	1,291	-	811	853	1,593	1,571	-	38.0	36.4	58.0	54.9
Mar	-	2,367	2,123	2,737	2,902	-	1,289	1,302	1,190	1,291	-	1,078	821	1,547	1,611	-	45.5	38.7	56.5	55.5
Apr	-	2,342	2,451	2,960		-	1,298	1,452	1,337		-	1,044	999	1,623		-	44.6	40.8	54.8	
May	-	2,478	2,607	3,216		-	1,438	1,597	1,322		-	1,040	1,009	1,894		-	42.0	38.7	58.9	
Jun	-	2,345	2,640	2,970		-	1,368	1,605	1,369		-	977	1,035	1,601		-	41.7	39.2	53.9	
Jul	2,537	2,332	2,764	2,857		1,308	1,319	1,279	1,303		1,229	1,013	1,485	1,553		48.4	43.4	53.7	54.4	
Aug	2,472	2,505	2,810	2,825		1,420	1,432	1,375	1,336		1,052	1,073	1,436	1,489		42.6	42.8	51.1	52.7	
Sep	2,315	2,398	2,679	2,891		1,524	1,467	1,382	1,419		790	931	1,297	1,472		34.1	38.8	48.4	50.9	
Oct	2,515	2,420	2,756	2,896		1,678	1,475	1,198	1,483		837	945	1,559	1,413		33.3	39.0	56.5	48.8	
Nov	2,357	2,513	2,690	2,846		1,561	1,399	1,457	1,388		796	1,113	1,234	1,458		33.8	44.3	45.9	51.2	
Dec	2,381	2,449	2,603	3,337		1,360	1,339	1,279	1,427		1,021	1,110	1,324	1,910		42.9	45.3	50.9	57.2	
Total	**14,576**	**28,616**	**31,056**	**34,846**	**8,730**	**8,850**	**16,480**	**16,976**	**15,939**	**3,856**	**5,725**	**12,136**	**14,080**	**18,907**	**4,874**	**39.3**	**42.4**	**45.3**	**54.3**	**55.8**

Source: The NRW section of BWB

Note: The data on NRW ratio do not include the data for the customers whose service pipelines have been disconnected due to arrear, etc. or water meters have not been installed.

Table 3-1.7 Change of NRW Ratio until 2030

Unit: %

Baseline	Scenario	NRW Ratio in Future									
2020		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030 Target
54.0	High	52.6	51.2	49.8	48.4	**47.0**	45.6	44.2	42.8	41.4	**40.0**
	Medium	51.6	49.2	46.8	44.4	**42.0**	39.6	37.2	34.8	32.4	**30.0**
	Low	51.1	48.2	45.3	42.4	**39.5**	36.6	33.7	30.8	27.9	**25.0**

Source: The JST

<u>High Scenario:</u>

- The scenario includes replacement of some parts of the asbestos pipelines with PVCs, ductile cast iron pipes, etc.
- Based on target ratio to reduce the Physical Component of Non-Revenue Water (from 37% to 25%:

-12 points) for the next five years as shown in the Project "Non-Revenue Water Reduction through Pipe Network Rehabilitation"

- 54% (in 2020) -12 points = 42% (The rate of replacement is almost half. The rest of the pipelines are going to be deteriorated year by year, therefore, 40% (rounded down) was applied for NRW ratio in 2030 considering safe side.)

Low Scenario:

- The scenario where the NRW reduction activities will be taken up systematically and positively, and some parts of the asbestos pipelines will be replaced with PVCs, ductile cast iron pipes, etc.
- **25%** as NRW ratio in 2030 based on the report of "Sogreah"

Medium Scenario:

- The scenario where some parts of the asbestos pipelines will be replaced with PVCs, ductile cast iron pipes, etc., but NRW reduction activities will not be taken up systematically.
- 30 % as approximately average NRW ratio between High and Low Scenario

5) Leakage Ratio

BWB calculates NRW ratio by deducting billed water from water production but does not conduct water balance analysis periodically due to inadequate experience. In the Survey, receiving the result of an average water balance analysis as of 2021, the JST applied about 30% of NRW ratio for a leakage ratio to forecast water demand in 2030.

(2) Water Demand

1) Daily Average Water Demand

The JST forecasted water demand in 2030, applying the key factors shown in Table 3-1.1. Water demand at high, medium and low levels of NRW ratio in 2030 is estimated at 154,000 m^3/day, 149,000 m^3/day and 146,000 m^3/day respectively (see Table 3-1.8).

Table 3-1.8 Water Demand Forecasting

No.	Items		2018	2020	2021	2025	2030
1	Blantyre City Population		800,264	830,073	843,744	898,429	961,115
2	Blantyre Rural Population (part)		451,220	474,284	485,967	532,697	591,431
3	Total Population of BWB Area	[1] +[2]	1,251,484	1,304,357	1,329,711	1,431,126	1,552,546
4	Service Population with House Connections		368,544	425,032	536,568	635,369	778,551
5	Service Population with Kiosks		167,555	161,518	92,920	112,124	137,391
6	Total Service Population	[4]+[5]	536,099	586,550	629,488	747,493	915,943
7	Service Coverage Ratio in Urban	[6]/[1]	67.0%	70.7%	74.6%	83.2%	**95.3%**
8	Domestic Water Consumption with House Connections (m^3/day)		24,163	26,098		63,537	77,855
9	Daily Domestic Per Capita Water Consumption with House Connections (LCD)	[8] x 1000/[4]	66	61		100	**100**
10	Domestic Water Consumption with Kiosks (m^3/day)		1,976	1,668		2,803	3,435
11	Daily Domestic Per Capita Water Consumption with Kiosks (LCD)	[10] x 1000/[5]	12	10		25	**25**
12	Domestic Water Consumption in Total (m^3/day)	[8] +[10]	26,139	27,767		66,340	81,290
13	Institutional Water Consumption (m^3/day)		11,685	9,108		25,315	31,020
14	Commercial Water Consumption (m^3/day)		4,070	3,157		8,776	10,754

No.	Items			2018	2020	2021	2025	2030
15	Industrial Water Consumption (m^3/day)			3,534	3,646		10,135	12,419
16	Non-Domestic Water Consumption in Total (m^3/day)		[14]+[15]	19,290	15,911		44,227	54,193
17	Water Consumption in Total (m^3/day)		[12]+[16]	45,429	43,678		110,567	135,483
18	NRW Ratio	High Scenario		42%	54%		47.0%	**40.0%**
		Medium Scenario					42.0%	**30.0%**
		Low Scenario					39.5%	**25.0%**
19	Leakage Ratio	High Scenario	[18] x 30%	-	-		14.1%	12.0%
		Medium Scenario					12.6%	9.0%
		Low Scenario					11.9%	7.5%
20	Water Demand in Total (m^3/day)	High Scenario	[17]/ (1-[17])	78,325	94,952		129,000	**154,000**
		Medium Scenario					127,000	**149,000**
		Low Scenario					125,000	**146,000**

Source: Prepared by the JST based on the data provided by the billing section of BWB and 2018 Population Census
Note: The data in 2018 and 2020 do not include the data such as the number and water consumption for the customers whose service pipelines have been disconnected due to arrear, etc. or water meters have not been installed. On the other hand, the data in 2021 include all the number of customers in the BWB's service area.

2) Daily Maximum Water Demand

Table 3-1.9 shows the daily maximum water demand where the daily average water demand is multiplied with the daily maximum factor of 1.20. The daily maximum water demand in 2030 based on leakage ratio of 12%, 9% and 7.5% are 185,000 m^3/day, 179,000 m^3/day and 175,000 m^3/day respectively.

Table 3-1.9 Daily Average and Maximum Water Demand

Items		2025	2030
Daily Ave. (m^3/day)	Leakage ratio: 12.0% (14.1%)	129,000	154,000
	Ditto: 9.0% (12.6%)	127,000	149,000
	Ditto: 7.5% (11.9%)	125,000	146,000
Daily Max. (m^3/day)	Ditto: 12.0% (14.1%)	155,000	185,000
	Ditto: 9.0% (12.6%)	152,000	179,000
	Ditto: 7.5% (11.9%)	150,000	175,000

Source: The JST
Note: The bracket shows NRW ratio in 2025.

3-1-2 Water Balance as of 2030

As shown in Table **3-1.10**, at present, the combined capacity of the three existing WTPs is about 133,000 m^3/day. The total design capacity of the three WTPs will be 208,000 m^3/day as of 2030, after the expansion of Walker's Ferry WTP that will add in an additional 75,000 m^3/day of water in 2023. The water demand predictions in Table **3-1.10** shows a potential surplus of 23,000 m^3/day and 33,000 m^3/day to be under the condition of 12% and 7.5% leakage ratio respectively in BWB's water service areas as of 2030.

However, currently WTP operation ratio is about 67% of design capacity in the past five years. In case where supply quantity of water is about 140,000 m^3/day (208,000 m^3/day x 67%), water balance as of 2030 is for short about 45,000 m^3/day and about 39,000 m^3/day in high and low scenario respectively.

Table 3-1.10 Water Balance

WTP	Treatment Capacity of the Existing WTP (m^3/day)	Expansion of Walker's Ferry WTP as of 2023 (m^3/day)	Design Capacity after Expansion of Walker's Ferry WTP (m^3/day)	Water Demand as of 2030 (m^3/day)			Water Balance as of 2030 (m^3/day)		
				Leakage Ratio (High, Medium and Low Scenario)					
				12.0%	9.0%	7.5%	12.0%	9.0%	7.5%
Walker's Ferry	96,000	75,000	171,000	-	-	-	-	-	-
Mudi	17,000	0	17,000						
Nguludi	20,000	0	20,000						
Total	**133,000**	**75,000**	**208,000**	185,000	179,000	175,000	**23,000**	**29,000**	**33,000**

Source: Prepared by the JST based on the result of an interview with BWB and site reconnaissance

Note: Since the commencement of operation in 2019, about 10,000 m^3/day or less is produced at Nguludi WTP due to drawdown of water level at Likbula River.

3-2 Efforts against Reduction of Power Consumption Rate

BWB has been organizing the monthly electricity costs by the main pumping stations. The JST checked the electricity costs by service reservoirs.

3-2-1 Power Consumption Rate in Main Pumping Stations (Based on Data in 2020)

Table 3-2.1 shows the power consumption rate per m^3 of each main pumping station based on the monthly electricity costs from August 2020 to July 2021.

Currently, BWB cannot reduce water production and electricity costs for pumping at Walker's Ferry WTP. Consequently, electricity costs at Walker' Ferry WTP make up approximately 84.4% (about MWK 987 million) of total electricity costs. In order to reduce the entire electricity costs in the BWB water supply service, the significant reduction of electricity costs generated at Walker's Ferry WTP and Chilekla relay pumping station is indispensable.

Table 3-2.1 Power Consumption Rate per m^3 by Main Pumping Stations

Main Pumping Stations	Power Consumption Cost: A (MWK/Month)	Flow Rate: B (m^3/month)	Power Consumption Rate per m^3 :A/B (MWK/m^3)
Walkers Ferry	590,492,579	2,460,034	240.0
Chileka	397,034,855	2,206,758	179.9
Nyambadwe	2,622,600	86,630	30.3
Mudi R/W	2,965,380	424,852	7.0
Mudi T/W	29,441,137	308,018	95.6
Chichiri	28,638,576	564,720	50.7
Zomba Rd.	6,521,760	239,762	27.2
Midima	6,077,041	35,332	172.0
Soche Booster	8,271,129	109,107	75.8
Nguludi Station	67,442,156	298,798	225.7
Kameza	22,034,108	222,312	99.1
Chigumula Booster	7,938,835	103,404	76.8
Total	1,169,480,155	7,059,727	165.7

Source: Prepared by the JST based on the data obtained from BWB

3-2-2 Electricity Costs by Service Reservoirs (Based on Data in 2020)

The JST organized electricity costs by service reservoirs, and considered the power consumption rate at each service reservoir following the process (1), (2) and (3).

(1) Distribution of Electricity Costs by Service Reservoirs and Clear Water Tanks

Table 3-2.2 shows a list of the service reservoirs and clear water tanks which receive water from each main pumping station. Each main pump station transfers water to the service reservoirs or the clear water tanks that an "x" is shown in Table 3-2.2. For example, the transmission pumps at Walker's Ferry WTP have transferred water to 18 out of the 23 service reservoirs and or clear water tanks.

Table 3-2.2 Service Reservoirs or Clear Water Tanks which receive Water from each Main Pumping Stations

No	Pumping Station / Reservoir Clear WT	Water demand (m^3/day)	Walker's Ferry	Chileka	Nyamb adwe	Mudi R/W	Mudi T/W	Chichiri	Zomba Rd.	Midima	Soche Booster	Nguludi Station	Kameza	Chigumula Booster	Rate per m^3 (MWK/m^3/day)
1	Walker's Ferry	0	x												240.0
2	Chileka	0	x	x											420.0
3	Chileka village / Airport	1,142	x										x		339.1
4	Kameza	9,182	x										x		339.1
5	South Lunzu	14,570	x	x											420.0
6	Nyambadwe	28,384	x	x	x										450.2
7	Ndirande	8,504	x	x											420.0
8	Chirimba	11,174	x	x											420.0
9	Mt. Pleaant	7,077	x	x											420.0
10	Sanjika	32	x	x											420.0
11	Unicef	497	x	x											420.0
12	Chimwankhunda	7,641	x	x							x				495.8
13	Mudi	0	x	x		x	x								522.5
14	Chichiri	3,302	x	x		x	x	x							573.2
15	Kanjedza	12,306	x	x		x	x	x							573.2
16	Bangwe Clinic	2,087	x	x		x	x	x		x					745.2
17	B.C.A	582	x	x		x	x	x		x					745.2
18	Chigumula	1,538	x	x		x	x	x						x	650.0
19	Zomba road	3,603							x			x			252.9
20	Upper mpingwe	1,122							x			x			252.9
21	Lower mpingwe	1,256							x			x			252.9
22	Mpingwe	0							x			x			252.9
23	Nguludi	0										x			225.7
	Total	114,000	18	15	1	6	6	5	4	2	1	5	2	1	448.2

Source: The JST

(2) Electricity Costs Distributed by Service Reservoirs and Clear Water Tanks

Table 3-2.3 shows the current monthly electricity cost distributed by service reservoirs and clear water tanks. However, people do not receive water from the clear water tanks and some of service reservoirs directly, so water demand at the three clear water tanks as well as other two service reservoirs such as No.22 and No.23 are not indicated in Table 3-2.4. The power consumption rates changes from about MWK225/m^3 to MWK745/m^3. It is observed that the electricity costs are more than MWK 100 million/month in the service reservoirs such as No.5 South Lunzu, No.6 Nyambadwe, No.8 Chirimba and No.15 Kanjedza

Table 3-2.3 Monthly Power Consumption Cost of each Service Reservoir or Clear Water Tank

No	Service Reservoir or Clear Water Tank	Daily Maximum Water Demand (as of 2020) (m^3/day)*1	Power Consumption Rate per m^3 (MWK/m^3) *2	Electricity Costs (MWK/month)
		A	B	C = A x B x 30 days / 1.2*3
1	Walker's Ferry (Clear Water Tank)	0	240.0	0
2	Chileka (Clear Water Tank)	0	420.0	0
3	Chileka village / Airport	1,142	339.1	9,682,669
4	Kameza	9,182	339.1	77,851,368
5	South Lunzu	14,570	420.0	152,967,527
6	Nyambadwe	28,384	450.2	319,480,094
7	Ndirande	4,304	420.0	89,281,802
8	Chirimba	11,174	420.0	117,313,600
9	Mt. Pleaant	7,077	420.0	74,300,013
10	Sanjika	32	420.0	335,962
11	Unicef	4,697	420.0	5,217,904
12	Chimwankhunda	7,641	495.8	94,702,464
13	Mudi (Clear water tank)	0	522.5	0
14	Chichiri	3,302	573.2	47,319,908
15	Kanjedza	12,306	573.2	176,353,358
16	Bangwe Clinic	2,087	745.2	38,882,137
17	B.C.A	582	745.2	10,843,030
18	Chigumula	1,538	650.0	24,992,583
19	Zomba road	3,603	252.9	22,781,094
20	Upper mpingwe	1,122	252.9	7,094,196
21	Lower mpingwe	1,256	252.9	7,941,453
22	Mpingwe	0	252.9	0
23	Nguludi	0	225.7	0
	Total	**114,000**	**448.2**	**1,277,341,161**

Source: The JST

*1: See Table 2-6.21 and Table 3-2.2. The power consumption rate shown in Table 3-2.4 is accumulated by using that shown in Table 3-2.1.

*2: See Table 3-2.2.

*3: Daily maximum factor: 1.2

3-2-3 Electricity Costs required for Pump Operation based on Water Demand in 2030

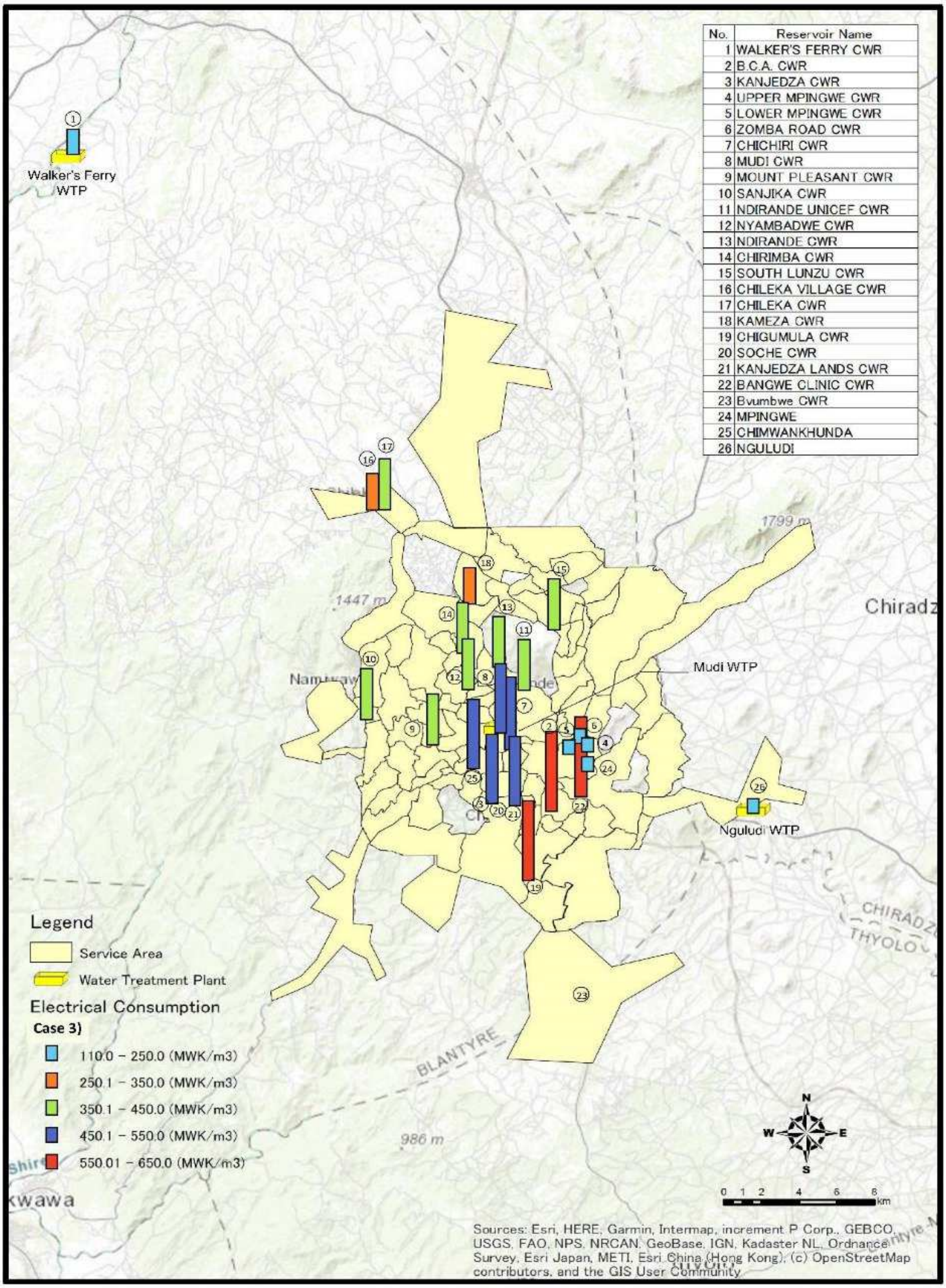
Table 3-2.4 shows the conditions for estimating electricity costs based on the water demand in 2030.

Table 3-2.4 Conditions to estimate Electricity Costs based on Water Demand in 2030

Items	Contents
Electricity cost data of each main pumping station	See Table 3-2.1
Distribution of electricity costs by service reservoirs from main pumping stations	See Table 3-2.2
Electricity costs by service reservoirs and clear water tanks	See Table 3-2.3
Water demand in 2030 (Daily Max.)	Case-1: 114,000 m^3/day, Track record in 2020 Case-2: 185,000 m^3/day, Water demand in 2030 (Leakage Ratio: 12%) Case-3: 175,000 m^3/day, Water demand in 2030 (Leakage Ratio: 7.5%) See Table 3-1.9

Source: The JST

Table 3-2.5 and Table 3-2.7 show the electricity costs by service reservoirs including clear water tanks, and pump stations based on water demand in 2030 respectively. The difference in water leakage ratio of 5.5% causes a gap in electricity costs of approximately MWK112 million per month. Therefore, it is of great importance to reduce leaks. Power consumption rate per m^3 by service reservoirs is illustrated in Figure 3-2.1.



Source: BWB

Figure 3-2.1 Energy Consumption Map of BWB

Table 3-2.5 Electricity Costs by Service Reservoirs or Clear Water Tanks based on Water Demand in 2030

No	Reservoir or Clear Water Tank	Water Demand（m³/day）*1			Power Consumption Rate per m³*2 (MWK/m³)	Monthly Electricity Costs (MWK/month)*3		
		Case 1 (2020)	Case 2	Case 3		Case-1 (2020)	Case-2	Case-3
1	Walker's Ferry (Clear W. T.)	0	0	0	240.0	0	0	0
2	Chileka (Clear W. T.)	0	0	0	420.0	0	0	0
3	Chileka village/Airp't	1,142	1,853	1,753	339.1	9,682,669	15,711,020	14,863,151
4	Kameza	9,182	14,901	14,095	339.1	77,851,368	126,341,019	119,507,192
5	South Lunzu	14,570	23,644	22,367	420.0	152,967,527	248,233,645	234,826,677
6	Nyambadwe	28,384	46,061	43,574	450.2	319,480,094	518,446,047	490,442,014
7	Ndirande	8,504	13,800	13,054	420.0	89,281,802	144,883,451	137,051,345
8	Chirimba	11,174	18,133	17,152	420.0	117,313,600	190,374,754	180,075,431
9	Mt. Pleaant	7,077	11,485	10,864	420.0	74,300,013	120,578,727	114,058,972
10	Sanjika	32	52	49	420.0	335,962	545,938	514,441
11	Unicef	497	807	763	420.0	5,217,904	8,472,532	8,010,585
12	Chimwankhun da	7,641	12,401	11,730	495.8	94,702,464	153,697,849	145,381,482
13	Mudi (Clear W. T.)	0	0	0	522.5	0	0	0
14	Chichiri	3,302	5,358	5,068	573.2	47,319,908	76,783,788	72,627,890
15	Kanjedza	12,306	19,970	18,892	573.2	176,353,358	286,183,695	270,735,221
16	Bangwe Clinic	2,087	3,387	3,204	745.2	38,882,137	63,101,964	59,692,557
17	B.C.A	582	944	893	745.2	10,843,030	17,587,320	16,637,158
18	Chigumula	1,538	2,496	2,361	650.0	24,992,583	40,560,135	38,366,377
19	Zomba road	3,603	5,847	5,531	252.9	22,781,094	36,969,486	34,971,477
20	Upper mpingwe	1,122	1,822	1,723	252.9	7,094,196	11,520,165	10,894,206
21	Lower mpingwe	1,256	2,039	1,928	252.9	7,941,453	12,892,215	12,190,383
22	Mpingwe	0	0	0	252.9	0	0	0
23	Nguludi (Clear W. T.)	0	0	0	225.7	0	0	0
	Total	114,000	185,000	175,000		1,277,341,161	**2,072,883,749**	**1,960,846,560**

Source: The JST
*1: See Table 2-6.21 Water demand in 2030 by each reservoir
*2: See Table 3-2.3 Monthly power consumption cost of each service reservoir or clear water tank
*3: A x B x 30 / 1.2: (Month / Day = 30 & Daily maximum/Daily average = 1.2)

Table 3-2.6 Electricity Costs by Main Pumping Stations based on Water Demand in 2030

Main Pumping Stations	Case-1 (2020)		Case-2		Case-3	
	Electricity Costs (MWK/month)	Water Flow Rate (m³/month)	Electricity Costs (MWK/month)	Water Flow Rate (m³/month)	Electricity Costs (MWK/month)	Water Flow Rate (m³/month)
Walkers Ferry	644,953,635	2,686,923	1,046,638,087	4,360,369	990,068,397	4,124,695
Chileka	433,653,330	2,410,287	703,737,551	3,911,441	665,701,275	3,700,032
Nyambadwe	2,864,482	94,620	4,648,515	153,550	4,397,267	145,251
Mudi R/W	3,238,876	464,036	5,256,085	753,044	4,972,000	712,342
Mudi T/W	32,156,489	336,426	52,183,916	545,957	49,363,430	516,448
Chichiri	31,279,908	616,804	50,761,390	1,000,957	48,017,790	946,856
Zomba Rd.	7,123,261	261,875	11,559,709	424,974	10,934,918	402,005
Midima	6,637,525	38,591	10,771,451	62,625	10,189,266	59,241
Soche Booster	9,033,974	119,170	14,660,436	193,390	13,868,055	182,938
Nguludi Station	73,662,337	326,356	119,540,078	529,614	113,079,062	500,989
Kameza	24,066,311	242,816	39,055,082	394,044	36,944,196	372,747
Chigumula Booster	8,671,032	112,941	14,071,450	183,282	13,310,903	173,376
Total	**1,277,341,161**	**7,710,845**	**2,072,883,749**	**12,513,247**	**1,960,846,560**	**11,836,919**

Source: The JST

3-2-4 Coverage by Photovoltaic Generation System in 2030

The impact of photovoltaic power generation systems was examined as follows. As shown in Table 3-2.7, the power consumption of Walkers Ferry and Chileka was 96.6 MW in 2020, and in future it is estimated that it will be 156.8 MW under Case-2 and 148.3 MW under Case-3. Therefore, it could be confirmed that even if another ongoing photovoltaic generation system project (42 MW: see Table 2-8.2) is completed, there will not be sufficient power generation to cover the power consumption needed by Walkers Ferry and Chileka. Even if Mudi Dam and the Mudi WTP were rehabilitated to reduce the burden on Walkers Ferry and Chileka, ESCOM's purchases of electricity would not end. As such, in parallel with the photovoltaic generation system project for self-sufficiency in electricity, as there is a need for studies on reducing electricity consumption at all water supply facilities, it is considered that this will not have an impact on the various considerations that follow this section.

Table 3-2.7 Coverage by photovoltaic generation system by each Pumping Station based on Water Demand in 2030

Pumping Stations		Case-1 (2020)		Case-2		Case-3	
		Power Consumption*1 (kWh/month)	Water Flow Rate (m^3/month)	Power Consumption*1 (kWh/month)	Water Flow Rate (m^3/month)	Power Consumption*1 (kWh/month)	Water Flow Rate (m^3/month)
Walkers Ferry	A	5,346,977	2,686,923	8,677,134	4,360,369	8,208,143	4,124,695
Chileka	B	4,314,413	2,410,287	7,001,479	3,911,441	6,623,057	3,700,032
Total	A+B	9,661,390	5,097,210	15,678,613	8,271,810	14,831,200	7,824727
Photovoltaic generation system*2	C	4,600,000		4,600,000		4,600,000	
Coverage by solar energy (%)	C/(A+B)	47.6		29.3		31.0	

Source: The JST

*1：(Power Consumption-kWh) = (Water Flow Rate - m^3/month) x (Power Consumption Rate per m^3 : Walker's Ferry 1.99 kWh/m^3 & Chileka 1.79 kWh/m^3)

*2：Converted to a monthly basis

3-2-5 Consideration of Electricity Costs considering the Production Capacity of Mudi WTP

Applying the water demand in 2030 of Case-3 (Safe side for a benefit analysis) (See Table 3-2.4), the JST examined the effects in reduction of the electricity costs by seasons and in that by a review of transmission routes.

(1) Reduction of Electricity Costs by Season

Table 3-2.8 shows the conditions of power consumption rate per m^3.

Table 3-2.8 Basis Conditions for Power Consumption Rate per m^3

Items	Contents
Electricity Costs by main pumping stations based on water demand in 2030	See Table 3-2.6
Power consumption rate per m^3 by main pumping station based on data in 2020	See Table 3-2.1
Water Production of Mudi WTP	● Case-3: 5,700 m^3/day (2020) ● Case-3-1: 13,636 m^3/day (Rainy season, 2030) (15,000 m^3/day: (Intake capacity from Mudi Dam) / 110% (Water loss)) ● Case-3-2: 7,727 m^3/day (dry season, 2030) (8,500 m^3/day: Intake capacity from Mudi Dam) / 110% (Water loss))

Source: The JST

Table 3-2.9 shows the change of the electricity costs by main pumping stations in case of rehabilitating Mudi WTP.

According to calculation of data shown in Table 3-2.9, the increase in water production in Mudi WTP is about 238,091 m^3/month in Case-3-1 and 60,819 m^3/month in Case-3-2. Consequently, MWK 99 million/month and MWK 25 million/month will be reduced for Case 3-1 and Case 3-2 respectively, resulting in reducing electricity costs of average MWK741 million/year (average of Case 3-1 and Case 3-2).

Table 3-2.9 Results of Electricity Costs by Main Pumping Stations

Main Pumping Stations	Case-3		Case-3-1		Case-3-2	
	Electricity Cost (MWK/Month)	Water Demand (m^3/month)	Electricity Cost (MWK/Month)	Water Demand (m^3/month)	Electricity Cost (MWK/Month)	Water Demand (m^3/month)
Walkers Ferry	990,068,397	4,124,695	932,918,409	3,886,604	975,469,947	4,063,877
Chileka	665,701,275	3,700,032	622,864,503	3,461,941	654,759,007	3,639,214
Nyambadwe	4,397,267	145,251	4,397,267	145,251	4,397,267	145,251
Mudi R/W	4,972,000	712,342	6,633,824	950,433	5,396,498	773,161
Mudi T/W	49,363,430	516,448	49,363,430	516,448	49,363,430	516,448
Chichiri	48,017,790	946,856	48,017,790	946,856	48,017,790	946,856
Zomba Rd.	10,934,918	402,005	10,934,918	402,005	10,934,918	402,005
Midima	10,189,266	59,241	10,189,266	59,241	10,189,266	59,241
Soche Booster	13,868,055	182,938	13,868,055	182,938	13,868,055	182,938
Nguludi Station	113,079,062	500,989	113,079,062	500,989	113,079,062	500,989
Kameza	36,944,196	372,747	36,944,196	372,747	36,944,196	372,747
Chigumula Booster	13,310,903	173,376	13,310,903	173,376	13,310,903	173,376
Total	1,960,846,560	11,836,919	1,862,521,623	11,598,828	1,935,730,339	11,776,101

Source: The JST

(2) Reduction of Electricity Costs by Review of Water Transmission Pipes Route

Table 3-2.10 shows the electricity costs calculated through a review of the water transmission pipes routes as mentioned in Table 2-6.24.The electricity costs of Option-1 is MWK 4,193,059/day, while that of Option-2 is MWK 2,311,692/day. The electricity costs of Option-2 is MWK 1,880,000/day lower than that of Option-1. As a noticeable point, in order to materialize Option-2, the new transmission pipelines of approximately 10 km should be laid between No.6 Nyambadwe and No.15 Kanjezda. Providing MWK 0.35 million/m as a unit cost of pipe laying, the cost of the pipe laying is estimated at MWK 3.5 billion.

Table 3-2.10 Comparison of Electricity Costs by Transmission Routes (Water Demand in 2030)

№	Reservoir	Power Consumption Rate*1 (MWK/m^3/day)	Option-1		Option-2	
			Water Flow Rate (2030) (m^3/day)	Electricity Costs (MWK/day)	Water Flow Rate (2030) (m^3/day)	Electricity Costs (MWK/day)
6	Nyanbadwe	76.0*2	0	0	30,417	2,311,692
13	Mudi(CW tank)	95.6	30,417	2,907,865	0	
14	Chichiri	50.7	25,349	1,285,194	0	0
	Total		55,766	4,193,059	30,417	2,311,692

Source: The JST

*1 : Table 3-2.1: Power Consumption Rate per m^3 of each Main Pumping Station

*2 : Average data apart from power consumption rate of Walker's Ferry and Chileka pumping station shown in Table 3-2.1

(3) Summary of Electricity Costs to bereduced

Total benefits on the transmission system is estimated at MWK 1.428 billion/year through increase in design capacity of Mudi WTP as below.

1) Reduction of Electricity Costs by Season
- MWK 741 million/year

2) Reduction of Electricity Costs by Review of Water Transmission Pipes Route
- MWK 687 million/year

3-3 Evaluation of Operation Condition on the existing Water Treatment Plant

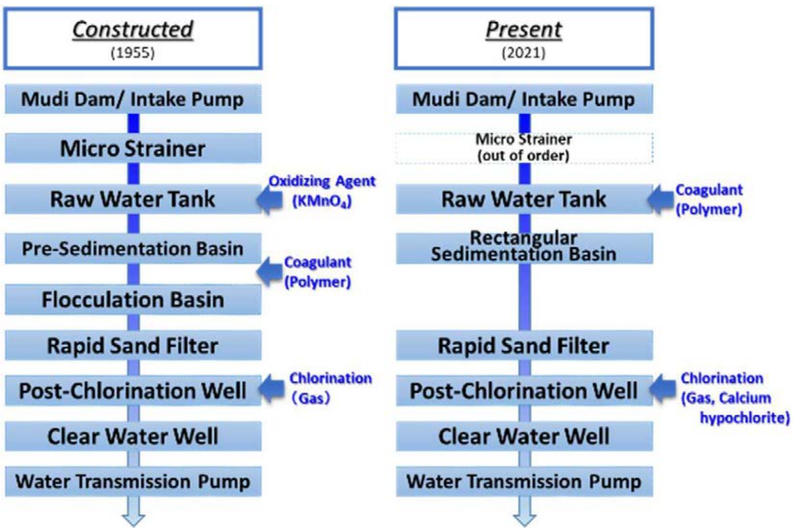
3-3-1 Transition of Mudi WTP

A layout of Mudi WTP is shown in Figure 3-3.1. Mudi WTP was constructed in the left bank of Mudi dam in 1955 next to BWB Headquarters. The treatment process diagrams as of 1955 and present ones are shown in Figure 3-3.2.

Source: The JST

Notes: PS: Pumping Station, MS: Micro Strainer, RW: Receiving Well, CoDW: Coagulant Dosing Well, SB: Sedimentation Basin, RSF: Rapid Sand Filter, PCW: Post-Chlorination Well, CWR: Clear Water Reservoir, WTPS: Water Transmission Pumping Station

Figure 3-3.1 Layout of Mudi WTP



Source: The JST

Figure 3-3.2 System Flow Diagrams of Mudi WTP

3-3-2 Water Production Capacity Evaluation of Mudi WTP

BWB has commonly recognized Mudi WTP with a design capacity of 45,000 m^3/day. Mudi WTP has been improved since constructed in 1955. Therefore, the JST evaluated the current water production capacity of Mudi WTP based on common design criteria of a rapid sand filter and a sedimentation basin.

(1) Rapid Sand Filtration

A filtration rate of the rapid sand filtration system is 120 to 150 m/day generally. According to CAD data on the rehabilitation project of Mudi WTP implemented in 2008, its design conditions are as follows:

- Surface area of filters: 8.648 m x 4.214 m x 8 ponds = 291.5 m^2
- In case of 120 m/day: 120 m/day x 291.5 m^2 = 34,980 m^3/day
- In case of 150 m/day: 150 m/day x 291.5 m^2 = 43,725 m^3/day

Therefore, it was estimated that a water production capacity of Mudi WTP is about 35,000 to 44,000 m^3/day by calculation of a rapid sand filtration.

(2) Sedimentation Basin

There are no flocculation ponds in the sedimentation process flow.

Surface loading rate of rectangular sedimentation basins is 15 to 30 mm/min generally. According to CAD data on rehabilitation project of Mudi WTP, its design conditions are as follows:

- Surface area of basins: 4.570 m x 22.048 m x 2 x 2 lines = 403.0 m^2
- In case of 15 mm/min.: 15 mm/min. /1000 x 24 x 60 x 403.0 m^2 = 8,706 m^3/day
- In case of 30 mm/min.: 30 mm/min. /1000 x 24 x 60 x 403.0 m^2 = 17,411 m^3/day

Therefore, it was estimated that a water production capacity of Mudi WTP is 9,000 to 17,000 m^3/day by calculation of a sedimentation basin. However, the water production capacity should be underestimated because of treatment system without a flocculation basin.

3-3-3 Current Condition of Mudi WTP

(1) Sedimentation Basin

Mudi WTP has currently a major challenge on the treatment process, because there are no rapid mixing basins and flocculation ponds required for appropriate coagulation as shown in Figure 3-3.2. There were flocculation basins with flush mixers when constructed in 1955, but now only the rectangular sedimentation basins have been functioning. Therefore, floc does not settle at the sedimentation basins and carries over to the rapid sand filtration as shown in Figure 3-3.3. Operation of the rapid sand filtration process has been highly loaded with carry-over of flocs. Moreover, it is difficult to rehabilitate Mudi WTP by using the existing structure in terms of layout, location and its actual water production capacity.

Source: The JST

Notes: [left] Existing Rectangular Sedimentation Basin, [right] Carry-over of Floc

Figure 3-3.3 Carry-over of Floc at the Sedimentation Basin

(2) Coagulant

Algaefloc as one of cation coagulant has been dosed to the receiving wells. Since there is toxic concern of an acrylamide monomer, its usage is restricted up to 70 mg/L. Although Algaefloc is dosed to the top of the receiving wells, the function of the mixing basin was insufficient.

Source: The JST
Notes: [left] Usage of Algaefloc, [right] Dosing Coagulant to Receiving Well

Figure 3-3.4 Dosing Coagulant

(3) Rapid Sand Filter

At current system of Mudi WTP, floc has not settled out at the sedimentation basins and carried over to the rapid sand filtration. Consequently the rapid sand filtration has been loaded by carry-over of floc highly as described earlier. In addition, backwash has not been carried out equally in the sand filters due to deterioration and the installation accuracy of the cleaning equipment. Current filtration system has serious problems on the treatment process, because sediment floc makes "mad-ball" and it causes not only deterioration of treated water quality but also frequent backwash to eliminate clogged filters as shown in Figure 3-3.5. Although frequency on replacement of filter media is once time every five to seven years generally, filter media has been replaced with new one every year in Mudi WTP.

Source: The JST
Notes: Unequaled Backwash due to Mud-ball of Filter Sand Layer

Figure 3-3.5 Mud-ball of Filter Sand Layer

Moreover, surface level of sand layer is designed considering an expansion rate of the sand layer at the time of backwash. It seems that lots of filter media flow out to drainage during backwashing, because the elevation of surfaces of the drainage trough is almost the same as that of sand layer.
It is difficult to improve Mudi WTP structurally because of the much deteriorated WTP which was constructed in 1955.

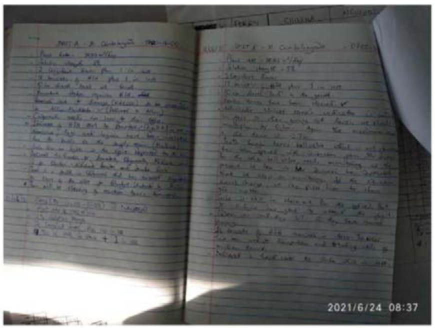
The current system of Mudi WTP has a major challenge on the treatment process because of the following reasons;

- Carry-over of floc to rapid sand filter
- Clogged filters by mad-ball
- Water loss (about 28%) between Mudi Dam intake point and Mudi WTP
- Outflow of filters from an effluent trough when backwashed

Therefore, it is necessary to improve Mudi WTP with an appropriate treatment process so as to eliminate carry-over and high frequent replacement of filter media.

(4) Sludge Removal

Sludge is transferred from the sedimentation tank to the sludge drying bed via the installed pipes. The Water Quality and Environmental Management Section determine the timing of sludge removal based on the turbidity of raw water and report to the Supply Officer. Basically, sludge removal is conducted once every two or three weeks, and the record is handwritten by the WTP operation staff (See Figure 3-3.6).



Source: The JST

Figure 3-3.6 Record of Sludge Removal

3-4 Examination for Possible Water Yield of Mudi Dam

Based on the rainfall and outflow discharge observation data obtained through the Survey in Blantyre, the JST established a runoff model for examining the water resource potential, prepared a series of dam inflows for 11 years using validating this runoff model (tank model method), and examined possible water yield by the simulation of dam reservoir operation.

The discharge monitoring was carried out by the Blantyre Water Resources Department, the Ministry of Forestry and Natural Resources, at the spillway of Mudi Dam during the rainy seasons in 2019 and 2020.

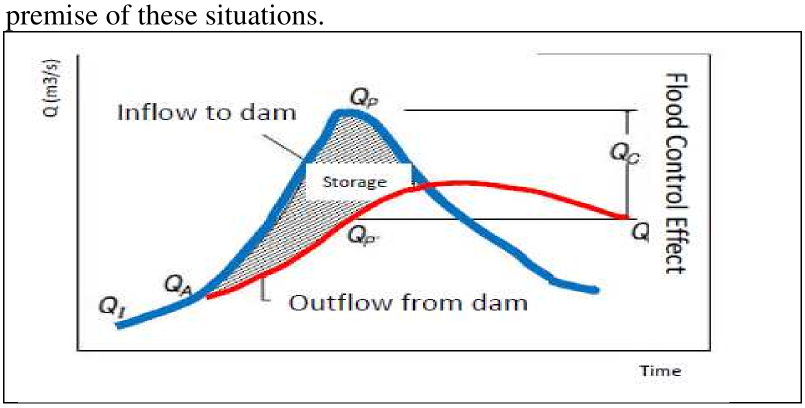
Monitoring Facilities at the Spillway of Mudi Dam

Monitoring of Velocity

Source: Blantyre Water Resources Department, MFNR

Figure 3-4.1 Discharge Monitoring at the Spillway of Mudi Dam

Monitoring data at the spillway of Mudi Dam show outflows (red line in Figure 3-4.2) after the reservoir, but it is not a direct inflow from the catchment (dam inflow). Taking into account the obtained data for monitoring discharges, it is judged that the data is insufficient and the monitoring accuracy is low. However, since there is currently no other valid monitoring data, an outflow analysis would be conducted on the premise of these situations.



Note: Inflow hydrograph shows in blue and outflow hydrograph shows in red

Figure 3-4.2 Conceptual Diagram of Inflow and Outflow in Reservoir

3-4-1 Examination Approaches

The approaches for examining the possible water yield that can be taken at Mudi Dam is as follows.

(1) Examination of Low Water Runoff Model applying a Tank Model Method

The parameters of the low water runoff model are determined and verified by inputting the daily rainfall and evapotranspiration for the outflow discharge observed during rainy seasons in 2019 and 2020. The low water runoff model is adopted by the tank model method.

(2) Long-term Low Water Runoff Analysis (validation of daily inflow for reservoir operation simulation)

As the catchment runoff (reservoir inflow) used for the reservoir operation simulation, the JST will analyze a long-term daily runoff for 11 years, which is a common standard for the examination of a reservoir operation plan. The planning period will be targeted from 2011 to 2020.

(3) Reservoir Operation Simulation

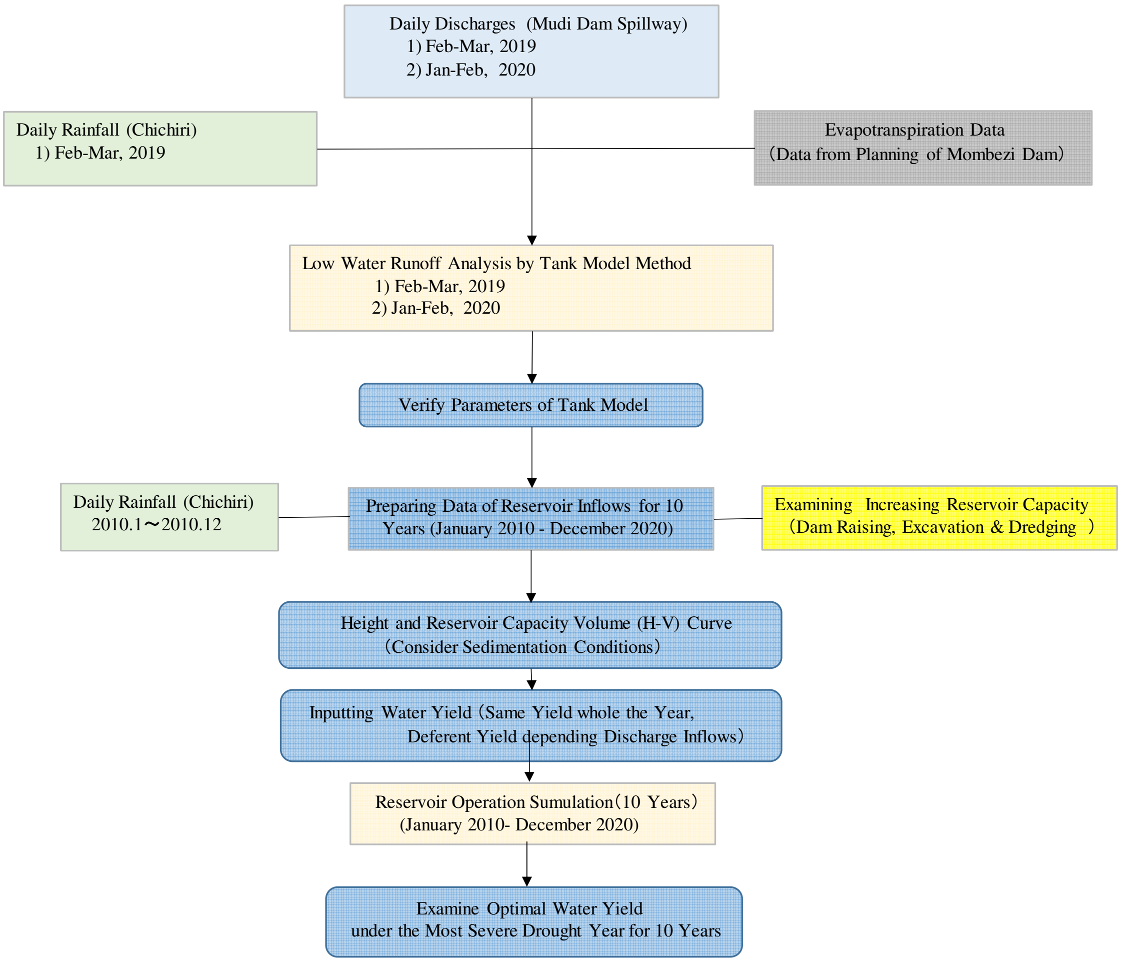
By inputting the relationship between reservoir level (H) and capacity (V) curve, raw water intake quantity (possible water yield), and dam water level specifications into the dam inflows for 11 years, the JST will simulate a 11-year reservoir operation. The parameters to be examined are as follows:

- Water yields (considering runoff features during the rainy season and dry season)
- Excavation volumes in the reservoir, and H-V curve that considers dredging and excavation works

(4) Examination of possible water yield

Based on the examination results described in “(3)", the JST will organize the possible water yield which is simulated in each case, and examine the most severe drought year during for 11 years.

Figure 3-4.3 shows the examination flow chart based on the above policy.



Source: The JST

Figure 3-4.3 Flow Chart to examine Possible Water Yield in Mudi Dam

3-4-2 Low Water Runoff Analysis by using Tank Model Method

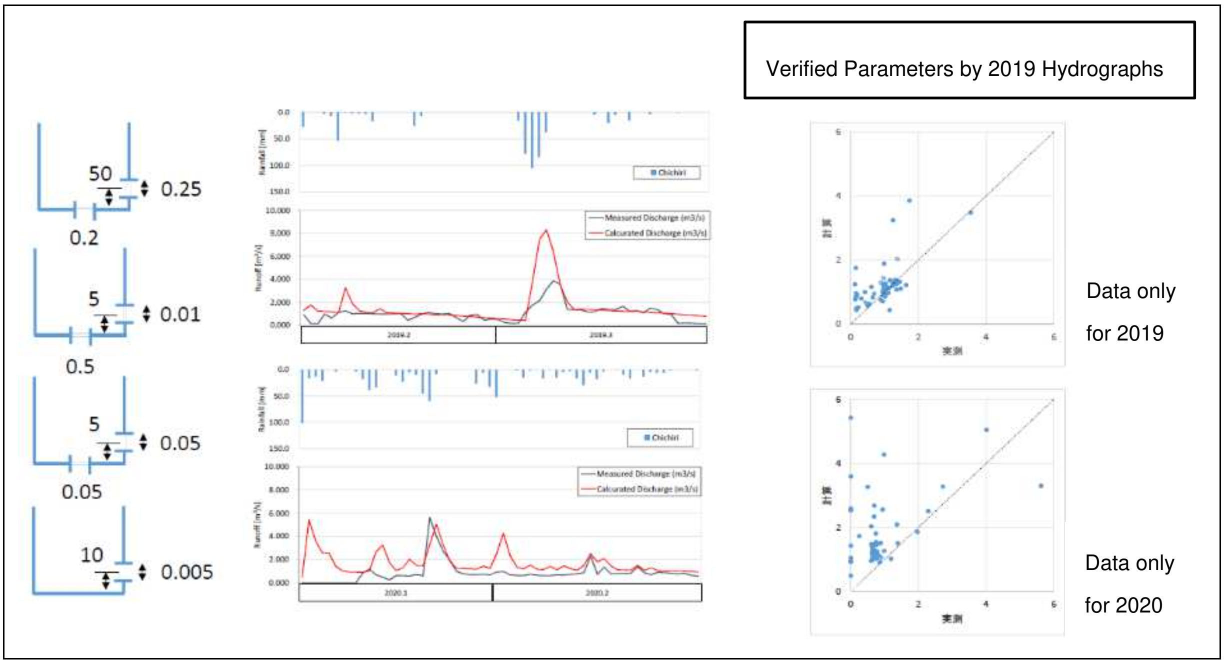
Since the every two-month observation data of the inflow discharge for two years at Mudi Dam was obtained from BWB, the JST determined parameters of the tank model method for these periods, and simulated the inflow discharge for 11 years by using the parameters. The input data for the verification of tank model method is daily rainfalls and evapotranspiration. The outline of these data is shown in Table 3-4.1.

Table 3-4.1 Input Data for verifying the Parameters for Tank Model

Items	Features (Place)	Remarks
1. Dairy Rainfall	Chichiri Stataion	
2. Evapotranspiration	Mombezi Dam (Planning)	Sogreah Report (2010)
3. Dam Discharge Outflow	Spillway at Mudi Dam	February-March, 2019, January to February 2020

Source: The JST

In a tank model verification process, the parameters verified by the 2019 hydrograph were relatively corresponded with the actual results as shown in Figure 3-4.4. When the parameters obtained by this process were applied for the 2020 hydrograph, the results were not corresponded with the actual data. The correlation coefficient is 0.753 and 0.379 in 2019 and 2020 respectively.

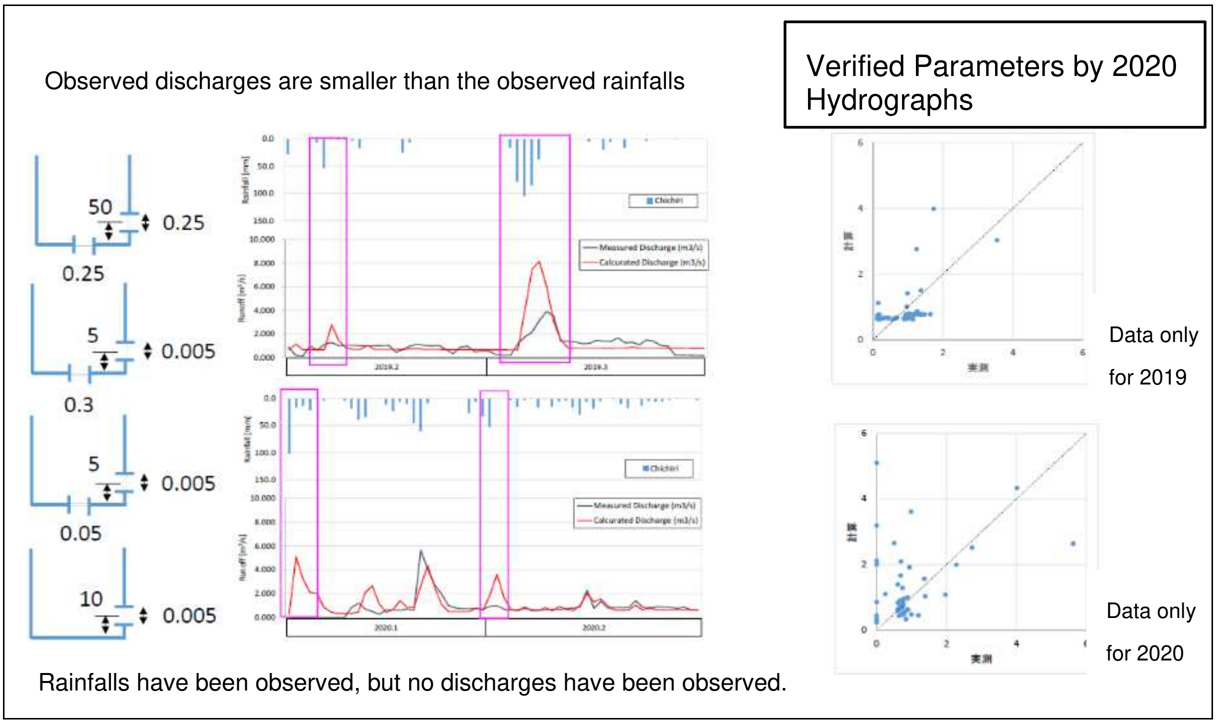


Source: The JST

Figure 3-4.4 Parameters verified in the 2019 Hydrographs and applying for the 2020 Hydrographs

Similar verifications were made in the 2019 hydrograph with constants that meet the 2020 verification results. The results shown in Figure 3-4.4 were observed, and there were some events in which rainfall was observed but no discharge, and other events in which the discharge decreased even when the volume of rainfall increased.

The observation discharge is represented as the average of two observation discharges in the morning and afternoon. It is envisaged that the low water discharges can be observed, but the peak discharge corresponding to the large hourly rainfall cannot be observed.



Source: The JST

Figure 3-4.5 Parameters verified in Hydrographs (2020) and applying for Hydrographs (2019)

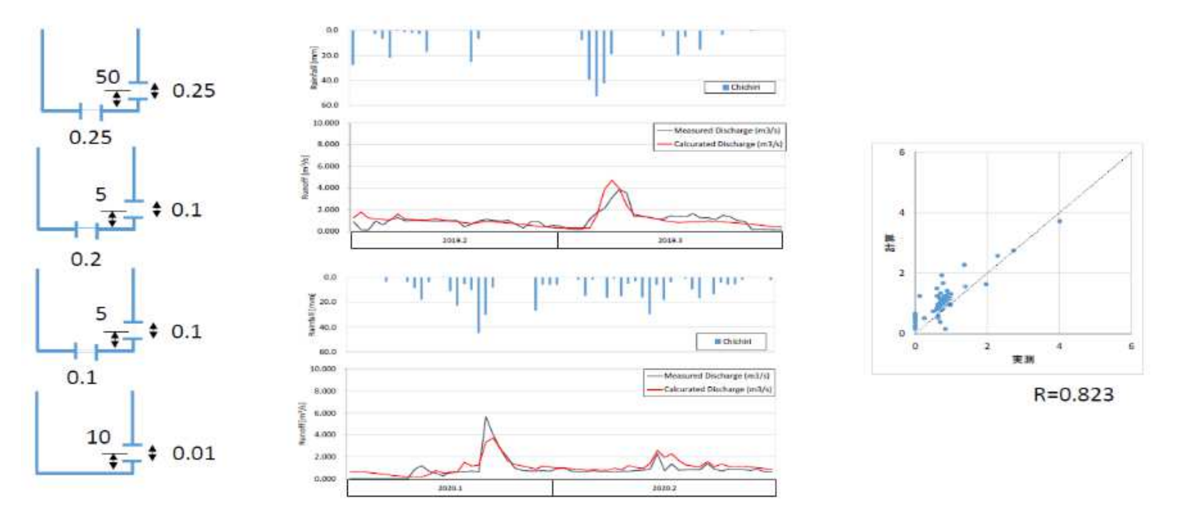
The parameter verification approaches for the tank model method are as follows:

a. Since the parameters verified in the 2019 hydrographs are a tendency to meet the actual hydrographs, the verification is made based on these parameters.

b. While rainfall is not observed, the daily rainfall itself is excluded during the period when there is a large discharge or when there is no discharge observation.

c. Since it is considered that the observed discharges are affected by the storage of Mudi Dam, the daily rainfall volume is arranged by back-calculating the peak discharge with respect to the actual rainfall from the concept of effective rainfall.

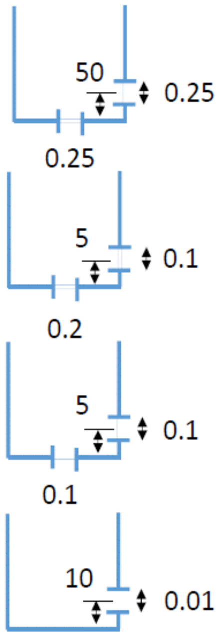
The verification results based on the above examination approaches are shown below. The correlation coefficient is to be r = 0.82, which is to be high (see Figure 3-4.6).



Source: The JST

Figure 3-4.6 Parameter Results verified by a Tank Model Method

The parameters verified by a tank model method are shown in Figure 3-4.7.

Parameters for Surface Runoff (1st Stage Tank) a1 Runoff hole : 0.25 s1 Height of runoff hole : 50 g1 Penetration hole : 0.2	
Parameters for fast intermediate flow (2nd Stage Tank) a2 : 0.10 s2 : 5 g2 : 0.20	
Parameters for slow intermediate flow (3rd Stage Tank) a3 : 0.10 s3 : 5 g3 : 0.10	
Parameters for groundwater flow (4th Stage Tank) a4 : 0.01 s4 : 10	

Source: The JST

Figure 3-4.7 Verified Parameters for 4-Stage Tank Model

3-4-3 Characteristics of Simulated Discharges by Tank Model Method

Applying the parameters for the discharge simulation by a tank model method, the inflow discharge for 11 years at Mudi Dam was simulated. The simulation results for discharges are summarized below.

(1) Annual inflow discharge, drought ranking and reservoir turnover rate

The daily inflow discharge for 11 years was simulated by the tank model method, and the annual total inflow discharge, drought ranking, and reservoir turnover rate (based on the initially planned capacity of 1.5 million m^3) are shown in Table 3-4.2.

Table 3-4.2 Annual Inflow Discharge, Drought Ranking and Reservoir Turnover Rate

Year	Annual Total Inflow Discharge (m^3)	Drought Ranking	Reservoir Turn Rate (Times/year) V= 1.5 Mm^3
2010	18,167,524	9	12.1
2011	10,814,625	3	7.2
2012	12,859,369	5	8.6
2013	17,746,240	8	11.8
2014	10,149,435	2	6.8
2015	23,598,373	11	15.7
2016	11,521,901	4	7.7
2017	13,206,702	6	8.8
2018	18,167,524	10	12.1
2019	16,489,904	7	11.0
2020	7,692,830	1	5.1

Source: BWB

According to Table 3-4.2, the drought years are 2020, 2014, and 2011. The turnover rates of the reservoir is about five times at the minimum and 12 times at the maximum.

(2) Organizing annual flow regime

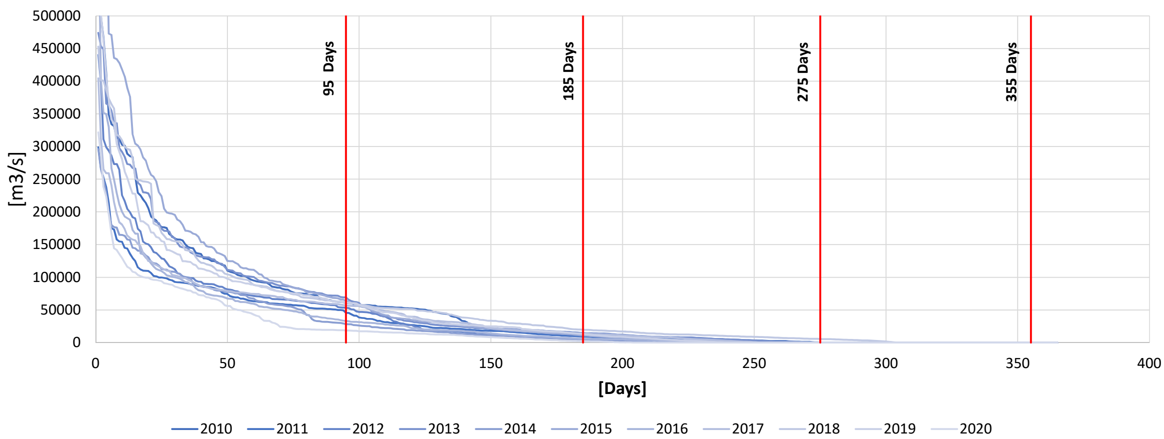
Table 3-4.3 shows the results of the flow regimes of inflow discharge. In most of the years, the annual flow regime is up to the 185-day discharge which is severe for water use.

Table 3-4.3 Annual Flow Regime of Inflow Discharge in Mudi Dam (m3/day)

Discharges/ Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
95-day	60,653	45,619	53,309	69,206	28,166	63,763	33,178	56,938	61,085	61,517	18,576
185-day	12,614	9,245	4,579	14,861	4,147	10,973	6,048	14,083	19,526	12,874	2,333
275-day	259	0	0	86	0	0	0	0	5,443	0	0
355-day	0	0	0	0	0	0	0	0	0	0	0

Source: Prepared by the JST based on data obtained from BWB

Annual flow regime is shown in Figure 3-4.8.

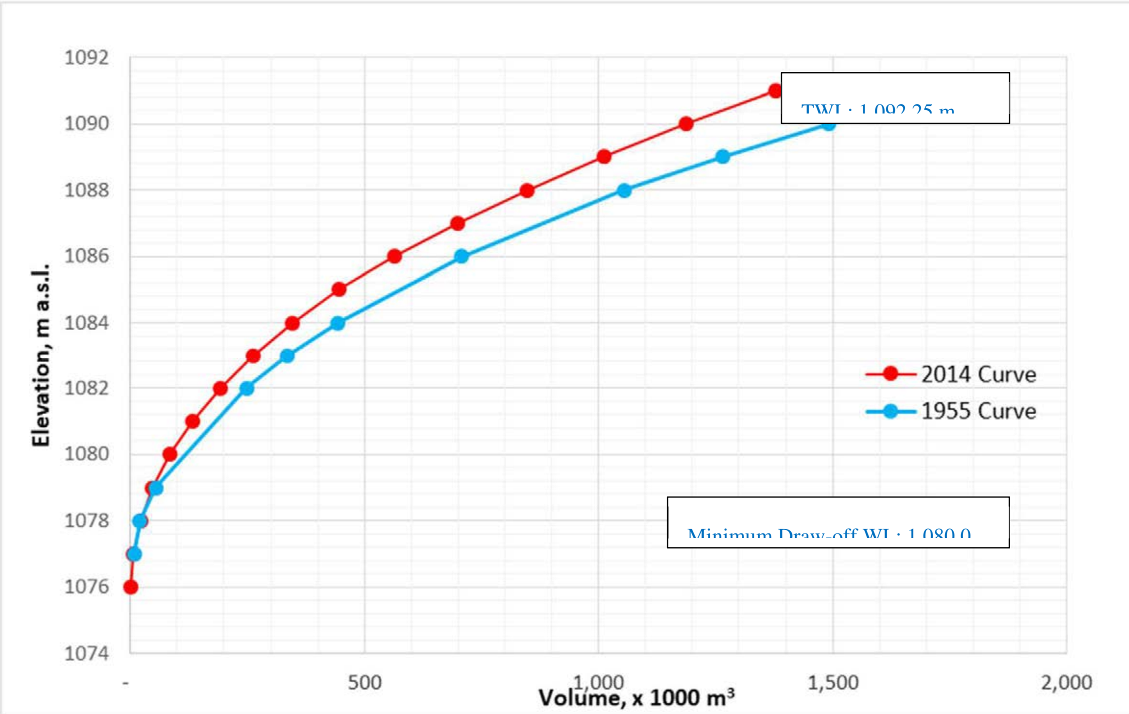


Source: Prepared by the JST based on data obtained from BWB

Figure 3-4.8 Annual Flow Regime of Inflow Discharge in Mudi Dam

3-4-4 Examination for Possible Water Yield through Reservoir Operation Simulation in Mudi Dam

In regard to water resource development plans, a safety factor (equivalent to the first place in 10 years) is set up to determine the drought year in a long-term plan. Therefore, a 10 year is the minimum year required for examining possible water yield. The JST conducted a reservoir operation simulation by estimating inflow of the dam for 11 years and verified by a tank model method, applying daily rainfall data from 2011 for 11 years. The relationship between reservoir water level and reservoir capacity volume (H-V curve) used for the reservoir operation simulation was conducted based on the hydrographic survey done in 2014, "(Nicholas O'Dmyer (NOD) Report, 2015)". In case where excavation and dredging work are considered, the H-V curve at the beginning of the operation in 1955 will be used. H-V curves are shown in Figure 3-4.9.



Source : Mudi and Hynde Dams Hydrographic Survey & Yield Verification (NOD Report, 2015)

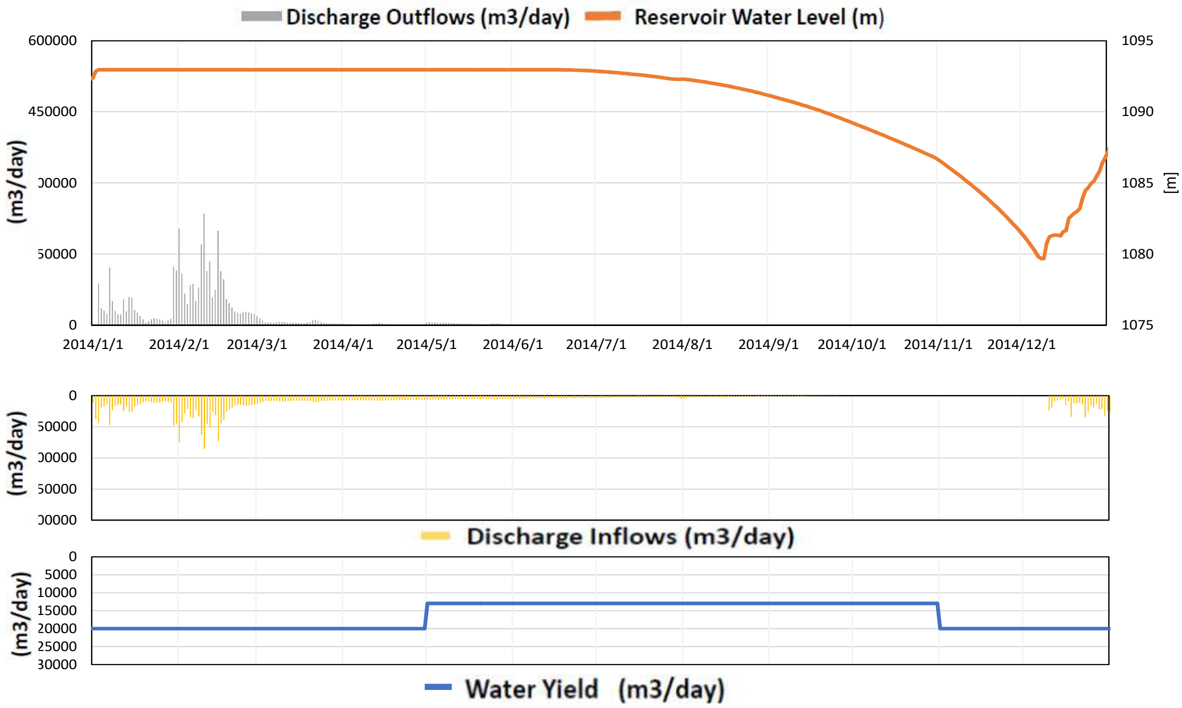
Figure 3-4.9 Height – Reservoir Capacity Volume (V) Curves (Year of 1955 and 2014)

Regarding the annual reservoir operation, as shown in Figure 3-4.10 (refer to the year of 2014 as an example), the reservoir operation is to store inflow discharge of the dam. The maximum water level for storing water to be set at the full water level of the dam (current operating water level +1.0m or +2.0 m, 1,092.96 m), and if water level exceeds the full water level, it is not used effectively and is discharged from the dam.

On the other hand, the lowest water level is 1,080.0 m when the water storage level gets down. If the dam inflow is larger than the water intake (water yield), the water storage level rises. However, if the dam inflow is smaller than the water intake, the water storage level gets down.

Several examination patterns of water yield is divided into two: the case where a certain water yield is taken in a year, and the case where the water yield is developed in the rainy season and the water yield developed in the dry season.

The upper section in Figure 3-4.10 shows the reservoir water level fluctuations and outflow discharge. The middle section in the same figure shows the inflow discharge of Mudi Dam, and the lower section in the same figure shows the water yield.



Source: The JST

Figure 3-4.10 Example of Reservoir Operation Simulation Results in 2014

The simulation results of water yield from 2010 for 11 years are shown below together with the simulation conditions. The possible water yield was set on the condition that there are no the days when the lowest water level is observed even in the most drought year (the year when the water level is the lowest for 11 years).

As for the flow regimes in Mudi Dam, large increase in inflow discharge are observed from January to March during the rainy season, and the inflow discharge exceeding the setting water level becomes the so-called "dead outflow discharge" that spill out from the spillway of the dam. Under the condition of simulating the effective use of the dead outflow discharge, the JST examined the various reservoir operations in order to develop water yield as much as possible in the rainy season. In other words, it is expected that the optimum reservoir operation can reduce the dead outflow discharge by increasing the water yield.

Therefore, the JST simulated reservoir operation not only under a constant water yield through the year but also under various water yield dividing into two or three terms. The term divisions for water yield simulation are set as shown in Table 3-4.4.

Table 3-4.4 Term Division for Water Yield Simulation

2-term	Rainy Season		Dry Season
	November - April (Six months)		May - October (Six months)
3-term	Rainy Season-1	Rainy Season-2	Dry Season
	January & February (Two months)	March, April, November & December (Four months)	May - October (Six months)

Source: The JST

Table 3-4.5 shows the setting conditions on reservoir operation simulations including cases that the dead outflow discharge is used as effectively as possible. Regarding the dam raising, the JST simulated the case where the Malawi Railway Bridge does not need to be improved (the dam height to be raised at 1.2 m) and the case where it needs to be improved (the dam height to be raised at 2.0 m). The height of 1.2 m is the maximum possible raising height of Mudi Dam, unless the Malawi Railway Bridge does not need to be relocated, as describes in Table 3-4.5.

Table 3-4.5 Simulation Cases for Examination of Possible Water Yield

Simulation Case	Reservoir Operation Water Level		Applying H-V Curves (in the year)
	Lowest Water Level (m)	Highest Water Level (m)	
1) Current Operation (CO) (Zero Option)	1,080.0	1,090.96	2014
2) Dam Raising (DR) : 1.2m	1,080.0	1,092.16	2014
3) Dam Raising (DR) :2.0m	1,080.0	1,092.96	2014
4) Excavation and Dredging (E&D)	1,080.0	1,090.96	1955
5) E&D＋DR : 1.2m	1,080.0	1,092.16	1955
6) E&D＋DR : 2.0m	1,080.0	1,092.96	1955
7) CO ＋Different Water Yield (DWY) depending on rainy and dry season	1,080.0	1,090.96	2014
8) DR:1.2m＋DWY	1,080.0	1,092.16	2014
9) DR: 2.0m＋DWY	1,080.0	1,092.96	2014
10) E&D＋DR:1.2m＋DWY	1,080.0	1,092.16	1955
11) E&D＋DR:2.0m + DWY	1,080.0	1,092.96	1955

Source: The JST

The results of possible water yield simulated for each term division are summarized in Table 3-4.6.

Table 3-4.6 Results of Possible Water Yield under 3-Term Division

Constant Water Yield Development throughout the Year			
Simulation Case	Output of Yield (m³/day)		
1) Current Operation (Zero・Option)	6,500		
2) Dam raising with height of 1.2 m (DR1.2 m)	7,000		
3) Dam raising with height of 2.0 m (DR2.0 m)	7,500		
4) Excavation and dredging (E&D)	8,500		
5) E&D＋DR1.2 m	9,000		
6) E&D＋DR2.0 m	10,000		
Water Yield Development during Rainy Season (RS) and Dry Season (DS) (2-Term Division)			
Simulation Case	Yield in RS (m³/day)		Yield in DS (m³/day)
7) Current Operation (Zero・Option)	8,500		6,500
8) Dam raising with height of 1.2 m (DR1.2 m)	11,000		7,000
9) Dam raising with height of 2.0 m (DR2.0 m)	12,000		7,500
10) E&D＋DR1.2 m	**15,000**		**8,500**
11) E&D＋DR2.0 m	16,000		9,000
Water Yield Development during Rainy Season with 2-Term (RS) and Dry Season (DS) (3-Term Division)			
Simulation Case	RS (m³/day)		DS (m³/day)
	RS1 January-February	RS2 March, April, Nov. & Dec.	May to Oct.
12) Current Operation (Zero・Option)	60,000	10,000	6,000
13) Dam raising with height of 1.2 m (DR1.2 m)	70,000	12,000	6,500
14) Dam raising with height of 2.0 m (DR2.0 m)	70,000	12,000	7,500
15) E&D＋DR1.2 m	85,000	14,000	8,500
16) E&D＋DR2.0 m	90,000	14,000	9,000

Source: The JST

The simulation results by reservoir operation are summarized below.

(1) Constant Water Yield Development throughout the Year

There is a tendency for the water yield development to increase, as the capacity of the reservoir increases. With a constant water yield development throughout the year, the effect of a large increase in water yield cannot be obtained even if the reservoir capacity increases, because it depends on an inflow rate during the dry season.

In Case-1 (zero-option), water yield is developed to be 6,500 m^3/day, and even in Case-6 including "dredging/excavation works + dam raising, 2.0 m", water yield is developed to be 10,000 m^3/day.

(2) Water Yield Development during the Rainy Season and the Dry Season (2-Term)

The water yield during the rainy season is constant. For this reason, the annual water yield development is divided into two terms: the rainy season and the dry season.

As the reservoir capacity increases, a possible water yield increases due to the raising of the dam and dredging works.

Therefore, in Case 11 "dredging & excavation works + dam raising, 2.0 m", which shows the largest reservoir capacity, the maximum water yield can be estimated at 16,000 m^3/day, as shown in Table 3-4.6. If the dam is raised by 1.2 m, possible water yield is estimated at 15,000 m^3/day.

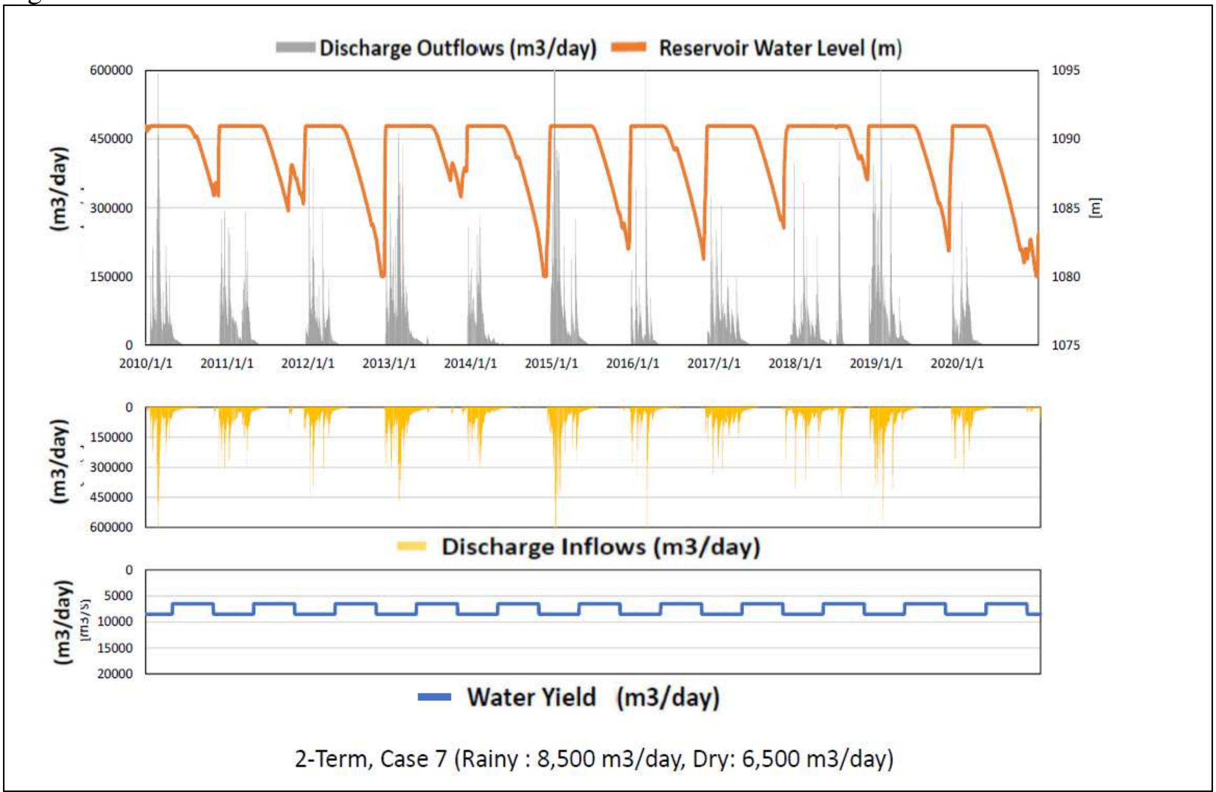
(3) Water Yield Development during the Rainy Season including two terms and the Dry Season (3-Term)

Since inflow discharge increases during the rainy season, this is a method of storing inflow and increasing water yield during the rainy season.

There is a tendency for reservoir inflow to be large from January to February, and this is the way to maximize water yield during these months. As the reservoir capacity increases, water yield increases.

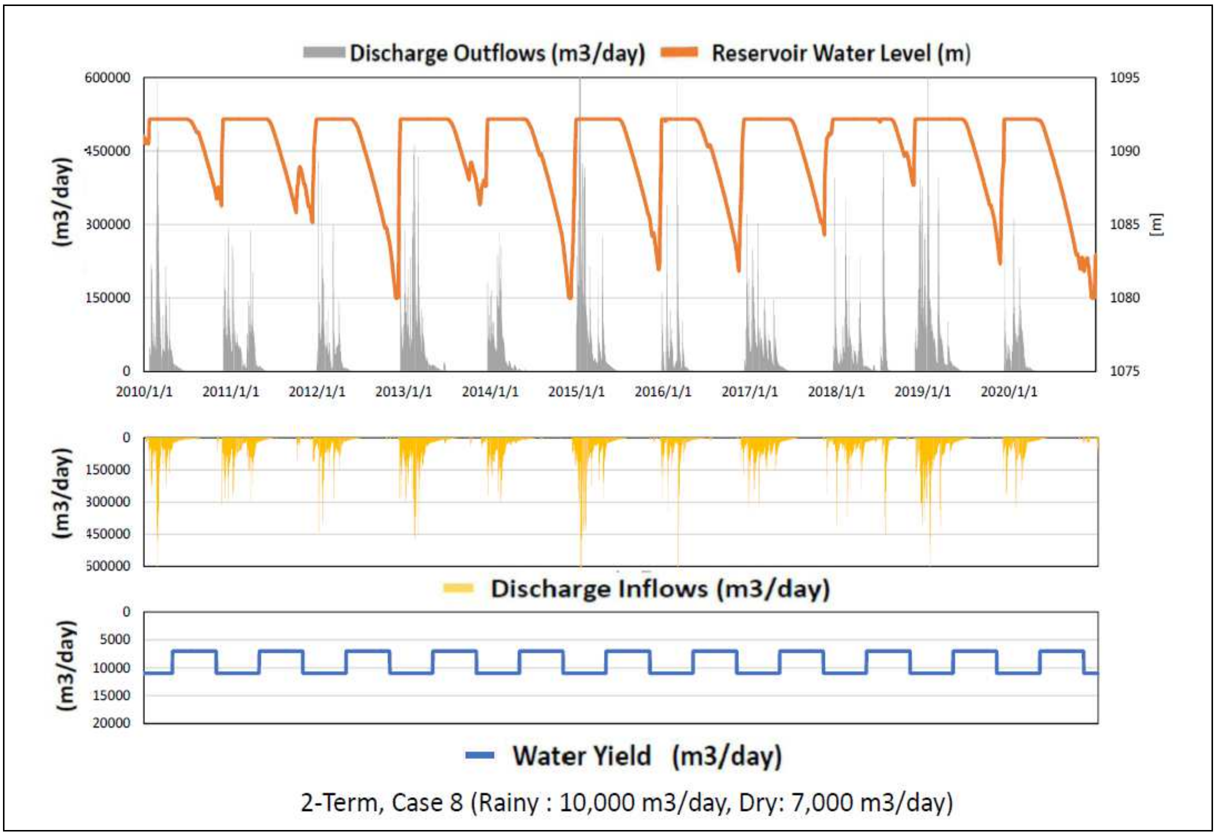
In Case 16 "Dredging and excavation works + dam raising, 2.0 m", water yield of 90,000 m^3/day can be developed as shown in Table 3-4-6. Even if height of the dam raising is to be 1.2 m (in Case 15), it is expected that water yield of 85,000 m^3/day can be developed.

The simulation results of reservoir operation in Case 7, 8 and 10 in the 2-term are shown in Figure 3-4.11 to Figure 3-4.13, while those in Case 12, 13 and 15 in the 3-term are shown in Figure 3-4.12 to Figure 3-4.15.



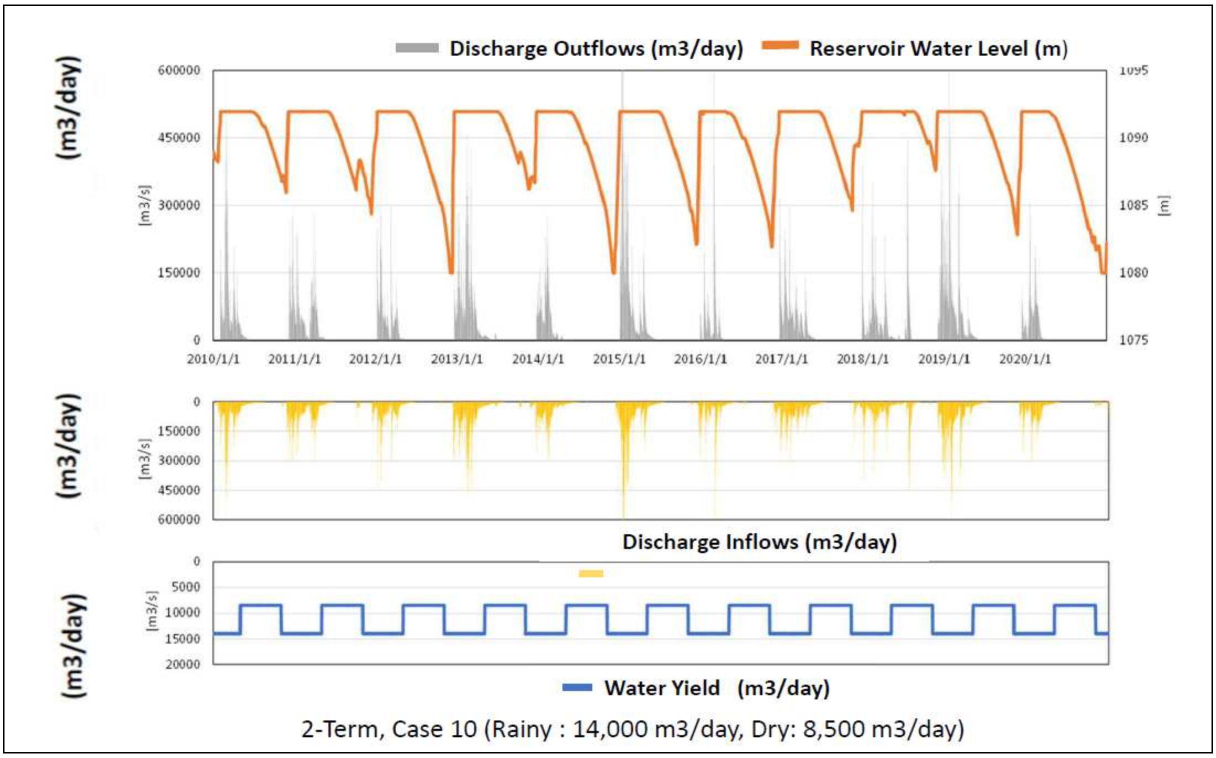
Source: The JST

Figure 3-4.11 Simulation Results of Reservoir Operation for Case 7 (2-Term)



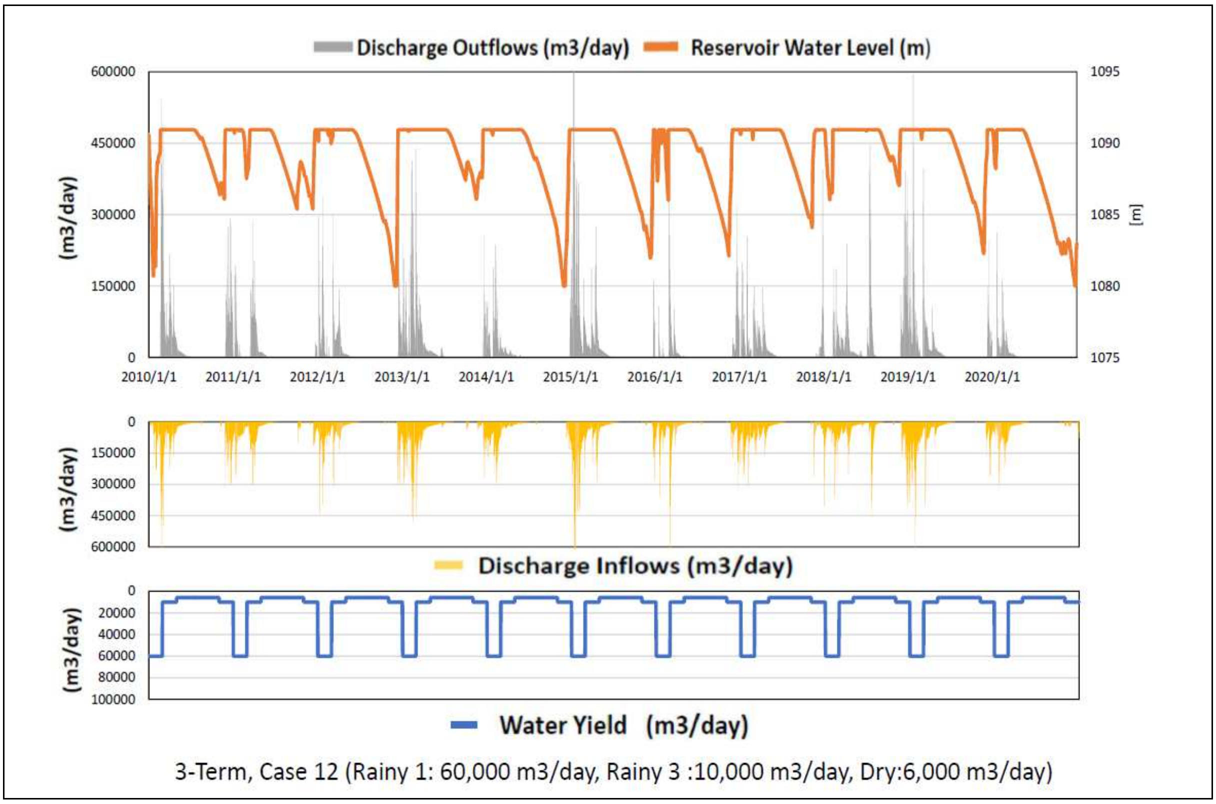
Source: The JST

Figure 3-4.12 Simulation Results of Reservoir Operation for Case 8 (2-Term)



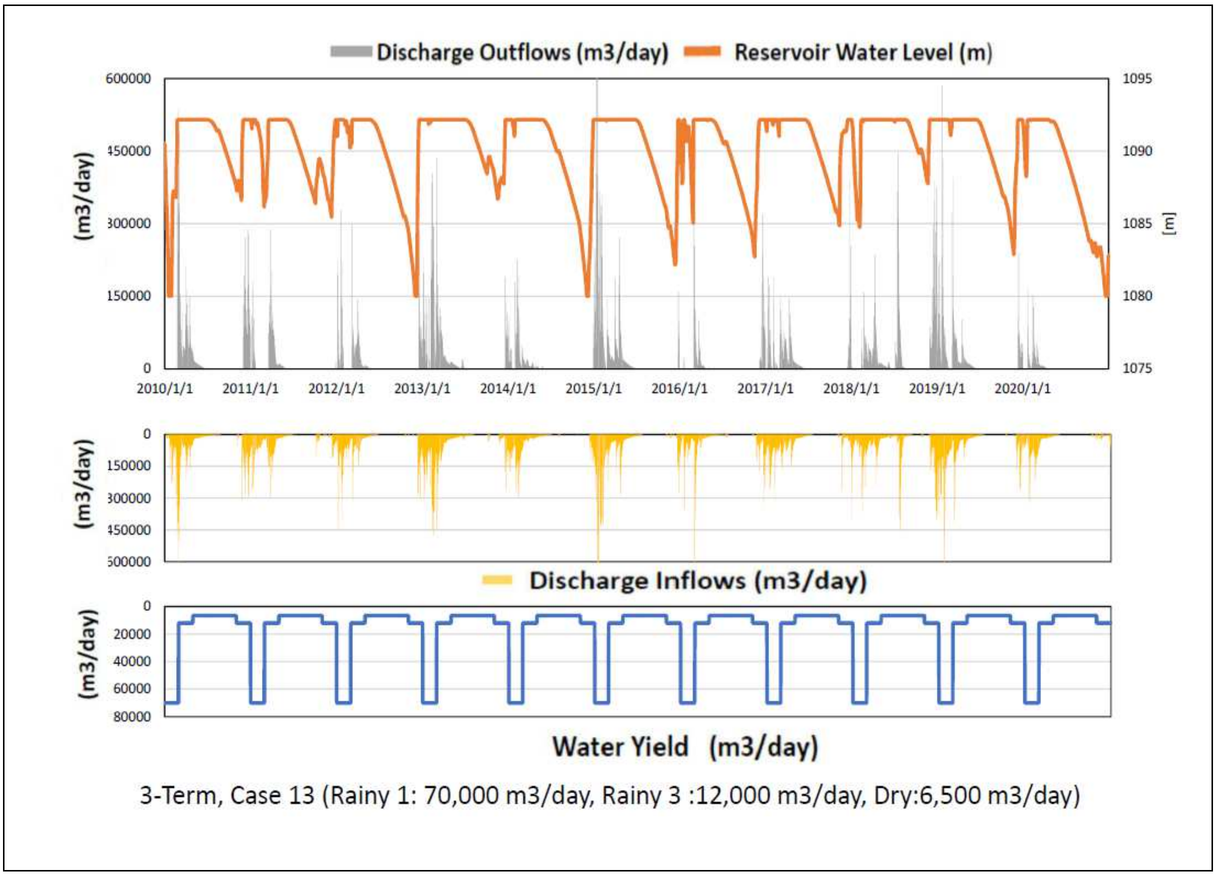
Source: The JST

Figure 3-4.13 Simulation Results of Reservoir Operation for Case 10 (2-Term)



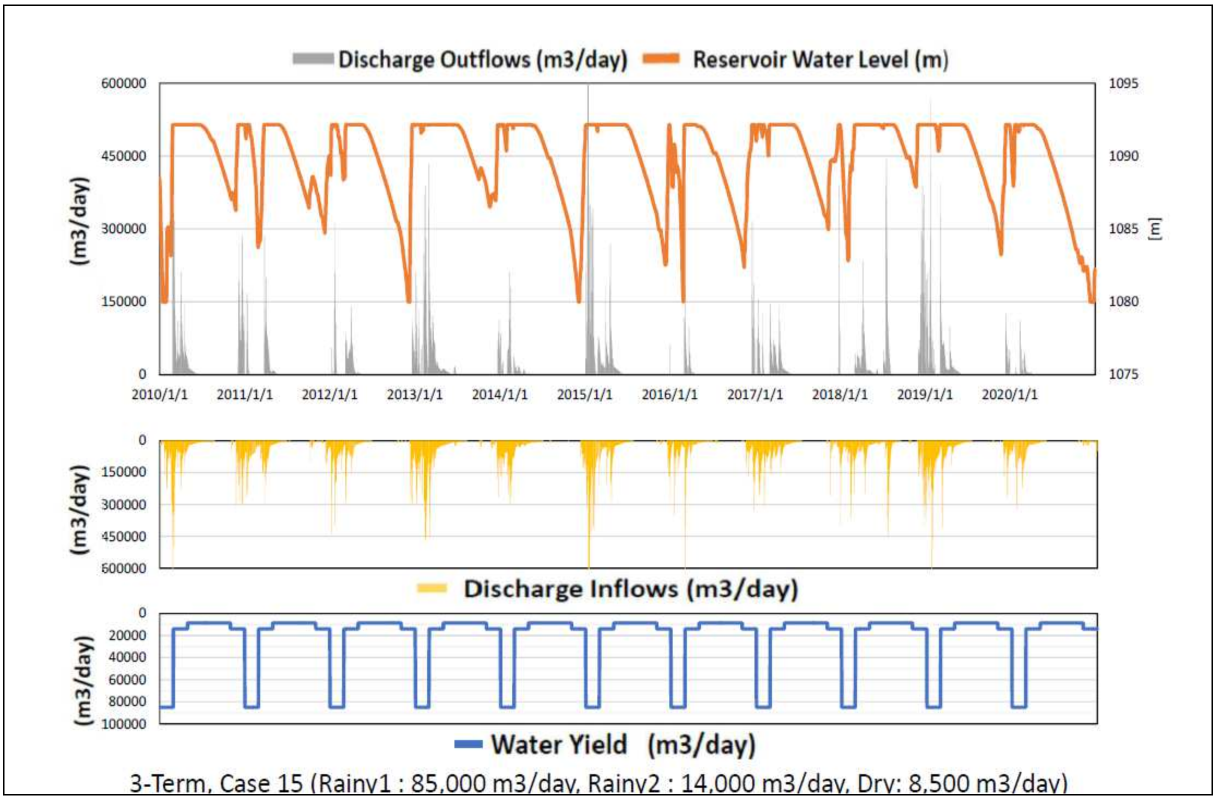
Source: The JST

Figure 3-4.14 Simulation Results of Reservoir Operation for Case 12 (3-Term)



Source: The JST

Figure 3-4.15 Simulation Results of Reservoir Operation for Case 13 (3-Term)



Source: The JST

Figure 3-4.16 Simulation Results of Reservoir Operation for Case 15 (3-Term)

3-4-5 Measures to increase the Water Yield at Mudi Dam

The measures to increase water yield are comprised of the dam raising, excavation and dredging works of the dam.

- Dam raising: Raising the dam body increases water storage capacity. Dead outflow is used for increasing the water storage volume at during the rainy season. There is the Malawi Railway track upstream of the reservoir which should be considered when planning and or designing dam raising (See Figure 3-4.17 and Figure 3-4.18).
- Excavation and dredging in the reservoir: It is assumed that excavation and dredging can secure a storage capacity of about 1.5 million m^3 at a storage water level of 1,090 m.

Dam Body and Malawi Railways	Dam Upstream View and Intake Tower

Figure 3-4.17 Dam Body, Upstream View, Intake Tower and Malawi Railways

	
Railway Bridge of Malawi Railways	Railway Bridge

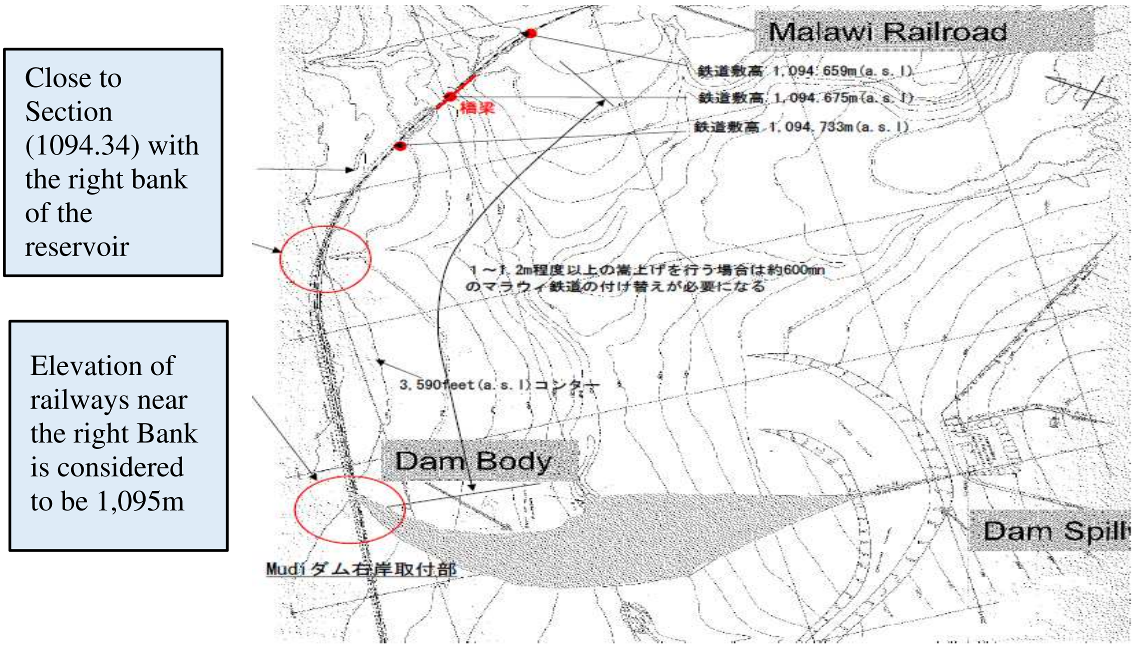
Figure 3-4.18 Railway Bridge of Malawi Railroads

(1) Examination of Dam Raising (preliminary planning)

The Malawi Railways crosses the site between the right bank of Mudi Dam and the reservoir, and it is observed that the lowest point of the railway elevation is positioned around the proximal points between the upstream bridge and the right bank of the reservoir at elevation of 1,094 m. The elevation of the railroad is 1,095 m, while the top level of Mudi Dam is 1,093.4 m.

As shown in Figure 3-4.19, the dam body is located closely to the railroad of the Malawi Railways even at the right bank abutment of Mudi Dam. The elevation of the railroad of the Malawi Railways near the right bank attachment is estimated at about 1,095 m, considering positional relationship with the contour at elevation of 1,094.23 m and elevation of the top of Mudi Dam as indicated in the photos.

On the alignment from the right bank to the reservoir, it may be possible to heighten the dam of about 1.0 m to 1.2 m without relocation of the railroad of the Malawi Railways. However, in case of further dam raising, it is necessary to relocate the railroad in distance of about 600 m including the replacement of bridges.



Source: The JST and BWB

Figure 3-4.19 Plan of Reservoir, Elevation Relationship between Bridge and Malawi Railways

According to information from the Blantyre Construction Office (Nakala Logistics Malawi, Blantyre), of Malawi Railways during the field survey, a new locomotive was introduced in order to increase transportation capacity. At the height of the locomotive, there was a concern that there would be insufficient clearance in the tunnel located from Blantyre Station to the bridge of Mudi Dam. Therefore, in order to secure clearance, the track elevation lowering works were carried out in the relevant section, and the works were completed in September 2021. The site condition of the section after construction is shown below.

	
Toward Mudi Dam Bridge	Toward the Blantyre Station

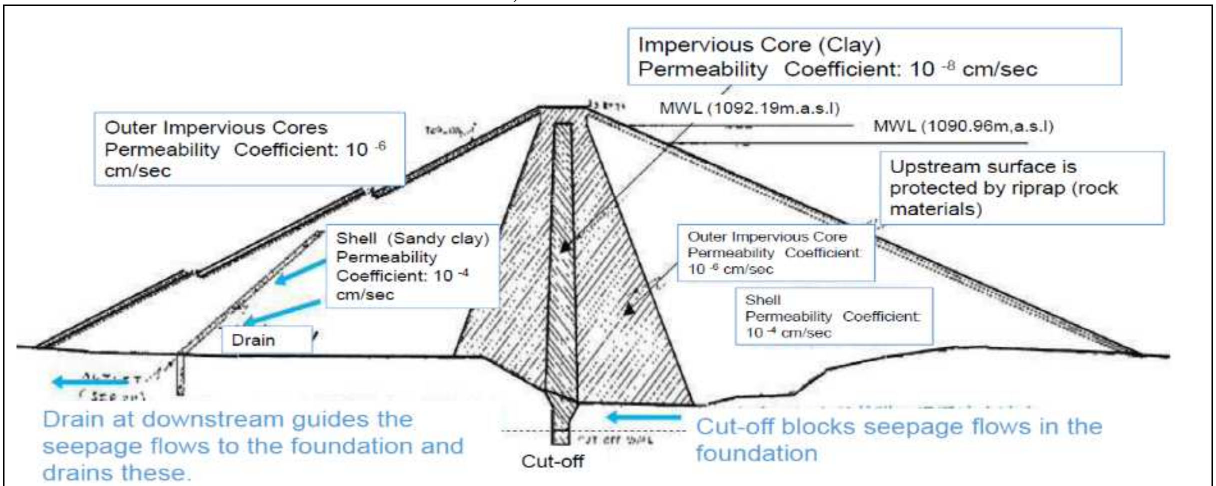
Figure 3-4.20 Situations after Railway Track Elevation Lowering Works (As of September, 2021)

As mentioned above, unless the height at the Malawi Railways bridge is changed, the dam height should be limited to be 1.2 m. If the dam height is raised more than 1.2 m, about the 600 m railway truck section of the bridge should relocated. In the Survey, JST estimated the costs for 1 to 2 m-dam height rasing and examined the dam structure up to height of 5 m.

As shown below, a core material zone with impermeability (permeability coefficient 10^{-8} cm/s) is thinly placed in an inner core material zone, and external core materials with a permeability coefficient about 10^{-6} cm/s are placed both the upstream and downstream sides. This is a design concept for the seepage flow at Mudi Dam.

The dam foundations are presumed to be a highly permeable gravel layers, and blocks water by that the inner core materials is dug down to the basement which is replace with the inner core materials. The shell material zones consisting of sandy clays are placed the upstream and downstream of the core material zones to ensure the stability of the embankment.

The seepage flow runs from the upstream shell material zone to the core zone, and further from the core zone to the downstream shell material zone, and is collected in the downstream drain to be drained.



Source：The JST

Figure 3-4.21 Measures against Seepage Flow in Mudi Dam

As mentioned above, it is judged that the dam foundation of Mudi Dam is a highly permeable gravel layer. In the past, no abnormal phenomenon has occurred in the dam body and the foundation. However, if dam body is raised, a higher water pressure than the current one will be generated in the dam foundation, and the following phenomena will be expected to be occurred.

- Increase in the water leakage from the dam foundation
- Seepage failure in the dam foundation due to increase in seepage flow velocity

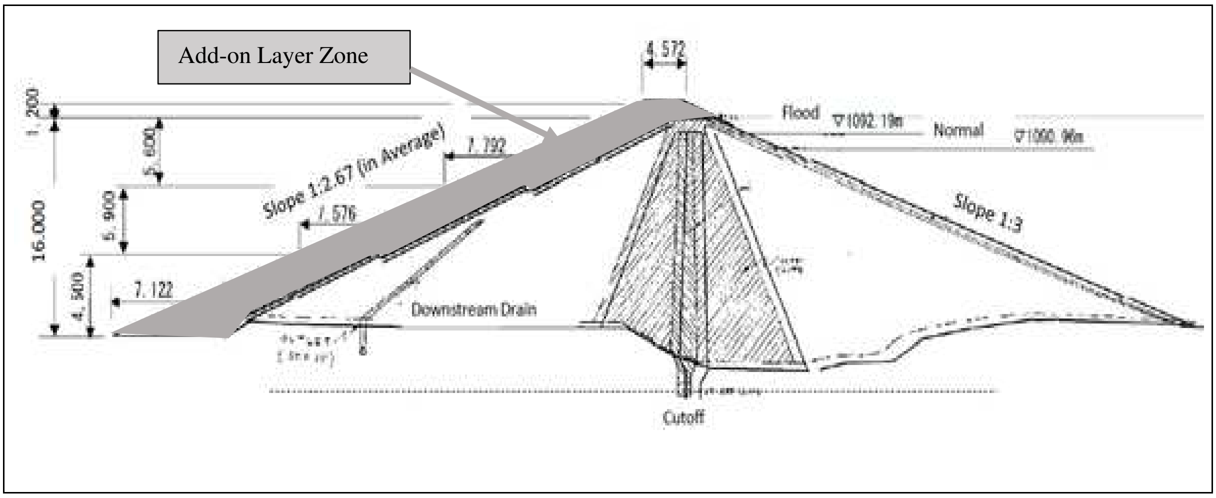
In order to prevent the occurrence of these phenomena, there are measures such as expansion of a water blocking zone by grouting, the installation of infiltration suppression like a core blanket. The measures of the dam raising cases for small scale (1-2 m in height) and large scale (5 m in height) are as follows:

1) Case for the dam raising is small scale

In the case of small scale, the increase in the seepage flow acting in the dam foundation is small, so dam raising is done by "add-on layer method" on the downstream side to utilize the reservoir of the existing dam. In the case of dam raising with a small scale, the dam height is adjusted by the raising of external core material. Since the permeability coefficient of the external core materials is about 10^{-6} cm/s, a sufficient impermeable function can be ensured. By additional laying on the downstream side, the axis of the top of the dam moves to the downstream side, but there is no effect to the impermeable function of the dam.

Regarding the influences by dam raising, it is possible to evaluate the stability to analyze the critical flow velocity and the hydraulic gradient by performing the seepage flow analysis in the dam embankment. If the evaluation result shows a low stability, the seepage flow can be suppressed by arranging blanket works in the upstream side. In this examination, as shown below, it is possible to place a layer on the downstream side.

The slope of the add-on layer zone (downstream slope, currently 1: 2.5) is set to an average gradient of "1: 2.67" to ensure the required stability for the physical properties of the material applied to the add-on layer. (See Figure 3-4.22).



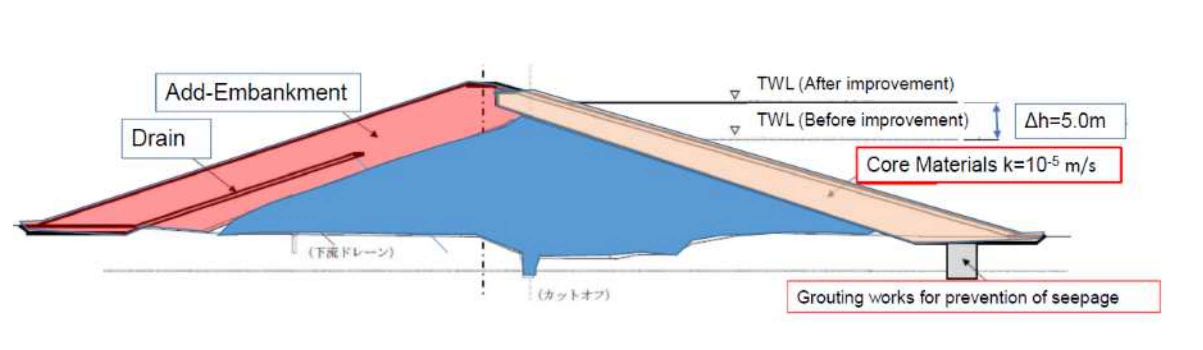
Source：The JST

Figure 3-4.22 Design Image for Small Scale Dam Raising (1-2 m in Height, Adopted Design)

2) Case for the dam raising is large scale

In the case of large scale, it is necessary to ensure the same level of safety as the existing dam considering the increase in the seepage flow acting in the dam foundation. The expansion of impermeable zone by grouting works is one of the measures. However, in the case of Mudi Dam, since the core material zone and cutoff are placed in the center of the dam to block seepage flow, grouting in the central zone and the expansion of impermeable walls cannot be applicable, because they may damage the core zone.

As a countermeasure, an upstream core zone (permeability coefficient 10^{-5} cm/s) and an impermeable zone by grouting is installed in the upstream side of the dam as shown below to suppress the seepage flow acting on the dam foundation. (See Figure 3-4.23)



Source：The JST

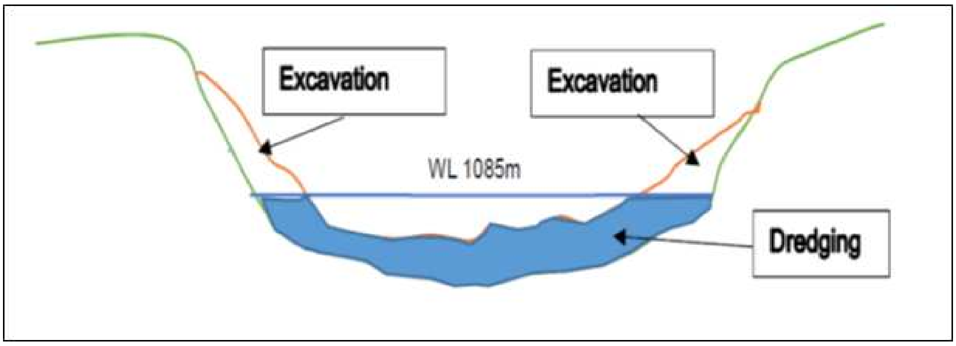
Figure 3-4.23 Design Image for Large Scale Dam Raising (5 m in Height)

For grouting in the case of a highly permeable dam foundation, careful work method is required after injecting high-concentration cement milk and mortar. As for the construction costs when raising the height assuming such a large scale with 5.0 m in height, the scale of the countermeasure work will be large, so the construction cost becomes equal to or higher than that of a new dam construction.

Based on the above examination results, the scale of raising Mudi Dam adopted small-scale raising rather than a large-scale raising in order to avoid changing the track of the Malawi Railway in terms of economic efficiency. The height of the dam raising adopted to be 1.2 m in consideration of the track elevation of the Malawi Railway and an economic efficiency described later on.

(2) Excavation and Dredging of the Reservoir (Preliminary planning)

The dredging and excavation works will be carried out in the dry season when the water storage level draws down. The design water level for the works will be set at 1,085m (above sea level). Excavation work will be carried out above this design water level (1,085 m), and dredging work will be carried out below this water level. The design sediment volume is 0.3 million m^3, which is the difference between the current sedimentation capacity (1.2 million m^3) and the design sedimentation capacity (1.5 million m^3) (see Figure 3-4.24)



Source：The JST

Figure 3-4.24 Plan of Excavation and Dredging

(3) Cost Estimate of Preliminary Construction

Table 3-4-7 shows the specification of dam renovation and the detail measures of construction by reservoir operation case. The railway tracks need to be relocated, when Mudi Dam is raised at a height of 2.0 m.

Table 3-4.7 Renovation of Mudi Dam by Reservoir Operation Case

Reservoir Operation	Specification of Dam Renovation	Dam Raising	Excavation & Dredging	Relocation of Railway Tracks
Cases 2, 8 & 13	Raising height:1.2m	X		
Cases 5, 10 & 15	Ditto	X	X	
Cases 3, 9 & 14	Raising height:2.0m	X		X
Cases 6 ,11 & 16	Ditto	X	X	X

Source：The JST

Notes:

- Case 1, Case 7, and Case 12 are excluded because they do not incur costs.
- X: Need to estimate cost

The preliminary cost estimate for construction cost on the raising of Mudi Dam including the improvement in the spillway is shown in Table 3-4.8.

Table 3-4.8 Cost for Dam Raising Works

No.	Work Items	Preliminary Cost （Million MWK）	
		Dam Raising (H=1.2m)	Dam Raising (H=2.0m)
1	Raising works in downstream slope （Unit Rate：MWK106,300/m^3） （Including the margin for 20%）	22,800 m^3× MWK127,500/ m^3) = 2,907	38,000 m^3× MWK127,500/ m^3) = 4,845
2	Reinforcement works in upstream slope & Seepage treatment works	850	1,063
3	Connecting works between dam body and spillways	850	1,063
4	Joint improvement works between dam body and spillway	850	1,063
Total in MWK（100 Million MWK）		5,457	8,033

Source：The JST

With regard to excavation and dredging works in the reservoir, BWB does not have information on the unit rate of construction, so the JST referred to the unit rate for excavation and dredging used for a similar project: the Preparatory Survey on Comprehensive Sediment Management Project in Sidi Salem Multipurpose Dam in Tunisia (hereinafter referred to as “Sidi Salem Dam Project”), which was funded by JICA.

The proposed design volume to be disposed after excavation and dredging is estimated at 300,000 m^3, which is divided into dredging work with volume of 100,000 m^3 and excavation work with that of 200,000 m^3 (See Table 3-4.9).

The unit rate of excavation work in Sidi Salem Dam Project is about MKW 2,143 /m^3. Considering sediment disposal costs, MKW 5,000 /m^3 which is a double of excavation work experientially will be applicable for excavation and disposal cost estimates.

In addition, since the unit rate for dredging work was not available in Malawi, the JST applied about eight times of the unit rate of the excavation for the unit rate of dredging based on the track record of the similar cases in Japan. Therefore, it was set to be MWK 17,143 /m^3 (≑MWK 17,000/m^3 after rounded down).

Table 3-4.9 Cost for Dredging and Excavation Works

Classification	Work Volume (m^3)	Unit Rate（MWK/m^3）	Cost （Million MWK）
Dredging Works	100,000	17,700	1,770
Excavation Works	200,000	5,000	1,000
Total Volume:	300,000		2,770

Source：The JST

In the case where the dam raising height is 2 m, the railway track section in distance of about 600 m located in the northern part of Mudi Dam have to be replaced. Out of the distance of 600 m, about 52 m is the bridge section. Based on the unit rate information from the Malawi Railways of Blantyre branch, the results of cost estimate are shown below.

Table 3-4.10 Cost for Railway Track Replacement Work for Malawi Railways

Section Classification	Length of Section	Unit Rate（MWK）	Cost （Million MWK）
Bridge Section	52 m (L) × 3.5 m (b) = 182 m^2≒ 190 m^2	2,833,500 MWK/m^2	538
Railway Track Section	550 m	1,558,400MWK/m	857
Total Cost	600 m		1,395

Source：The JST

The results of preliminary construction cost estimate are summarized as shown in Table 3-4.11.

Table 3-4.11 Summary of Preliminary Construction Cost Estimate for Cases

Reservoir Operation Case	Cost Estimate	Dam Raising	Excavation & Dredging	Railway Tracks Replacement	Total (million MWK)
Cases 2, 8 & 13	Hight:1.2m	5,457	-	-	5,457
Cases 5 ,10 & 15	Ditto	5,457	2,770	-	8,157
Cases 3, 9 & 14	Height:2.0m	8,033	-	1,395	9,428
Cases 6, 11 & 16	Ditto	8,033	2,770	1,395	12,198

Source：The JST

3-4-6 Optimum Scale of Possible Water Yeild of Mudi Dam

Since a final decision of water resource potential depends on a construction cost, optimum scale of water resource potential should be considered. The JST calculated the rate of a facility utilization at Mudi WTP based on the estimation of the possible water yield as shown in Table 3-4.6. In addition, the JST figured out Benefit (B) /Cost (C) based on the following conditions and indicated relation between a Cost Benefit Ratio (hereinafter referred to as "B/C") and a design capacity of Mudi WTP.

- 50 years applied for electricity costs to be reduced as benefit (B).
- Project cost is composed of the renovation of Mudi Dam, the recovery of Mudi Dam intake and the rehabilitation of Mudi WTP.
- Water loss of 10% of intake volume at a peak in a rainy season as shown in Table 3-4.6 was considered to calculate water production capacity calculated.

Table 3-4.12 shows the rate of facility utilization for Case 7 to Case 16 that dead outflow discharge shown in Table 3-4.6 is utilized effectively. The rates of facility utilization is 27 to 28 % and 81 to 97 % in case of examination divided into three terms (Case 12 to Case 16) and two terms (Case 7 Case 11) a year respectively. Of course, if the rate of facility utilization is low, dead outflow can be used effectively at the maximum, but since suspension period of excessive water production capacity is long throughout year, investment is wasted. Meanwhile, if the rate of facility utilization is high extremely, there are some issues on stable water supply.

Table 3-4.12 Rate of Facility Utilization at Mudi WTP

In case of examination divided into two terms a year					
Items	Case 7	Case 8	Case 9	Case 10	Case 11
Water Production Capacity (m^3/day)	7,000	9,000	10,000	**13,000**	14,000
Monthly Average Water Production (m^3/day)	6,800	7,700	8,900	**10,200**	11,400
Rate of Facility Utilization	97%	86%	89%	**85%**	81%
B/C	1.23	0.88	1.06	**1.24**	1.16

Medium Value between two and three terms										
Items	Est. 1	Est. 2	Est. 3	Est. 4	Est. 5	Est. 6	Est. 7	Est. 8	Est. 9	
Water Production	18,000	22,000	26,000	30,000	34,000	38,000	42,000	46,000	50,000	

In case of examination divided into two terms a year										
Items	Case 7		Case 8		Case 9		Case 10		Case 11	
Capacity (m^3/day)										
Monthly Average Water Production (m^3/day)	11,700	12,000	12,300	12,600	12,900	13,200	13,500	13,800	14,100	
Rate of Facility Utilization	**65**	**55**	**47**	**42**	**38**	**35**	**32**	**30**	**28**	
B/C	1.14	1.12	1.11	1.09	1.08	1.07	1.05	1.04	1.03	
In case of examination divided into three terms a year										
Items	Case 12		Case 13		Case 14		Case 15		Case 16	
Water Production Capacity (m^3/day)	54,000		59,000		63,000		72,000		81,000	
Monthly Average Water Production (m^3/day)	15,100		16,400		17,700		19,900		22,000	
Rate of Facility Utilization	28%		28%		28%		28%		27%	
B/C	1.02		1.01		1.02		1.07		1.02	

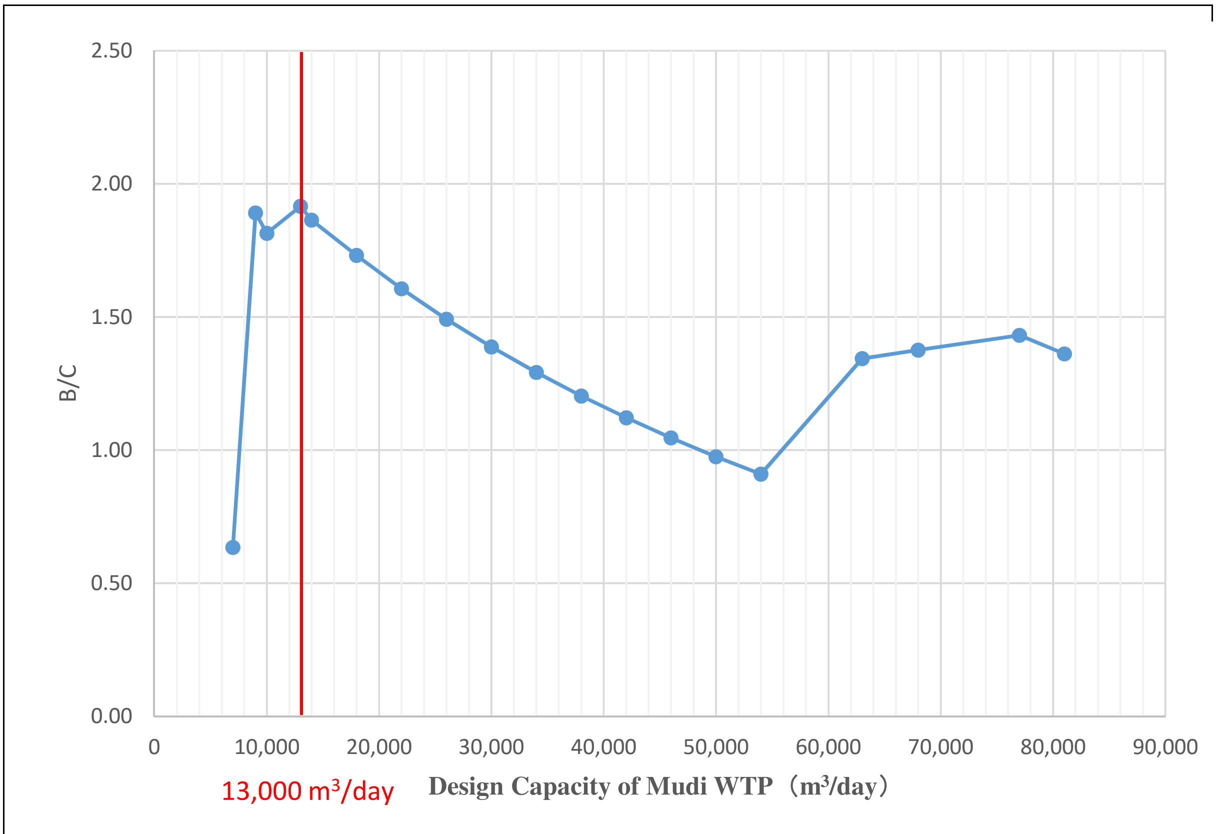
Source: The JST

Note:

Est.: Estimation

Accordingly, the JST made a diagram of the B/C and the water production capacity between 7,000 m^3/day in case of examination divided into two terms and 81,000 m^3/day in case of examination divided into three terms, and showed optimum B/C with water production capacity (see Figure 3-4.25). As a result of the diagram, the B/C is highest in case of the water production capacity of 13,000 m^3/day (at Case 10 of the two terms).

However, following improving in the accuracy of the inflows in Mudi Dam, B/C ratio should be analyzed furthermore in detail.



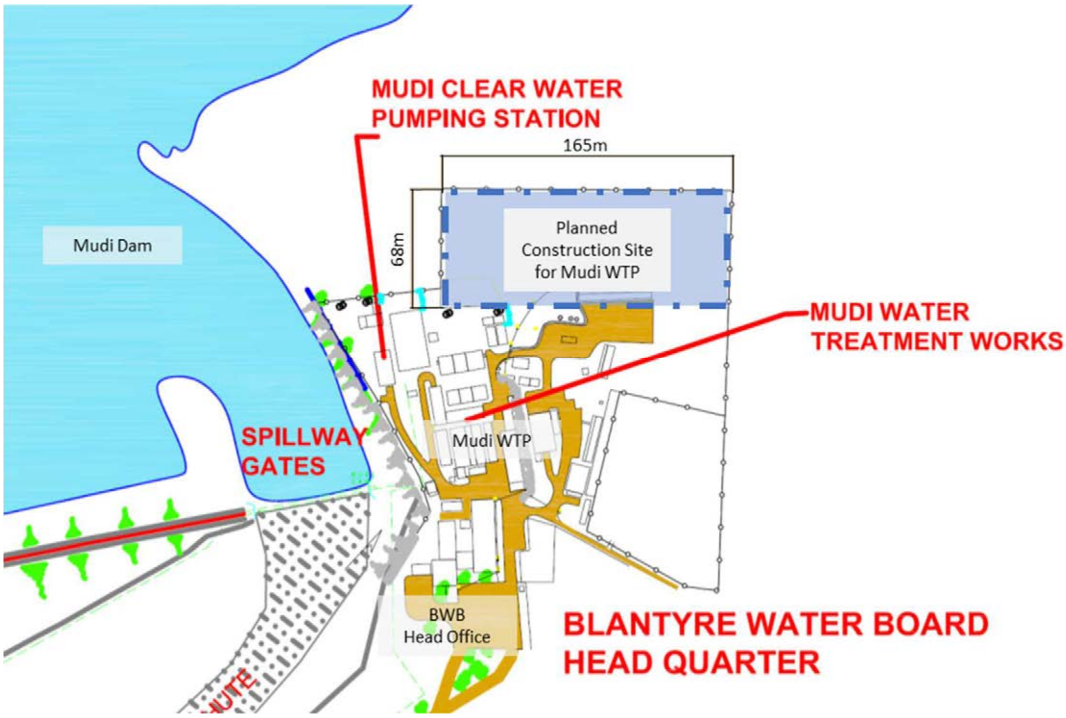
Source: The JST

Figure 3-4.25 B/C and Water Production Capacity

3-4-7 Proposed Construction Site for the New Mudi WTP based on the Water Production Capacity

As described in 3-4-6, the treatment capacity of the new Mudi WTP to be rehabilitated is estimated at about 13,000 m^3/day based on the water source potential of Mudi Dam and water demand in water service area. Therefore, the planned construction site required for the new Mudi WTP is suitable around the north side of the existing Mudi WTP as shown in Figure 3-4.26 and Figure 3-4.27. The JST confirmed that the boundary of the BWB site was partitioned by block walls, the archive room and the material storage at the planned construction site can be relocated.

Moreover, the ground elevation of the construction site for the new Mudi WTP is as same as that of the existing Mudi WTP.



Source: The JST edited figure based on the CAD data prepared in WTP Rehabilitation Project (2008)

Figure 3-4.26 Planned Construction Site for New Mudi WTP

Figure 3-4.27 Current Condition of Planned Construction Site for New Mudi WTP

3-4-8 Environment and Social Considerations for Mudi Dam Improvement

The project components such as the raising of the dam with height of 1.2 m and the excavation & dredging works (total sediment volume: 300,000 m^3) in the reservoir may affect the environment and social considerations.

The dam catchment area of Mudi Dam is designated as a controlled water catchment area under the

Nidrande-Mudi Dam Controlled Water Catchment Area Control Order that came into effect in 2007. Therefore, no relocation measures of residents are required.

The JST surveyed the Acts, the regulations, the guidelines related to environment and social considerations, the Environmental Impact Assessment (hereinafter referred to as "EIA") process, and the site disposing sediment materials due to excavation and dredging works.

(1) Acts and Guidelines on Environment and Social Considerations

The Acts, regulations and guidelines related to environment and social considerations are shown in Table 3-4.13.

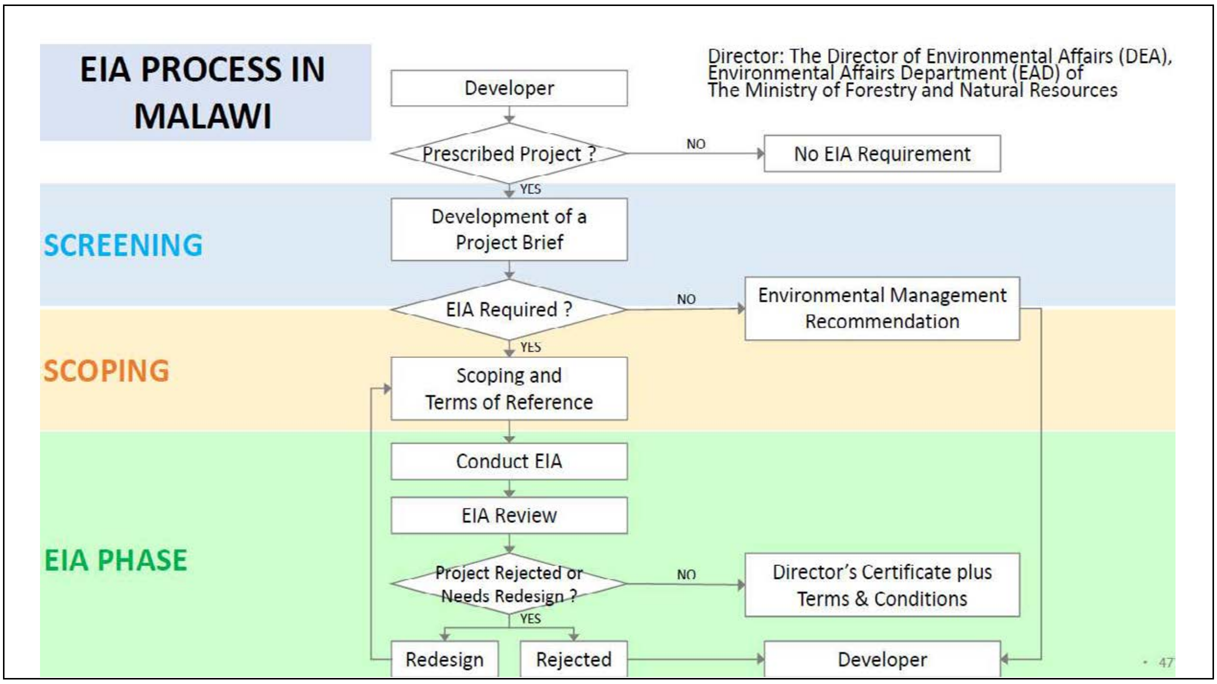
Table 3-4.13 Acts, Regulations and Guidelines Related to Environment and Social Considerations

No.	Title of Acts and Guidelines	Year Enacted
1	Environment Management Act (EMA)	2016
2	Forestry Act	1997
3	National Parks and Wildlife Amendment Act	2004
4	Water Resources Act	2013
5	Land Act	2016
6	Customary Land Act	2016
7	Guidelines for Environmental Impact Assessment	1997

Source：Malawi: Environmental Law Context Report (2019.8), Websites

(2) EIA Process in Malawi

The EIA reprocess including screening and scoping in Malawi is shown in Figure 3-4.28.



Source: Guidelines for EIA

Figure 3-4.28 EIA Process in Malawi

The necessity of EIA depends on the project brief. According to the guidelines, the director of the Department of Environment Affairs (hereinafter referred to as "DEA") of the Ministry of Forestry and Natural Resources (hereinafter referred to as "MFNR") receives the project brief and calls for the Technical Committee on the Environment (TCE) for advice. The TCE assesses the necessity for EIA based on the project screening criteria and recommends a series of process to the DEA. The DEA decides whether EIA is needed or not.

The maximum working days required for major procedures of EIA from the date that the director receives the document is shown in Table 3-4.14.

Table 3-4.14 Maximum Working Days for EIA Procedures

No.	Assessment Procedures	Working Days
1	Determining the need for an EIA once a Project Brief is received by the Director	15
2	Review of each draft of EIA terms-of-reference submitted to the Director	10
3	Review of first draft of an EIA report	50
4	Review of second and subsequent drafts of an EIA Report	25

Source: Guidelines for Environmental Impact Assessment (MFNR, Malawi)

If an EIA is not required, the director of the DEA issues a certificate that EIA is unnecessary and advises developers and or relevant implementation organizations on an environmental management of projects.

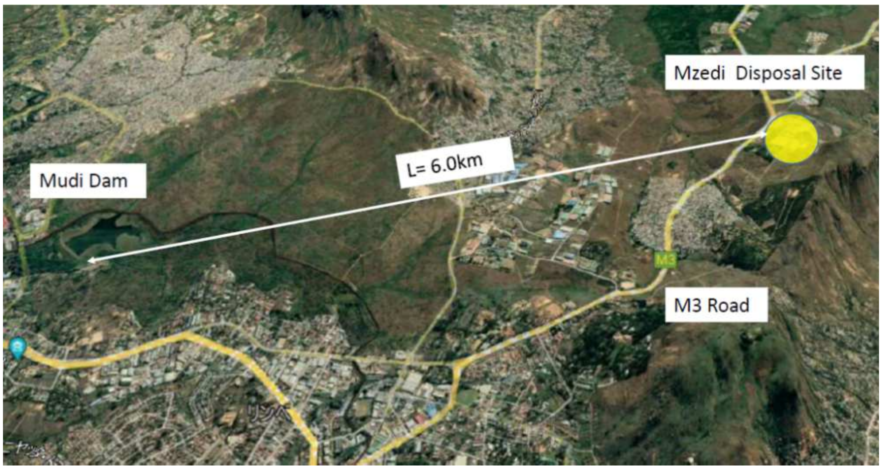
On the other hand, an EIA is required, the director of the DEA informs the developer and/or relevant implementation organizations to conduct the EIA and prepare its report.

The agency which is in charge of EIA is the DEA of the MFNR, and the director of the DEA makes the final approval. The local branch of the DEA located in Blantyre City accepts application documents of a project brief and EIA, but does not assess the documents. The headquarters of the DEA is responsible for assessment of the application documents and notification of the assessment result.

(3) Disposal Site for Sediment Materials in Mudi Dam

The JST surveyed the sites allowable for disposing sediment materials produced from dredging and excavation works in Mudi Dam.

One of the candidates is the Mzedi disposal site, which was introduced by the Blantyre Environmental Affairs (BEA) of the MFNR. A straight distance between Mudi Dam and the disposal site is estimated at about 6 km (See Figure 3-4.29 and Figure 3-4.30).



Source: The JST

Figure 3-4.29 Candidate Site for disposing Sediment Materials (Mzedi Disposal Site)

	
Overview of the Disposal Site	Current Conditions of the Disposal Site

Source: The JST

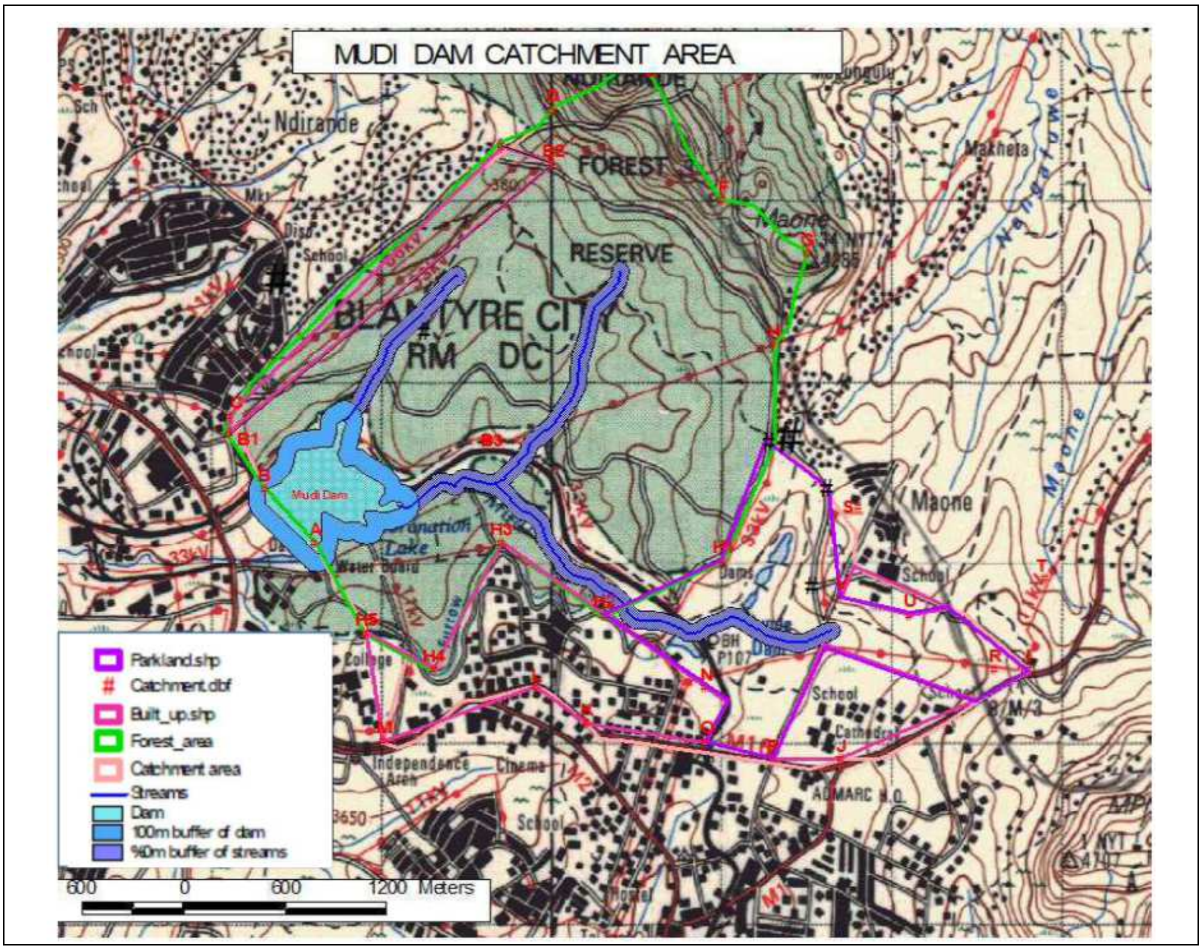
Figure 3-4.30 Current Conditions at Mzedi Disposal Site (November 2021)

The Health Services Department of Blantyre City Council is in charge of this disposal site. According to the result of the meeting with the person in charge (Director of Health and Social Services), if any harmful substances are not contained in sediments, the disposal of sediment materials can be accepted.

3-5 Conservation Conditions of the Catchment Area of Mudi Dam and Conservation Plan

3-5-1 Conservation Conditions

The catchment of Mudi Dam is designated as a conservation area, and new development activities and housing construction are prohibited. Figure 3-5.1 shows the conditions of designation areas based on Nidrande-Mudi Dam Controlled Water Catchment Area Control Order Water Resources that came into effect in 2007.



Source: The JST and BWB GIS Section

Figure 3-5.1 Designation Areas for Catchment Conservation Plan (Forest Area, Buffer Stream)

The JST had reconnaissance of the catchment by guidance of BWB. The current conditions of the catchment are shown in Figure 3-5.2. There is an outer road, and there are no residences in the catchment of Mudi Dam from this road, but there are many houses, schools, associations, mosques, etc. in the outer area of the outer road. Although there are no large trees in the catchment, there are many tall grasses such as bushes and short trees.

Current Conditions in Western Area of Catchment

Current Conditions in Eastern Area of Catchment

Hynde Old Dam (Currently Swamp)

View the lake from the upper area of Mudi Dam

Source: The JST

Figure 3-5.2 Current Conditions of Mudi Dam Catchment

Tree planting activities as part of catchment conservation have been carried out mainly by BWB (see Figure 3-5.3). Currently, the planted area reaches 540 ha (about 61% of the total catchment area) and the number of trees planted is estimated at 600,000 (Data in 2020 by BWB). The tree species are 1) Mtangaranga, 2) Mbawa, 3) Mthethe, 4) Katope, 5) Gilisidia and 6) Lunguzi, which are all planted locally.

Tree planting and seedling planting activities in the catchment are carried out annually in cooperation with stakeholders such as schools, associations, Muslim associations, banks, rotary clubs, Lions clubs and youth clubs. In particular, the JST confirmed that the cooperation provided by Lions clubs was largest.

Planting Activities (WESM)

Bird Watching

Source: Website

Figure 3-5.3 Catchment Conservation Activities

3-5-2 Conservation Plan

Under the Control Order, deforestation, development activities, and housing construction are prohibited in Mudi Dam catchment. Therefore, it may be possible to conserve the catchment by continuing the current tree planting activities. However, in the current condition where sediments is being accumulated in reservoirs, it is envisaged that sediment outflow occurs due to runoff, even if the land is covered with forests according to the increase in afforestation area.

For these countermeasures, it is considered that construction of Sabo (check) dam in the streams of the main tributary catchments is effective way. In addition, by construction of sedimentation storage dams directly at upstream of the reservoir, it is possible to collect sediments that could not be captured by the Sabo dam. As a catchment conservation plan, the JST proposes measures for these facilities (see Figure 3-5.4).

	
Sedimentation Storage Dam	Image of Excavation of Sediment at a Dam

Source: Ministry of Land, Infrastructures and Transport (MLIT), Japan

Figure 3-5.4 Sedimentation Storage Dam and Excavation Works

3-5-3 Approval for Mudi Dam Renovation

As mentioned above, prohibited activities as per the "Control Order" issued in 2007 consist of garbage dumping, septic tanks installation, road constructions, settlement formation, hunting, and pesticide spraying, etc. According to the act, the Nidrande-Mudi Dam Catchment Management Controlled Committee will review and decide on the facilities construction or new construction of buildings and structures. The Committee consists of the Regional Forestry Officer, South, Blantyre City Assembly Chief Executive Officer, Chief Executive Officer of BWB, South, Regional Land Commissioner, South and Water Officer, South.

In the case of the improvement in Mudi Dam, BWB will apply to this Committee for approval of works.

3-6 Needs by BWB, organizing Challenges and their Analysis

The JST fact findings work in BWB identified key challenges within the area of finances, water quantity and water quality.

3-6-1 Organizing Challenges and their Analysis

(1) Challenges in Finance

From 2015 to 2020, BWB has been facing financial deficits and accumulation of debt every year. In 2020 for example, BWB had an annual deficit of MWK9, 256 million. Electricity costs account for approximately 40% (as of 2020) of the overall expenditure for the BWB's water supply service and is the main contributing factor to the negative financial status of BWB. The water transmission system contributed the largest to the total electricity cost with Walker's Ferry WTP alone makes up approximately 85% of that cost. Therefore, one of the urgent challenges for BWB is to reduce the electricity costs of transmitting water through the Walker's Ferry WTP. Another contributing factor to the distressing financial situation in BWB is the poor sales performance that it has long been experiencing. It was revealed through the fact findings work that even with the increase in the quantity of water supplied and the number of customers also expanded, water sales either remained stagnant or even shrank in other times due to deficiencies in water meter reading and billing management system.

Therefore, to improve the financial condition of BWB, there are actions that need to be undertaken as follow;

1) Review the water supply operations with the objective to the reduce the electricity costs by lowering the dependency on pumps to transmit water;
2) Improve the water meter reading and billing management throughout Blantyre city to ensure increase in water sales and collection.

(2) Challenges in Water Quantity

In Blantyre, water demand is increasing by years as the population is growing. The total design capacity of the overall WTPs as of 2030 is forecasted to be greater than the water demand (daily maximum) in all the scenarios such as low, medium and high leakage ratio by 23,000 to 33,000 m^3/day. However, the actual water production is currently at 67% of the overall design capacity of the WTPs due to drawdowns at the water source and the deterioration of Mudi WTP. This being the case, the water production in 2030 may be short at around 35,000 to 45,000 m^3/day. BWB has been forced to operate backwashing frequently which has resulted in generation of much treated water loss of approximately 28% including water required for WTP operation of 10%, because Mudi WTP has deteriorated remarkably. It is therefore important to restore the function of Mudi WTP.

Furthermore, since the NRW ratio at BWB is over 50%, there is a need to also strengthen the water demand management by also reducing the NRW in order to secure additional quantity of water to supply to the consumers.

Even though the present design capacity of the water transmission system can adequately meet the current water demand, it is a challenge to stabilize the water transmission system to ensure that the design capacity is capable of meeting the water demand in 2030.

(3) Challenges in Water Quality

The quality of treated water at Mudi, Walker's Ferry and Nguludi WTP are analyzed according to the Malawi national water standards and the WHO water quality guideline. However, in case that the water treatment capacity cannot keep up with high turbidity of raw water during the rainy season, the rate of water flowing into the WTP is controlled so that the treated water quality conforms to the Malawi national water standards.

There are no a mixing chamber or a flocculation pond in the already aged Mudi WTP, which results in the occurrence carryover in the sedimentation basin and mud ball in the filtration. In addition, the equipment in Mudi water intake facility and Mudi WTP have deteriorated significantly, and some of the pumps are also malfunctioning due to breakdowns, therefore, the water production at Mudi WTP is unstable. BWB therefore is considering introducing the common water treatment processes like a rapid sand filtration in Mudi WTP to substantially improve the water production quality and quantity.

Moreover, there is also another pressing challenge to prevent the sediment discharge from the catchment area into Mudi Dam in order to reduce sedimentation load of raw water at Mudi WTP during rainy season.

3-6-2 Cooperation Needs

In response to the above challenges, the JST organized the cooperation needs as follows:

(1) Cooperation Needs on Financial Aspect

1) **Facilities' Development (Finance & Facility)**

Considering that electricity costs make up about 40% of the total water supply service costs, reducing the electricity consumption of pumps, which account for most of the total electricity consumption in BWB, is the best measure for improving the BWB's water supply service. In enabling this, the key course of action is to significantly reduce the power consumption of the pumps in Walker's Ferry WTP and Chileka relay pump station which consumes the most power among the pumps in Blantyre, while to increase water production in Mudi WTP which consumes less power in Blantyre. This reveals that electricity costs of Walker's Ferry WTP system makes up approximately 34% of total expenses of the BWB's water supply service without the development of photovoltaic power generation systems, while 11% with that.

In spite of that, the current average water production at Mudi WTP is approximately 5,700 m^3/day which is only about 34% of its total design capacity (17,000 m^3/day: the JST estimated this, considering size of the existing sedimentation basin). The low water production is due to the drawdown of Mudi Dam and low performance of Mudi WTP due to its deteriorative status. In addition, about 30% of the treated water is usually wasted in Mudi WTP.

Therefore, in order to increase the intake yield, it is essential that BWB renovates Mudi Dam including the intake facilities. Furthermore, to increase water production and income through the reduction of water loss, BWB rehabilitates Mudi WTP.

Moreover, if the renovation works on Mudi Dam and the rehabilitation of Mudi WTP are materialized, it is possible for BWB to reduce power consumption through changing the transmission system and reducing the reliance on pumps. Additionally, the change of the transmission system will positively impact the BWB's finances.

Not only the reduction of electricity costs but also the reduction of NRW at 24 points (from approximately 54% to 30%) by 2030, needless to say, contributes to improvement in the BWB's finance.

2) **Enhancement of Management Capacity (Finance & Management)**

Dam management, catchment protection and WTP's O&M have not been carried out systematically and on a regular basis. Therefore, BWB needs to strengthen those management capacities while performing necessary renovation works to Mudi Dam and Mudi WTP. Since the Mudi WTP's current treatment process only utilizes sedimentation tanks as means to reduce turbidity as opposed to a more effective process which requires a receiving chamber, a mixing chamber, a flocculator, flocculation pond, sedimentation basins, and filtration chambers, the BWB's staff are not familiarized with the latter treatment process (common process). Therefore, an appropriate technical assistance is necessary for BWB to ensure that it is prepared to adopt and operate the common water treatment process to as part of their normal water supply system operation.

With regards to the water meter reading and billing management system which are the main revenue (financial) arms for BWB's, a technical cooperation is also crucial to strengthen these systems through implementation of relevant activities such as meter reading accuracy, calibration of water meters and optimization of the billing management system which will directly correspond to an increase in the BWB's income. Regarding a technical cooperation in this sector, the increase in income which resulted in improvement in BWB's finance was verified by the short-term volunteer's activities (Yokohama Water Bureau's staff participated) as the JICA program.

(2) Cooperation Needs on Water Quantity Aspect

1) **Facilities' Development (Quantity & Facility)**

It has been planned that the Walker's Ferry WTP production capacity will be expanded to 75,000 m^3/day by 2023 through financial support from India. This quantity of water will also adequately meet the estimated water demand in Blantyre in 2030 as predicted by this Survey. However, currently, considering that actual quantity of intake in the whole Blantyre is lower than design capacity, it is of great importance that BWB also focuses on ensuring that there is reliable and stable quantity of water supply for Blantyre. Therefore it is important one of the ways to achieve that is to implement NRW reduction activities as a more optimum option than the development of water sources which is a very costly option for BWB who is already facing a financial struggle. Measures such as the replacement of the deteriorated AC pipelines which make up about 46% of the total distribution pipelines will significantly reduce NRW while also preventing the contamination of the supplied water.

Mudi WTP is also in a very deteriorative state which affects its performances. Therefore, rehabilitation of Mudi WTP is indispensable for BWB to eliminate the treated water loss so as to increase water production, etc. after securing a quantity of intake at Mudi Dam as much as possible.

In addition to the proposed improvements in the WTP, the transmission system itself should also be augmented to cope with the increase in future water demands and ensure stability in supplied water.

2) Enhancement of Management Capacity (Quantity & Management)

Even though the distribution pipelines are replaced with new ones, approximately 54% of the total pipeline lengths have yet to be replaced. In order to secure more water as much as possible, it is vital that NRW reduction activities such as leak detection, pipe repair works, water balance analysis, monitoring work, etc. must be continuously performed out by BWB.

(3) Cooperation Needs on Water Quality Aspect

1) Facilities' Development (Quality & Facility)

Normally, the treated water quality at Mudi WTP conforms to the Malawi national water standards and the WHO water quality guideline, however it has been observed that the rate of water flowing into the WTP is controlled to meet the Malawi national water standards even for the fluctuation of seasonal water quality. Therefore, it is necessary to rehabilitate and upgrade the capability of Mudi WTP to enable it to handle the appropriate water treatment process, as described in "(1) cooperation needs in terms of financial and water quantity aspect" in order to stabilize and to ensure the consistency of the quality of treated water.

2) Enhancement of Management Capacity (Quality & Management)

Since BWB does not have the experience in O&M of a WTP that implements a more complex water treatment process, it is necessary to strengthen the capacity and capability of the WTP to implement the coagulation operation, water quantity & quality management, and filtration pond management such as backwashing. In addition, in order to ensure that raw water quality that comes through the system is stable, a technical assistance on catchment conservation including dam management, and measures to control sedimentation and surface runoffs at Mudi Dam, is required.

3-7 Draft Cooperation Approaches to BWB

3-7-1 Development Direction

Basic water supply service is being provided to the citizens in Blantyre by BWB. However, the population in the city has been growing at an extreme annual growth rate which result in an increasing water demand. Under the present condition where BWB is under a large financial debt, BWB has procured financial resources through bilateral cooperation and is planning the expansion of water supply facilities to meet the growing future water demand.

However, there is the present issue of poor sales performances experienced by BWB which is disproportionate to the increasing quantity of water it produces and the growing number of customers depending on BWB water service. The cost of water supply service is higher than the income, which contribute to the financial deficit that BWB has been experiencing year after year.

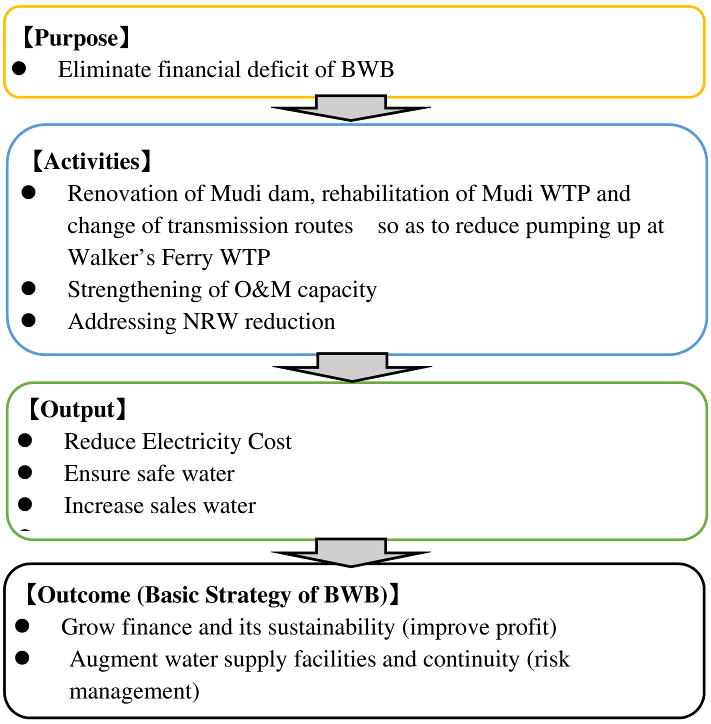


Figure 3-7.1 Future direction that BWB focuses

Based on the above circumstances, as BWB advocated goals in the management strategy, BWB has future visions to gain a stable income and to develop efficient water supply system in order to manage sustainable water supply service. For this reason, BWB has to reorganize water supply service for the augmentation of water supply facilities, the promotion of water supply system efficiency, capacity development of the BWB's staff and the elimination of financial lost (about MWK9.25 billion as 2020) due to increase in productivity of water supply service. In addition, BWB can expect the increase in income (approximately MWK20,485 million for nine years) by the reduction of NRW ratio from 53% (as of 2020) to 30% through NRW reduction.

Accordingly, it is anticipated that BWB focuses on the growth of the water supply service and its sustainability through the BWB's business plan based on the BWB's basic strategy and assistance by development partners such as JICA, etc. (see Figure 3-7.1).

3-7-2 Cooperation Approaches

In response to the cooperation needs, the JST narrowed down the draft cooperation plans according to the flow shown in Figure 3-7.2 based on the future direction that BWB intends to adopt as shown in Figure 3-7.1.

Based on the cooperation needs, Table 3-7.1 summarizes the countermeasures and their effects necessary for improving the overall BWB water supply service. In addition, the JST evaluated the priority by scoring from the viewpoints of the "Urgency[8]" of the Project, the "Impact[9]" of the Project on the cooperation needs, and the "Immediate Effect[10]" of the Project.

Based on the result of the evaluation, "No.1 Renovation of Mudi Dam and Rehabilitation of Mudi WTP", "No.2 Rehabilitation of Mudi WTP (without Renovation of Mudi Dam)", "No.3 Reduction of pumping stations", "No.6 Assistance in management capacity of Mudi WTP" and "No.7 Assistance in education for water meter calibration and water meter reading, / billing settlement and development of billing system" ranked as the top three. It is useful to implement those countermeasures in order of their level of feasibility.

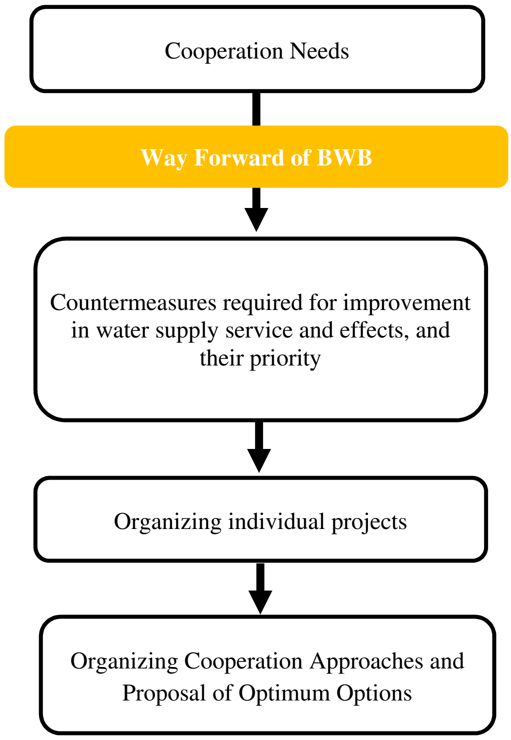


Figure 3-7.2 Flow for narrowing down Cooperation Plans

Table 3-7.1 Countermeasures required for Improvement in Water Supply Service Management and Priority

No.	Cooperation Needs Abbreviation shown in "3-6-2 Cooperation Needs"	Countermeasures	Effect	Urgency	Impact	Quick Effect	Total
1.	Finance - Facility Quantity - Facility Quality - Facility	Renovation of Mudi Dam and rehabilitation of Mudi WTP	● Reducing pump operation cost at Walker's Ferry WTP ● Securing quantity of water supply due to water loss reduction ● Securing quantity of water supply due to	3	3	3	9

[8] Urgency: Unless projects are carried out, it is anticipated that the BWB's water supply service is hindered. In such case, "High: 3" is scored.
[9] Impact: if there are impacts in all the sections: finance, water quantity and water quality, "High: 3" is scored. On the other hand, if there is only one impact, "Low: 1" is scored.
[10] If the implementation of projects make quick effect, "High: 3" is scored.

No.	Cooperation Needs Abbreviation shown in "3-6-2 Cooperation Needs"	Countermeasures	Effect	Urgency	Impact	Quick Effect	Total
			increase in water production capacity ● Stabilize treated water quality				
2. *	Finance - Facility Quality - Facility	Rehabilitation of Mudi WTP	● Reducing pump operation cost at Walker's Ferry WTP ● Securing quantity of water supply due to water loss reduction ● Stabilize treated water quality	**3**	**2**	**3**	**8**
3.	Finance - Facility	Reduction of pumping stations	● Reducing pump operation cost	**3**	**1**	**3**	**7**
4.	Quantity - Facility	Replacement of AC pipelines	● Securing quantity of water supply due to leak reduction	2	2	2	6
5.	Quantity - Facility	Rehabilitation (increase in pipe diameter) of transmission Pipelines	● Securing stabilized water in appropriate water pressure	1	1	3	5
6.	Finance - Management Quality - Management	Assistance in management capacity of Mudi WTP	● Strengthening management capacity of WTPs ● Stabilize treated water quality	**3**	**2**	**3**	**8**
7.	Finance - Management	Assistance in education for water meter calibration and water meter reading/ billing settlement, and development of billing system	● Increase in income of water supply service	**3**	**1**	**3**	**7**
8.	Quantity - Management	Assistance in leak detection activities	● Securing quantity of water supply due to leak detection	3	1	1	5
9.	Quality - Management	Assistance in development of management capacity on dam & catchment area	● Strengthening management capacity of dams and catchment areas	2	1	3	6

Source: The JST
Note:
Score: High: 3, Moderate: 2, Low: 1
* Since there is almost no track record of dam renovation as a grant aid project, JST propose only the rehabilitation of Mudi WTP other than "1.".

3-7-3 Individual Project (Draft)

Based on countermeasures shown in Table 3-7.1, the detailed individual project (draft) and their locations are shown in Table 3-7.2 and Figure 3-7.3 respectively.

Table 3-7.2 Outlines of Individual Projects (Draft)

Type	Countermeasures		Individual Project (Draft)	Scheme	Purpose and Reasons	Effect	Priority required for improvement in water supply service*
Infrastructure Development	No.1 Renovation of Mudi Dam and rehabilitation of Mudi WTP	A	**[Renovation of Mudi Dam]** ● Heightening embankment ● Dredging sediment at Mudi Dam	Grant	● Augment storage capacity through heightening of embankment to store ineffective discharge during rainy season ● Augment storage capacity through dredging sediments and excavating dam body	● Increase in water production from 5,700 to 10,700 m^3/day at Mudi WTP ● Reduction of electricity cost for pumping at Walker's Ferry WTP due to reduction of a quantity of water transferred from Walker's Ferry WTP	High
		B	**[Recover of Mudi Dam Intake]** ● Improving Intake Tower	Grant	● Improve intake tower through dredging sediment and or rehabilitate itself		High
		C	**[Rehabilitation of Mudi WTP]** ● Rehabilitation of Mudi WTP (with Mudi Dam Renovation)	Grant	● Reduce electricity cost through utilization of Mudi WTP whose electrical utility rate is lower than that of Walker's Ferry WTP ● Rehabilitate Mudi WTP with appropriate treatment process (considering of receiving chamber, mixing chamber, flocculator, sedimentation basin and filtration pond) to eliminate carry-over and a high frequency of filtration medias	● Reduction of electricity cost for pumping at Walker's Ferry WTP will reduce the quantity of water transferred from Walker's Ferry WTP ● Secure more quantity of water supply by increase in water production from 5,700 to 10,700 m^3/day. ● Reduction of electricity cost by reducing the number of pumping station through change of transmission route after augmentation of Mudi WTP ● Improvement in quality of treated water, as WTP process is optimized	High
	No. 2 Rehabilitation of Mudi WTP	D	**[Rehabilitation of Mudi WTP]** Rehabilitation of Mudi WTP (without Mudi Dam Renovation)	Grant	● Reduce electricity cost through utilization of Mudi WTP whose electrical utility rate is lower than that of Walker's Ferry WTP ● Rehabilitate Mudi WTP with appropriate treatment process (considering of receiving chamber, mixing chamber, flocculator, sedimentation basin and filtration	● Increase in water production from 5,700 to 6,800 m^3/day at Mudi WTP ● Reduction of electricity cost for pumping at Walker's Ferry WTP will reduce the quantity of water transferred from Walker's Ferry WTP	High

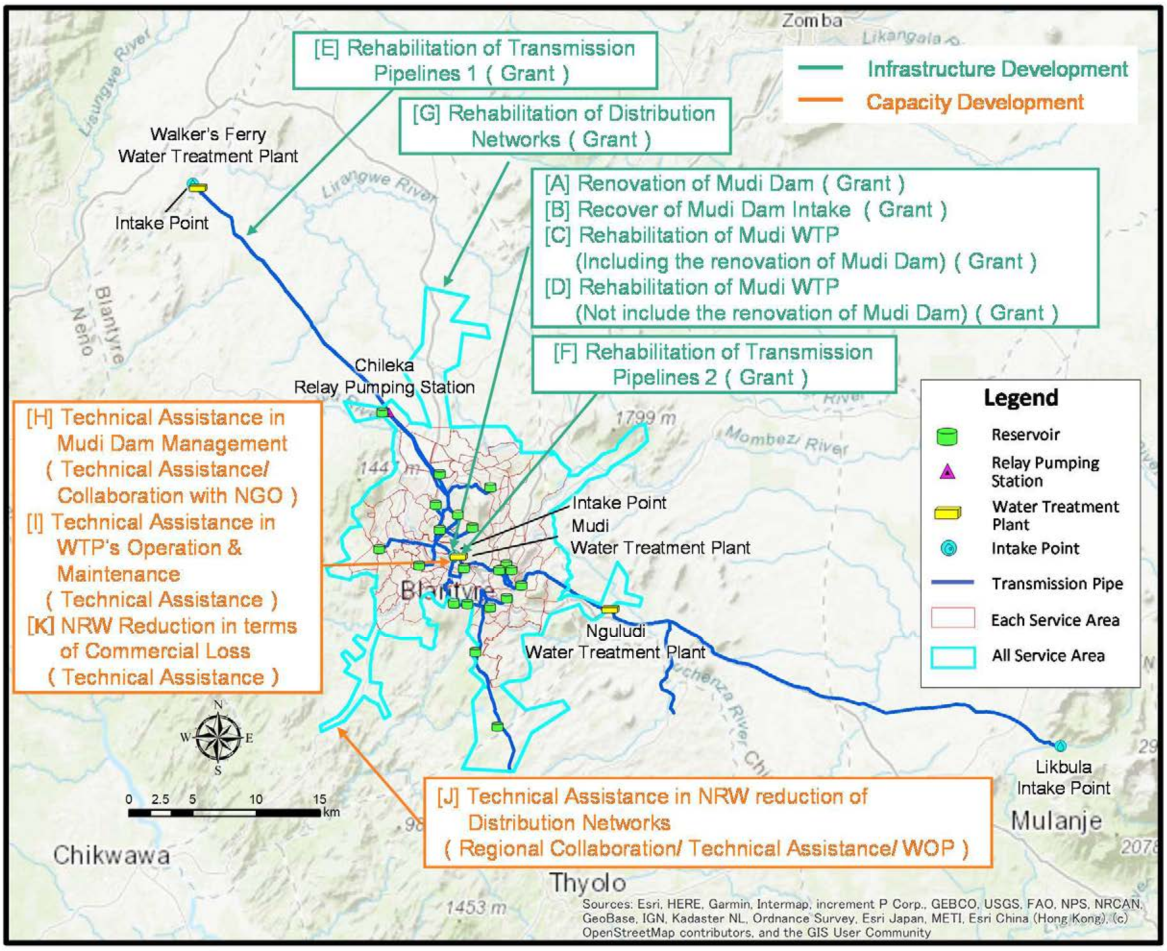
Type	Countermeasures		Individual Project (Draft)	Scheme	Purpose and Reasons	Effect	Priority required for improvement in water supply service*
					pond) to eliminate carry-over and a high frequency of filtration medias	Improvement in quality of treated water (Continuity of operation even in high turbidity), as WTP process is optimized.	
	No.5 Rehabilitation (increase in pipe diameter) of transmission Pipelines	E	**[Rehabilitation of Transmission Pipelines-1]** ● Replacing the existing pipelines	Grant	● Augment (a 20-30% increase in diameter) a part of the transmission pipelines to meet water demand in 2030	● Ensuring a stable water supply for more than 20 hours per day in terms of water pressure in 2030.	
	No.3 Reduction of pumping station	F	**[Rehabilitation of Transmission Pipelines-2]** ● Replacing the existing pipelines	Grant	● Have a review of transmission route, e.g. water is supplied from Mudi WTP to Mt. Pleasant, while water is not supplied from Mudi WTP to Kanjedza service reservoir, which results in the reduction of electricity cost of pumping station at Mudi WTP. Kanjedza service reservoir receives water from Walker's Ferry through the proposed transmission pipelines.	● Reduction of electricity cost by reduction of the number of pumping station.	High
	No.4 Replacement of AC pipelines	G	**[Rehabilitation of Distribution Networks]** ● Replacing the existing distribution pipelines	Grant	● Replace the deteriorated AC pipes of approximately 460 km with other material pipes (Total cost of this Project was estimated to be about USD23 Million by BWB.) ● Unless BWB implements NRW reduction, there may be a shortage water of approximately 54,000 m^3/day, so replace AC pipes that 50 years have passed since laid.	● Secure more quantity of water to supply ● Increase in income of water supply service in combination with "J".	
Capacity Development	No.9 Assistance in development of management capacity on dam & catchment area	H	**[Technical Assistance in Mudi Dam Management]** ● Dam Management ● Catchment prevention	Technical Assistance/ Collaboration with NGO	● Strengthening daily dam management such as measurement of water level and inflow rate, so that dam can be operated appropriately to examine water source potential anytime ● Provide awareness to the general public on the importance of dam catchment conservation in collaboration with NGOs such as Lions Club.	● Strengthening of dam and catchment management to ensure the preservation of the integrity and quality of water source and dam.	

Type	Countermeasures	Individual Project (Draft)		Scheme	Purpose and Reasons	Effect	Priority required for improvement in water supply service*
	No.6 Assistance in management capacity of Mudi WTP	I	**[Technical Assistance in WTP's O&M]** ● Sedimentation and filtration Management ● Record Management (water flow, water quality, chemical, dosing management, etc.)	Technical Assistance	● Strengthen capacity for WTP's O&M on regular WTP process as Mudi WTP is rehabilitated. ● Systemize operation record management required for WTP's O&M, and promote efficiency in O&M by introducing ICT.	● Strengthening of O&M capacity for chemical dosing, water quantity, water quality, backwash, etc. of WTP. ● Stabilization of water quality due to strengthening of O&M capacity.	High
	No.8 Assistance in leak detection activities	J	**[Technical Assistance in NRW reduction of Distribution Networks]** ● Water Balance Analysis ● Leakage Detection ● Water pressure Control	Reginal Collaboration/ Technical Assistance/ Water Operation Partnership (hereinafter referred to as "WOP")	● Unless BWB implements NRW reduction, there may be a shortage water of approximately 54,000 m^3/day ● Strengthen capacity of NRW reduction team which was established in 2021 in collaboration with LiSCaP	● Secure quantity of water supply ● Increase in income of water supply service in combination with "G".	
	No.7 Assistance in education for water meter calibration and water meter reading/ billing settlement, and development of billing system	K	**[Technical Assistance in NRW Reduction in terms of Commercial Loss]** ● Water Meter Reading ● Billing	Technical Assistance	● Improve accuracy of water meter reading and billing settlement so as to increase sales water in proportion to the increase water production and number of customers.	● Increase the revenue for the water supply service. ● High synergy effect in combination with "G" and "J".	High

Source: The JST

Note:

* "High" is indicated as the top three scores based on Table 3-7.1.



Source: The JST

Figure 3-7.3 Individual Projects

3-7-4 Organizing Cooperation Approaches and Proposal of Optimum Options

(1) Organizing the Cluster of "Water Supply Business Growth Support-Urban Water Supply"

Combination of cooperation categories is defined as shown in Table 3-7.3 in order to organize cooperation approaches focusing on the individual projects.

- "I." is the combination that a technical assistance is introduced at the end of the infrastructure development by development partners in order to operate water supply facilities sustainably. Regarding scaling-up assistance, experience on LiSCaP which has been conducted in LWB can be expected as a useful sector. However, as staff members of NRW reduction team is very limited, it is anticipated that a workshop through online medium is the best option.
- "II." is similar to "I." but domestic and regional collaboration is not included in "II." "II" is composed of infrastructure development and technical assistance by development partners.
- "III." includes only infrastructure development. Capacity development depends on the BWB's policy.

Table 3-7.3 Combination of Cooperation Categories

Combination of Cooperation Categories	Assistance in Improvement of Basic Service (Development of Facilities)	Assistance in Capacity Development of BWB Growing (Strengthening capacity of BWB)	Scaling-up of Development in Domestic and Region
I.	X	X	X
II.	X	X	
III.	X		

Source: The JST

Based on cooperation needs, the JST combined the individual projects considering the following main points focusing on improvement of the overall water supply service and set nine options ("a." to "i.") which consist of individual projects (see Table 3-7.4).

- All combined individual projects
- All combined individual projects with exception of the projects on distribution pipelines
- All combined individual projects with exception of the projects on transmission & distribution pipelines
- All combined individual projects with exception of the projects on dam renovation and transmission & distribution pipelines
- All combined individual projects with exception of the technical assistance projects on dam management as well as the projects of distribution pipelines
- All combined individual projects with exception of the technical assistance projects on dam management as well as WTP's O&M
- Only facilities' development

Table 3-7.4 Options of Individual Project's Combination

Combination by Cooperation Categories	Options	A. Renovation of Mudi Dam	B. Recover of Mudi Dam Intake	C. Rehabilitation of Mudi WTP (with Mudi Dam Renovation Dam	D. Rehabilitation of Mudi WTP (without Mudi Dam Renovation	E. Rehabilitation of Transmission Pipeline-1	F. Rehabilitation of Transmission Pipeline-2	G. Rehabilitation of Distribution Networks	H. Technical Assistance in Mudi Dam Management	I. Technical Assistance in WTP's Operation & Maintenance	J. Technical Assistance in NRW Reduction of Distribution Networks	K. Technical Assistance in NRW Reduction in terms of Commercial
I.	a.	X	X	X		X	X	X	X	X	X	X
II.	b.	X	X	X			X		X	X		X
II.	c.		X		X					X		X
II.	d.	X	X	X		X			X	X		X
II.	e.	X	X	X			X			X		X
I.	f.		X		X			X		X	X	X
III.	g.	X	X	X								
III.	h.		X		X							
III.	i.	X	X	X		X						

Source: The JST
Note: The individual projects underlined is highly prioritized.

(1) Consideration of Cooperation Approaches

The design capacity of 13,000 m^3/day (Case 10) is an optimum size for Mudi WTP from the result of B/C analysis. Cooperation approaches and their consideration in Case 10 are shown in Table 3-7.5. After reviewing the results of the various cooperation approaches, Option "b." is desirable in terms of contribution to the assurance of BWB's finance, the sustainability of the BWB's water supply service as well as cost effectiveness. In addition to those points, Option "c." is further desirable considering the past experience of grant aid project and a prompt promotion of projects. Moreover, "f." is more preferable than "b." and "c.", considering the current progress of the business plan in BWB and ease of addressing projects.

Option "c." and "f." do not include the renovation of Mudi Dam and technical assistance on dam management, resulting in that optimum change of transmission system is not included due to non-large increase in water production. Therefore, depending on water demand change, it is recommended that the renovation of Mudi Dam and the expansion of Mudi WTP are examined for implementation as the next step.

In "3-8", the JST analyzed the validation and effects by Option "b.", "c." and "f.".

Table 3-7.5 Provisional Cooperation Approaches (In Case 10 of Water Source Potential) and their Consideration

Combination of Cooperation Categories	Option	Project Cost (MWK billion)	Power Consumption Cost to be reduced for 50 years-1 (MWK billion)	Power Consumption Cost to be reduced for 50 years-2 (MWK billion)	Income due to NRW Reduction (MWK billion)	B/C	Consideration
		1)	2)	3)	4)	5) ＝(2)+3) + 4)) / 1) x100	
I.	a.	58.8	17.4	34.4	20.5	1.23	B/C ranks third after Option "b". However, the materialization of dam renovation needs further discussion.
II.	b.	23.2	17.4	34.4		2.23	B/C ranks second after Option "e". Technical assistance is introduced as infrastructure is being developed, resulting in stability of facility operation. This option includes six prioritized projects (Draft), which may contributes to the overall financial improvement. However, the materialization of dam renovation needs further discussion as mentioned in Option "a".
II.	c.	7.9	3.8			0.49	B/C is less than 1.00. However, this option includes four prioritized projects (Draft) and technical assistance is introduced as water supply facilities are developed and there are lots of projects like this option as a grant aid in the past.
II.	d.	37.1	17.4			0.47	B/C is less than 1.00. Capacity of transmission is insufficient to meet water demand in 2030. Currently, there are the existing AC transmission pipelines in Blantyre where water leakage do not occur frequently. Therefore, the urgency to replace the transmission pipelines is low.
II.	e.	22.5	17.4	34.4		2.30	B/C ranks the highest. Like option "b.", this option includes six prioritized projects (Draft), but the materialization of dam renovation needs further discussion as mentioned in Option "a".

Combination of Cooperation Categories	Option	Project Cost (MWK billion)	Power Consumption Cost to be reduced for 50 years-1 (MWK billion)	Power Consumption Cost to be reduced for 50 years-2 (MWK billion)	Income due to NRW Reduction (MWK billion)	B/C	Consideration
		1)	2)	3)	4)	5) ＝(2)+3) + 4)) / 1) x100	
I.	f.	25.6	3.8		20.5	0.95	There are lots of projects like this option as a grant aid in the past. BWB plans the rehabilitation of distribution networks specifically and LisCap has experience on NRW reduction, which contributes to the BWB's NRW issues. Collaboration. Therefore, this Option can be addressed easily.
III.	g.	16.1	17.4			1.08	Since the existing WTP has not been operated based on an appropriate treatment process, a human resource development on WTP's O&M is required in case where appropriate WTP process is introduced.
III.	h.	5.4	3.8			0.71	This option includes only two prioritized projects (Draft). In addition, since technical assistance is not introduced in this option, what concerns BWB is the lack of O&M capacity similar to Option "g".
III.	i.	33.9	17.4			0.51	Since technical assistance is not introduced in this option, what concerns BWB is the lack of O&M capacity similar to Option "g".

Source: The JST

Note:

- Further detail survey is required for the estimate of quantitative benefits through "K. Technical Assistance in NRW Reduction in terms of Commercial".
- "c." and "h." do not include Mudi Dam renovation and strengthening of a dam management capacity.
- Table 3-7.5 targets only power consumption costs to be reduced and income due to NRW reduction as benefit.
- "2)" is the electricity cost to be reduced through burden reduction at Walker's Ferry WTP, while, "3)" is that through the change of transmission system from Mudi WTP.
- Considering that NRW ratio of 54% to 30% from 2022 to 2030 is reduced and NRW is recovered every three years, income was multiplied reduced NRW by the revised water tariff.

Table 3-7.6 shows the breakdown of the projects.

Table 3-7.6 Breakdown of Project Costs

Unit: MWK billion

Options	A. Renovation of Mudi Dam	B. Recover of Mudi Dam Intake	C. or D. Rehabilitation of Mudi WTP	E. Rehabilitation of Transmission Pipeline-1	F. Rehabilitation of Transmission Pipeline-2	G. Rehabilitation of Distribution Networks	H. Technical Assistance in Mudi Dam Management	I. Technical Assistance in WTP's Operation & Maintenance	J. Technical Assistance in NRW Reduction of Distribution Networks	K. Technical Assistance in NRW Reduction in terms of Commercial	Total
a.	7.3	0.7	8.1	17.9	4.0	17.7	0.7	1.4		1.1	**58.8**
b.	7.3	0.7	8.1		4.0		0.7	1.4		1.1	**23.2**
c.		0.7	4.7					1.4		1.1	**7.9**
d.	7.3	0.7	8.1	17.9			0.7	1.4		1.1	**37.1**
e.	7.3	0.7	8.1		4.0			1.4		1.1	**22.5**
f.		0.7	4.7			17.7		1.4		1.1	**25.6**
g.	7.3	0.7	8.1								**16.1**
h.		0.7	4.7								**5.4**
i.	7.3	0.7	8.1	17.9							**33.9**

Source: The JST

Note:

- "C." and "D." is a design capacity of 13,000 m3/day and 7,000 m3/day respectively.
- Consulting service fee is not included in the project costs

3-8 Validity of Draft Cooperation Plans and Its Effect

3-8-1 Validation of Draft Cooperation Plans

(1) BWB's Policy

BWB focuses on "Infrastructure Growth and Business Continuity", "Financial Growth and Sustainability", "Customer and Stakeholder Satisfaction" and "Capacity Development and Productivity" as polices in BWB STRATEGIC PLAN 2020-2025. Safe and stable water supply is significant for BWB under financial soundness. The draft cooperation plans aligns with these policies and are highly prioritized in the BWB's water supply service.

(2) Japanese Government's Policy to Malawi

According to the Development Cooperation Policy for Malawi (January 2018), Malawi focuses on sustainable growth and advocates for "Building a Productive, Competitive and Resilient Nation" according to the Malawi Growth & Development Strategy III (MGDSIII). Japanese government has been focusing on developing the capacity of human resources with infrastructure developments that are concurrent to economic growth within respective strategic sectors. It is essential that Japanese government expands its assistance to Malawi by strengthening its financial base to improve income and promote development projects for a sustainable growth in terms of deepening the bilateral relation.

(3) Validity of Draft Cooperation Plans

The draft cooperation plan which consist of the following proposals including; renovation of Mudi dam; rehabilitation of Mudi WTP; assistance in O&M of Mudi Dam and the WTP; and assistance in the improvement in framework for water meter reading & billing management will collectively contribute to the soundness of BWB's financial state. The cooperation plans will trigger financial growth through reducing BWB's operation costs, while simultaneously increase water sales and therefore ensure sustainability of the BWB's water supply service and water supply infrastructure. Furthermore, the draft cooperation plans aligns with the Japanese government's cooperation policy to support the continuity of the water supply service.

3-8-2 Financial Impact of BWB

(1) Option "b."

The renovation of Mudi Dam and the rehabilitation of Mudi WTP will enable the reduction of water loss from 25% to 10% between the intake facility and Mudi WTP, the reduction of electricity costs through the change of transmission system as well as limiting the cost of filters through the reduction of replacement frequency. Table 3-8.1 shows cost benefit (B/C). BWB can potentially gain MWK84,865 million[11] over 50 years which equates to an expected B/C ratio of 3.55. This may generate benefits of MWK1,233 million annually by increasing the income and reducing cost of electricity and filter replacements even though depreciation is considered.

(2) Option "c."

This Option does not include the renovation of Mudi Dam. The rehabilitation of Mudi WTP will enable the reduction of water loss from 25% to 10% between the intake facility and Mudi WTP, the reduction of electricity costs through the change of some transmission system as well as limiting the cost of filters through the reduction of replacement frequency. Table 3-8.2 shows cost benefit (B/C). BWB can potentially gain MWK25,326 million over 50 years which equates to an expected B/C ratio of 3.16. This may generate benefits of MWK349 million annually by increasing the income and reducing cost of electricity and filter replacements even though depreciation is considered.

(3) Option "f."

This Option does not include the renovation of Mudi Dam. The rehabilitation of Mudi WTP will enable income increase through the reduction of water loss from 25% to 10% between the intake facility and Mudi WTP, the reduction of electricity costs through the change of some transmission system, limiting the cost of filters through the reduction of replacement frequency as well as income increase through NRW reduction for distribution networks.

Table 3-8.3 show the cost benefit (B/C). BWB can potentially gain MWK 45,811 million over 50 years[12] which equates to an expected B/C ratio of 1.78. This may generate benefits of MWK 404 million annually by increasing the income and reducing cost of electricity and filter replacements even though depreciation is considered as that of "b." and "c." are done.

Conditions of calculation are as follows:

- O&M cost is excluded because it is almost the same at any WTPs
- If BWB implements activities on commercial loss, increase in monthly water supply service income can be MWK1,801 million[13] theoretically, but the activities depend on approaches and performance of BWB. The benefits from activities on commercial loss is excluded.
- 110%, 15%[14] and 70% shown in Table 3-8.1, No. "4)", represent water losses based on a design standard, the treated water loss to be improved and revenue water ratio (refer to the medium scenario) respectively.
- Average intake quantity (Option "b."): 11,000 m^3/day (water quantity to be reduced: 11,000 m^3/day / 110% x 15% x 70% (revenue water ratio))
- Average intake quantity (Option "c."): 7,000 m^3/day (water quantity to be reduced: 7,000 m^3/day / 110% x 15% x 70% (revenue water ratio))
- Average water production (about 5,700 m^3/day) is deducted to calculate water quantity targeted.
- Electrical utility rate at Mudi WTP: MWK 7 /m^3
- Electrical utility rate on the transmission system from Walker's Ferry WTP: MWK 190.7 /m^3[15]

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[11] MWK67,892 million and MWK44,421 million are expected for the benefit of respective 40 years and 30 years. B/C is 2.84 and 1.74 respectively.

[12] Income through NRW reduction is calculated until the year of 2030 for nine years.

[13] 135,483 m^3/day (water consumption as of 2030) / (1- (30%-9%)) = 171,497 m^3/day, (171,497 m^3/day-135,483 m^3/day) x 30 days x MWK1,667/m^3 (unit revenue of BWB per m^3)

[14] Ratio of treated water loss between Jan. 2020 and Mar. 2021 is 28%, but JST applied 15% for the ratio of the treated water loss considering safe side.

[15] Actually, 95% of the power consumption may be covered with the planned photovoltaic power generation systems. Power

- Unit revenue: MWK 1,667 /m^3
- Pipe rehabilitation (NRW reduction) project is based on BWB's business plan
- Cost of filter replacement: MWK26 million per replacement (Source: information on budgetary arrangement)

Table 3-8.1 B/C for Renovation of Mudi Dam and Rehabilitation of Mudi WTP

No.	Items		Contents	Cost (MWK Mil.) (C)	Benefit (MWK Mil.) (B)
1)	Construction Cost	Ls.	Renovation of Mudi Dam & Rehabilitation of Mudi WTP	23,234	
2)	Electricity Cost	For 50 years	Pumping up at Mudi WTP	639	
3)	Electricity Cost to be reduced	For 50 years	Pumping up at Walker Ferry		17,401
4)	Tariff Income	For 50 years	Increase in revenue water at Mudi WTP (Intake quantity /110% x 15% x 70%)		31,944
5)	Electricity Cost to be reduced	For 50 years	Change of Transmission Route		34,350
6)	Cost of filter replacement to be reduced	For 50 years	Rehabilitation of Mudi WTP		1,170
Total	In case of rehabilitation of Mudi WTP		(C) = 1) + 2)	23,873	
			(B) = 3) + 4) + 5) + 6)		84,865
B/C			**(B) / (C)**	**3.55**	

Source: The JST

Table 3-8.2 B/C for Rehabilitation of Mudi WTP

No.	Items		Contents	Cost (MWK Mil.) (C)	Benefit (MWK Mil.) (B)
1)	Construction Cost	Ls.	Rehabilitation of Mudi WTP	7,863	
2)	Electricity Cost	For 50 years	Pumping up at Mudi WTP	141	
3)	Electricity Cost to be reduced	For 50 years	Pumping up at Walker Ferry		3,828
4)	Tariff Income	For 50 years	Increase in revenue water at Mudi WTP (Intake quantity /110% x 15% x 70%)		20,328
6)	Cost of filter replacement to be reduced	For 50 years	Rehabilitation of Mudi WTP		1,170
Total	In case of rehabilitation of Mudi WTP		(C) = 1) + 2)	8,003	
			(B) = 3) + 4) + 5) + 6)		25,326
B/C			**(B) / (C)**	**3.16**	

Source: The JST

Table 3-8.3 B/C for Rehabilitation of Mudi WTP, Distribution Replacement and Technical Assistance

No.	Items		Contents	Cost (MWK Mil.) (C)	Benefit (MWK Mil.) (B)
1)	Construction Cost	Ls.	Rehabilitation of Mudi WTP, Rehabilitation of Networks, etc.,	25,572	

consumption rate was applied considering remaining 4.5% of power consumption and all the power consumption at Chileka relay pumping station.

No.	Items		Contents	Cost (MWK Mil.) (C)	Benefit (MWK Mil.) (B)
2)	Electricity Cost	For 50 years	Pumping up at Mudi WTP	141	
3)	Electricity Cost to be reduced	For 50 years	Pumping up at Walker Ferry		3,828
4)	Tariff Income-1	For 50 years	Increase in revenue water at Mudi WTP (Intake quantity /110% x 15% x 70%)		20,328
5)	Tariff Income-2	For 9 years	Increase in revenue water in distribution pipelines		20,485
6)	Cost of filter replacement to be reduced	For 50 years	Rehabilitation of Mudi WTP		1,170
Total	In case of rehabilitation of Mudi WTP		(C) = 1) + 2)	25,713	
			(B) = 3)+4) + 5) + 6)		45,811
B/C			**(B) / (C)**	**1.78**	

Source: The JST

3-8-3 Effect by the Cooperation Plan to Citizens

(1) Maintaining Current Water Tariff for Poverty Households

According to the "Average Salary in Malawi 2021" of "Salary Explore" website, the monthly average household expenditure in Malawi is MWK81,000[16]. Applying MWK1,667[17] per m^3 being the average water tariff, the monthly water bill in an average household is MWK 24,000 (eight persons / household x 60 LCD x 30 days). The proportion of the monthly water bill to the overall household expenditure is about 29.6% (MWK24,000 / MWK 81,000). This is more than seven-fold of the rate (4%) of the monthly bill to the disposal income, which is advocated as a maximum rate of water bill to household disposal income in developing countries by World Bank. It is therefore indicative that the current water tariff is too high for the majority of the citizens to pay for. It is particularly harder for about 16,000 households which makes up approximately 20%[18] in Blantyre city to afford the water bill as of 2021.

In Option "b.", the annual benefit through implementing the cooperation plan is estimated at MWK1,697 million (MWK84,865 million / 50 years). Therefore, the current water tariff can be sustained for approximately 5,892 households, which makes up about 37% (5,892 / 16,000 households) of the total poverty households. Consequently, the benefit will contribute to the reduction of household economic strain.

On the other hand, in Option "c." and "f.", the current water tariff can be sustained for approximately 1,757 households and 3,180 households, which makes up about 11% (1,757 / 16,000 households) and 20% (3,180/ 16,000 households) of the total poverty households respectively by the same calculation as above. Consequently, the benefit will contribute to the reduction of household economic strain.

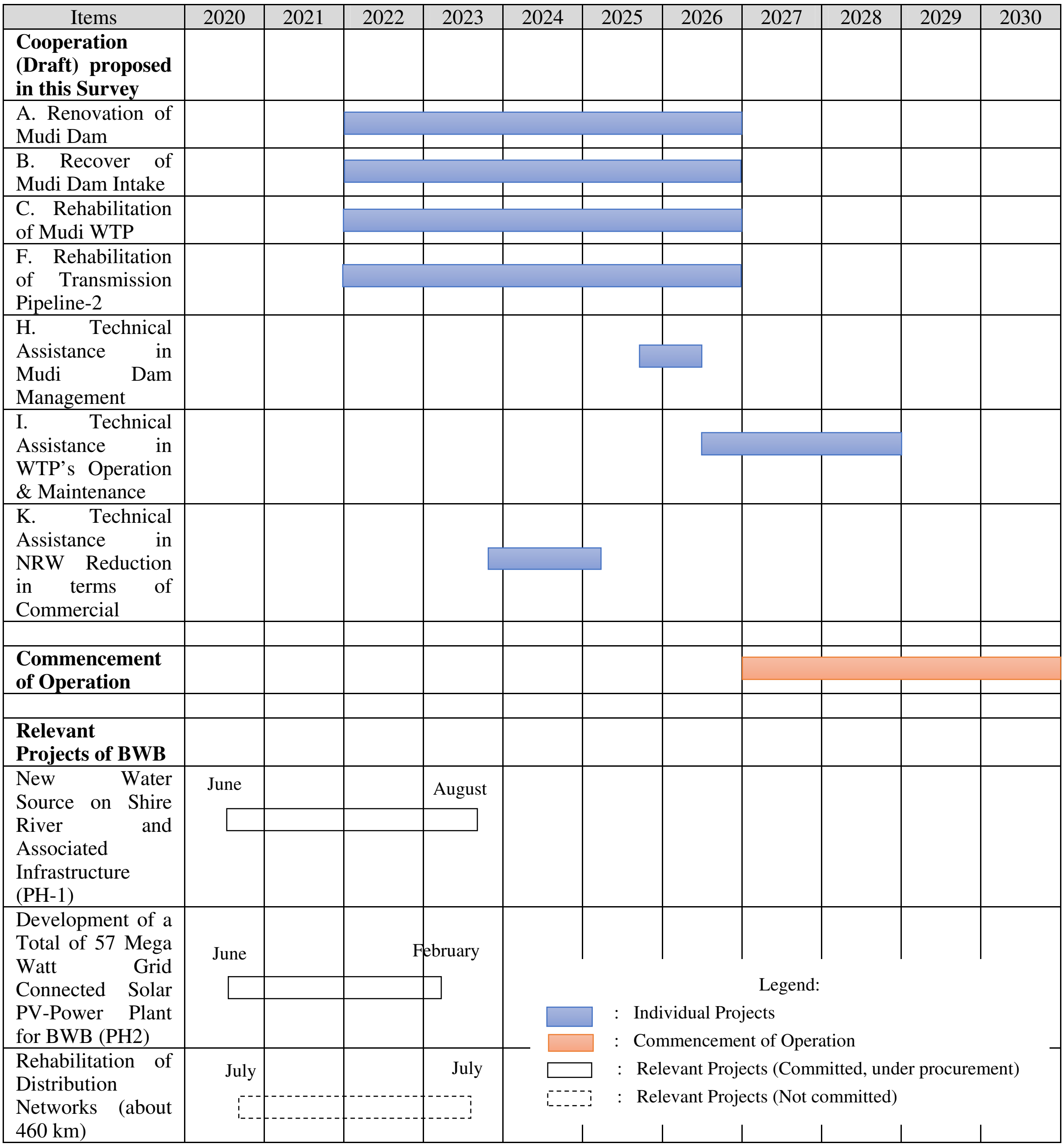
(2) Provision of Stable and Safe Water

Average water production of approximately 10,700 m^3/day and 6,800 m^3/day is secured by the renovation of Mudi Dam and the rehabilitation of Mudi WTP in Option "b." and Option "c." respectively. For each Option, 9,700 m^3/day and 6,200 m^3/day as water consumption is estimated based on the water production of 10,700 m^3/day and 6,800 m^3/day considering leakage ratio of 9% and daily water consumption rate of 100 LCD. Therefore, it will be able to supply approximately 97,000 and 62,000 people, respectably, with safe and high quality water that meets the Malawi national water standards and the WHO water quality guideline throughout the year.

[16] Malawi 2020 Poverty Report (https://bit.ly/3wr5b0O) of the National Statistical Office
[17] Based on the new water tariff revised in November 2021
[18] 2020 Malawi Poverty Report

3-8-4 Timeframe of the Development Projects

Time frames of development project in Option “b”, Option “c.” and Option “f.” with other relevant projects are shown in Figure 3-8.1 to Figure 3-8.3.



Source: The JST

Note: Individual Projects include survey periods for about two years.

Figure 3-8.1 Time Frame of Development Projects (Option “b.”)

Items	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Cooperation (Draft) proposed in this Survey											
B. Recover of Mudi Dam Intake											
D. Rehabilitation of Mudi WTP											
I. Technical Assistance in WTP's Operation & Maintenance											
K. Technical Assistance in NRW Reduction in terms of Commercial											
Commencement of Operation											
Relevant Projects of BWB											
New Water Source on Shire River and Associated Infrastructure (PH-1)	June			August							
Development of a Total of 57 Mega Watt Grid Connected Solar PV-Power Plant for BWB (PH2)	June			February							
Rehabilitation of Distribution Networks (about 460 km)	July			July							

Source: The JST

Note: Individual Projects include survey periods for about two years.

Figure 3-8.2 Time Frame of Development Projects (Option "c.")

Items	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Cooperation (Draft) proposed in this Survey											
B. Recover of Mudi Dam Intake											
D. Rehabilitation of Mudi WTP											
I. Technical Assistance in WTP's Operation & Maintenance											
G. Rehabilitation of Distribution Networks	Based on the BWB's rehabilitation project										
J. Technical Assistance in NRW Reduction of Distribution Networks	Based on the collaboration between BWB and LisCaP										
K. Technical Assistance in NRW Reduction in terms of Commercial											
Commencement of Operation											
Relevant Projects of BWB											
New Water Source on Shire River and Associated Infrastructure (PH-1)	June			August							
Development of a Total of 57 Mega Watt Grid Connected Solar PV-Power Plant for BWB (PH2)	June			February							
Rehabilitation of Distribution Networks (about 460 km)	July			July							

Source: The JST

Note: Individual Projects include survey periods for about two years.

Figure 3-8.3 Time Frame of Development Projects (Option "f.")

CHAPTER 4 Cooperation among Water Utilities

4-1 Collaboration among Water Utilities in Malawi

Table 4-1.1 shows existing or ongoing domestic, regional and international cooperation among water utilities in Malawi. Each will be described in detail below after section 4-1-2.

Table 4-1.1 Domestic, Regional and International Collaboration among Water Utilities in Malawi

	Relevant Organizations	Status	Area of Cooperation
Domestic Collaboration			
1	WASAMA - all five Water Boards	Existing	Conference, Committee, Training, etc. Members includes NGO, private enterprises, etc.
2	LWB/LiSCaP - other Water Boards	Ongoing	Knowledge co-creation since 2021 in JICA's technical cooperation project: NRW, human Resource Development (hereinafter referred to as "HRD"), new technology, water source conservation, environmental education
Regional Cooperation			
3	eThekwini (South Africa) - BWB	Ongoing	EU-WOP programme since 2019: billing, tariff collection, customer services, NRW reduction
4	eThekwini & Cape Town (South Africa) - BWB	Applying	EU-WOP programme: Water services in general including catchment management and NRW
5	eThekwini in South Africa - LWB	Completed	EU-WOP programme (2013): Performance improvement plan
6	LWB - Water and Sanitation Corporation (hereinafter referred to as "WASAC") - Embu Water and Sanitation Company (hereinafter referred to as "EWASCO")	Ongoing	Knowledge co-creation by Water Utilities Regional Partnership in Africa by JICA
International Cooperation			
7	Sub-Saharan Africa Water Utilities (44 utilities in eight countries)	Ongoing	Executive Forum for Enhancing Sustainability of Urban Water Service in Sub-Saharan Africa by JICA
8	YWWB (Japan) - LWB/LiSCaP	Ongoing	JICA Long-term Advisor since 2019: NRW management
9	YWWB (Japan) - BWB	Completed	JICA Volunteers (2014-2019): Technical improvement against leakage, tariff collection, catchment conservation, etc.
10	YWWB (Japan) - BWB	Ongoing	Online knowledge exchange (2020-2023)

Source: Prepared by the JST based on interviews to BWB, WASAMA, LiSCaP, etc.

4-1-1 Water Resource Policy in Malawi

The overall goals of the National Water Resources Policy, enacted in 2005, are to ensure the sustainable management and use of water resources. It stipulates to supply sufficient quantities and quality of water, ensures the potential for efficient and effective water sanitation services that meet the basic requirements of all Malawi people, and strengthens the country's natural ecosystems.

The National Water Resources Policy addresses the issues in sustainable management through the conservation of catchment areas. Responsibility for this implementation is mandated with relevant departments such as the Water, Forestry and Land Resources Conservation Departments.

Under the National Water Resources Act enacted in 2013, it stipulated the establishment of the National Water Resources Authority by replacing the National Water Resources Board and the Catchment Management Committee. In addition, the act also stipulated establishing the River Basin Authority (RBA).

According to the survey results related to the current organizations under the enforcement of the above acts, few River Basin Authorities have been established in basins, but the Catchment Management Committee still manages river basins. Water rights are granted based on "Section 38" in the National Water Resources Act, and the right are granted to conventional water users to take water as “conventional right for taking water”.

With regard to the control of river flow conditions during droughts, as a result of interview from the person concerned, under the National Water Resources Committee, the members of the Catchment Management Committee as well as stakeholders from agriculture and water supply organizations gathered and discussed volume of water intake as well as the priority of water intake for each sector.

The policy for water resource development is targeted to meet the increasing water demand in the future: (i) efficient use during dry season; (ii) effective use of abundant water resources in the rainy season; and (iii) water resources development from Lake Malawi to the Shire River basin with abundant water. It is recognized that the utilization of conventional water resources is important for sustainable development.

The orders of priority for water use are (i) clean water (drinking water); (ii) agriculture (irrigation water); and (iii) livestock water. The requirement for setting the environmental flow has also been discussed, but since the environmental flow impacts greatly on intake for clean water and agricultural water, it has been examined by region and catchment.

For water resource management in each catchment, the Malawi National Guidelines: Integrated Catchment Management and Rural Infrastructure were developed in November 2015. These guidelines address the principles and concepts of Catchment Management (CM), CM Planning, guidelines on establishing CM Committee and Water User Associations (WUAs). Along with showing various countermeasures such as soil and water conservation, erosion control and farm management, practical countermeasures at the village level are revealed in the guidelines.

4-1-2 Current Status of Domestic Cooperation of Water Utilities in Malawi

(1) Water Services Association of Malawi (WASAMA)

There is an existing domestic cooperation network by WASAMA consisting of five water boards in Lilongwe, Blantyre, Central, Northern and Southern regions as key members. WASAMA is an association that was established under the initiative of the Ministry responsible for water sector (currently, the Ministry of Forestry and Natural Resources) in 1998. WASAMA’s roles are a secretary of conference, committees, training provision, public relations and communication. WASAMA is a member of IWA as well as the Eastern and Southern Africa Water and Sanitation (hereinafter referred to as “ESAWAS”) Regulators Association, however does not have a water regulating function.

Table 4-1.2 shows WASAMA’s overview. Issues of WASAMA are: stability of finance and funds (sometimes, areas of subscription), organizational strengthening (currently, three staff), the expansion of the membership for revenue increase and support from the Ministry, etc.

Table 4-1.2 Overview of WASAMA

Organization	Four staff including an Executive Secretary in 2020, however three staff in 2021 (Finance& Administration Officer, Program Officer, Administrative Assistant). No seconded staff from member organizations.
Board	Six board members composed of CEOs of five water boards and a principle secretary from the Ministry. The current President is CEO of BWB.
Committee	Engineering & Technique, Benchmarking, Water Quality, Public Relations, Human Resource Development, Scientific
Members	18 members corporate and individual members consisting of five water boards, private enterprises, domestic and international NGOs
Income	Subscription, water sector magazine, training fee, conference fee, consulting fee and donation
Training	- Area: Plant operation, Plumbing, Supervisory, Customer Care, Area Mechanic, Finance, Delivery & Effectiveness, Financial Management and Book Keeping, Monitoring & Evaluation, Water Quality Monitoring, Water Monitoring Assistance - Training venue and accommodation in Mangochi - Theoretical training in the training venue and practices in facilities of South Region Water

	Board (hereinafter referred to as "SRWB") such as water treatment plant - Facilitators are staff from Technical and Vocational Education and Training (TVET) college, water boards, etc.

Source: Prepared by the JST (based on an interview to WASAMA)

(2) Knowledge Co-creation in JICA's Technical Cooperation Project

Domestic cooperation among water utilities in Malawi has been strengthened through knowledge co-creation in the JICA's technical cooperation project with LWB "LiSCaP".

The first workshop was held in June 2021 as shown in Table 4-1.3, in which case studies of NRW reduction, HRD, new technology, public relations, etc. were presented by each water board as well as environmental education by the Ministry of Forestry and Natural Resources.

Although a liaison for this cooperation has not been yet assigned officially in LWB, the workshop rotated by water boards will take place twice over the next two years under the LiSCaP.

Table 4-1.3 Knowledge Co-creation Workshop in JICA's Technical Cooperation Project

No	Time	Place and Host	Topics
1st	June 2021	Lilongwe. LWB	Good practices and failures in NRW reduction. HRD, new technology, water sources conservation, public relations and environmental education

Source: Prepared by the JST based on an interview to LiSCaP)

4-1-3 Proposed Direction on Domestic Cooperation of Water Utilities in Malawi

Utilizing and promoting the above domestic cooperation networks anchored by WASAMA and LWB/LiSCaP is a basic direction. However, classroom/theoretical training (partially practices) or the provision of opportunities for knowledge sharing and learning will probably be the immediate cooperative approaches, since all institutions have limited financial resources and personnel to provide on-the-job training (OJT) and technology transfer for a certain period by dispatching staff.

From the viewpoint of the original responsibility of association, WASAMA's leadership, coordination function, funding are essential and therefore its organizational capability should be strengthened for cooperation among water utilities and water sector and sustainability.

In the future assistance to BWB by Japan, regardless of the cooperation scheme (grant aid, technical cooperation project, etc.) and areas, disseminating the efforts by BWB and progress regularly and providing opportunities for knowledge sharing and learning in each process in cooperation with the above cooperation will contribute to strengthening the capacity of water boards in Malawi.

4-2 Proposed Direction of Regional Collaboration in Sub-Saharan Africa

4-2-1 Experiences of Malawi for Regional Cooperation

(1) WOP Program by EU/UN-Habitat

BWB has participated in and been applying newly for WOP program[19] funded by European Union (EU) on the initiative of Global Water Operators' Partnerships Alliance (GWOPA) of UN-Habitat.

ater utilities of South Africa.

Table 4-2.1 shows the WOP program related to BWB, of which mentors to BWB are mainly water utilities of South Africa.

[19] WOP Program: Peer support between two or more water operators, carried out on a not-for-profit basis. Through mentorship, WOPs progressively strengthen beneficiary utilities' capacity and performance on management, financial and technical levels to implement operational and organizational changes that lead to better and more sustainable services. African Water Association (hereinafter referred to as "AfWA") has joined as a coordinator in Africa.

Table 4-2.1 WOP Program

	Relevant Organizations (Mentor - Mentee)	Status	Area of Cooperation
1	eThekwini (South Africa) - BWB	Ongoing	- Commenced in 2019 but face-to-face activities have been suspended due to COVID-19 - Area: Billing, collection, customer service and NRW reduction - Online workshop in November 2020 (proposal writing, opinion exchange about pilot activities)
2	eThekwini & Cape Town (South Africa) - BWB	Applying	- Area: Catchment management, NRW, distribution, capacity development, water safety plan, energy efficiency, master planning, public relations, etc.
3	eThekwini (South Africa) - LWB	Completed	- Performance Improvement Plan (2013)
4	BWB - SRWB	Rejected	- Area: GIS - Sharing of BWB's experiences and knowledge of GIS which were supported by VEI funded by EU and European Investment Bank from 2009 to 2011

Source: Prepared by the JST based on an interview to BWB

(2) Water Utilities Regional Partnership in Africa by JICA

LWB has partnership with water utilities: WASAC of Rwanda and EWASCO of Kenya under the Water Utilities Regional Partnership in Africa by JICA.

Workshops were held twice with support from JICA. LWB hosted the second workshop in which other four water boards including BWB and YWWB participated as guests. Table 4-2.2 shows topics in workshops.

Table 4-2.2 Workshop on NRW in Water Utilities Regional Partnership

Workshop	Time	Place and Host	Topics
1st	Nov. 2018	Kigali, Rwanda and WASAC	- Sharing the current status of strengths and issues through water utilities' benchmarking by performance indicators - Preparation of performance improvement action plan
2nd	Sep. 2019	Lilongwe, Malawi and LWB	- Sharing practices of performance improvement action plan - Sharing good practices, failures and lessons in NRW reduction - Visiting DMAs of LWB, call center, mobile billing system, etc.

Source: Prepared by the JST based on an interview to LiSCaP)

(3) Executive Forum for Enhancing Sustainability of Urban Water Service in Sub-Saharan Africa by JICA

The first "Executive Forum for Enhancing Sustainability of Urban Water Service in Sub-Saharan Africa" took place by JICA with participation of executives including general manager and CEO from 14 water utilities of eight countries to network water utilities and share knowledge, experiences and lessons in Kigali, Rwanda in November 2019.

The forum provided participants with awareness through presentations, group discussions, comparison among water utilities from the viewpoint of water supply business management, and became an opportunity to establish a new network of water utilities in Africa. LWB participated in the forum from Malawi.

(4) Support from YWWB

YWWB has dispatched its staff as a JICA long-term advisor to LWB under the above LiSCaP, while utilizing JICA's volunteer scheme for a total of 20 staff to identify issues and propose improvements throughout BWB's water services over the two terms for six years from 2014 to 2019. Since 2020 after the completion of the volunteer scheme, cooperation through online knowledge exchanges has been continued after confirmation by both BWB and YWWB (see Table 4-2.3).

Table 4-2.3 Support from YWWB

	Relevant Organizations	Status	Area of Cooperation
1	YWWB - LWB/LiSCaP	Ongoing	JICA Long-term Advisor since 2019: NRW management
2	YWWB - BWB	Completed	JICA Volunteers (2014-2019): Technical improvement against leakage, tariff collection, catchment conservation, etc.
3	YWWB - BWB	Ongoing	Online knowledge exchange (2020-2023) Dispatching staff for distribution (NRW reduction, supervision, drawing management, etc.) and commerce (tariff management, customer management, visiting lecture, etc.)

Source: Prepared by the JST based on an interview to YWWB)

4-2-2 Proposed Direction and Considerations of Regional Cooperation in Sub-Saharan Africa

As a result of interviews to BWB, LWB (LiSCaP), WASAC, EWASCO, all water utilities have regarded regional cooperation as a thing that contributes to the development of their own water supply business. Specifically, there is higher needs for cooperation by sharing good practices and knowledge in areas such as NRW reduction, water demand management, water distribution management, planning, design and GIS database.

(1) Proposed Direction of Regional Cooperation in Sub-Saharan Africa

Strategic support by Japan is effective for cooperation between the two water utilities as promoted by the EU-WOP, in order to further enhance synergies and effects. For example, for the ongoing cooperation between two water utilities: eThekwini in South Africa and BWB, the "South-South Cooperation + Japan" can be taken based on the multi-relationship that includes YWWB, which has individual relationship with both water utilities.

Through promoting continuous support with Malawi (mainly BWB) by particularly YWWB and collaboration with the established network, sharing knowledge with other water utilities such as LWB is very beneficial in the development of the Malawi water supply sector.

In addition to the ongoing "Water Utilities Regional Partnership in Africa" and "Executive Forum for Enhancing Sustainability of Urban Water Service in Sub-Saharan Africa" that JICA has supported, scale-up of regional and international cooperation is in sight by cooperation in Southern Africa due to the geographical conditions of Malawi (e.g. strengthening relationship with South Africa's water sector) as well as by cooperation with various associations such as AfWA and the ESAWAS Regulator Association. It is expected that relevant organizations such as water utilities including BWB will actively participate in regional and international cooperation platforms and activate relationship and mutual information sharing with others suffering from similar problems, which will lead to awareness of their own issues and improvement actions.

BWB is also willing to participate in and cooperate with such regional and international cooperation (learning from other water utilities, while providing their own knowledge, etc.), a regional technical cooperation project can be considered to develop and shape these regional and international cooperation.

(2) Considerations of Regional Cooperation in Sub-Saharan Africa

As a result of interviews as well, considerations of regional cooperation are summarized below:

- Funding/subsidizing costs for workshop, accommodation and transport of participants is an issue.
- Although it is possible to maintain sustainability through regular workshops at the organizational level, there is a limit to practical cooperation that leads to capacity development at the individual level.
- In practical cooperation such as WOP, a solid system design is necessary, especially from the standpoint of becoming a facilitator (mentor) who will leave his/her workplace for a certain period of time due to reasons such as lack of personnel in the organization to which he/she

belongs and having his own work.

- Although such practical cooperation takes the form of theoretical training and practices supposedly by several facilitators (mentors) and participation of up to five trainees/mentees in a period of one to two weeks, funding/subsidizing facilitator (mentor) remuneration, costs for accommodation, transportation, etc. are issues.
- From the perspective of expanding cooperation, stakeholders have a shared picture of regional cooperation with participation from especially English-speaking countries in Eastern Africa and Southern Africa.