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Lake Rukwa Basin IWRMD Plan: Final Report
Volume II (e): Muze Sub-basin Water Resources Management and Development Plan

by

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Atlanta, Georgia, USA

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Lake Rukwa Basin Integrated Water Resources Management and Development Plan

Final Report: Volume II (e)

Muze Sub-basin Water Resources Management and Development Plan

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Disclaimer

The views expressed in this report are those of WREM International Inc. and do not necessarily reflect the views of the Lake Rukwa Basin Water Board, or the views of the Ministry of Water of the United Republic of Tanzania.

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Preamble

This report is one of six Final IWRMD Plan Report volumes developed under the project "Lake Rukwa Basin Integrated Water Resources Management and Development Plan (IWRMDP)." This project was carried out for the Ministry of Water, United Republic of Tanzania, under the Water Sector Development Program (WSDP).

A brief description of these reports is provided below.

Volume I: Lake Rukwa Basin IWRMD Plan Main Report – Volume I contains the synthesis of information generated from all project activities with emphasis on the main study findings, conclusions, and recommendations. It contains results from the basin-wide integrated assessments and recommended actions that cut across sub-basins.

Volume II: Sub-basin Water Resources Management and Development Plans – Volume II (a) to (f) of the report series presents the sub-basin specific water resources management and development plans for Katuma, Songwe, Momba, Luiche, Muze, and Rungwa. The sub-basin plans are the basis for development of the basin-wide IWRMD Plan.

Volume III: IWRMD Plan Implementation Strategy and Action Plan – Volume III presents the IWRMD Plan implementation strategy and action plan which includes two main components: (a) the implementation strategy which highlights the administrative and financial modalities of the IWRMD Plan implementation, and identifies the key players to be involved in implementation of the Plan and their corresponding roles; and (b) the Action Plan which outlines the requisite steps to be taken and preparatory activities necessary to kick-start the Plan implementation process. The report also presents the Monitoring and Evaluation Strategy for the IWRMD Plan implementation process and a Communication Plan for information dissemination to the public to facilitate sustained stakeholder engagement and feedback.

Volume IV: Capacity Building and Stakeholder Participation Plan – Volume IV presents the proposed capacity building and stakeholder participation mechanisms. The report identifies the different basin stakeholder groups, assesses their capacity needs, and proposes capacity building measures to enable them to effectively participate in basin water resources management activities, particularly IWRMD Plan implementation.

Volume V: Rukwa Decision Support System (Rukwa DSS v3.0) – Volume V describes the third version of the Lake Rukwa Basin Decision Support System (Rukwa DSS v3.0) developed to support integrated water resources planning and management. The Rukwa DSS v3.0 is a state of the science information and modeling tool including comprehensive databases; data management and analysis tools; and detailed models for hydrologic forecasting, river simulation, and scenario/policy assessment. The report is a systematic guide to the use of this modern information, modeling, and assessment system for integrated planning and management of the basin water resources.

Volume VI: Lake Rukwa Basin Monitoring Plan – This volume provides recommendations for comprehensive monitoring of the basin climate, surface water hydrology, groundwater hydrology, and water quality. The condition of the existing monitoring networks is critically reviewed and existing gaps identified. Guiding principles for the design of effective monitoring networks are outlined and used as the basis for specific recommendations on network upgrade, expansion, efficient operation, and coordination. Important data management issues are discussed, and an integrated data and information management process is outlined.

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List of Acronyms and Abreviations

BMUs	Beach Management Units
CC	City Council
CITES	Convention on International Trade in Endangered Wild Flora
COSTECH	Commission for Science and Technology
COWSO	Community Owned Water Supply Organization
DC	District Council
DSS	Decision Support System
EFA	Environmental Flow Assessment
EFRs	Environmental Flow Requirements
FAO	Food and Agriculture Organization of the United Nationa
GBIF	Global Biodiversity Information Facility
GEF	Global Environmental Facility
GoB	Government of Belgium
GoT	Government of Tanzania
GR	Game Reserve
HEC	Human Elephant Conflict
HIMA	Hifadhi ya Mazingira
IMP	Integrated Management Plan
IUCN	The World Conservation Union
IWRDMP	Integrated Water Resources Development and Management Plan
LRBWB	Lake Rukwa Basin Water Board
MC	Municipal Council
MoLDF	Ministry of Livestock Development and Fisheries
MSY	Maximum Sustainable Yield
MW	Mega Watts
NEAP	National Environmental Action Plan
NEMC	National Environment Management Council
NGO	Non Governmental Organization
MNRT	Ministry of Natural Resources and Tourism
PID	Pelvic Inflammatory Disease
SADC	Southern African Development Cooperation
SMUWC	Sustainable Management of the Usangu Wetland and its Catchment
SRF	Systematic Reconnaissance Flight
TAFIRI	Tanzania Fisheries Research Institute
TAFORI	Tanzania Forestry Research Institute
TANAPA	Tanzania National Parks
TanBIF	Tanzania Biodiversity Information Facility
TAWIRI	Tanzania Wildlife Research Institute
TC	Town Council
TTB	Tanzania Tourism Board
TShs	Tanzanian Shillings
WB	The World Bank
WCS	Wildlife Conservation Society
WCST	Wildlife Conservation Society of Tanzania
WMA	Wildlife Management Area
WREM	Water Resources and Energy Management Incorporated

1. Introduction

The Government of the United Republic of Tanzania is implementing the Water Sector Development Programme (WSDP; 2006–2025) to strengthen the existing water resources management framework, improve the delivery of sustainable water supply and sanitation services, and strengthen the capacities of sector institutions. The program includes four main components: (i) Water Resources Management and Development (WRMD); (ii) Community Water Supply and Sanitation (CWSS); (iii) Commercial Water Supply and Sewerage (CWS); and (iv) Sector Institutional Strengthening and Capacity Building.

The current project falls under the Water Resources Management and Development component whose overall objectives are as follows:

(i) Develop a sound water resources management and development framework in all nine water basins for optimizing water resources utilization in a sustainable manner for the various competing uses.

(ii) Promote good governance of water resources through: empowering water users; encouraging participatory and transparent decision-making in the allocation, utilizationprotection and conservation of water resources; devolving ownership to the user level; granting secure water use permits with responsibilities to the water users, community groups, local government and basin boards; and promoting economic instruments to encourage wise use of water.

(iii) Strengthen the capacity of basin boards to address trans-boundary water resources issues.

The overarching objective of the Lake Rukwa Basin IWRMD project is:

"To develop a basin-wide Integrated Water Resources Management and Development (IWRMD) Plan for the Lake Rukwa Basin by (i) assessing water resources and identifying current and future water demands of different sectors, (ii) formulating/evaluating alternatives that will meet those needs, (iii) recommending specific water resources development and management options for the short term (up to 2015), medium term (up to 2025), and long term (up to 2035), and (iv) building capacity of staff of the basin water board and office and other stakeholder agencies to ensure successful development and implementation of the Plan."

This report volume constitutes the Water Resources Management and Development (WRMD) Plan for the Muze Sub-basin, one of the six sub-basins of the Lake Rukwa Basin. The Sub-basin WRMD Plans are the basis and important inputs to the Lake Rukwa Basin Integrated Water Resources Management and Development (IWRMD) Plan. The Sub-basin Plans highlight the major water resources management and development issues and challenges specific to each sub-basin and identify water allocation priorities between competing users within the different sub-basins. In developing the Sub-basin Plans, a number of detailed assessments were carried out. These included (a) water availability assessments under historical and future climate conditions; (b) current sectoral water use assessments and future water demand projections; (c) water balance assessments under historical and future climate conditions; and (d) identification of specific priority intervention measures to address the sub-basin water needs in the short-, medium-, and long-term. To ensure reliability and relevance of the assessment findings, significant time and effort was dedicated towards collection, review, and quality control of the required information and data used in carrying out different technical assessments. All major sub-basin stakeholders were visited and accorded the opportunity to provide input, express their opinions, and raise any concerns regarding the Plan development process. Likewise, all basin regional secretariats and districts were visited, and discussions were held with relevant officials to solicit their input into the Plan development process. Specifically, discussions were held with heads of departments in all basin districts on thematic issues to leverage local experience, seek guidance as key stakeholders, and access relevant district-specific and up-to-date data and information. Detailed data/information gathering questionnaires were circulated to all district heads of departments soliciting sector-specific water use related data and information at ward and village levels. The questionnaire response was 100%, indicating that the districts embraced the Plan development process and importance with great enthusiasm. All relevant documents were reviewed and critically assessed including the latest Regional and District Socioeconomic Profiles; District Development Plans; National Sample Census of Agriculture Reports; Livestock Sample Survey Census reports; and several other important sectoral planning documents. In addition, detailed questionnaires were also administered to several households (about 50 households per ward) in 40 wards spread across all basin districts. The data and information captured in the household questionnaires were vital in establishing baseline socio-economic conditions and the level of dependence on water resources by local communities. Overall, the detailed consultative and data/information gathering process generated significant useful data/information that formed the basis for all the assessments carried out and findings presented in the IWRMD Plan reports.

Based on the data and information gathered, several hydrological and water resources assessments were conducted at sub-basin and basin levels. These studies revealed that the Muze Sub-basin is not experiencing any significant water stress under current water demand levels. However, the situation could change in the short to medium term due to projected increases in irrigation water demand corresponding to planned irrigation developments. The situation is likely to be exacerbated by potential climate change impacts. Assessment findings reveal that the sub-basin is already experiencing climate change impacts and is vulnerable to future climate change. Projected climate changes are expected to impact the sub-basin hydrology, agriculture, and water resources. This is because increasing temperatures lead to higher evapotranspiration and reduce surface water flows, soil moisture, groundwater recharge, and lake/reservoir levels. Furthermore, higher crop evapotranspiration will further increase irrigation demand. The combined impacts of rising water use levels and climate change portend reduction of natural water supplies and increased stresses on all water related sectors. The water balance assessment findings highlight significant decrease in streamflow in the Muze River due to the reinforcing impacts of climate change and increasing water demands.

The detailed sub-basin assessment findings, conclusions, and potential intervention measures were extensively reviewed and discussed by sub-basin stakeholders at different fora. Several technical assessment reports containing these findings and conclusions (Interim Reports I and II) were widely circulated to all major stakeholders for review and comments. The reports were also presented at several stakeholder consultation meetings and workshops facilitated by the LRBWB and the project team. Stakeholder comments were extensive and provided guidance to address priority stakeholder interests and concerns. These comments are reflected in the strategic objectives and priority interventions discussed in this report. The interventions were grouped into five strategic program areas to be implemented over the planning period (2016 to 2035):

(1) Water Security Enhancement Program;
(2) Water Resources Monitoring and Assessment Program;
(3) Water Permit Compliance Monitoring Program;
(4) Environment Flow Assessment and Monitoring Program; and
(5) Integrated Watershed Management and Environmental Conservation.

The total estimated budget to implement the Muze Sub-basin WRMD Plan from 2016 to 2035 is about 4.17 Billion TShs. The Plan is expected to be reviewed every five years to benefit from updated water resources assessments and additional water resources data collection. The review will also ensure that the Plan is continuously re-aligned to address other emerging sub-basin challenges and to leverage new development opportunities as they arise.

The report is organized into six chapters. Chapter 1 introduced the IWRMD planning process and its general findings for the Muze sub-basin. Chapter 2 provides a general overview of the sub-basin including its location, topography, climate, water availability, and socioeconomic conditions. Chapter 3 discusses the current sectoral water use levels and water demand projections. Chapter 4 presents the sub-basin water balance assessments and highlights the strategies for addressing current and anticipated water deficits. Chapter 5 discusses the sub-basin Plan strategic goals, objectives and priority intervention measures. Lastly, Chapter 6 presents the Strategic Action Plan and estimated budget.

2. Overview of the Muze Sub-basin

2.1 Location

Muze is the smallest sub-basin in the Lake Rukwa Basin with an area about 354 km^2 covering parts of Sumbawanga MC, Sumbawanga DC, and Nkasi DC (**Figure 2.1**). The sub-basin population is about 19,631 (2012 National Census) all of whom live in rural areas. The sub-basin has no major urban center. The sub-basin has an average population growth rate of 3.6% which is above the Tanzania national average of 2.9%. The sub-basin population is projected to increase to about 48,417 by 2035, an increase of about 147% (see **Figure 2.2**).

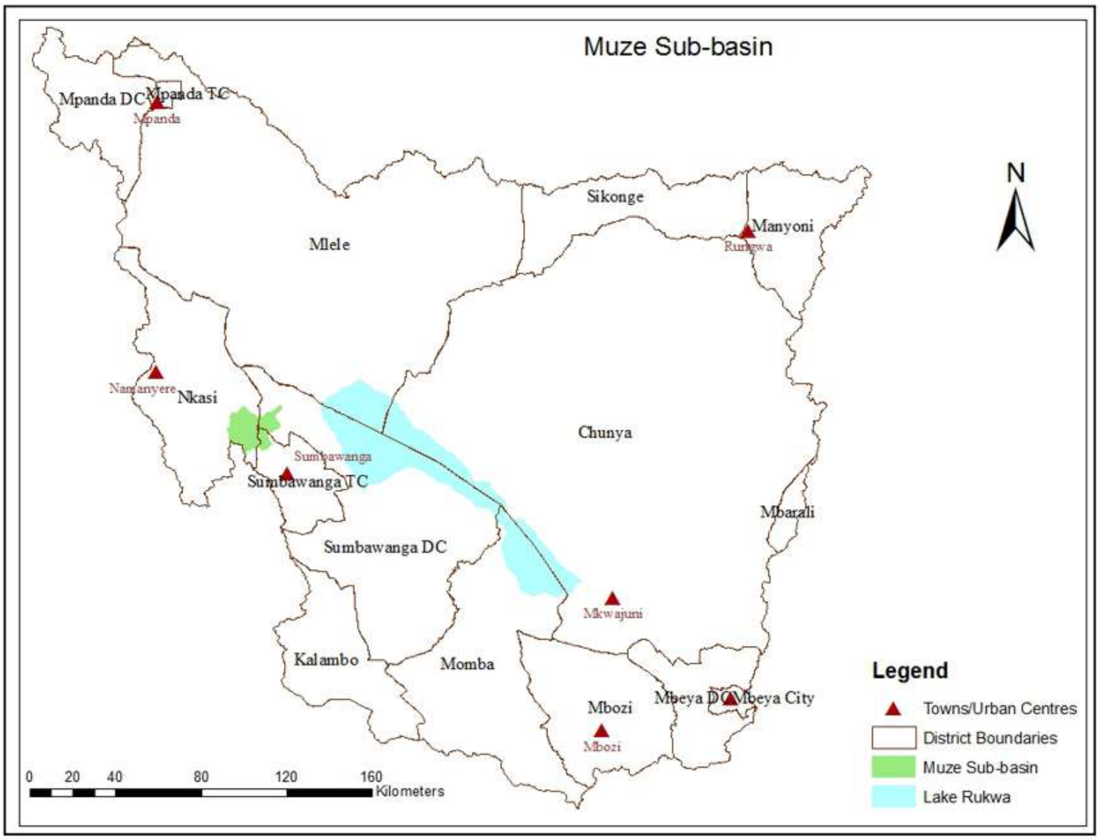

Figure 2.1: Location of the Muze Sub-basin.

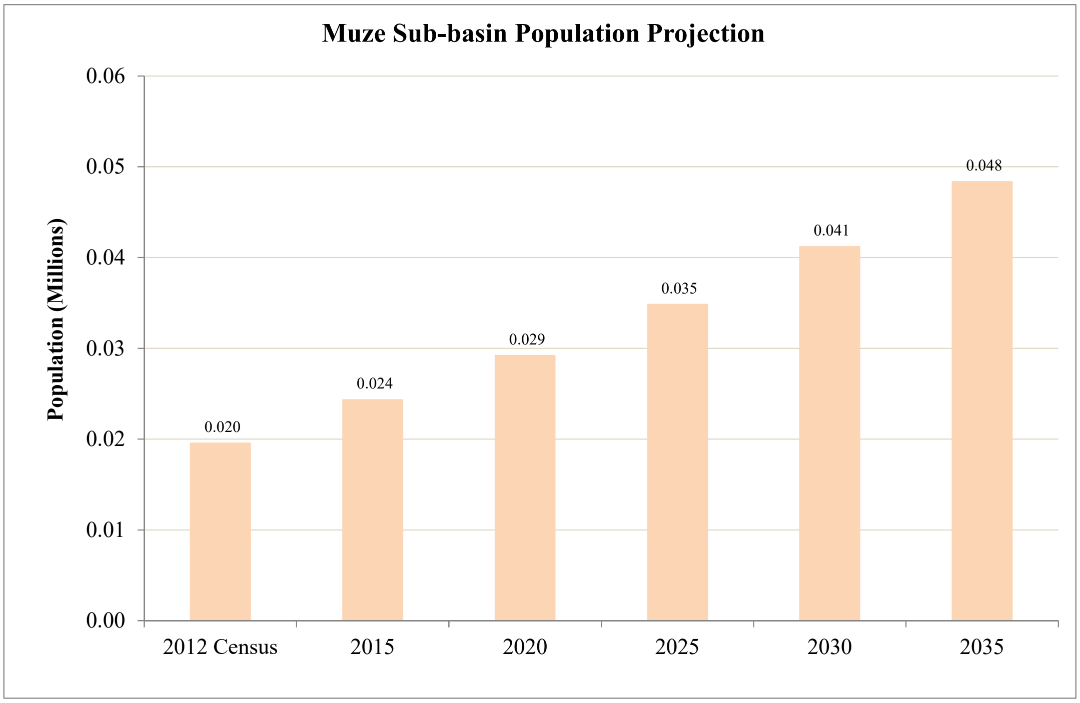

Figure 2.2: Muze Sub-basin Population Projection.

2.2 Socioeconomic Conditions

Detailed socioeconomic surveys and assessments were conducted to establish baseline conditions and the level of dependence on the basin's water resources by riparian communities. Detailed findings are presented in ***Volume II: Lake Rukwa Basin Socioeconomic Profile***. Findings for the Muze Sub-basin are summarized next.

2.2.1 Socioeconomic Importance

Agriculture is the dominant activity employing more than 95% of the sub-basin population. Major crops grown include paddy, maize, beans, sugarcane, and vegetables. Other activities include livestock keeping and fishing. There are no industries in the sub-basin except for small scale carpentry workshops, maize mills, oil seed extracting mills, and saw mills.

2.2.2 Occupation and Source of Household Income

According to a detailed household survey conducted under the study (WREM International, 2013), the majority (65.4%) of household heads are engaged in agriculture (crop farming and livestock keeping) as their primary occupation (**Figure 2.3**). Other significant occupation categories include formal and self-employment (retail shops, street vending, brick and craft making, charcoal burning, and transportation). The major source of household income is the sale of agricultural produce (food and cash crops). About 45.3% of the households depend on agricultural produce sales as their main household income (see **Figure 2.4**).

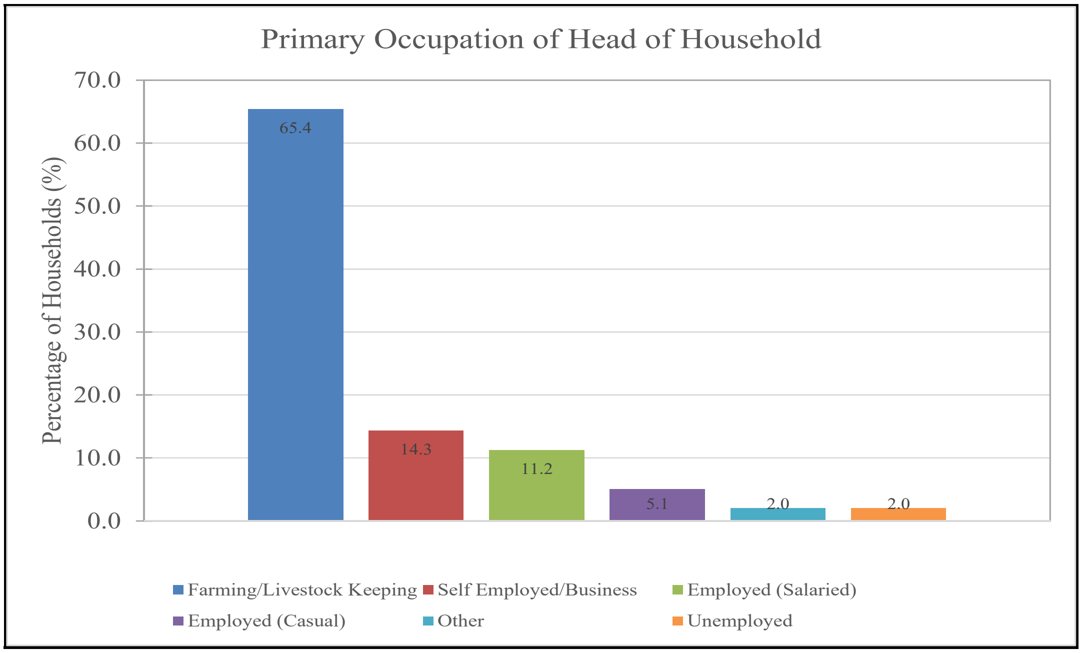

Figure 2.3: Primary Occupation of Head of Household.

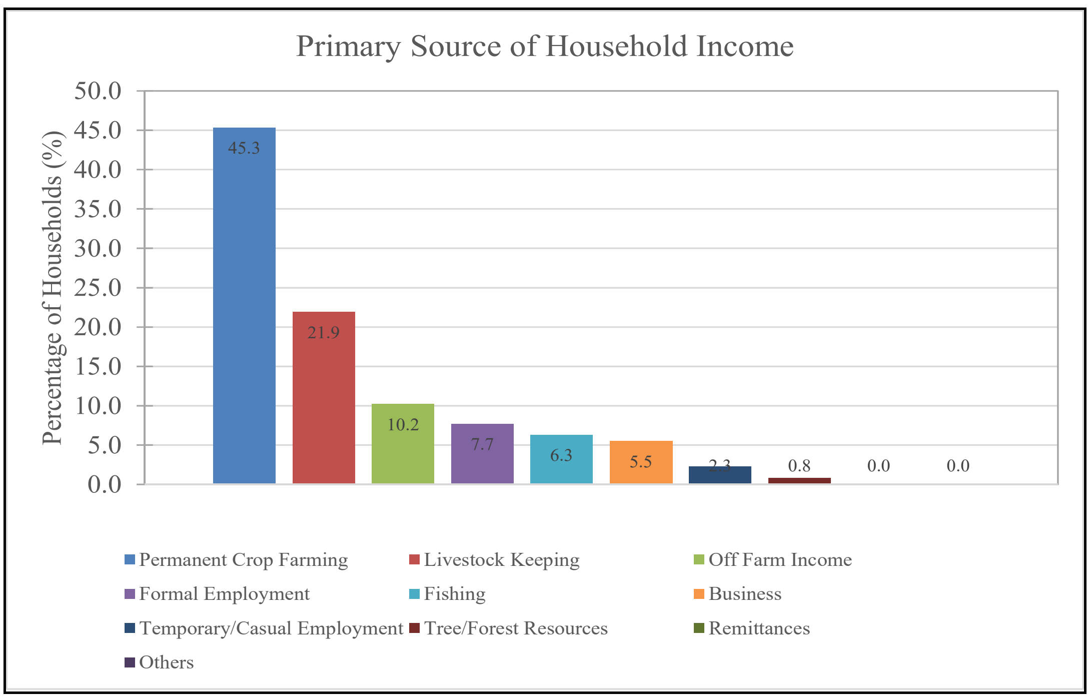

Figure 2.4: Primary Source of Household Income

2.2.3 Access to Social Services

Domestic Water Supply: Domestic water supply coverage is very low in all sub-basin districts. Access to clean drinking water in rural areas varies from 40% in Sumbawanga MC to 45% in Sumbawanga DC. These coverage levels are all lower than the 2015 national targets.

Sanitation: The majority (more than 95%) of households rely on traditional pit latrines for their household sanitation. This has implications for water pollution due to poor latrine location and construction. Most pit latrines flood during heavy rains and contaminate neighboring water bodies. The problem is most pronounced in crowded, poorly-planned settlements in urban and peri-urban areas.

Energy Source: Fuel wood in the form of firewood and charcoal is the most important source of energy for more than 95% of the sub-basin population. It is mostly used for domestic cooking and lighting and in diverse subsistence economic activities such as brick making, pottery and tobacco curing. Over-reliance on fuel wood is responsible for the wide spread deforestation observed in many sub-basin areas. This has serious environmental consequences including soil erosion, drying up of water sources, and heavy sediment transport and deposition in surface water bodies.

Health Services: The status of health services in the Muze sub-basin is poor compared to other parts of Tanzania. For example Sumbawanga MC has a high number of people per health facility estimated to be about 7,000. There is also a general shortage of medical staff in all sub-basin districts. For example the mean doctor/population ratio for Sumbawanga DC is about 1:258,375 well below the WHO recommended standard of 1:10,000 and national average of 1:25,000.

2.3 Water Availability

Detailed water resources availability assessments were conducted for the whole basin and the findings are contained in *Interim Report I, Volume II: Water Availability Assessments*. Findings for Muze sub-basin are summarized next. For more details please refer to the above report volume.

2.3.1 Climate

The sub-basin is mostly characterized by a tropical climate and experiences one long rainy season (November to April). The dry season starts from around June to October with the driest months being July and August (**Figure 2.5**). Annual rainfall ranges from 900 mm to 1000 mm.

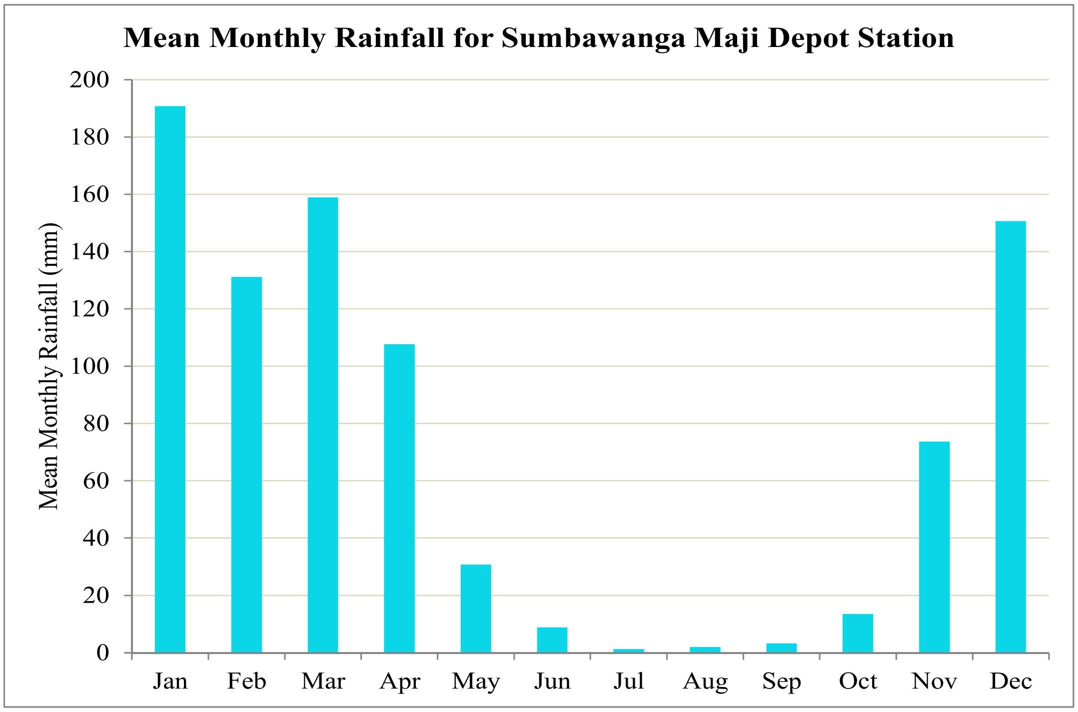

Figure 2.5: Mean Monthly Rainfall for Sumbawanga Maji Depot Station in Sumbawanga Town.

2.3.2 Surface Water Resources

The sub-basin is drained by the River Muze which originates from the Ufipa Plateau, meanders through isolated swamps, cuts across the Lyambalyamfipa escarpment into the Rukwa Valley, and finally discharging into swamps on the northwestern shores of Lake Rukwa. The river is fed by several tributaries, the most notable of which are the Nkomolo River, (originating from the Kilangala hills and draining the western and northern parts) and Rivers Tutumbwe and Namyima (draining the southern part of the sub-basin).

The Muze River exhibits strong seasonality, high flows in the rainy season, and low flows the rest of the year (see **Figure 2.6**). The river registers peak flows from April to May and very low flows from June to October.

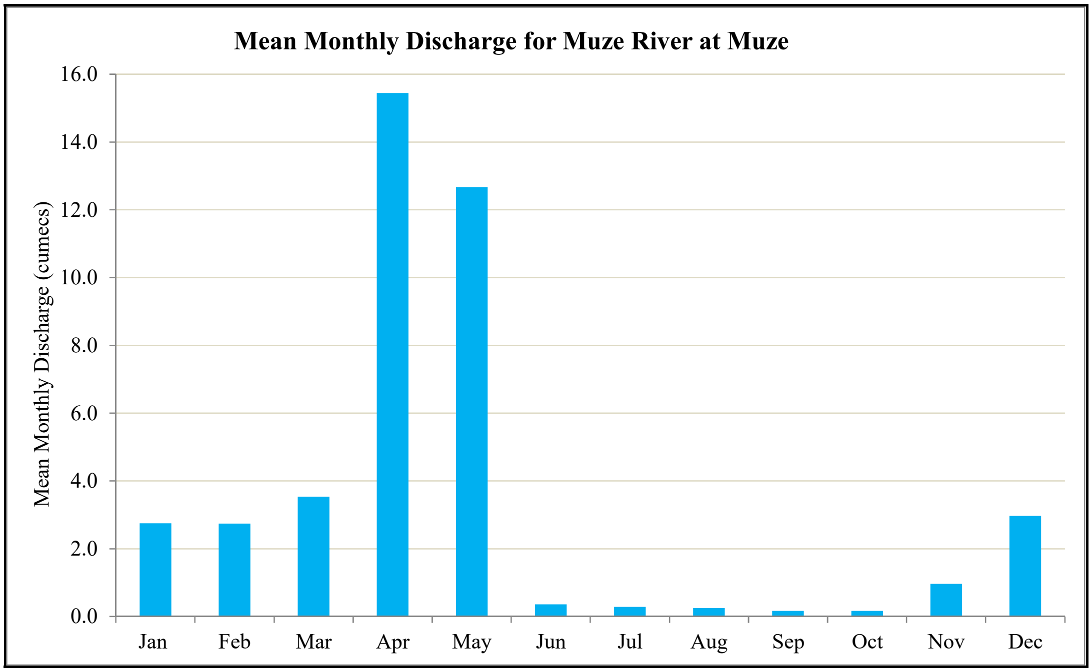

Figure 2.6: Mean Monthly Discharge for the Muze River at Muze.

The Lake Rukwa Basin Water Board operates and maintains a water resources data collection network for the sub-basin consisting of one hydrometric station (Muze River at Muze – 3CD1) and one climatic station shown in **Figure 2.7.** There is no water quality monitoring station. The Muze hydrometric station has significant data gaps due to inconsistencies in the monitoring program mostly attributed to inadequate funding. Its rating curve is outdated and needs recalibration.

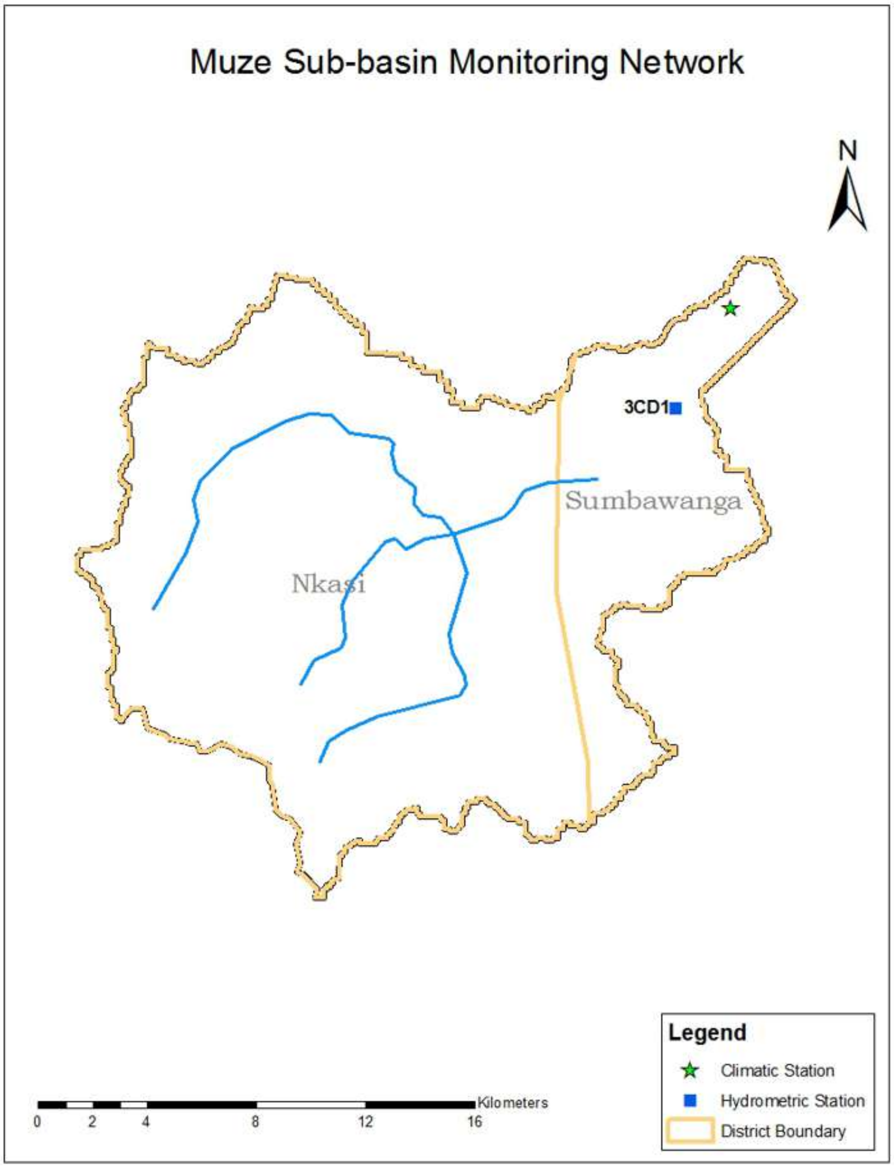

Figure 2.7: Muze Sub-basin Water Resources Monitoring Network.

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2.3.3 Groundwater Resources

There is no existing groundwater monitoring network in the Muze Sub-basin to provide the necessary data to estimate groundwater potential and aquifer characterization. Nevertheless, groundwater is a major source of domestic water supply in most sub-basin rural areas. A clearer picture of the sub-basin groundwater potential, yield, and spatial distribution will only be possible after establishment of a groundwater monitoring network and collection of the necessary data.

3. Sectoral Water Use and Demand Projections

3.1 Water Use and Demand Projections

The major water uses in the Muze Sub-basin are the domestic and livestock sectors which account for 80% and 15% of the total water consumption respectively. There is only one major irrigation scheme (the Muze traditional irrigation scheme). However, there are no significant irrigation activities going on due to inadequate water supply infrastructure. There are also no signifinat industrial or mining activities. The total water demand for the Muze sub-basin is projected to increase from 0.39 MCM in 2015 to 18.14 MCM by 2035. The projected increments in the individual sectors are as shown in **Figure 3.1** and **Table 3.1**. If the planned sub-basin irrigation developments are implemented, it is projected that irrigation will account for about 95% of the total sub-basin water use by 2035. Smaller increments are projected for the domestic and livestock sectors. Detailed discussion of water demand projections for all Lake Rukwa sub-basins is contained in a separate report volume **(*Interim Report 2, Volume I: Water Demand Projections*)**. All the sectors mostly rely on surface water sources (rivers, streams, dams). Groundwater is an important source of domestic water supply in a number of rural communities. Although it currently accounts for only 35% of total sub-basin domestic water supply, potential exists for increased groundwater use in future especially once efforts have been made to assess its potential, yield, and spatial distribution. **Figure 3.2** shows the location of major water uses in the Muze sub-basin.

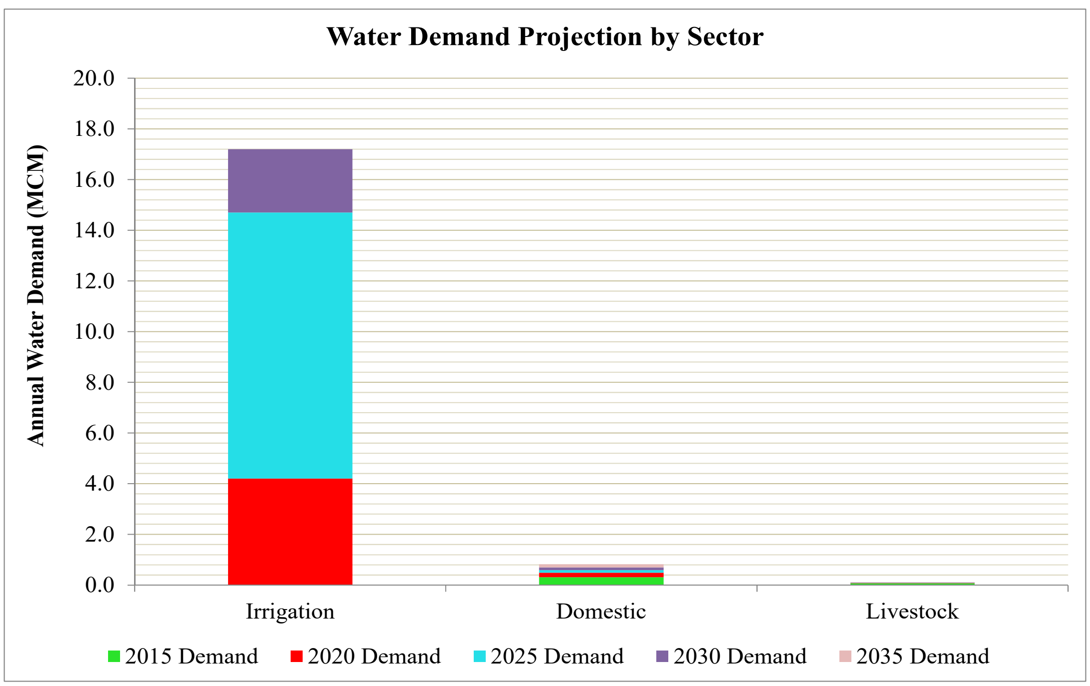


Figure 3.1: Muze Sub-basin Water Demand Projections.

Table 3.1: Muze Sub-basin Water Demand Projections.

Sector	Demand Projection (MCM)				
	2015	2020	2025	2030	2035
Irrigation	0.00	4.20	14.70	17.20	17.20
Domestic	0.31	0.49	0.59	0.70	0.82
Livestock	0.07	0.08	0.09	0.10	0.12
Sub-basin Total	**0.39**	**4.77**	**15.38**	**18.00**	**18.14**

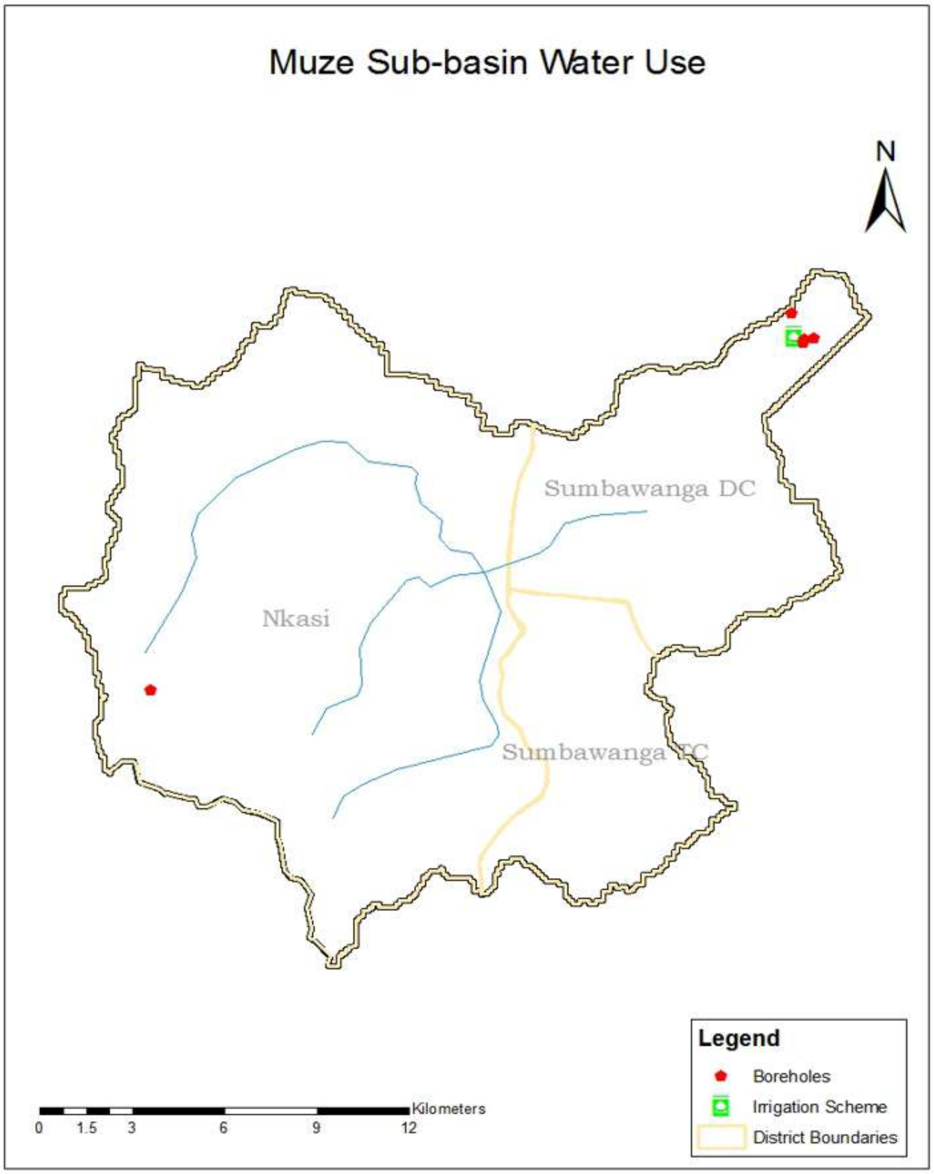


Figure 3.2: Location of Major Water Uses in the Muze Sub-basin.

3.1.1 Irrigation Water Use

There is only one major irrigation scheme in the sub-basin, the Muze traditional irrigation scheme, which is currently non-functional due to lack of water storage infrastructure. Current irrigation water use is insignificant, limited to small vegetable gardens. However, the situation is likely to change in the near future once the ongoing rehabilitation of the water storage dam is completed. The scheme has a potential irrigable area of about 700 ha. The main crops grown are paddy, maize, sugarcane, and vegetables. The Muze River is the main source of water supply.

Based on the existing national and local irrigation development plans, the annual irrigation water demand for the Muze sub-basin is projected to increase to about 17.2 MCM in 2035 (**Figure 3.3**). The high increase in irrigation water demand is mostly attributed to major irrigation developments under different national initiatives, especially SAGCOT, Kilimo Kwanza, and BRN.

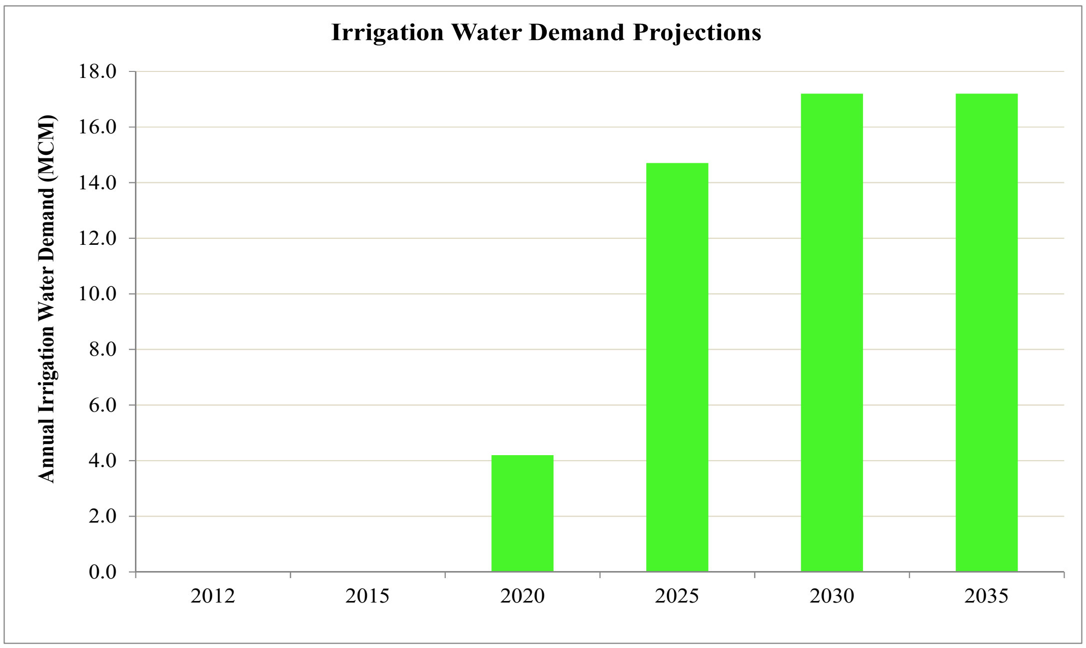


Figure 3.3: Irrigation Water Demand Projections for the Muze Sub-basin.

Issues and Challenges

Although the Muze Sub-basin is currently not water stressed, the projected increase in irrigation water demand is likely to exert significant pressure on the sub-basin water resources in the long run. Muze is a traditional irrigation scheme with inadequate and poorly constructed infrastructure exhibiting high water losses and low water use efficiency. It is important that the ongoing and planned developments are not restricted to rehabilitation of the water storage dam but also address other important aspects of the irrigation infrastructure, such as linning water supply canals, constructing return flow canals, and training farmers in good on-farm water management practices.

3.1.2 Domestic Water Use

Domestic water supply coverage in the Muze sub-basin is generally low. The sub-basin domestic water demand is projected to increase from 0.31 MCM in 2015 to about 0.82 MCM by 2035, an increase of about 162% (see **Figure 3.4**).

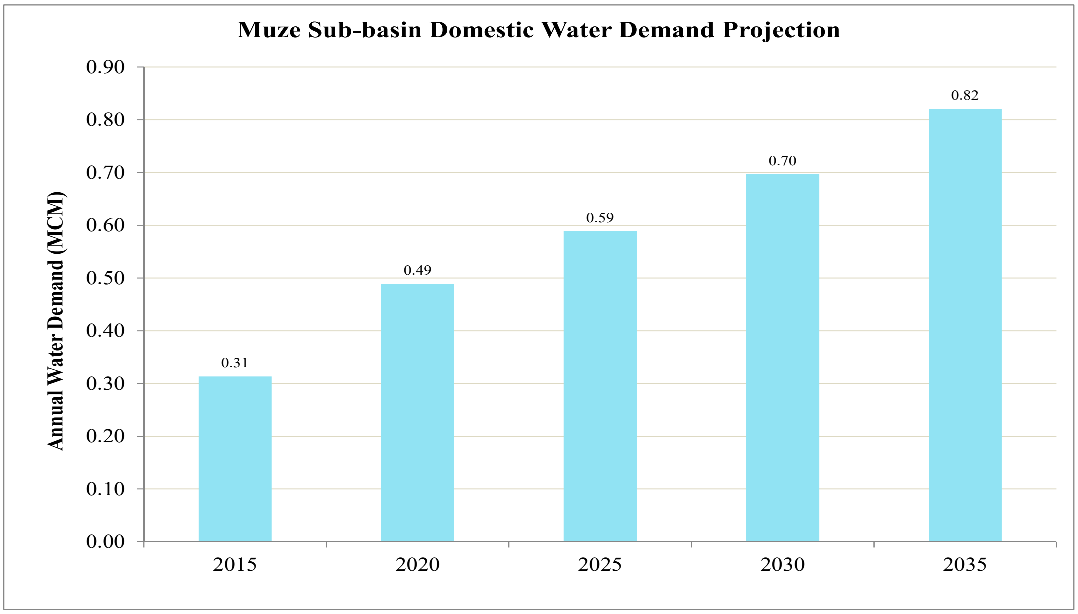


Figure 3.4: Muze Sub-basin Domestic Water Demand Projections.

(1) Urban Water Supply

Muze is a predominatly rural watershed with no notable urban centers. Thus domestic water supply is insignificant.

(2) Rural Water Supply

The main sources for rural water supply include bore holes, springs, gravity flow schemes, rivers, streams, and rainwater harvesting from roof-tops. Groundwater is a major source of water supply in rural areas due to its wide spatial distribution, perennial availability, and reasonably good quality. Of the 15 existing rural water supply sources in the Muze sub-basin, 7 are boreholes. Implementation of the rural water and sanitation component of WSDP has helped improve rural water supply and sanitation coverage in most sub-basin districts. WSDP has begun to focus on new projects in villages that do not have a water supply or that have had but which cannot be viably rehabilitated.This second round of rural water supply infrastructure expansion is expected to significantly improve the rural water supply coverage to within or above the national targets. The biggest challenge, however, is sustainability of the rehabilitated and new water supply infrastructure. Because the rural water supply schemes serve poor communities, they are usually poorly managed and maintained resulting in frequent breakdowns.

3.1.3 Environmental Flow Requirements

The National Water Policy (2002) and Water Management Act (2009) emphasize the importance and need for determining environmental flow requirements and resource allocation as an integral part of integrated water resources planning and management. The Water Resources Management Act (2009) prioritizes environmental flow requirements (only second to domestic water use) in the hierarchy of water allocation and requires that specific minimum flows be maintained to sustain freshwater ecosystems and ecosystem services. Environmental flow requirements present a significant water use tradeoff with far reaching socioeconomic implications for the local population which mostly depends on irrigated agriculture for survival and household income. Unfortunately, specific environmental flow requirements (EFRs) have not yet been determined for any river section in the sub-basin. A planning priority should be to conduct environmental flow assessments and establish EFRs for all critical sub-basin river sections.

3.1.4 Livestock Water Use

Livestock keeping is one of the major socio-economic activities in the Muze sub-basin. Domestic animals constitute one of the most important non-land assets owned by the majority of people in rural areas. Livestock products such as milk, meat, eggs, and ghee are a good source of protein to farmers while the surplus is sold to enhance household incomes. Local and regional demand for livestock products is high and there isvery good potential for sustained growth of the livestock industry.

The most commonly kept livestock include cattle, goats, and sheep, most of which are indigenous and free ranging with a few hybrids and dairy cattle in isolated ranches. Other livestock kept include pigs, donkeys, chicken, ducks, and pigeons. Total livestock population in the sub-basin is approximately 22,285. **Figure 3.5** shows sub-basin population for the different livestock types. Chicken is the most commonly kept, accounting for about 44% of the total livestock population. Cattle and goats are also popular and account for 29% and 16% of the total sub-basin livestock population respectively. The main sources of water for livestock include rivers, streams, swamps/marshes, and temporary ponds during the rainy season. The annual livestock water consumption is projected to increase from about 0.0723 MCM in 2015 to about 0.118 MCM in 2035 (see **Figure 3.6**). This is a relatively small increase compared to the projected increase in irrigation water demand.

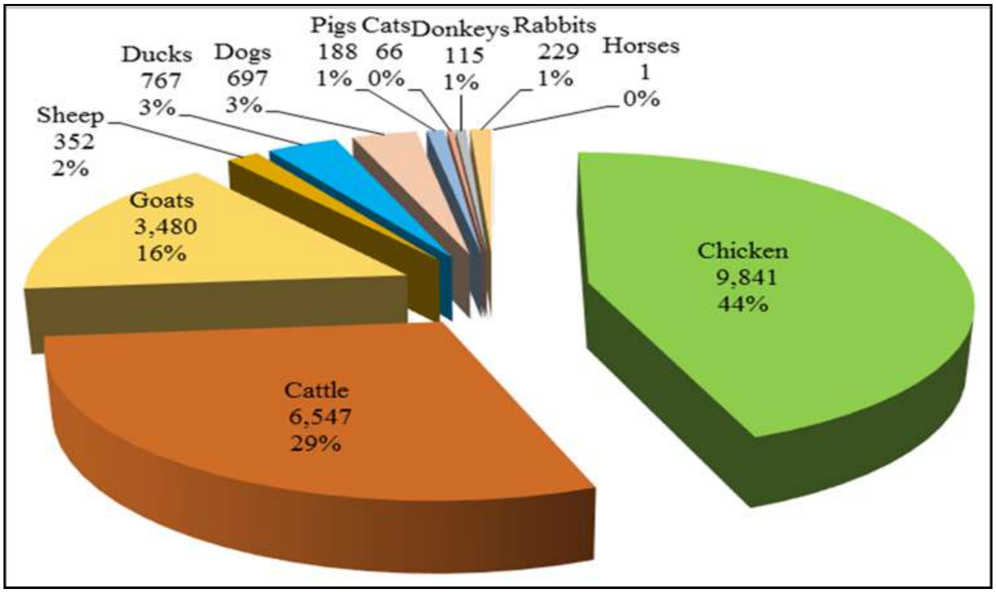


Figure 3.5: Muze Sub-basin Livestock Population.

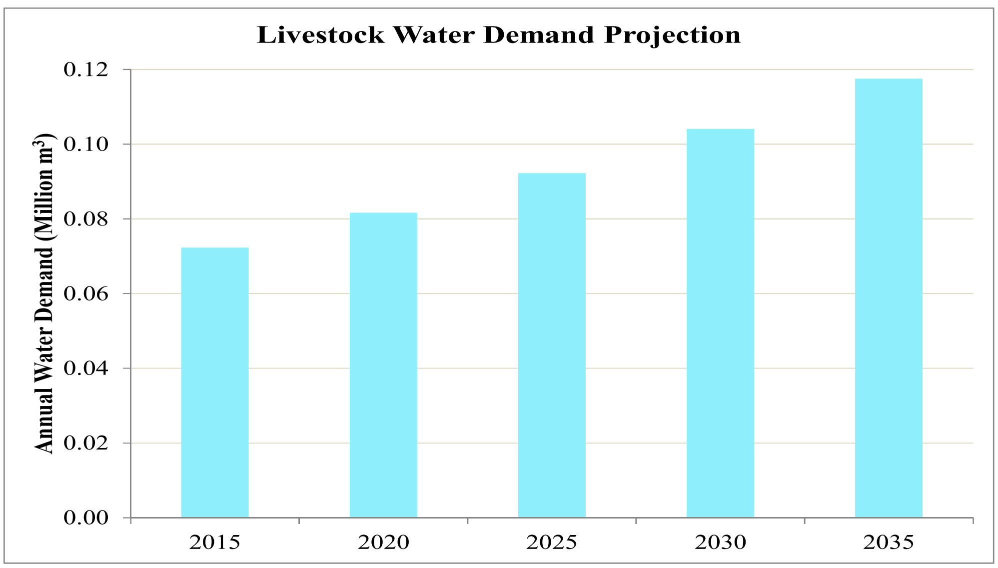


Figure 3.6: Livestock Water Demand Projections for Muze Sub-basin.

Issues and Challenges

Lack of village land use plans in several parts of the sub-basin means there are no formally demarcated areas for livestock grazing. As a result livestock grazing takes place on communal lands where other socio-economic activities like farming are also carried out resulting in conflicts between farmers and pastoralists. Lack of designated livestock watering areas also results in pastoralists watering their animals directly in water sources used for other uses. This often results in destruction of water sources and the surrounding catchment areas. The situation is exacerbated by the uncontrolled influx of livestock from neighboring regions which is putting substantial pressure on the sub-basin's natural resources. Several areas have exceeded their livestock carrying capacity thus resulting in overgrazing, soil erosion, land compaction, destruction of wetlands and river banks, and intense land and water use competition and conflicts. There is also reported pollution of surface water sources from cattle dip and slaughter house effluents. Pastoralists are reported to be engaged in bush burning to create a flush of new grass for livestock before the rainy season, and to control parasites harmful to livestock. Uncontrolled bush burning has been responsible for destruction of forests and other wildlife habitats. This practice is also reported to contribute to excessive soil erosion and floods as a result of stripping the soil of vegetation cover.

3.1.5 Mining Water Use

Mining is not a major socioeconomic activity in the Muze sub-basin. Good potential for coal mining exists in the Rukwa region with deposits estimated to be about 20 million tons. The coal field is believed to extend from Namwele on the Ufipa plateau to Muze in the Rukwa Valley. If proved to be commercially viable, the coal presents a significant source of energy for both domestic use and potential thermal energy generation. Results from surveys conducted in 1988 by Ruben, a geologist from Norway, indicate availability of significant coal deposits in Kizungu village, Muze Ward in Sumbawanga DC. Preliminary estimates indicate deposits of about 10 million m^3 of coal deposits (Sumbawanga DC, 2011). Large scale commercial mining of coal has not yet commenced. In 2004, a company called M/S Upendo Group Ltd ventured into coal mining in the area and identified possible markets for coal products of up to 6,000 tons per month. However, production output has been very low due to inadequate equipment, difficulty in accessing the mines especially during the rainy season, and poor road infrastructure making it very expensive to transport coal products to potential markets. Mining water use in the Muze Sub-basin is presently insignificant and is projected to remain very low in the long run compared to the irrigation water use.

3.1.6 Industrial Water Use

Presently, there are no industries in the Muze Sub-basin, and industrial water use is insignificant. It is also projected to remain limited in the long run compared to other water use sectors.

3.1.7 Water Use for Hydropower Generation

The sub-basin has no known hydropower potential sites, and hydropower water use is not a significant planning consideration.

3.1.8 Wildlife Water Use

There are no major wildlife protected areas in the Muze Sub-basin, and wildlife water requirements are not an important concern.

4. Sub-basin Water Balance and Deficit Management

4.1 Water Balance Assessment

With no major ongoing irrigation activities in the Muze sub-basin, the current water demand is low compared to water availability. **Figures 4.1** and **4.2** show that the sub-basin does not experience seasonal water deficits under the current (2015) water demand levels during the wet and dry seasons. This is the case even when seasonal environmental flow requirements are taken into consideration. (EFRs were tentatively estimated for Muze River assuming that they reprersent the same proportion of monthly mean flow as in the Luiche Sub-basin.) However as the demand levels increase, deficits begin to occur during the wet season with increasing frequency (3.8% and 7.7% under the 2025 and 2035 demand targets respectively). No deficits are observed during the dry season under all demand targets even after consideration of environmental flow requirements. Deficits are mostly observed at a monthly time scale (see **Table 4.1**) with increasing frequency as the water demand levels increase. Monthly deficits become more significant when environmental flow requirements are taken into consideration. The most severe deficits are observed during November and December, at the beginning of the rainy season when high water amounts are required for paddy nurseries and fields.

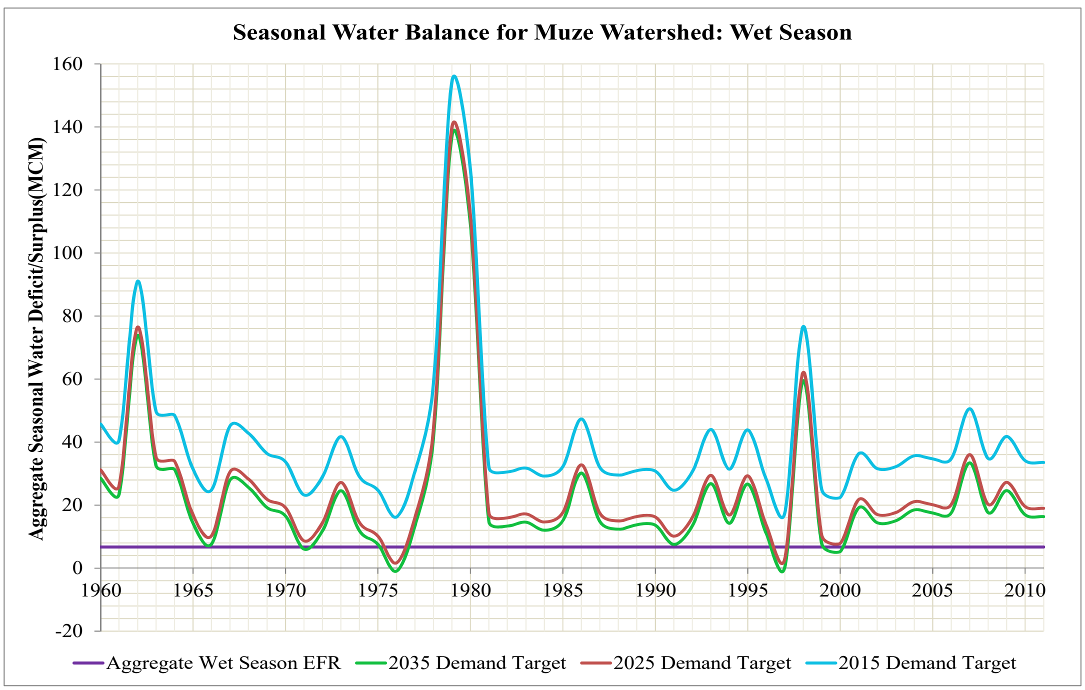


Figure 4.1: Wet Season Water Balance for the Muze Watershed.

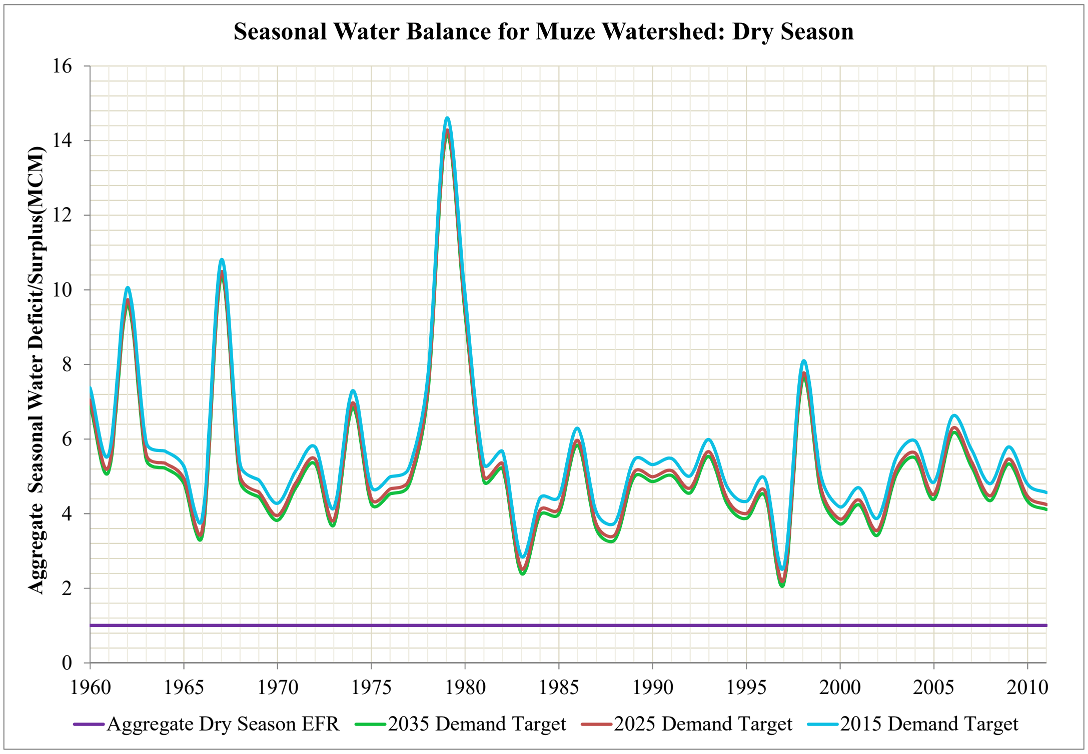


Figure 4.2: Dry Season Water Balance for the Muze Watershed.

Table 4.1: Frequency of Water Deficits.

Demand	Seasonal Deficits				Monthly Deficits												
		Wet Season	Dry Season			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	Without EFR	0.000	0.000		Without EFR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	With EFR	0.000	0.000		With EFR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.038
2025	Without EFR	0.000	0.000		Without EFR	0.113	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.925	0.811
	With EFR	0.038	0.000		With EFR	0.340	0.075	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.925	0.811
2035	Without EFR	0.019	0.000		Without EFR	0.226	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.962	0.811
	With EFR	0.075	0.000		With EFR	0.509	0.170	0.075	0.000	0.000	0.000	0.000	0.000	0.038	0.000	0.962	0.830

The current Muze sub-basin water stress level is generally low given that the water demand is low compared to water availability. Though water stress is expected to increase with growth in water demand, the sub-basin is not likely to experience any significant water stress over the planning horizon. **Figure 4.3** shows that by 2035, on average, the sub-basin water demand will be met in nine out of ten years in wet and dry seasons.

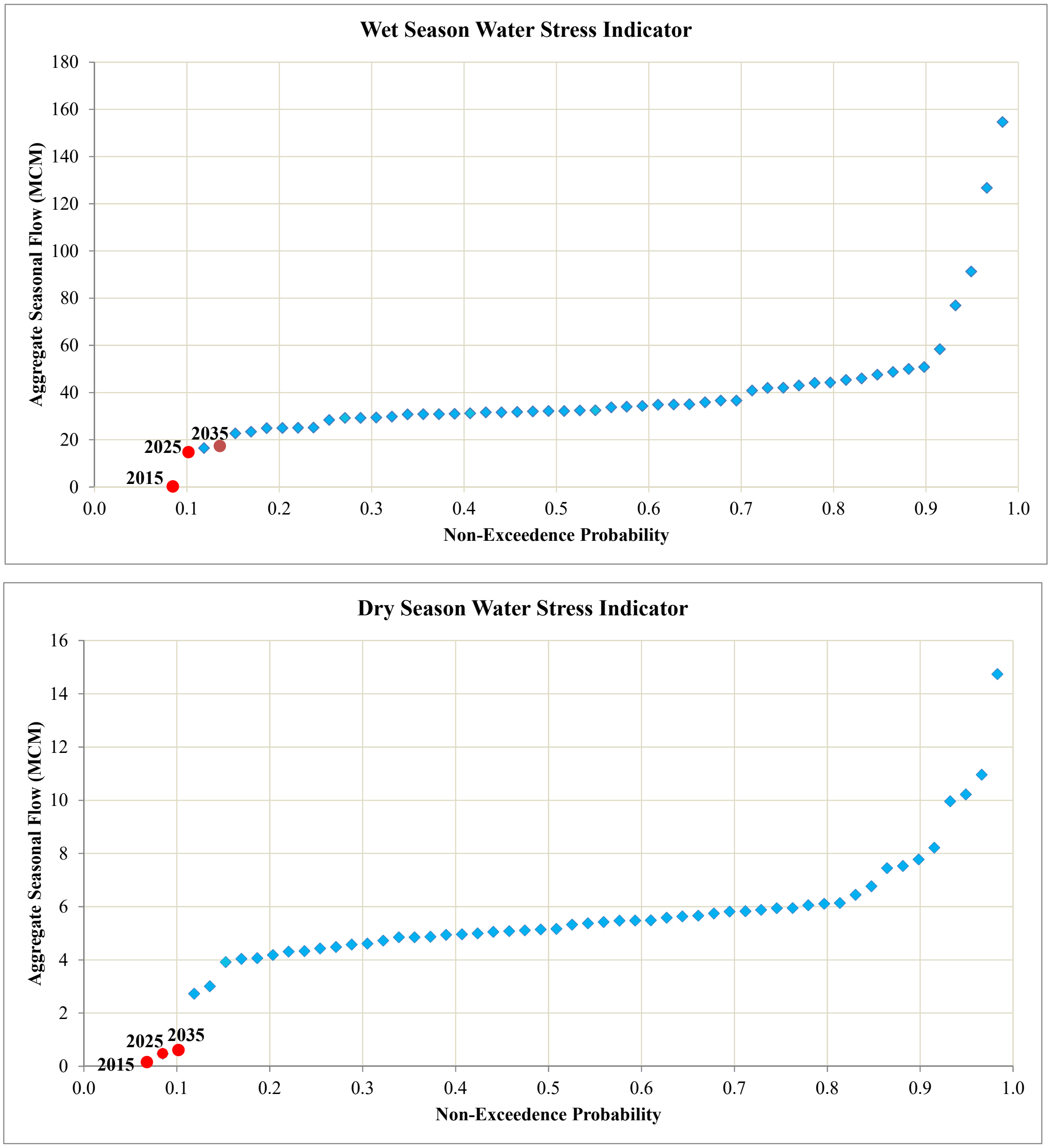


Figure 4.3: Muze Sub-basin Water Stress Indicator.

4.2 Strategy to Address Projected Water Deficits

The previous water balance assessments indicate that the Muze sub-basin is not likely to experience any significant water stress over the planning horizon. Even with implementation of the planned irrigation activities in the medium to long-term, the sub-basin water demand is projected to remain generally low compared to available water supply. The main concern is related to the projected monthly water deficits that are likely to occur in November and December during preparation of paddy nurseries and fields. These could potentially be addressed by the construction of a storage reservoir to harness excess wet season run-off for use in the dry season. Such storage should be developed in parallel with measures to improve irrigation efficiency. These interventions would address the projected sub-basin water demand growth and minimize potential water deficits over the planning horizon. These two strategic intervention areas are discussed next.

4.2.1 Increase Sub-basin Water Storage Capacity

Surface water will continue to be the major source of water supply. The main challenge with reliance on surface water is its seasonality and vulnerability to potential future climate change. Assessments show that the water storage capacity required to meet the projected water demands over the planning horizon (2015 to 2035) is estimated to be about 7.67 MCM.

Preliminary topographical analysis was conducted and only one potential storage site was identified at location (31.4675 E; 7.7551 S) as shown in **Figure 4.4**. The potential storage determination was based on information about topography as represented by a digital elevation model (DEM) at 90 m spatial resolution (latitude and longitude). The DEM was analyzed using ArcGIS to evaluate the storage that would be created from the construction of a dam (of a certain height at different locations). The following site-specific information was computed:

(i) The volume and surface area of the inundated land that would result by building a dam at the site.
(ii) The width of the dam.
(iii) The catchment area upstream of the dam site.

Potential dam heights of 10 m to 70 m were assessed at 10 m increments. Three potential development options were identified for the dam site:

(i) **Option 1**: 7.6 MCM reservoir capacity with a surface area about 0.77 km^2, dam height and width 30 m and 450 m respectively, and catchment area upstream of the dam about 96 km^2.
(ii) **Option 2**: 7.3 MCM reservoir capacity with a surface area about 0.51 km^2, dam height and width 40 m and 360 m respectively, and catchment area upstream of the dam about 228 km^2.
(iii) **Option 3**: 24.5 MCM reservoir capacity with a surface area about 1.43 km^2, dam height and width 60 m and 450 m respectively, and catchment area upstream of the dam about 228 km^2.

Due to potential uncertainties in DEM resolution, the previous reservoir features should be viewed as estimates that would have to be refined by more detailed field surveys during the follow-up pre-feasibility studies. These caveats notwithstanding, the analysis carried out herein examined practically all potential river locations and provides fairly good guidance on the most promising site for reservoir development.

Based on inundation area and required dam width in relation to storage capacity, **Option 2** was deemed to be most attractive and was assessed further. These assessments included detailed simulations of this reservoir using 52 (1960 to 2011) years of monthly natural flows developed by a hydrologic model driven by historical rainfall and potential evapotranspiration inputs. These climatic inputs were estimated based on the CRU climatological database and proper averaging over the upstream watershed.

These assessments indicate that this potential reservoir can effectively reduce water deficits. Specifically, under the 2035 water demand targets, the frequency of water deficits for November and December respectively decreases from 0.981 to 0 and from 0.846 to 0.019 (see **Figure 4.5**). More detailed results from these assessments can be found in **Annex A**.

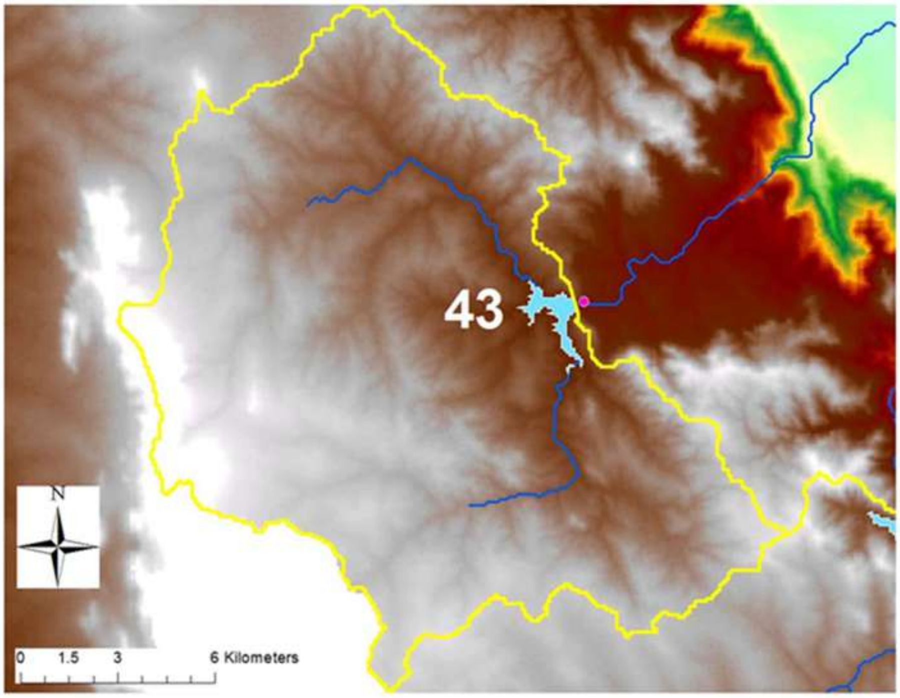
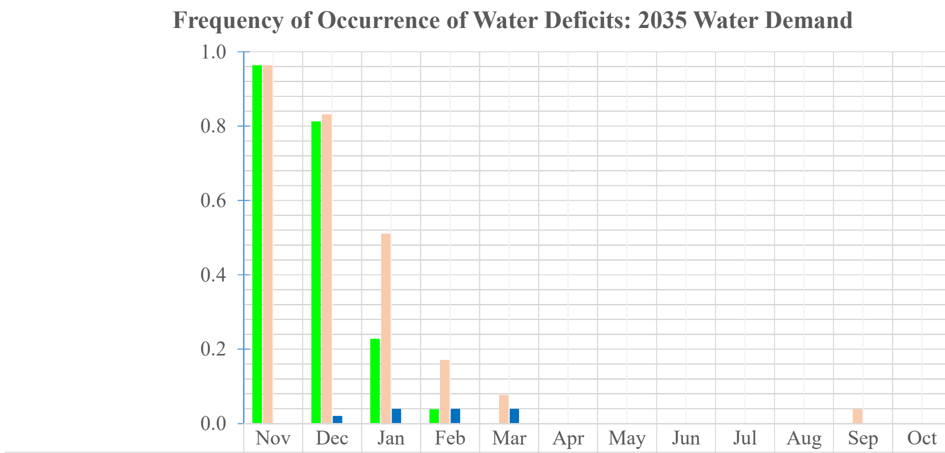


Figure 4.4: Location of Potential Reservoir Option 2 in Muze Sub-basin.

4.2.2 Improvements in Irrigation Water Use Efficiency

The Muze traditional irrigation scheme, like most other schemes in the Lake Rukwa Basin, is characterized by inadequate and poorly constructed infrastructure resulting in high water losses and low water use efficiency. The scheme has temporary and poorly constructed water intake works and unlined irrigation canal systems that cannot supply adequate water to all the irrigation command areas. Thus, any strategy to provide sustainable irrigation supplies should first focus on improving irrigation water use efficiency. Studies in other Tanzanian basins (e.g., the Great Ruaha sub-basin) have demonstrated that modest improvements in traditional irrigation infrastructure can result in appreciable water use efficiency gains and water conservation (SMUWC, 2001). Improved infrastructure involves constructiing concrete water intake structures, lined primary/secondary/tertiary canals, and drainage/return canals.

As part of the water balance assessments for the Muze sub-basin, a specific scenario was run to demonstrate the benefits of irrigation efficiency improvements. A consumption rate of 1 liters/sec/ha was assumed to represent the agricultural water use conditions *after* the planned irrigation infrastructure improvements, while the current water use rate was assumed to be 1.56 l/s/ha, similar to the rate estimated for other Tanzanian basins (WREM International, 2016) . Simulations under historical hydrological conditions (1960 to 2011) indicate that the development of the reservoir site, Option 2, combined with the above-described improvements in irrigation efficiency (from 1.56 l/s/ha to 1.0 l/s/ha) would fully eliminate the projected monthly water deficits under all water demand targets (see **Figure 4.5**). Detailed simulation results from these assessments are presented in **Annex A**.



	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Without EFR	0.962	0.811	0.227	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
With EFR	0.962	0.830	0.509	0.170	0.076	0.000	0.000	0.000	0.000	0.000	0.037	0.000
EFR + Reservoir	0.000	0.019	0.038	0.038	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EFR + Reservoir + Irr Eff	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure 4.5: Frequency of Water Deficits in the Muze Sub-basin.

4.2.3 Recommended Interventions

The Muze Sub-basin has sufficient water resources to meet its projected water demands over the planning horizon 2015 to 2035. However, it is recommended to develop the sub-basin water storage capacity to address potential water deficits in future years. A potential storage site has been identified and recommended for further study to establish feasibility based on technical, economic, and environmental considerations. Storage should be complemented by appropriate water demand management measures to upgrade the irrigation infrastructure in all traditional schemes and to train farmers in modern agronomic practices.

5. Strategic Goals, Objectives, and Priority Interventions

5.1 Vision and Mission

The Lake Rukwa Basin Vision and Mission statements define the overall strategic goal for water resources management and development in all the Lake Rukwa sub-basins. The two statements capture in a concise manner what the basin stakeholders collectively aspire to achieve in the short to long term. The basin vision and mission, therefore, provide the strategic context within which the Muze Sub-basin WRMD Plan is developed.

LAKE RUKWA BASIN VISION:	*"A well-managed basin with improved standard of living for its people through sustainable utilization of water resources"*
LAKE RUKWA BASIN MISSION:	*"To ensure water resources management is strengthened through integrated water resources management for sustainable utilization of water and other renewable natural resources"*

(*Source: LRBWB, 2015*)

5.2 Strategic Goal

The overall goal of the Muze Sub-basin WRMD Plan is to eradicate poverty and stimulate socioeconomic transformation through sustainable management, equitable access, and efficient use of the sub-basin water resources. This goal is to be realized through progressive improvements to existing water resources management and use practices to achieve a sustainable balance between water availability and demand without compromising environmental integrity.

5.3 Strategic Objectives

The matrix below presents the strategic objectives and intervention areas to be addressed by the Muze Sub-basin WRMD Plan. They describe the broad outcomes expected following implementation of the Plan over the planning horizon (2015 – 2035).

Strategic Objective	Strategic Intervention Areas
Strategic Objective 1: To achieve sustainable balance between water supply and demand in an environmentally friendly manner.	• Ensure availability of water resources of adequate quantity and quality to satisfy current and future sub-basin water demands. • Achieve sustainable water demand growth over the planning horizon.
Strategic Objective 2: To ensure availability of adequate and reliable ter	• Establish a groundwater resources monitoring network to cover all important sub-basin aquifers. • Update and re-validate rating curve for operational

resources data for all watersheds and aquifers.	hydrometric stations.
Strategic Objective 3: To identify and register all sub-basin water uses and ensure full compliance with permitting requirements.	• Undertake comprehensive annual water use surveys to identify and register all basin water uses. • Establish a water abstraction and use monitoring network to quantify sub-basin water use. • Strengthen permit enforcement and compliance monitoring mechanisms.
Strategic Objective 4: To determine and ensure compliance with environmental flow requirements for all critical river sections in the sub-basin.	• Undertake detailed environmental flow assessments for all critical sub-basin river sections and establish appropriate environmental flow requirements. • Monitor and ensure compliance with the established environmental flow requirements.
Strategic Objective 5: To promote integrated watershed management and environmental conservation	• Protect vulnerable watersheds and reverse sub-basin environmental degradation. • Control pollution from point and non-point sources.

5.4 Priority Intervention Measures

GOAL 1: Sustainable balance between water supply and demand achieved by 2035

The overarching objective for the Muze Sub-basin WRMD Plan is to ensure sustainable management and development of the sub-basin water resources presently and in the foreseeable future. Besides the projected demand growth and future climate change impacts, the Water Management Act (2009) specifically recognizes environment water requirements as a legitimate water use priority that must be considered and fulfilled in water resources planning and management decisions. The main challenge of the Plan is to balance water supply and demand without compromising environmental integrity. This challenging proposition can best be achieved though a judicious mix of supply as well as demand side management interventions.

Objective 1: To achieve sustainable water demand growth over the planning horizon.

The Muze Sub-basin aggregate consumptive water demand is projected to increase from 0.39 MCM in 2015 to 18.14 MCM by 2035. Irrigation water demand is projected to account for about 95% of the total water demand by 2035. Therefore managing water demand growth for the irrigation sector is a key objective toward achieving sustainable balance between water supply and demand.

Action 1.1.1: **Rehabilitation and upgrading irrigation water supply infrastructure in traditional irrigation schemes.**

Irrigation water supply infrastructute in traditional schemes should be upgraded to minimize water losses and improve irrigation water use efficiency. Assessment results show that improvements in irrigation water use efficiency by 15% to 30% would translate up to 50% water savings (other factors being constant). This activity is ongoing for the Muze traditional irrigation scheme and requires coordination from the LRBWB to ensure the intended objective of irrigation efficiency improvements and reduction in irrigation water use is achieved. As a condition for irrigation water permit renewal, the LRBWB should require that permit holders demonstrate substantive and verifiable progress toward improving irrigation water use efficiency. The LRBWB should set efficiency improvement targets to be met by existing permit holders prior to permit renewal. For new irrigation water permit applications, the LRBWB should require that the applicants commit to a time-bound plan to line all their irrigation canals, install permanent water diversion control and quantity measuring structures and devices, construct lined return canals, and agree to a self-monitoring water abstraction program with mandatory periodic submission of water abstraction data to the LRBWB.

Action 1.1.2: **Comprehensive and routine monitoring of water abstractions/use.**

There are no systematic measurements of water use/withdrawals in the Muze sub-basin. Unless water managers have accurate knowledge of how much water is being taken out of the system, where and when, it is difficult to determine spatial and temporal deficits and pinpoint system inefficiencies. There is need for a comprehensive water abstraction/use monitoring network to ensure routine collection of water use data. Establishing the network should be undertaken in collaboration with water users. For example, as part of the special conditions implied under all water permits issued under Section 48 of the WRM Act (2009), the LRBWB should require all water permit holders install water abstraction/use measuring devises, keep records of their daily water abstractions/use, and submit this data regularly to the LRBWB. The LRBWB should then, as part of its compliance monitoring program, undertake random spot checks to cross check the validity and reliability of the water abstraction/use records of individual permit holders. The LRBWB should make it known to permit holders that failure to install water abstraction/use monitoring devises or deliberate recording or submission of false data would constitute an offence resulting in stiff penalties. To supplement the self-monitoring program, the LRBWB should install water abstraction/use monitoring devises at a few strategic locations to enable it to verify the aggregate water use records provided by the water users.

Objective 2: To ensure availability of water resources of adequate quantity and quality to meet current and future sub-basin water demands.

Sub-basin water assessments indicate that, generally, the Muze sub-basin has adequate water resources and is currently not water stressed, save for localized water shortages during prolonged dry periods. However, the projected water demand growth and potential climate change impacts are expected to change the situation. Assessment findings highlight potential future decrease in the Muze River flows due to the reinforcing impacts of climate change and increasing water demands. There is, therefore, need for implementation of appropriate adaptation measures to cope with the projected water demand growth.

Action 1.2.1: **Construct water storage infrastructure to increase sub-basin storage capacity**.

Preliminary topographical analysis was conducted for the Muze sub-basin and a specific potential storage site was identified with storage capacity up to 24.5 MCM. It is recommended that the identified site be assessed in more detail to establish its technical, economic, and environmental feasibility.

Action 1.2.2: **Conjunctive use of surface and groundwater.**

Considering that groundwater is likely to be a key resource for domestic water supply coverage under a changing climate, there is need for a comprehensive monitoring of the sub-basin groundwater resources to characterize their potential and monitor their use. Upon availability of adequate data, detailed groundwater assessments should be conducted to identify areas with high groundwater potential to be considered for future development and use. The outcomes of the basin-wide groundwater assessments will be valuable in developing a holistic plan for conjunctive surface water and groundwater use as part of the broader sub-basin water security program.

GOAL 2: Adequate and reliable water resources data available for all sub-basin watersheds.

Reliable, consistent, and contemporaneous data is needed to quantify the river flows at several locations estimate rainfall and evapotranspiration over the watersheds upstream of the locations where river flow is measured and determine groundwater levels and fluxes in sub-basin aquifers. Review of the available data for the hydrometric station of Muze River at Muze shows large data gaps and questionable data quality due to nsistencies and irregularities in the existing data collection and quality control procedures. The existing rating curve is outdated and needs updating and re-validation.

There is currently no groundwater monitoring network in Muze. Establishing a groundwater monitoring network is crucial to groundwater characterization and sustainable use.

Likewise, no water quality monitoring is currently carried out, and no data on river sediment load and deposition to various water bodies is being collected. Without such data, any interventions to safeguard the sub-basin water quality are bound to be speculative and of limited value.

Objective 1: Upgrade and expand the existing water resources monitoring network to cover all important watersheds and aquifers.

The status of the current monitoring network cannot support integrated water resources management. Specific recommendations are made below regarding priority actions.

Action 2.1.1: **Strengthen existing surface water resources monitoring network.**

Given the small size of the Muze sub-basin, the existing surface water monitoring locations are sufficient. However, they are not presently functional. The following actions must be taken as soon as possible: (a) Begin to collect data from the existing network based on a routine and consistent schedule; (b) update and re-validate the rating curve for the Muze River at Muze; and (c) implement a routine inspection and maintenance program for the monitoring equipment to minimize data collection gaps.

Action 2.1.2: **Establish a groundwater resources monitoring network.**

The Muze sub-basin has no groundwater monitoring network. It is recommended that a comprehensive groundwater monitoring network be established to ensure characterization and sustainable use of groundwater resources.

Action 2.1.3: **Establish a sub-basin water quality monitoring program.**

Priority intervention measures relative to water quality monitoring include: identify and monitor pollution "hotspots"; monitor sediment river load (i.e., suspended solids and bedload) and its deposition in various water bodies; and conduct sub-basin wide water quality surveys to bridge data gaps.

Action 2.1.4: **Undertake consistent and timely collection of water resources data and maintenance of the monitoring network.**

There is need for consistent and timely data collection to ensure availability of adequate and reliable water resources data/information to support planning and management efforts. Although monitoring costs for a small sub-basin like the Muze are not significant, the current revenue generated by the LRBWB from water permit fees is very small to sustain network operations for all the Lake Rukwa sub-basins. Because data collection activities cannot be halted pending availability of adequate funding, the LRBWB should explore other potential options to ensure sustainable and consistent data collection. For example, the LRBWB should consider training the river gage reader at Muze to take daily gage readings and relay the information by phone text messages. The LRBWB could also collaborate with extension workers or village leaders to receive completed data forms from the gage reader and forward them to the sub-basin offices in Sumbawanga Town. Local communities neighboring the monitoring station should be sensitized about the importance of the installed monitoring equipment and help safeguard them against vandalism.

GOAL 3: All sub-basin water uses registered and fully compliant with permitting requirements by 2035.

Effective monitoring and regulation of water use is importantto assess the integrity of the water distribution system, issue permits, and collect water use fees. There are several water users who have either not applied for water use permits or who are using water in disregard of the conditions attached to their water permits. Continued illegal use of water is a disincentive to existing permit holders and potential new applicants. There is, therefore, a need to strengthen the water use regulatory and enforcement mechanisms to ensure compliance with the law.

Objective 1: Strengthen water resources regulatory and enforcement mechanisms.

Monitoring water usage and enforcing compliance with water permit conditions for the many water users scattered across the sub-basin is a challenge requiring cooperation from water users and local communities. However, this cooperation is not forthcoming due to various reasons. The LRBWB is supposed to conduct routine public awareness and sensitization campaigns to ensure that the communities are enlightened and become more vigilant in reporting illegal water users and other offenders (for example illegal cutting of trees, wetland drainage, cultivation around water sources and close to river banks). However, the awareness campaigns are seldom conducted due to funding constraints. There is need for more active engagement with Local Government Authorities (especially at ward and village levels) and local Water User Groups to solicit their active involvement in water permit enforcement and sensitization campaigns. There is also need for the LRBWB to routinely review and update the Water Permit Register to ensure timely follow up with pending applications and those that require renewal. A major concern of existing permit holders is that they do not "see" the privilege of being permit holders since there are so man illegal water users. It is unrealistic to expect permit holders to comply with permit conditions when they are surrounded by illegal water users who do not comply with the law and are not held accountable. It is, therefore, important to strengthen the existing regulatory mechanisms to guarantee the rights of existing permit holders and impose costly penalties to illegal water users.

Action 3.1.1: **Conduct comprehensive annual surveys of all sub-basin water uses to validate their legal status, update the water permit database, and apprehend illegal water users.**

Water permit compliance monitoring can be a very expensive exercise if the LRBWB staff are required to regularly traverse the sub-basin and inspect all water users. This kind of activity cannot be planned as a routine undertaking in view of the current budgetary constraints. However, budgetary constraints cannot be the reason for inaction. Other creative ways of performing this function should be explored. For example, the LRBWB could engage all key sub-basin stakeholders in an annual basin event dubbed "*Operation zero tolerance for illegal water use in Muze sub-basin.*" This would be a 'community policing' (or community ownership) activity that could attract corporate sponsorship and leverage support and resources from sources other than the LRBWB. Under such an arrangement, the LRBWB would play a coordination role and leverage the strength of the different stakeholders. The process would also be viewedas transparent and not manipulated by powerful interest groups (big commercial irrigation farmers, politicians and others). Being an annual event would ensure planning and resources mobilization for effective implementation. In the final analysis, comprehensive permit compliance monitoring should go beyond a few under facilitated LRBWB staff and instead become a community responsibility jointly planned with key stakeholder agencies including police, Local Government Authorities, local leaders, Water User Associations, Water User Groups, NGOs, and CBOs. The LRBWB should ensure that the annual survey is as detailed as possible to capture and verify the required monitoring information during the survey and update the water permit database accordingly. The annual event could be supplemented by a few targeted routine enforcement activities by LRBWB staff as and when resources become available.

Action 3.1.2: **Expedite processing and issuance of water permits as an incentive to attract new permit applicants.**

One of the complaints by water users (especially those in areas far from the LRBWB offices in Mbeya) is the logistical burden of the water permit application process (the requirement to travel long distances to Mbeya City to follow up on water permit applications). Another complaint is that the permit application process takes too long, years in some cases, and yet water users cannot suspend their water use activities for a pending water permit. These procedural issues serve as disincentives to water permit applicants and thus exacerbate illegal water use. It is important that the LRBWB expedite the permit application process and make it more efficient and less cumbersome to permit applicants. Addressing these kinds of "small" concerns could make a big and quick difference as the LRBWB addresses other regulatory challenges that require significant time and financial resources to implement.

Action 3.1.3: **Develop appropriate technical tools for objective assessment of water permit applications and compliance monitoring.**

Processing a permit application is a complex process that requires careful consideration of potential impacts on downstream water users including the environment. This kind of assessment cannot be carried out through a simple visual inspection or a few spot stream flow measurements at the time of inspection. There is a need to develop specialized technical tools that can be used for objective and technically defensible assessments. Such tools can be incorporated in the Rukwa DSS, help give credibility to the permitting process, and instill stakeholder confidence in the water allocation and permitting process.

GOAL 4: Environmental Flow Requirements Determined for all Critical River Sections and Compliance Ensured by 2035.

Determination and consideration of environmental flow requirements in sub-basin water allocation decisions is not optional and should not be ignored. The environment is a legitimate, albeit a silent, water user whose needs must be considered and fulfilled in all water allocation decisions.

Objective 1: To determine and ensure compliance with the environmental flow requirements for all critical sub-basin river sections.

Provisions for environmental flow requirements present a significant water use tradeoff with far reaching socioeconomic implications for the local population. Unfortunately, specific EFRs have not yet been determined for all critical sub-basin river sections. It is, therefore, important that realistic environmental flow requirements be established through a transparent and technically robust procedure to ensure credibility of the recommended flows.

Action 4.1.1: **Conduct detailed EFAs for all critical sub-basin river sections and establish the applicable EFRs.**

Detailed Environmental Flow Assessments should be carried out for all critical sub-basin river sections to establish accurate EFRs to be used in water allocation decisions.

Action 4.1.2: **Monitoring compliance with environmental flow requirements.**

Once the EFRs have been determined for all critical river sections, the LRBWB should undertake routine surveillance and monitoring to ensure compliance with the EFRs. The LRBWB should also carry out periodic review of the EFRs for different river sections and modify them in response to increased water demands for other sectors, where necessary.

GOAL 5: Integrated Watershed Management and Environmental Conservation Achieved by 2035.

The Muze River has been observed to carry significant sediment loads, usually during the rainy season. This is attributed to the widespread deforestation especially in the upstream watersheds due to agricultural expansion, illegal logging, charcoal burning, and wild fires. Poor agricultural practices and overgrazing are also contributing to increased river erosion and siltation. These factors combine with the heavy seasonal rains to produce runoff with high loads of sediments and organic matter resulting in turbidity, colour, odour and taste problems in surface water sources. Poor household sanitation and unregulated use of agrochemicals are other causes of surface and groundwater pollution.

Objective 1: To protect vulnerable watersheds and reverse environmental degradation.

This intervention will target critically degraded watersheds where specific integrated watershed management measures will be implementedto reduce erosion and sediment exports from the upstream watersheds.

Action 5.1.1: Demarcation and protection of catchments upstream of important water sources.

Rampant deforestation, over grazing, and wetland degradation are responsible for destroying important catchments thus undermining their capacity to sustain downstream water sources. The Water Resources Management Act (2009) Section 37 (1) provides for establishing protected zones on land draining to or above important water sources. There is need to undertake systematic identification, survey, acquisition, and protection of catchments draining to important water sources. This initiative should be complemented by intensified enforcement of Section 34 of the Act prohibiting human activities near water sources (restriction of human activities to within sixty meters from river banks, lake shores, dams, and other important water sources).

Action 5.1.2: Identify, demarcate, and protect recharge areas for important groundwater supply aquifers.

The Water Resources Management Act (2009) Section 37 (1) provides for establishing groundwater controlled areas for water supply and commercial, industrial, agricultural development. The groundwater controlled areas should be identified following detailed groundwater assessment, characterization, and mapping.

Action 5.1.3: Preparation and enforcement of implementation of village land use plans.

Preparation of village land use plans in all sub-basin areas will ensure demarcation of specific areas for livestock grazing and watering. Strict enforcement of land use plans will ensure that livestock stays away from communal lands where other socio-economic activities like farming are carried out, thus minimizing conflicts between farmers and pastoralists. Similarly, designating livestock watering areas and facilities will ensure that pastoralists do not water their animals directly in water sources used by other users.

Action 5.1.4: Promote sustainable management and utilization of sub-basin forestry resources.

This will focus on reversing the current trend in sub-basin deforestation by implementating a sub-basin-wide tree planting, agro-forestry, soil and water conservation, and river bank protection initiative using community based forestry management practices. This activity will also support a sub-basin-wide forest survey, classification, and mapping program to establish the extent and severity of forest encroachment and degradation. Local communities will be sensitized and trained on sustainable management and forest use. Local communities will also be encouraged to participate in forest management within their vicinities through development of comprehensive community based forest management plans.

Action 5.1.5: Promote sustainable management and utilization of sub-basin wetland resources.

A comprehensive sub-basin-wide wetlands inventory should be undertaken to establish the spatial distribution of wetlands and extent of their degradation. Communities should be sensitized to develop community based wetlands management plans that will be the basis for sustainable use and management of local wetland resources.

Objective 2: To control pollution from point and non-point sources.

Action 5.2.1: Regulate and control pollution from Agrochemical Use.

Agrochemicals can be a big source of non-point pollution if not applied in a controlled manner. Although agrochemicals are currently not widely used in the sub-basin, there is need for vigilance to monitor agrochemical applicationand ensure proper use and pollution minimization. Extension workers should sensitize farmers on proper handling (storage and application) of agrochemicals to minimize misuse.

Action 5.2.2: Improve sanitation and hygiene in rural households.

Most sub-basin households use traditional pit latrines, which if poorly located or constructed, can lead to contamination of nearby water sources with fecal bacteria and pathogens. One of the consequences of this problem is the high incidence of water borne diseases in the region. Diarrhoea—a common water borne disease—ranks among the top five causes of illness and death in the sub-basin. Funds should be availed at the local community level to train local artisans in sanitation technologies; construct pilot demonstration facilities; rehabilitate old and construct new sanitation facilities in schools, health centers, and other community places; and help improve household latrines.

6. Strategic Action Plan and Budget

6.1 Strategic Action Plan

The Muze Sub-basin Strategic Action Plan (SAP) is based on the specific goals, objectives and actions discussed in detail in the previous chapter. The SAP shows the proposed sequencing and duration ofthe planned activities. It provides specific timelines for achieving desired targets during the implementation process and is thus a useful tool for monitoring implementation progress against budget expenditures. The Muze Sub-basin SAP is presented in the matrix below.

Muze Sub-basin Strategic Action Plan

FIVE YEAR PHASE	Jul 2016 - Jun 2020					Jul 2020 - Jun 2025					Jul 2025 - Jun 2030					Jul 2030 - Jun 2035				
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PROGRAM 1: Water Security Enhancement Program	→	→	→	→	→	→	→	→	→	→										
COMPONENT 1: Water Resources Infrastructure Development	→	→	→	→	→	→	→	→	→	→										
OBJECTIVE: To enhance basin water storage and supply capacity																				
TASK 1.1.1: Preliminary assessment and ranking of potential water storage sites	→																			
TASK 1.1.2: Prefeasibility studies of priority potential water storage projects		→	→																	
TASK 1.1.3: Feasibility studies of priority water storage projects				→	→															
TASK 1.1.4: Construction of priority water storage projects						→	→	→	→	→										
COMPONENT 2: Technical Support for Water Use Efficiency Improvement	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
OBJECTIVE: To provide technical support for water use efficiency improvements in traditional irrigation schemes and urban water supply																				
TASK 1.2.1: Provide technical assistance to Irrigation associations in planning and implementation of irrigation water supply infrastructure improvements	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
TASK 1.2.2: Monitoring and evaluation of water use efficiency improvements in irrigation schemes..	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
PROGRAM 2: Environmental Flow Assessment and Monitoring Program	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
OBJECTIVE: To ensure compliance with environmental flow requirements for all critical sub-basin river sections																				
TASK 2.1: Conduct environmental flow assessments and determine the environmental flow requirements for all critical sub-basin river sections.	→	→	→	→	→															
TASK 2.2: Monitor compliance with the established environment flow requirements						→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
PROGRAM 3: Water Resources Monitoring and Assessment Program	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
OBJECTIVE: To ensure availability of adequate and reliable water resources data and information.																				
COMPONENT 1: Strengthen water resources monitoring capacity	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
TASK 3.1.1: Establish a sub-basin groundwater monitoring network	→	→	→	→																
TASK 3.1.2: Establish a sub-basin water quality monitoring network	→	→	→																	
TASK 3.1.3: Coordinate establishment of water abstraction/use monitoring network	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
TASK 3.1.4: Update and re-validate rating curve for operational hydrometric stations	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
TASK 3.1.5: Conduct routine and timely collection of water resources data.	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
COMPONENT 2: Strengthen water resources assessment	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
TASK 3.2.1: Conduct groundwater resources assessment and mapping						→	→	→												
TASK 3.2.2: Conduct water quality baseline survey						→														

Muze Sub-basin Strategic Action Plan (continued)

FIVE YEAR PHASE	Jul 2016 - Jun 2020					Jul 2020 - Jun 2025					Jul 2025 - Jun 2030					Jul 2030 - Jun 2035				
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PROGRAM 4: Water Permit Compliance Monitoring Program																				
OBJECTIVE: ***To register all sub-basin water use and ensure compliance with permit conditions.***																				
TASK 4.1: Conduct comprehensive annual water use surveys and register all water uses																				
TASK 4.2: Develop technical tools for evaluation of water permit applications and compliance monitoring																				
TASK 4.3: Conduct routine processing of permit applications, compliance monitoring, and update of water permit database																				
PROGRAM 5: Integrated Watershed Management and Environmental Conservation																				
OBJECTIVE: ***To ensure that all vulnerable watersheds are protected and environmental degradation reversed.***																				
TASK 5.1: Promote and support the development and implementation of village land use plans.																				
TASK 5.2: Identify, demarcate, and protect watersheds upstream of major water supply sources.																				
TASK 5.3:Identify, demarcate, and protect recharge areas for important groundwater supply aquifers.																				
TASK 5.4: Provide technical and financial support for catchment afforestation activities in critical watersheds.																				
TASK 5.5: Provide technical and financial support for wetland restoration and conservation activities in critical watersheds.																				
TASK 5.6: Regulate and control pollution from agrochemical use.																				
TASK 5.7: Support and promote improved sanitation and hygiene in rural households.																				

LEGEND	
	Duration of time-bound Program
	Continuous Program
	Duration of time-bound Program Component
	Continuous Program Component
	Duration of time-bound Task
	Continuous Task

6.2 Budget Estimates

The total estimated budget required to implement the Muze Sub-basin WRMD Plan from 2016 to 2035 is about 4.17 Billion TShs. The budget estimates are derived using unit costs from several planning documents including the Lake Rukwa Basin Business Plan (2010/11 – 2014/15), WSDP—Programme Implementation Manual, District Development Plans, Five Year Development Program-1 and several other sources. **Table 6.1** and **Figures 6.1** and **6.2** show a summary of the budget estimates by program and by implementation phase. Program 1 (Water Security Enhancement) has the highest budget allocation (51%) because of the high capital costs associated with constructing water storage and supply infrastructure. Phase 1 activities account for the highest percentage of the budget (31%) because of the initial investments in the water resources monitoring network and the several initial technical studies to be undertaken under most programs. The detailed budget breakdown is presented in **Table 6.2**.

Table 6.1: Budget Estimates by Program and Implementation Phase.

Muze Sub-basin WRMD Plan Summary Budget Estimate (TShs Billion)					
PROGRAM	**Phase 1 (2016-2020)**	**Phase 2 (2020-2025)**	**Phase 3 (2025-2030)**	**Phase 4 (2030-2035)**	**TOTAL**
PROGRAM 1: Water Security Enhancement Program	0.78	0.53	0.58	0.73	**2.62**
PROGRAM 2: Environmental Flow Assessment and Monitoring Program	0.14	0.05	0.05	0.14	**0.39**
PROGRAM 3: Water Resources Monitoring and Assessment Program	0.09	0.03	0.03	0.03	**0.17**
PROGRAM 4: Water Permit Compliance Monitoring Program	0.14	0.14	0.14	0.14	**0.56**
PROGRAM 5: Integrated Watershed Management and Environmental Conservation Program	0.11	0.11	0.11	0.11	**0.42**
TOTAL	**1.26**	**0.85**	**0.91**	**1.15**	**4.17**

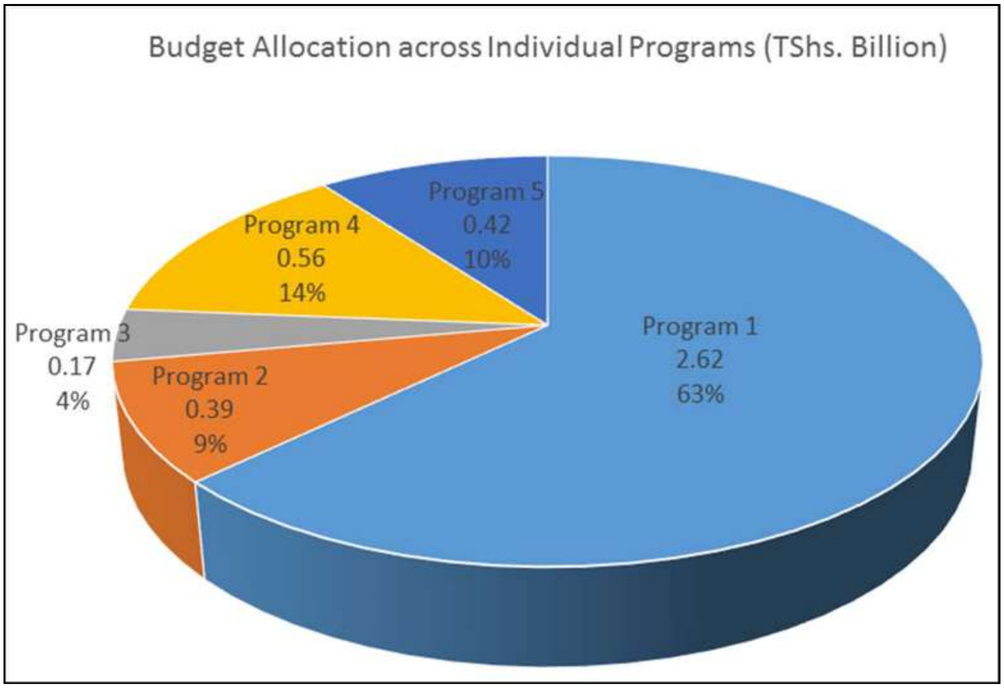


Figure 6.1: Budget Allocation across Individual Programs.

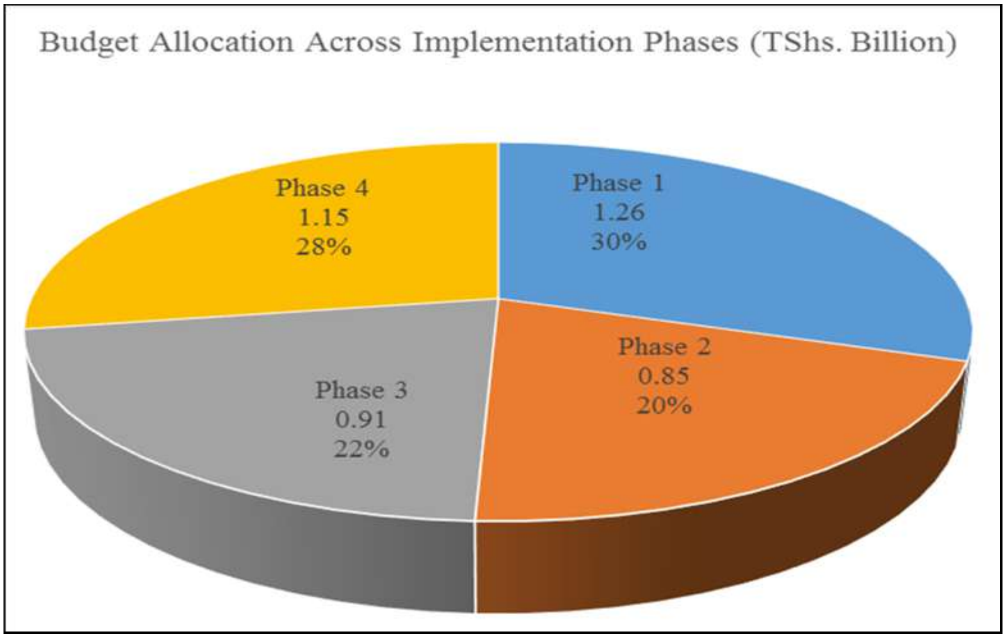


Figure 6.2: Budget Allocation across Implementation Phases.

Table 6.2: Budget Estimates for the Muze Sub-basin WRMD Plan Implementation.

	Muze Sub-basin WRMD PLAN BUDGET ESTIMATES (TShs. Millions)			
	Jul 2016 - Jun 2020	Jul 2020 - Jun 2025	Jul 2025 - Jun 2030	Jul 2030 - Jun 2035
PROGRAM 1: Water Security Enhancement Program				
COMPONENT 1: Water Resources Infrastructure Development				
Strategic Action 1.1.1 : Assess potential for and construct surface water storage infrastructure to increase sub-basin water storage capacity.	750	500	500	500
Strategic Action 1.1.2 : Assess potential for and construct medium to large scale groundwater supply schemes to increase sub-basin water supply capacity.	-	-	50	200
COMPONENT 2: Technical Support for Water Use Efficiency Improvement	-	-	-	-
Strategic Action 1.2.1 : Provide technical assistance to Irrigation associations in planning and upgrading of irrigation water supply infrastructure and monitor water use efficiency improvements.	30	30	30	30
Program 1 Sub-total	*780*	*530*	*580*	*730*
PROGRAM 2: Environmental Flow Assessment and Monitoring Program				
Strategic Action 2.1 : Conduct environmental flow assessments and determine environmental flow requirements for allcritical sub-basin river sections.	92	-	-	92
Strategic Action 2.2 : Conduct routine field visits to monitor compliance with established environmental flow requirements.	40	40	40	40
Strategic Action 2.3 : Conduct regular public awareness raising campaigns on the importance of maintaining environmental flow requirements and consequences of violations.	11	11	11	11
Program 2 Sub-total	*144*	*51*	*51*	*144*
PROGRAM 3: Water Resources Monitoring and Assessment Program				
COMPONENT 1: Strengthen water resources monitoring capacity				
Strategic Action 3.1.1 : Rehabilitate existing surface water resources monitoring networkand update and re-validate rating curves for all operational hydrometric stations.	32	10	10	10
Strategic Action 3.1.2 : Establish network of groundwater level monitoring boreholes to cover all major sub-basin aquifers.	42	-	10	10
Strategic Action 3.1.3 : Establish sub-basin water quality monitoring network to cover all important pollution prone areas.	1	-	-	1
Strategic Action 3.1.4 : Conduct routine and consistent network visits for data collection and equipment maintenance.	8	8	8	8
Strategic Action 3.1.5 : Conduct routine training for technicians and gage readers to ensure collection of reliable data and proper maintenance of monitoring equipment.	2	2	2	2
COMPONENT 2: Strengthen water resources assessment capacity				
Strategic Action 3.2.1 : Conduct sub-basin groundwater assessments and mapping	-	5	-	-
Strategic Action 3.2.2 : Conduct sub-basin water quality baseline survey.	1	-	-	-
Program 3 Sub-total	*86*	*25*	*30*	*31*

Table 6.2: Budget Estimates for Muze Sub-basin WRMD Plan Implementatin (continued)

	Muze Sub-basin WRMD PLAN BUDGET ESTIMATES (TShs. Millions)			
	Jul 2016 - Jun 2020	Jul 2020 - Jun 2025	Jul 2025 - Jun 2030	Jul 2030 - Jun 2035
PROGRAM 4: Water Permit Compliance Monitoring Program				
Strategic Action 4.1 : Conduct comprehensive annual water use surveys to locate, verify, map, register and regularize all water withdrawals, waste water discharges and hydraulic infrastructure.	50	50	50	50
Strategic Action 4.2 : Conduct routine processing of new water permit applications and renewals.	10	10	10	10
Strategic Action 4.3 : Develop technical tools for evaluation of water permit applications and compliance monitoring	5	-	-	-
Strategic Action 4.4 : Undertake routine update of the water permit database.	-	-	-	-
Strategic Action 4.5 : Conduct routine field visits to check compliance with permit conditions and apprehend illegal water users.	40	40	40	40
Strategic Action 4.6 : Conduct regular public awareness raising campaigns on the dangers of illegal water abstraction and non-compliance with permit conditions.	40	40	40	40
Program 4 Sub-total	***145***	***140***	***140***	***140***
PROGRAM 5: Integrated Watershed Management and Environmental Conservation Program				
Strategic Action 5.1 : Identify, demarcate, and protect watersheds upstream of major water supply sources	20	20	20	20
Strategic Action 5.2 : Identify, demarcate, and protect important groundwater recharge areas.	20	20	20	20
Strategic Action 5.3 : Provide technical and financial support for catchment afforestation activities in critical watersheds	40	40	40	40
Strategic Action 5.4 :Provide technical and financial support for wetland restoration and conservation activities in critical watersheds	10	10	10	10
Strategic Action 5.5 : Provide technical and financial support for preparation and implementation of village land use maps	7	7	7	7
Strategic Action 5.6: Regulate and control pollution from agrochemical use.	4	4	4	4
Strategic Action 5.7: Support and promote improved sanitation and hygiene in rural households.	5	5	5	5
Program 5 Sub-total	***106***	***106***	***106***	***106***
GRAND TOTAL	1,261	852	907	1,151

7. References

SMUWC 2001: Sustainable Management of the Usangu Wetland and its Catchment. Series of Technical Reports developed as part of the SMUWC project.

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WREM International 2013: Lake Rukwa Basin Integrated Water Resources Management and Development Plan, Interim Report I: Lake Rukwa Basin Socioeconomic Profile and Water Resources Management Framework. Technical Report prepared for the Ministry of Water, United Republic of Tanzania, by WREM International Inc., Atlanta, Georgia, USA, 163 pp.

WREM International 2016: Rufiji River Basin Integrated Water Resources Management and Development Plan, Interim Report II, Volume V: Water Balance and Scenario Assessments. Technical Report prepared for the Ministry of Water, United Republic of Tanzania, by WREM International Inc., Atlanta, Georgia, USA, 368 pp.

8. ANNEX A: Assessments of Reservoir Development Options

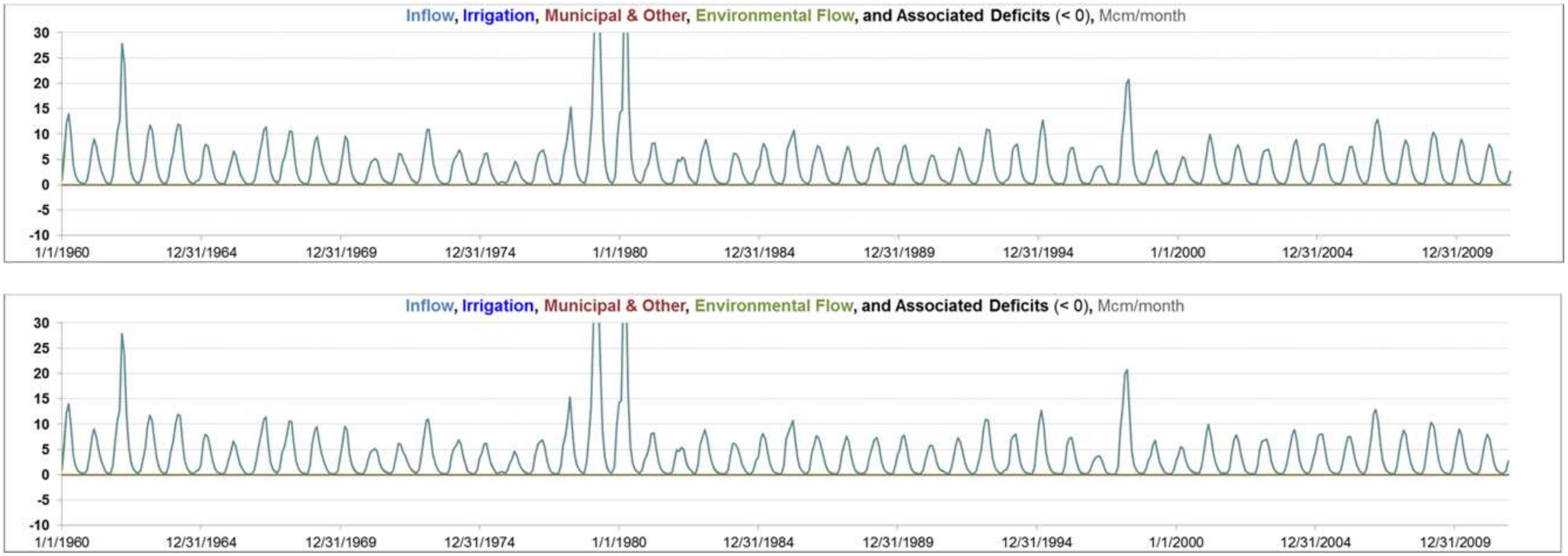

Figure A.1: Muze catchment simulated sequences (Mcm/month) of watershed inflow, irrigation water supply, municipal and other water supply, environmental flow, and associated deficits (negative values) for irrigation efficiencies 1.56 (*top graph*) and 1.00 (*bottom graph*) l/sec/ha. The simulations assume a 7.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions and 2015 water demand targets. Potential storage sites up to 25 Mcm have been identified in the Muze catchment, and the above storage is likely feasible.

Table A.1: Muze catchment monthly irrigation, municipal and other, and environmental flow water use deficits from 2015 demand targets, and potential annual hydropower production for irrigation efficiencies 1.56 (*top*) and 1.00 (*bottom)* l/sec/ha. The simulations assume a 7.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions.

Muze			Water Demands:			2015		Storage Capacity:			7.3	Mcm
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1.56	lt/sec/ha					
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		4.430										
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1	lt/sec/ha					
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		4.430										

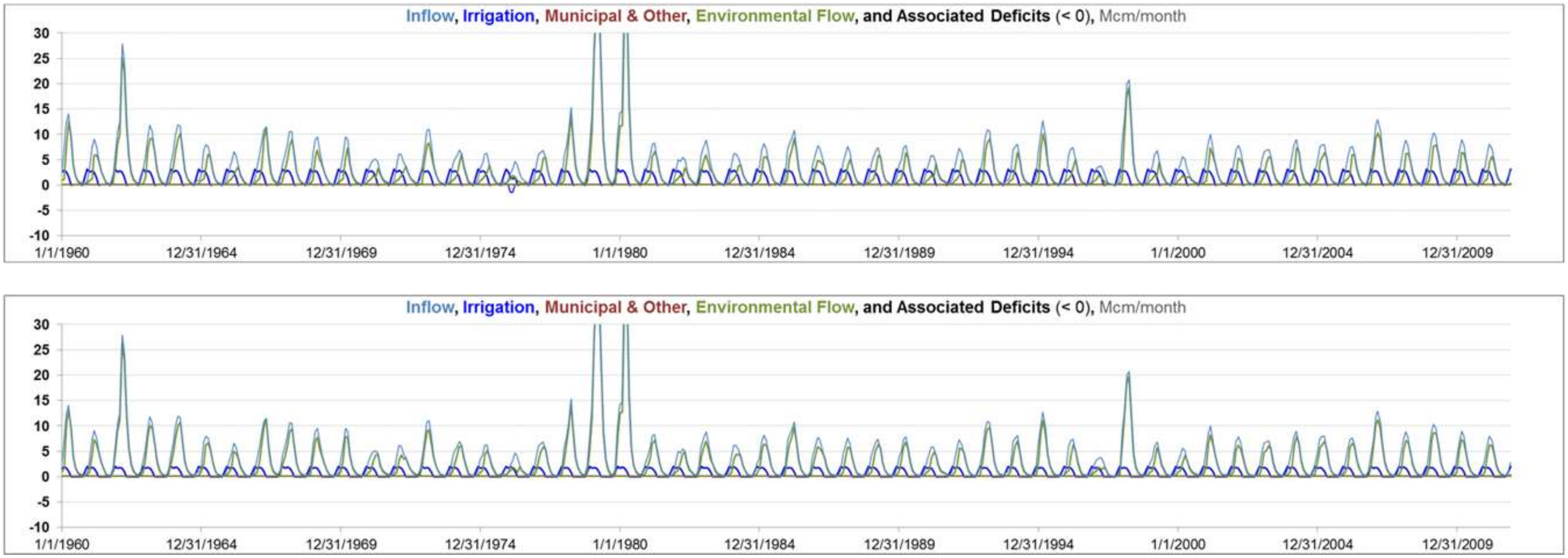

Figure A.2: Muze catchment simulated sequences (Mcm/month) of watershed inflow, irrigation water supply, municipal and other water supply, environmental flow, and associated deficits (negative values) for irrigation efficiencies 1.56 (*top graph*) and 1.00 (*bottom graph*) l/sec/ha. The simulations assume aa7.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions and 2025 water demand targets. Potential storage sites up to 25 Mcm have been identified in the Muze catchment, and the above storage is likely feasible.

Table A.2: Muze catchment monthly irrigation, municipal and other, and environmental flow water use deficits from 2025 demand targets, and potential annual hydropower production for irrigation efficiencies 1.56 (*top*) and 1.00 (*bottom)* l/sec/ha. The simulations assume a 7.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions.

Muze			Water Demands:			2025		Storage Capacity:			7.3	Mcm
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1.56	lt/sec/ha					
Dfct Freq	0.000	0.019	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	1.453	1.389	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	1.453	1.389	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		4.165										
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1	lt/sec/ha					
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		4.365										

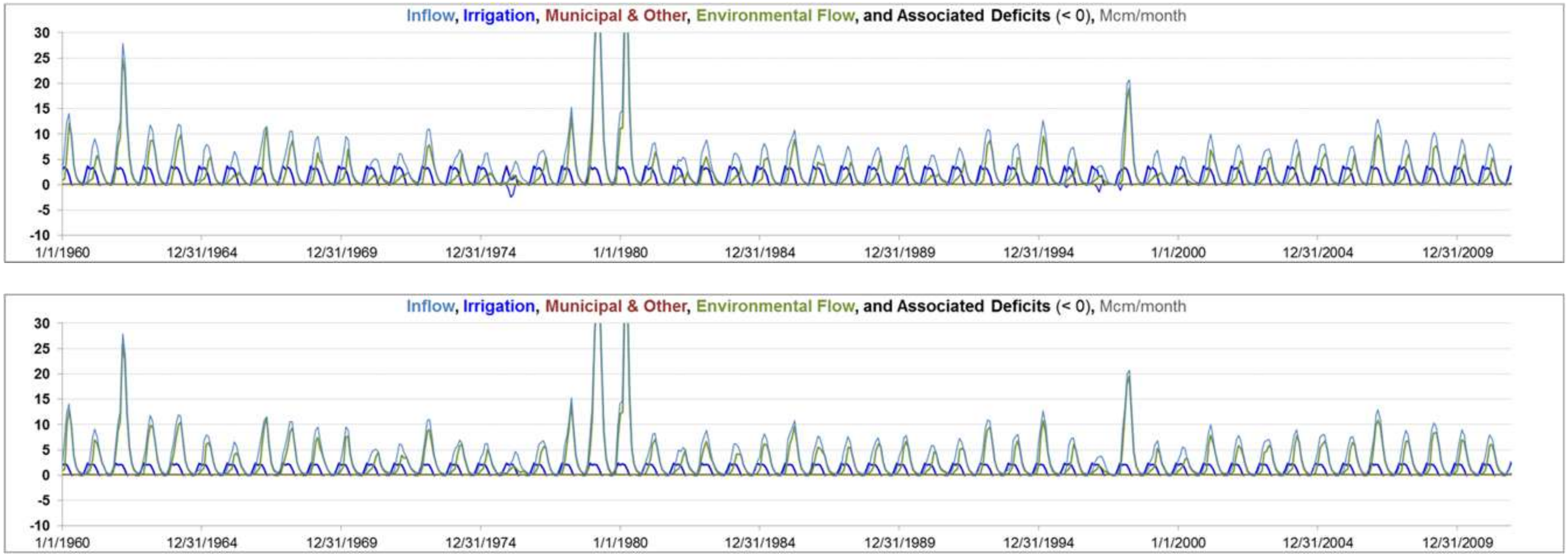

Figure A.3: Muze catchment simulated sequences (Mcm/month) of watershed inflow, irrigation water supply, municipal and other water supply, environmental flow, and associated deficits (negative values) for irrigation efficiencies 1.56 (*top graph*) and 1.00 (*bottom graph*) l/sec/ha. The simulations assume a 7.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions and 2035 water demand targets. Potential storage sites up to 25 Mcm have been identified in the Muze catchment, and the above storage is likely feasible.

Table A.3: Muze catchment monthly irrigation, municipal and other, and environmental flow water use deficits from 2035 demand targets, and potential annual hydropower production for irrigation efficiencies 1.56 (*top*) and 1.00 (*bottom)* l/sec/ha. The simulations assume a7.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions.

Muze			Water Demands:		2035		Storage Capacity:			7.3	Mcm
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:		1.56	lt/sec/ha						
Dfct Freq	0.038	0.038	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019
Avg Dfct (> 0)	0.730	1.412	1.633	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.038
Max Dfct	0.897	2.398	1.860	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.038
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		3.967										
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:		1	lt/sec/ha						
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		4.322										