United Republic of Tanzania
Ministry of Water

Water Sector Development Program (WSDP)

(Contract Ref.: ME-011/2009-10/C/11)

Lake Rukwa Basin IWRMD Plan: Final Report

Volume I: Basin Plan

by

WREM International Inc.
Atlanta, Georgia, USA

April 2016

Lake Rukwa Basin Integrated Water Resources Management and Development Plan

Final Report: Volume I

Basin Plan

WREM International Inc.
Atlanta, Georgia, USA

April 2016

Acknowledgements

The work reported herein was funded through Contract Agreement ME-011/2009-10/C/11 by the Ministry of Water, United Republic of Tanzania.

WREM International wishes to thank the management and staff of the Lake Rukwa Basin Water Board and the Ministry of Water for their guidance, cooperation, and logistical support. In particular, the discussions with and input of Mr. Hamza Sadiki, Department of Water Resources (DWR) Director, Dr. George Lugomela, DWR Assistant Director, and Mr. Florence Mahay, Basin Water Officer—Lake Rukwa Basin Water Board, are highly valued and appreciated. Furthermore, we thank the regional secretariats, districts, and the many stakeholders for their input and advice.

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.

Report Citation

The contents of this report, in whole or in part, *cannot be used* without proper citation. The report should be cited as follows:

WREM International 2016: Lake Rukwa Basin Integrated Water Resources Management and Development Plan, Final Report, Volume I: Basin Plan. Technical Report prepared for the Ministry of Water, United Republic of Tanzania, by WREM International Inc., Atlanta, Georgia, USA, 106 pp.

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.

Executive Summary

The overarching objective of the Lake Rukwa Basin Integrated Water Resources Management and Development (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."

The above objective is consistent with Section 31 of the Water Resources Management Act (2009) which provides specific guidance on the scope and primary focus of the IWRMD Plan expected to include:

- Sub-basin water balance assessments under historical and projected future conditions;
- Identification of options for satisfying current and future water demand for water stressed sub-basins;
- Water resources classification;
- Determination of the reserve requirements for each water resource class;
- Identification of any other measures (policy, legal, institutional, technical and financial capacity, etc.) necessary to achieve the objectives of the Plan; and
- Plan implementation measures.

Comparison of the project terms of reference (ToRs) and the legal provisions for IWRMD Plan development shows that some strategic issues (i.e., water resources classification and determination of the reserve) were not part of the Project ToRs and are not discussed in detail in this version of the Plan. It is envisioned that the basin IWRMD Plan will periodically be reviewed (i.e., every five years) to address emerging issues and challenges and ultimately reflect the entire scope and content of the Water Resources Management Act (2009).

The following chapters describe the outcomes of the detailed basin water resources assessments and the identification of management options for each sub-basin and sector undertaken by the project. In line with this IWRMD Plan scope, the studies carried out sought to answer the following important questions:

- How much water is available in the basin (where and when) and how is this likely to change in the future?
- How much water is currently used (when and where) and what are the projected future basin water requirements?
- Can the available water resources satisfy the current and future basin water needs?
- If not, what measures should be implemented to ensure that the water needs of the basin stakeholders are satisfied in an equitable and sustainable manner?

The above questions define the strategy and approach that guided the preparation of the IWRMD Plan. The IWRMD Plan preparation effort was valuable even when these questions could not be fully answered. In such instances, the Plan identifies the underlying challenges and outlines specific strategies to overcome them.

IWRMD Plan preparation required that significant time and effort be dedicated to the collection, review, and quality control of data and information required for technical assessments. All major basin stakeholders were visited and accorded the opportunity to offer their input, opinions, and concerns regarding the IWRMD Plan development process. All regional secretariats and districts were also visited and the relevant officials engaged to provide input to the Plan development process. Discussions were held with department heads in all basin districts on thematic issues to leverage local experience, seek guidance as important stakeholders, and access relevant district-specific current information and data. Detailed data/information gathering questionnaires were circulated to all district heads of departments soliciting sector-specific water use data and information at ward and village levels. All relevant documents including, among others, 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 were accessed and thoroughly reviewed. In addition, detailed questionnaires were administered to about 50 households per ward in 40 wards distributed 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 useful data and information that formed the basis for the assessments carried out and the findings presented in the project reports. Careful review of the data and information gathered revealed the following critical planning constraints:

(a) The basin lacks sufficient and good quality water resources data and information to adequately support water resources planning and management. Where they exist, historical data are spatially sparse over large basin watersheds, temporally intermittent, and to a large extent incomplete to support detailed hydrologic and water resources assessments in all sub-basins.

(b) In addition to hydrologic data scarcity and gaps, there are no systematic measurements of water use/withdrawals for most sub-basins. Thus, the estimation of natural watershed outflows and actual water abstractions (i.e., supply and demand) involves significant uncertainties for most basin watersheds. Furthermore, groundwater monitoring data is completely lacking. Under these data and information circumstances, detailed water balance assessments were only possible for selected sub-basins. Studies were also carried out for watersheds/sub-basins with inadequate or no data, but they required several critical assumptions, and their findings need to be revisited at the next planning cycle when additional data will be available.

Detailed hydrological and water resources assessments were carried out for four sub-basins with long enough and consistent data records that supported model calibrations and meaningful water resources assessments. These sub-basins include Katuma at Sitalike (3C8), Songwe at Galula (3A17), Momba at Tontela (3B2), and Luiche at Uzia (3CD2). Using a variety of local and international information sources, it was also possible to develop models and carry out assessments for Lake Rukwa. Assessments for the other watersheds/sub-basins relied on regionalization of model parameters based on careful consideration of topographical and hydrological similarities between watersheds. Uncertainties associated with the results and findings have been highlighted in the relevant report sections.

Notwithstanding the data and information shortcomings, water balance assessments were carried out for all sub-basins, and the findings helped highlight the existing water stresses and challenges and derive lessons for the IWRMD Plan development and implementation process. Fortuitously, the gaged areas of Katuma at Sitalike and Songwe at Galula are among the most critical basin watersheds with respect to water use and management issues. Extensive irrigation activities take place in the Katuma watershed (with outlet at Sitalike) located upstream of the Katavi National Park. This has important implications for the park wildlife since the Katuma River is the Park's main and only water source during the dry season. Likewise, the Songwe watershed (with outlet at Galula) encompasses Mbeya City and captures the impacts of intensive domestic and industrial water use in the City as well as irrigation activities in peri-urban areas. Thus, despite the data constraints and modeling challenges encountered, the detailed assessment findings from these critical watersheds provide useful insights into what is most likely to happen in other less stressed basin areas if appropriate planning and management measures are not promptly taken.

The findings from the water resources assessments support the following major conclusions:

(a) Several basin watersheds are already experiencing water stress even under current water demand levels. The most stressed watersheds are watersheds with intensive irrigated paddy cultivation. Where it is extensive, especially in the Katuma sub-basin, paddy production dwarfs all other water uses. High water use in paddy growing sub-basins is mostly attributed to the fact that paddy is produced by traditional schemes characterized by poor irrigation infrastructure and inefficient irrigation practices associated with high water losses.

(b) Although on an annual average basis some sub-basins appear not to experience deficits, more detailed analysis at a monthly time scale shows that all sub-basins are vulnerable to water deficits. This is due to the irrigation calendar for paddy cultivation where significant irrigation withdrawals take place during certain months of the year causing deficits.

(c) Lake Rukwa sub-basins experience water stress at different times of the year and for different reasons. Unlike the other sub-basins that experience water stress during the wet season (paddy growing season), the Songwe sub-basin is dominated by urban and industrial water demands and experiences shortages during the dry season when supply is low. Thus, individual sub-basins have unique water issues and warrant unique solutions.

(d) Contrary to subsection 6(2) of the Water Resources Management Act (2009), current water allocation decisions do not explicitly take into consideration environmental flow requirements. This is largely attributed to the lack of data on environmental flow requirements for specific basin river sections. Environmental flow requirements were established at two basin locations as part of this project (i.e., Katuma at Sitalike and Songwe at Galula), and their critical importance for water resources planning was clearly illustrated in the water balance assessments. Significant work remains to replicate such assessments to other parts of the basin.

(e) Lake Rukwa basin is already experiencing climate change and is becoming increasing vulnerable to its impacts. Climate change is expected to impact the basin hydrology and water resources primarily through increased evapotranspiration from watersheds, wetlands, and lakes. Higher evapotranspiration is likely to reduce surface water flows, soil moisture, groundwater recharge, and lake levels. In addition to supply side impacts, higher evapotranspiration is likely to increase agricultural water demand (due to increased crop evapotranspiration) and possibly demand for other water uses. The water balance assessment findings highlight notable decreases in future streamflow in all major rivers in the basin. Particularly, Lake Rukwa, being the ultimate recipient of flows from all basin areas, is most vulnerable to the reinforcing impacts of climate change and increasing water demands.

The study findings highlight the key water resources management challenges and call for several priority intervention measures:

(a) Rehabilitation, upgrade, and expansion of the existing *surface water* resources monitoring network is necessary to ensure consistent collection of adequate and good quality data in all basin watersheds.

(b) Comprehensive groundwater monitoring needs to be initiated as soon as possible to begin collection of adequate data to characterize groundwater availability and distribution.

(c) Irrigation efficiency improvements in paddy growing sub-basins are a critical component of the strategy to address water deficits. Modernization of the water infrastructure in traditional irrigation schemes is highly recommended to reduce water losses. This, coupled with the use of drought resistant crop varieties and diversification from paddy growing to other less water intensive high value crops, could reverse the current trend of unsustainable water use and growth.

(d) If feasible, water supply augmentation measures in water stressed watersheds are recommended to reduce deficits. This could be achieved through construction of storage dams that can mitigate monthly water deficits through water transfers from the wet to the dry season or from wet to dry years. Preliminary topographical and hydrologic analyses were conducted for all sub-basins, and promising water storage sites were identified for individual watersheds. Other potential water supply augmentation measures include inter-basin water transfers and conjunctive use of surface and groundwater resources.

(e) Full scale assessments to establish environmental flow requirements at critical river sections are urgently needed. This will ensure that environmental flow requirements are indeed considered in water allocation decisions as mandated by Tanzanian law.

(f) It is imperative that all basin water resources planning and management decisions consider future climate change impacts. A comprehensive climate change adaptation and mitigation strategy is necessary to ensure that climate change issues are given due attention in basin planning and management processes.

The above assessment findings, conclusions, and priority action areas were extensively reviewed and discussed by basin stakeholders at different fora. Several technical assessment reports containing these findings and conclusions (Interim Reports I and II) were widely circulated by the Basin Water Board to all major stakeholders for review and comments. The reports were also presented at several stakeholder consultation meetings and workshops facilitated by the project team. This stakeholder review process provided extensive comments which guided the IWRMD Plan to focus on priority stakeholder interests and concerns. These comments are reflected in the IWRMD Plan strategic objectives and priority actions discussed in this report. The interventions were grouped into six 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 Enforcement and Compliance Monitoring Program;
(4) Environment Flow Assessment and Monitoring Program;
(5) Integrated Watershed Management and Environmental Conservation; and
(6) Human and Institutional Capacity Development Program.

The total estimated budget required for implementation of the Rukwa IWRMD Plan over the period 2016 to 2035 is about 176.68 Billion TShs. Katuma and Songwe sub-basins together account for about two-thirds of the total budget (66%), reflecting the critical challenges these two sub-basins are facing and the significant resources required to address them. The Water Security Enhancement Program has the highest budget allocation (55%) because of the high capital costs associated with construction of water storage and supply infrastructure. The IWRMD Plan is expected to be reviewed every five years to benefit from the collection of new data and updated water resources assessments. The review will also ensure that the Plan is continuously re-aligned to address other emerging basin challenges and to leverage new basin development opportunities as they arise.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

BMUs	Beach Management Units
BRN	Big Results Now
CC	City Council
CITES	Convention on International Trade in Endangered Wild Flora
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 Nations
GDP	Growth Domestic Product
GoT	Government of Tanzania
Ha	Hectares
IUCN	World Conservation Union
IWRDMP	Integrated Water Resources Development and Management Plan
IWRM	Integrated Water Resources Management
LGA	Local Government Authority
LRBWB	Lake Rukwa Basin Water Board
MC	Municipal Council
MCM	Million Cubic Meters
MDA	Ministries, Departments and Agencies
MTEF	Medium Term Expenditure Framework
MW	Mega Watts
NEMC	National Environment Management Council
NGO	Non-Governmental Organization
NSGRP	National Strategy for Growth and Reduction of Poverty
PPP	Public-Private Partnership
SADC	Southern African Development Cooperation
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SMUWC	Sustainable Management of the Usangu Wetland and its Catchment
TANAPA	Tanzania National Parks
TDV 2025	Tanzania Development Vision 2025
TC	Town Council
TShs	Tanzanian Shillings
ToR	Terms of Reference
URT	United Republic of Tanzania
UWSA	Urban Water Supply and Sanitation Authority
WASH	Water, Sanitation and Hygiene
WB	The World Bank
WCST	Wildlife Conservation Society of Tanzania
WREM	Water Resources and Energy Management Incorporated
WRMD	Water Resources Management and Development
WSDP	Water Sector Development Program

1. Introduction

The Government of the United Republic of Tanzania is implementing the Water Sector Development Program (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. The overall objectives are summarized below:

(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, utilization, protection and conservation of water resources; devolving ownership to the user level and 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 WRMD component comprises three main sub-components:

(i) Strengthen the institutional capacity for improving water resources management in all basins (including the systems for water resources planning, management, and development) as well as for reducing stress.
(ii) Coordinate the development and implementation of Integrated Water Resources Management and Development (IWRMD) plans.
(iii) Implement priority water resources (single and multi-purpose) management and development investments identified by the Government.

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 is the Main Report of the Final IWRMD Plan. The report contains a 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.

The report is organized in ten chapters. This introduction serves as Chapter 1. Chapter 2 provides a general overview of the Lake Rukwa Basin including its geography and topography, climate, and hydrography. Chapter 3 is dedicated to Basin situation analysis, summarizing the major findings and conclusions. Chapter 4 presents the IWRMD Plan strategic development framework, and Chapter 5 highlights sub-basin water assessments and recommended actions. Chapter 6 discusses the findings of sectoral water assessments and summarizes the recommended actions. Chapter 7 sets forth the IWRMD Plan strategic goals and objectives. Chapter 8 presents the implementation strategy and action plan, and Chapter 9 discusses the implementation arrangements and priorities. Chapter 10 provides details of the strategic action plan and budget. Lastly, Annex A highlights the IWRMD Plan logical framework analysis.

2. IWRMD Plan Development Approach and Scenario Assessment Process

2.1 IWRMD Plan Development Approach

2.1.1 Conceptual Framework

Figure 2.1 depicts the conceptual framework followed in the development of the Lake Rukwa Basin IWRMD Plan. This approach included four sequential steps from I (bottom) to IV (top).

Step I focused on individual sub-basins and involved detailed assessments of (a) current and projected water use levels and (b) current and future water supplies. The former were carried out independently of the latter and aimed to determine *aspirational* water use targets in individual sub-basins and sectors assuming unlimited water supplies. Likewise, the latter aimed to determine the sub-basin water supply capacity under pristine conditions—conditions without anthropogenic influences.

Step II continued to focus on the individual sub-basins, but its purpose was to integrate the independent water use and availability assessments of Step I and determine the extent to which supplies can meet demands. Specifically, Step II assessments aimed to determine existing or projected supply-demand deficits (if any), quantify water use tradeoffs across the sub-basin sectors, identify and assess promising water management options that may be able to reconcile supply and demand deficits, and develop stakeholder consensus on acceptable sectoral water use levels. These assessments are sectorally integrated *within* each sub-basin, but they are not concerned with possible adverse impacts to downstream sub-basins and Lake Rukwa. Because of this, the water use levels and associated management interventions identified in this step are tentative and subject to revision, pending the basin-wide assessments in Step III.

Step III focused on restoring the physical and socio-economic interactions *between* sub-basins and aimed to assess the *basin-wide* impacts of sub-basin water uses as well as the *basin-wide* benefits of the tentative sub-basin water management interventions. Stage III assessments are sectorally *and* regionally integrated and had three important goals: (a) provide a holistic understanding of water use impacts and benefits, (b) evaluate the combined effectiveness of alternative water management interventions, and (c) develop stakeholder consensus on the acceptable water use levels in each sub-basin and on the most effective water management interventions to be included in the basin plan.

The sub-basin water use levels agreed upon in Step III are not necessarily the same as the water use levels tentatively proposed in Step II. Thus, the purpose of **Step IV** is to revise the sub-basin sectoral water use levels and associated management interventions to be consistent with those of the basin-wide IWRMD plan agreed upon in Step III. These revisions form the basis of the final *sub-basin/sectoral plans*.

Stakeholder participation, interaction, input, and agreement were essential throughout all IWRMD Plan development stages, with sub-basin stakeholder caucuses convening individually during Stages I, II, and IV, and all basin stakeholders convening together during Stage III.

Figure 2.1: IWRMD Plan Preparation Approach Intended to (a) Integrate Regional Resources and Sectoral Interests and (b) Develop Stakeholder Consensus on a Shared Vision Basin Plan.

2.1.2 Sequencing of Project Tasks and Activities

Preparation of the IWRMD Plan was undertaken in the four major phases described below:

1. Inception Phase

Project implementation commenced with the Inception Project Phase (July 2012) which lasted for two months. The project team visited all regional and district administration offices, held discussions with several stakeholders, and collected documents, information and data. Specifically, meetings were held with officials from all basin regional secretariats and districts. The purpose of these meetings was to (i) raise awareness regarding project goals, activities, and expectations; (ii) introduce the project team to regional and district administrative officials; and (iii) seek guidance and support regarding implementation of different project activities in the districts and local communities. Follow up meetings were also held with most department heads in all districts to explain the project objective and expected outputs, and emphasize the importance of their active participation and provision of credible and accurate data. A detailed questionnaire was also circulated to all districts soliciting district specific water resources management and water use data and information. Finally, a comprehensive inventory and preliminary review of previous and on-going basin initiatives, data sources, government sectoral policies, laws, and development plans was undertaken. Information and data gathered during the Inception Phase was very useful in carrying out the technical assessments in the subsequent phases. The output from this phase was the Project Inception Report.

2. Interim Phase I

Interim Phase I included the following tasks:

(i) **Water Resources Availability Assessments** – This involved collection, quality control, compilation, and analysis of all required data, information, and knowledge base necessary to characterize temporal and spatial availability of water resources (surface and groundwater, if possible) in the Lake Rukwa Basin. Extensive discussions were held with relevant officials and stakeholders to leverage their knowledge and understanding of the local water resources issues in different basin areas. A comprehensive water resources availability assessment report was prepared to summarize the outputs of this task.

(ii) **Current Water Use and Demand Assessments** – This task involved collection, quality control, compilation, and analysis of all required data, information, and knowledge base necessary to characterize current temporal and spatial water demand and use in the Lake Rukwa Basin. Detailed water use/demand data were collected from all basin districts from official documents, household surveys, and extensive discussions with relevant officials. The major output from this task was a detailed report on the basin current water use and demand assessment.

(iii) **Socio-economic Assessments** – This task involved collection, quality control, compilation, and analysis of all data, information, and knowledge base necessary to characterize the baseline socio-economic conditions in different basin areas and the level of dependence of the local communities on water resources for their livelihood and household income. Detailed socio-economic data were collected from all basin districts from various official documents, household surveys, and extensive discussions with relevant officials. A comprehensive report of the Lake Rukwa Basin Socio-economic Profile was prepared and comprised the main output of this task.

(iv) **Review of the Water Resources Policy, Legal, and Institutional Framework** – Comprehensive review was undertaken of existing water resources related policies and legislation and of the institutional framework for integrated water resources management in the basin. The review also addressed transboundary aspects of water resources management given that some portion of the basin is shared with Zambia. A detailed report was prepared that highlighted the main issues and challenges hindering effective water resources management and development in the Lake Rukwa Basin.

(v) **Development of Lake Rukwa Basin Decision Support System (Rukwa DSS v1.0)** – This involved development of the first version of the Rukwa DSS including comprehensive databases and data management and analysis tools. The databases were populated with the collected data and information. A two-week training workshop was conducted for staff of the LRBWB on the Rukwa DSS v1.0 to demonstrate its structure and technical capabilities.

3. Interim Phase II

The following tasks were accomplished during the Interim Phase II:

(i) **Water Demand Projections (2015 – 2035)** – This task involved systematic projection of sectoral water demands for the period 2015 to 2035. The sectoral demands were aggregated at sub-basin and basin levels. The main output from this task was a detailed report on basin water demand projections over the planning horizon (2015 – 2035).

(ii) **Sub-basin Water Balance Assessments** – Water balance assessments were conducted for the individual sub-basins and for the entire basin. These were intended to assess the capacity of individual sub-basins to satisfy their respective current and future water demands without compromising environmental integrity. The assessments were made under historical and potential future climate conditions. A comprehensive report on basin water balance assessments was prepared at the end of this task.

(iii) **Sub-basin Environmental Flow and River Health Assessments** – Environmental Flow Assessments (EFAs) were conducted for four Lake Rukwa sub-basins (i.e., Katuma, Songwe, Momba, and Luiche) and specific recommendations were made on applicable desired modified flow regimes for each to maintain proper functioning of important ecological biodiversity and processes, as well as to reverse the observed trajectory of environmental degradation caused by the present flow regimes. Two EFA methodologies were employed: the Building Block Methodology (BBM) and the Desktop Reserve Model (DRM). The BBM methodology was used in Katuma and Songwe, two of the most critical sub-basins with respect to water use and water resources management issues. The DRM methodology was applied to four sub-basins with reasonable hydrological data records, i.e., Katuma, Songwe, Momba, and Luiche. River Health Assessments (RHA) were also conducted in Katuma and Songwe to identify river reaches that are currently in poor or deteriorating health, highlight the likely underlying causes, and guide effective and efficient management actions. These environmental and river health assessments were described in a report comprising the output of this task.

(iv) **Pre-feasibility Studies for Mwamapuli and Kakese Irrigation Projects** – Prefeasibility studies were conducted for construction of three dams under the Mwamapuli and Kakese irrigation development projects. The proposed dams include the Katuma and Dirifu dams, under the Kakese irrigation project, and the Ilalangulu dam, under the Mwamapuli irrigation project. The prefeasibility studies were intended to provide preliminary assessment of the technical and environmental viability of the proposed dam developments. The preliminary findings are intended to guide follow-up detailed feasibility studies that will be conducted at a later date to ensure technical feasibility, operational effectiveness, and cost efficiency. The output from this task was a detailed prefeasibility study report for the three potential dam sites.

(v) **Development of Lake Rukwa Basin Decision Support System (Rukwa DSS v2.0)** – This involved development of the second version of the Rukwa DSS that added the following new datasets and tools to the DSS v1.0: (i) River Gage Rating Tool (RGRT) and associated datasets; (ii) Water Permit Data Tool (WPDT) and water permitting dataset; (iii) Water Quality Data Tool (WQDT) and water quality data; and (iv) Groundwater Data Tool (GWDT) and borehole data. Extensive hydro-climatic data from various international sources was also included to facilitate climate change assessments. A two-week training workshop was conducted for the LRBWB staff to demonstrate the Rukwa DSS v2.0 functionalities and technical capabilities, and to develop the staff capacity to use it.

4. Final Project Phase

The final project phase included the following tasks:

(i) **Preparation of the Lake Rukwa Basin IWRMD Plan: Main Report** – This involved conducting basin-wide integrated assessments and formulating recommended actions that cut across sub-basins. It also included synthesis of information generated from all project activities (with emphasis on the main study findings, conclusions, and recommendations) into a consolidated Lake Rukwa Basin IWRMD Plan Main Report.

(ii) **Preparation of Sub-basin Water Resources Management and Development Plans** – This involved preparation of specific water resources management and development plans for six sub-basins: Katuma, Songwe, Momba, Luiche, Muze, and Rungwa.

(iii) **Preparation of IWRMD Plan Implementation Strategy and Action Plan** – This task included two main components: (a) preparation of an implementation strategy which highlights the administrative and financial modalities of the IWRMD Plan implementation, including identification of the key players to be involved and their corresponding roles, and (b) preparation of an Action Plan which outlines the requisite steps to be taken and preparatory activities necessary to kick-start the Plan implementation process. Other activities undertaken included preparation of a Monitoring and Evaluation Strategy for the IWRMD Plan implementation process and a Communication Plan for information dissemination and sustained stakeholder engagement and feedback.

(iv) **Preparation of a Capacity Building and Stakeholder Participation Plan** – This involved (a) identification of all basin stakeholder groups, (b) assessment of their capacity needs, and (c) recommendation of the necessary capacity building measures to enable them to effectively participate in basin water resources management activities, particularly IWRMD Plan implementation.

(v) **Development of Lake Rukwa Basin Decision Support System (Rukwa DSS v3.0)** – This involved development of the third version of the Rukwa DSS that added detailed models for hydrologic simulation and forecasting, river simulation, and scenario/policy assessment tools to the DSS v2.0. The Rukwa DSS v3.0 is a state of the science information, modeling, and assessment system for integrated planning and management of the basin water resources. A two-week training workshop was conducted for the LRBWB staff on the Rukwa DSS v3.0 to demonstrate its functionalities and technical capabilities, and to develop staff capacity to utilize the software tools.

(vi) **Development of Lake Rukwa Basin Monitoring Plan** – This addresses the data and information needs in Lake Rukwa through a comprehensive monitoring plan of the basin climate, surface water hydrology, groundwater hydrology, and water quality. The plan also addresses important data management issues, and recommends the adoption of an integrated data and information management process.

2.1.3 Project Deliverables

A complete list of all major project deliverables is presented in **Table 2.1** below. The Final Report volumes are based upon the detailed assessment findings and conclusions described in Interim Reports I and II. Namely, the interim reports are essential components of the IWRMD Plan, describing the science underpinning the plan recommendations. The Lake Rukwa Basin IWRMD Plan, therefore, comprises all the report volumes in Interim Report I, Interim Report II, and Final Report.

Table 2.1: Major Project Deliverables

Phase	Deliverable	Report Volumes	Date Delivered
Inception Phase	Inception Report	Final Inception Report	November 29, 2012
Interim Phase I	Interim Report I	**Volume I**: Lake Rukwa Basin Socio-economic Profile and Water Resources Management Framework. **Volume II**: Water Resources Availability Assessment. **Volume III**: Current Water Demand and Use Assessment. **Volume IV**: Rukwa DSS v1.0	June 6, 2014
Interim Phase II	Interim Report II	**Volume I**: Water Demand Projections (2015 – 2035). **Volume II**: Sub-basin Water Balance Assessments. **Volume III**: Sub-basin Environmental Flow and River Health Assessments. **Volume IV**: Pre-feasibility Studies for Mwamapuli and Kakese Irrigation Projects. **Volume V**: Rukwa DSS v2.0.	March 18, 2015
Final Phase	Final Report	**Volume I**: Lake Rukwa Basin IWRMD Plan Main Report. **Volume II**: Sub-basin Water Resources Management and Development Plans. **Volume III**: IWRMD Plan Implementation Strategy and Action Plan. **Volume IV**: Capacity Building and Stakeholder Participation Plan. **Volume V**: Rukwa DSS v3.0 **Volume VI**: Lake Rukwa Basin Monitoring Plan	April 30, 2016

2.2 Water Management Scenario Assessment Process

Development of the Lake Rukwa IWRMD Plan was guided by the formulation and assessment of multiple water management and development scenarios. These assessments, conducted using the Rukwa DSS, quantified the relative merits, risks, and tradeoffs of promising alternative management and development options, and they provided the technical basis for the basin plan recommendations.

2.2.1 Water Management Scenarios

The number of relevant scenarios that can potentially inform the planning process in the Lake Rukwa Basin is very large. This is because scenarios may differ in three major attributes:

- Water demands (consumptive use targets) for each sector, sub-basin, and planning horizon.
- Climatic and hydrologic conditions that occurred in the historical past or can potentially occur in the future.
- Water management options to be assessed for potential inclusion in the basin plan including: (a) water supply sources to meet water demand targets, such as surface water, groundwater, or a combination of both; (b) water storage infrastructure options; and (c) water use efficiency improvement measures.

The scenario attributes are described below.

2.2.1.1 Water Demand Targets

Water demand (or water use) *targets* were derived for each sector and major sub-basin as described in Interim Report II, Volume I ("*Water Demand Projections*"). Water demands were derived for off-stream and in-stream water use sectors. Off-stream water use sectors withdraw water from surface water and/or groundwater sources (i.e., rivers, lakes, wetlands, and aquifers) and consume all or part of the withdrawn amount at off-stream sites. Such sectors include domestic water supply, irrigated agriculture, livestock keeping, mining, and industrial sectors. In-stream water use sectors derive benefits from water in the rivers, lakes, or wetlands and do not abstract or appreciably consume it. Such sectors primarily include hydropower, wildlife, and the aquatic environment and ecosystems.

Five water use target levels (scenarios) were developed and used in the assessments for each sub-basin: unimpaired flow (assuming no consumptive water uses taking place); water use in the baseline year (2010); and projected water use in three target years—2015, 2025, and 2035. The future sectoral water demands were derived from existing sectoral policies and programmes. Environmental flow requirements were assessed at two critical river nodes (Katuma at Sitalike and Songwe at Galula) based on detailed environmental flow assessments (EFAs), and at two other river nodes (Momba at Tontela and Luiche at Uzia) based on rapid (desktop) EFAs. Environmental flow demand targets differ by location and season and are incorporated as hard requirements (constraints) in the assessment models. Evaluation of the assessments results identified the management interventions that most effectively meet the off-stream water demand targets and satisfy environmental flow targets.

2.2.1.2 Climatic and Hydrologic Conditions

Assessments were carried out for historical as well as plausible future climatic conditions generated by global circulation models. While the historically observed climate is unique, *many* alternative future climate conditions are plausible. These potential future climates are collectively referred to as a climate ensemble. Each member of the ensemble consists of climate variable sequences (most importantly rainfall and potential evapotranspiration demand—PET) generated by global circulation models (GCMs) which are recognized by the International Panel for Climate Change (IPCC). In all, 23 GCMs were used to generate the climate ensembles. Furthermore, each future climate ensemble depends on a particular greenhouse gas (GHG) emission scenario encoded in the GCM. As described in Interim Report I, Volume II ("*Water Resources Availability Assessments*"), the Lake Rukwa Basin climate assessments employed two different emission scenarios, a mild GHG emission scenario (RCP4.5) and an intense GHG emission scenario (RCP8.5), each of which gives rise to a 23-member future climate ensemble. Thus, a total of 47 hydro-climatic conditions (historical and future) were used to assess climate change. For each case, key climatic variables (i.e., rainfall and PET) were properly downscaled to the scale of each sub-basin, used as input to calibrated rainfall-runoff models, and generated streamflow and soil moisture responses in monthly time increments. For the historical climate, these sequences were 52 years long, starting in the 1960s when reliable observations became available. The future climatic and hydrologic sequences extended up to 2097 and were distinguished in two 45-year periods. The resulting inflow sequences served as the hydrologic basis to assess the response of (i) each sub-basin to alternative water use targets and water management options (described below) and (ii) Lake Rukwa after the sub-basin contributions were routed through the entire river network. Scenario inter-comparisons were carried out for the historical period and each of the two future periods.

2.2.1.3 Water Management Options

Water storage infrastructure options: These management options are related to potential water storage infrastructure in the individual sub-basins that can significantly alter the river flow. The potential storage determination was based on information about the sub-basin 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 at different locations from the construction dams of a certain height. 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; and
(iii) The catchment area upstream of the dam site.

Because the potential storage was determined based on preliminary topographical analysis for which the accuracy of the results is limited by the DEM resolution, the values of the reservoir volume, inundated area, dam width, and upstream watershed area should be viewed as estimates that need to be refined by more detailed field surveys and analysis during the follow-up pre-feasibility studies. These caveats notwithstanding, the analysis provided fairly good guidance on the most promising dam sites and potential development options.

Water use efficiency improvement measures: Water use efficiency improvement measures aim to reduce unnecessary water losses and the wasteful use of water in a particular sector without impacting sector production. In Lake Rukwa Basin, nearly 90% of the total consumptive water use occurs in the agricultural sector. A significant portion of irrigation diversions, however, is lost to evaporation and infiltration and does not benefit crop production. These water losses are mainly due to lack of modern irrigation infrastructure and inefficient irrigation practices. It is estimated that irrigation efficiency can be improved up to 50% through a combination of infrastructure and management measures (although potential percent improvements are expected to vary across sub-basins). In the scenario assessments, water use efficiency improvement options were incorporated through reductions in per capita irrigation water use. For example, management scenarios were assessed for per capita irrigation water use of 2.0 l/ha/s, 1.56 l/ha/s, and 1.0 l/ha/s, the first rate corresponding to the typical value used in irrigation planning studies, the second to an average rate estimated for other Tanzanian sub-basins, and the third to rate associated with improved and modern irrigation schemes.

Additional water savings can be achieved by water use efficiency improvements in sectors other than agriculture. However, the water use requirements (and potential water savings) in these sectors are relatively small, typically less than 5–10% of total consumptive use. Thus, water use efficiency scenarios for these sectors were not explicitly formulated; instead, they were considered to be part of the overall water use efficiency improvement options.

2.2.1.4 Alternative Water Management Scenarios

Each sub-basin was assessed for all possible combinations of the previous demand, climate, and water management options. Namely, the combined scenarios were numerous and comprised three broad classes:

(i) Historical climate **X** [UIF, 2010D, 2015D, 2025D, 2035D] **X** [Mgt. options]
(ii) RCP4.5 **X** 23 GCMs **X** [UIF, 2010D, 2015D, 2025D, 2035D] **X** [Mgt. options]
(iii) RCP8.5 **X** 23 GCMs **X** [UIF, 2010D, 2015D, 2025D, 2035D] **X** [Mgt. options]

In the above, “UIF” indicates *unimpaired flow sequences*; “2010/15/25/35D”, *water use targets for the indicated year*; and “**X**”, combination of all possible cases.

2.2.2 Performance Criteria and Metrics

Several performance criteria and metrics—a particular criterion can be assessed by several metrics—were calculated and used to (1) characterize the individual sub-basin and basin wide response to different water use levels, climate scenarios, and management options and (2) quantify the benefits, risks, and tradeoffs implied by each scenario for each sub-basin and sector. Among others, these criteria and metrics included:

(i) Water use deficits from specific targets and frequency of deficit occurrence.
(ii) Percentage of water use targets (and of actual water use) to mean annual basin yield.
(iii) Streamflow reductions and frequencies of occurrence in the wet and dry seasons at critical river nodes relative to unimpaired flow conditions, reductions due to climate change alone, and reductions from combined climate and consumptive water use changes.
(iv) Environmental flow deficits and frequency of occurrence relative to environmental management class requirements.

These criteria and metrics were derived based on stakeholder consultations and were selected to represent the many and varied socio-economic and environmental interests in the Lake Rukwa Basin.

2.2.3 Data, Models, and Scenario Assessments

The development of the IWRMD Plan relied *critically* on quantitative data analysis and detailed models of the sub-basin and basin-wide response to historical and future hydro-climatic conditions, water use levels, and management options. The components of the modeling and scenario assessment process are depicted in **Figure 2.2** and are described next along with the associated modeling tools.

Database development: First, all available hydro-climatic data and water use data (including rainfall, PET, streamflow, groundwater levels, borehole yields, water quality parameters, and water use permits, among others) existing in various organizations and forms were compiled, and their quality and completeness were carefully assessed. Data gaps were noted, and where possible, likely biases and errors were identified and corrected. The data were then entered into databases which formed the information component of the Lake Rukwa Decision Support System (Rukwa DSS). Separate databases and user interfaces were designed for surface water, groundwater, water quality, and water use data to reflect and support the specific monitoring procedures and requirements followed by the BWB staff in each data category. These databases currently house the existing historical data but can also facilitate the collection, archival, and management of future measurements. Specialized data analysis tools were also developed to facilitate the use of the data in model development. One such tool is the river gage rating tool (RGRT) which facilitates the development of rating curves from stage-discharge data, and subsequently uses them to convert river stage measurements to discharges. This tool has many unique features and has been provided with training to all Tanzanian BWBs. The RGRT was used extensively to update the rating curves at key river locations and to generate daily and monthly streamflow sequences that supported the development of hydrologic watershed models (described next). Inspection of the rating curves can also identify clear stage-discharge measurement priorities across the flow range and guide the BWB flow measurement schedule. The various features and functionalities of the Rufiji data bases and analysis tools are described in Volume V of the Final Report (*Rukwa DSS v3.0*).

In addition to data from basin organizations, data available from international sources were also compiled and used in various assessments. Notable among these data are the climate projections available through the Intergovernmental Panel for Climate Change (IPCC). Monthly climate projections for 2015 to 2099 were compiled for (i) temperature, rainfall, and potential evapotranspiration; (ii) two greenhouse concentration (GHC) scenarios, a mild GHC scenario (RCP4.5) and an intense GHC scenario (RCP8.5); and (iii) 23 global circulation models (GCMs). These voluminous data sets were subsequently properly downscaled (through state of the science methods) and used to create plausible future climate sequences for all Lake Rukwa Basin watersheds. These sequences were the basis of the detailed climate assessments reported in Interim Report I, Volume II (*Water Resources Availability Assessments*), and Interim Report II, Volume II (*Sub-basin Water Balance Assessments*).

Hydrologic watershed model development: Second, rainfall-runoff models were developed for each major sub-basin and used to characterize the watershed runoff and soil moisture storage response to rainfall and potential evapotranspiration forcing, particularly under variable climatic conditions. The Rukwa sub-basin models are physically-based (of the Sacramento model type) and are designed to simulate the important hydrologic processes operating at the watershed scale including interception, infiltration/percolation, evapotranspiration, surface and subsurface runoff, soil moisture storage, and channel routing. The models include two subsurface soil moisture storage compartments and have a monthly temporal resolution. Model parameters are calibrated to concurrent sequences of rainfall, PET, and streamflow. Model calibration is assessed through several performance measures including error and correlation statistics between simulated and observed streamflows, and expected frequencies of outlier data values. The development of the watershed models is described in Interim Report II, Volume II (*Sub-basin Water Balance Assessments*). The model errors remaining after parameter calibration provide very useful guidance on needed improvements of the hydro-climatic monitoring network. Such information was extensively used in the development of the Lake Rukwa monitoring plan (Final Report, Volume VI, *Basin Monitoring Plan*).

Decadal simulation of historical watershed streamflows: Third, the calibrated rainfall-runoff models were used in connection with available historical rainfall and PET observations (from local and/or international sources) to simulate the sub-basin streamflow response over several decades outside the model calibration period. These long (multi-decadal) streamflow sequences represent the natural flow response of the respective watersheds (unimpaired flows) and were used to characterize the watershed water supply availability, including its inter-annual to decadal hydrologic variability and the frequency and severity of historical droughts and wet climatic periods. Natural streamflow series were also generated for ungaged watersheds (i.e., watersheds without or insufficient data to support formal hydrologic model calibration). This was achieved through proper regionalization of model parameters based on topographic and hydro-climatic watershed similarities. The quantitative understanding of droughts and floods is critical knowledge for assessing (i) the natural capacity of watersheds to meet specific water use targets during critical hydrologic periods and (ii) the relative effectiveness of alternative storage development options to mitigate any existing water supply–demand gaps. The simulated flow sequences are presented and discussed in Interim Report II, Volume II (*Sub-basin Water Balance Assessments*) and are also included in the *Rukwa DSS v3.0* (Final Report, Volume V) as part of the database used by the modeling tools.

Watershed and lake simulation and scenario assessments: Lastly, detailed water balance models for individual watersheds and the entire Lake Rukwa Basin were developed to quantify their response to (i) historical and future climate conditions, (ii) current or projected water use targets, and (iii) alternative management interventions, such as new storage reservoirs and improved irrigation schemes. These models are part of the *Rukwa DSS* and provided the means to determine the basin-wide and sectoral impacts and tradeoffs associated with different sub-basin water use levels. Notable modeling contributions were (a) the development of the Lake Rukwa model and (b) the development of tools to identify and assess promising storage development options that may exist practically anywhere in the basin watersheds. The Lake Rukwa model helped develop a new understanding of the unique way in which Lake Rukwa interacts with the surrounding wetlands and the underlying aquifer, and enabled the critical lake assessments reported in Interim Report II, Volume II (*Sub-basin Water Balance Assessments*).

The storage assessment tools combined (i) geospatial (GIS) methods for the identification of alternative reservoir sites based on basin topography (using available digital elevation models, DEMs), (ii) hydrologic regionalization methods to generate climatically consistent inflow series at the identified reservoir sites, and (iii) detailed reservoir simulation and assessment methods to assess the relative effectiveness of the identified reservoir sites for different hydrologic, demand, and management scenarios. These tools enabled the assessment of multiple reservoir development options (of different sizes) at nearly 3,800 river sites in the Lake Rukwa Basin, and identified the most promising development options recommended for each sub-basin [Final Report, Volume II (a) to (f): *Sub-basin Water Resources Management and Development Plans*].

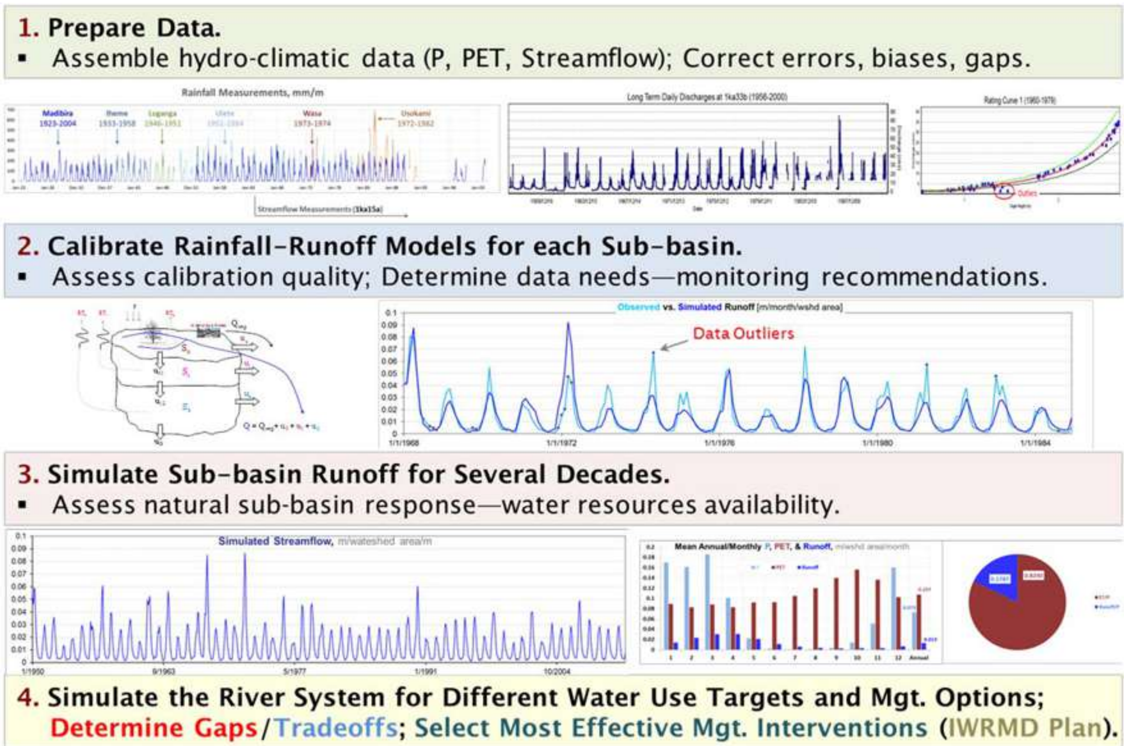

Figure 2.2: Modeling and Scenario Assessment Process.

3. The Lake Rukwa Basin - Overview

3.1 Location

The Lake Rukwa Basin is an internal drainage basin located in the south-western part of Tanzania (**Figure 3.1**). The basin lies within the Rift Valley with Lake Tanganyika on the northwest and Lake Malawi on the southwest. It covers an area of about 88,000 km^2 extending over parts of the following districts: Mbozi, Chunya, Momba, Mbeya Rural, and Mbeya Urban in Mbeya region; Nkasi, Sumbawanga Rural, Kalambo, and Sumbawanga Urban in Rukwa region; and Mpanda Rural, Mpanda Urban, and Mlele in Katavi region. The major urban center is the City of Mbeya with a population of about 385,279 (2012 National Census). Other urban centers include regional and district headquarters and smaller towns such as Tunduma, Mbalizi, Laela, and Vwawa.

Figure 3.1: Main River Basins in Tanzania.
(*Source:* MoW, 2010)

3.2 Climate

Most of the basin falls within the southern highland zone of Tanzania whose climate is greatly influenced by its diverse physiographic features and highly variable topography. The basin is characterized by tropical wet climate with mean annual rainfall ranging from about 650 mm in the south to as high as 2,500 mm in the Ufipa highlands. The basin climate is highly variable, with the basin peripheries exhibiting cooler temperatures and the basin floor, much of which is covered by Lake Rukwa, being much warmer and receiving less rainfall. The basin experiences only one rainy season with most rainfall occurring during November to April. The months of June to September receive virtually no rain.

Temperatures vary according to altitude but generally range from about 12 ^{o}C in the highlands to about 30 ^{o}C in the lowland areas, with the southern part of the basin being warmest. Seasonally, temperatures are high during September to December, cool during June and July, and fairly warm for the rest of the year.

3.3 Topography

The Lake Rukwa basin has varying altitude and terrain, with features ranging from steep escarpments and towering highlands on the outer margins, to lowland flat plains, valley bottoms and great depressions (Baker and Baker, 2002). The basin is bordered in the south east by the Mbeya Range, in the west by the slopes of the Ufipa escarpment, and in the north-east by rocky cliffs and rolling hills that reach as high as 1,707 m at Mount Sange (Baker, 2002).

3.3.1 Highland Plateau Zone

The highland plateau zone covers the south-eastern part of the basin including the central Mbeya plain and Poroto highlands and parts of Mbozi and Mbeya DC. This area is traversed by several hills punctuated by fertile valleys with altitude ranging from 600 to 2,400 m above sea level and mean annual rainfall ranging from 700 to 2,300 mm. This area is characterized by generally good soils, reliable and plentiful rainfall, moderate temperatures, and high agricultural potential for smallholder farmers. There are three predominant soil types of moderate to high fertility including deep volcanic soils, clay soils with a good mixture of sand and alluvial loam, and silt soil within the valleys. The prevalent vegetation types include a mixture of acacia bushland and grassland of brachystegia woodlands most of which have been widely cleared to create land for the expanding agricultural activities. Major crops grown in this zone include coffee, maize, beans, tea, and banana, and to a smaller extent Irish and sweet potatoes, paddy, pyrethrum, and cocoa. Livestock keeping is also widely practiced.

3.3.2 Lowlands Zone

This part of the basin covers the north and central Chunya plain and Msangani plateau. The predominant features are the vast miombo woodlands and popular gold mining areas. The topography of the area is predominantly flat and undulating with scattered small hills and rock outcrops. The altitude ranges between 1,000 to 1,800 m above sea level, with mean annual rainfall ranging between 600 to 1,000 mm and the rainy season occurring during December to March. The predominant soil types include deep reddish brown loamy sands of poor fertility and dark grey clays in valleys. Common vegetation types include wooded grasslands of *Acacia Commiphora* bushlands and *Brachystegia Julbernadia* woodland. In addition to gold mining, the area is also popular for tobacco growing accounting for more than 80% of all tobacco production in the basin. Other common crop types grown in this area include maize, groundnuts, finger millet, sorghum, banana, cocoa, oil palm, cashew nuts, and paddy. This zone is free from tsetse flies and is also attractive for livestock keeping, bee keeping, and hunting.

3.3.3 Ufipa Plateau

The Ufipa Plateau lies between the two wings of the rift valley formed by Lakes Rukwa and Tanganyika. The plateau forms the western edge of the basin, an area which is densely populated, highly productive, and characterized by intensive land use for both subsistence farming and livestock keeping. The topography comprises gentle plains with moderately slopping hills and plateau lying at an altitude between 1,000 to 2,400 m above sea level. The plateau is mostly grassland and considered to be one of the most productive areas in the basin with good fertile ferralitic soils and reliable rainfall ranging between 800 to 1,200 mm. Major crops grown include maize, finger millet, beans, groundnuts, and cassava. Other socioeconomic activities include fishing and mining of coal and gemstones.

3.3.4 Rukwa Valley

The Rukwa Valley lies between the *Lyambalyamfipa* escarpment and Lake Rukwa and stretches north-westwards from the lake. This area is characterized by extensive flat plains with mean annual rainfall ranging from as high as 1,250 mm in the northern part and reducing southwards to as low as 800 mm on the leeward side of the *Lyambalyamfipa* escarpment. The elevation varies from 1,000 - 1,100 m in the northern section of the valley to 800 - 900 m along the shores of Lake Rukwa. Most areas near the escarpment have a high water table even during the dry season. The valley soils are predominantly sandy loams with moderate to good drainage. The higher parts of the valley are mostly covered in tropical wooded grassland, while the lower parts close to the lake are dominated by extensive grassland consisting of grasses, reeds, and rushes of both permanent and seasonal types. The lake shores are water logged with extensive swamps especially around the northern lake shore and the Ugalla River valley. The inhabited part of the valley is a 1 - 10 km wide strip of land along the escarpment. Major crops grown include maize, paddy, fruits, finger millet, sorghum, and cassava. Livestock keeping, fishing, and lumbering are also commonly practiced in the area.

3.3.5 Katumba Plains

The Katumba Plains represent one of the largest zones occupying most of the north central part of the basin. The area is situated between 1,000 to 1,500 m above sea level and receives mean annual rainfall between 900 to 1,000 mm. The predominant soil type is sandy loam with moderate to good drainage. The area is largely uninhabited, dominated by vast miombo woodlands, and widely infested with tsetse flies. Cultivation takes place in a few isolated and densely populated settlements scattered in the plains. Tobacco is a popular commercial crop grown in isolated complexes. Other crops grown, mostly for subsistence, include maize, beans, cassava, groundnuts, and sunflower. Bee keeping is a popular activity in the plains with honey and bee wax being an important source of household income in most habited areas. Livestock keeping is also practiced in settled areas although on a small scale.

3.4 Hydrologic Features

The basin hydrology is characterized by an extensive network of seasonal and perennial rivers that feed and drain several small lakes and large expanses of swamps and wetland systems before discharging into Lake Rukwa. The complex hydrological system enables the basin to support its vast and unique terrestrial and aquatic ecosystems and a great diversity of plant and animal species, many of them endemic to the basin.

3.4.1 Lake Rukwa

Lake Rukwa is the main hydrological feature of the basin. The lake, which is an inland drainage lake with no outlet, is quite shallow with a mean depth of about 4 m and a highly changing shoreline. The lake experiences very high evaporation rates on the order of 2,000 mm per annum compared to average annual rainfall of about 900 mm. The lake stretches lengthwise for about 165 km, with widths of 37 km in the north basin and a maximum width of 48 km near the middle (Seegers, 1996). The lake experiences significant water level fluctuations and is reported to have completely dried up several times in the past 200 years (Nicholson, 1999). Lake levels were very low during the first half of the 19th century, very high during the last decades of the 19th century, and again declined significantly during the first half of the 20th century. The lake levels recovered again in the second half of the 20th century and experienced highs in the late 1980s. Relatively high levels have generally persisted in recent decades but are exhibiting declining trends.

The northern and western shores of Lake Rukwa are covered by extensive wetlands that include both permanent swamps and temporary floodplains. The swamps are dominated *by Cyperus papyrus* and *Phragmites mauritianus*, among other species. Other permanent or semi-permanent swamps, extending over about 39,000 ha, cover the south-western shores of the north basin and the section between the north and south basins. A significant part of the flood plain (53,000 ha) is an extensive wetland system, which drains the Katavi Plains into Lake Rukwa. Nearly all of the flood plain and wetland system described here forms part of the Katavi-Rukwa ecosystem, a protected area with unique biodiversity and wildlife. Most of the area falls within the Katavi National Park, which encompasses the Katuma River and Lakes Katavi and Lake Chada including their seasonal floodplains. Much of the northern section of Lake Rukwa is within the Rukwa Game Reserve which lies to the southeast of the basin and borders the expanded Mlele Game Controlled Area. On the north-eastern shore of the lake is the recently upgraded Lukwati Game Reserve, situated in Chunya district. The Uwanda Game Reserve covers much of the remaining lake ecosystem. Lake Rukwa lies to the southeast of the protected area complex and borders the Rukwa and Lukwati Game Reserves.

3.4.2 Lake Rukwa Sub-basins

For purposes of this study, the Lake Rukwa basin has been sub-divided into five major sub-basins as stipulated in the project terms of reference. These sub-basins are shown in **Figure 3.2** and include Katuma, Songwe, Momba, Rungwa, Luiche, and Muze. All areas around the lake and outside these five sub-basins have been designated as lake shore areas. A brief description of the hydrology of the individual sub-basins is given below.

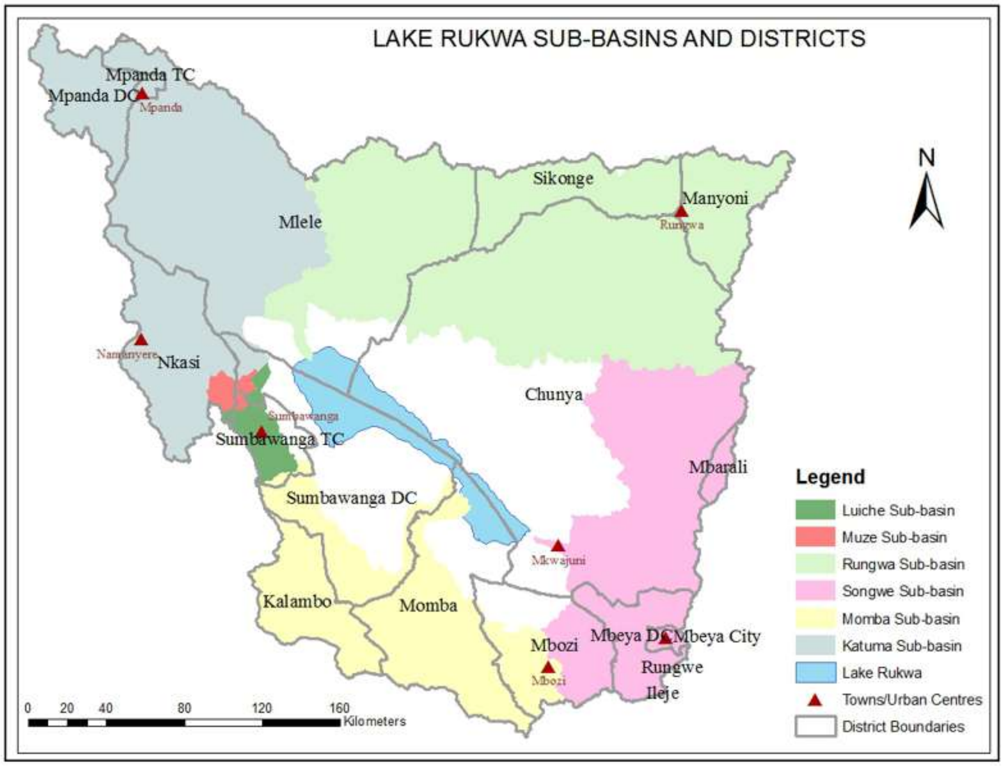

Figure 3.2: Lake Rukwa Sub-basins.

1. Songwe Sub-basin

Songwe sub-basin forms the eastern part of Lake Rukwa basin and extends over an area of about 10,800 km^2 covering parts of Chunya, Mbeya DC, Mbeya Urban, Mbozi, Mbarali, and Rungwe districts. It is drained by three major rivers: River Lupa originating from the eastern plateau and draining the northern and central parts of the sub-basin; and Rivers Songwe and Zira which originate from the Poroto Mountains and drain the southern part of the sub-basin. The rivers flow through the gold mine zone, traversing extensive flat low lands and merge before finally discharging into the southern basin of Lake Rukwa. The sub-basin population is about 843,278 (2012 National Census), 40% of whom live in Mbeya City and the surrounding peri-urban areas. The sub-basin forms part of the southern highland zone of Tanzania mostly characterized by a tropical climate.

2. Katuma Sub-basin

Katuma sub-basin occupies the northwestern part of Lake Rukwa Basin and extends over an area of about 15,800 km^2 covering parts of Mpanda DC, Mpanda TC, Mlele, Sumbawanga DC, and Nkasi districts. It is drained by four major rivers, Katuma, Kavuu, Msaginya, and Msadya. River Katuma originates from the Ufipa plateau, flows southwards traversing a belt of permanent swamps and discharges into Lake Katavi. The river leaves Lake Katavi and flows northeastwards through a large expanse of swamps and finally discharges into a swampy flood plain on the northwestern shores of Lake Chada. Lake Chada is also fed by River Msaginya, which originates from Mlele Hills to the east and flows through an extensive flood plain before discharging into the lake. The Kavuu River leaves Lake Chada at its south-western shore and flows south to a more permanent swampland, which is additionally fed by hot springs. In these swamps the river receives inflows from several smaller seasonal tributaries from both sides of the Rukwa Valley, including River Msadya, which originates from the Ufipa Plateau and drains the southwestern part of the sub-basin, and River Lukima, which originates from Mlele Hills and drains most of the northeastern part of the sub-basin. From the swamp, the river flows southeastwards another 50 km to finally discharge into the swamps at the northwestern shores of Lake Rukwa.

3. Momba Sub-basin

Momba sub-basin occupies the southwestern part of Lake Rukwa Basin and extends over an area of about 9,750 km^2 covering parts of Sumbawanga DC, Momba, Kalambo, and Mbozi districts. It is drained by four main rivers, Momba, Mtembwa, Saesi, and Nkana. River Mtembwa originates from the Ufipa plateau and drains the northwestern part of the sub-basin. It flows southwards through several vast swamps where it is joined by other smaller rivers before discharging into the Iyunga Samyva swamp. The river then exits the swamp and flows southeastwards before joining River Saesi which originates from the Nthumbe Hills. River Saesi drains the western part of the sub-basin and discharges into Tesa swamp where it is joined by several smaller rivers that drain the southern part of the sub-basin. From the swamp, Saesi River flows northeastwards, is joined by rivers Kipanda and Matonto (originating from Izombo plateau), and crosses the Lyambalyamfipa escarpment into the Rukwa Valley. In the valley, Saesi River is joined by Nkana River to form the Momba River. River Nkana originates from the southern highlands in Mbozi District and drains the southeastern part of the sub-basin. It is fed by several rivers including Mpemba and Mko from the Chingambo Ranges. Momba River flows northeastwards across the Rukwa Valley and finally flows into the western shores of Lake Rukwa.

A small portion of the Momba River watershed (in the southwest) extends into Zambia. Thus, Momba is a transboundary (shared) river, and its integrated planning and management requires the development of mutually agreed upon plans with Zambia.

4. Rungwa Sub-basin

Rungwa sub-basin occupies the northern part of Lake Rukwa Basin extending over parts of Chunya, Mlele, Sikonge, and Manyoni districts. It covers an area of about 21,640 km^2 and is the largest sub-basin draining approximately 25% of the Lake Rukwa Basin area. The Rungwa River originates from Rungwa Swamp on the eastern plateau, flows northwards traversing vast expanses of permanent swamps, receives inflows from several smaller tributaries, and finally discharges into the Itumba swamp on the northern shores of Lake Rukwa. The main Rungwa tributaries include Rivers Musa and Mkombizi, which drain the eastern and northern parts of the sub-basin respectively, and Rivers Piti and Mwipa draining the southern part of the sub-basin.

With a population of about 50,289 (2012 National Census), Rungwa is the most sparsely populated sub-basin in Lake Rukwa basin comprising less than 2% of the total basin population. Vast parts of the sub-basin fall within protected areas (game reserves, forest reserves, game controlled areas, etc.) that are mostly uninhabited and dominated by vast miombo woodlands.

5. Luiche Sub-basin

Luiche is one of the two smallest sub-basins in Lake Rukwa basin covering an area of only 913 km^2. The sub-basin covers parts of Sumbawanga MC, Sumbawanga DC, and Nkasi districts. It is drained by River Luiche, which originates from the southern part of the Ufipa Plateau and traverses a vast expanse of swamps before grooving its way through the *Lyambalyamufipa* escarpment into the Rukwa Valley and finally emptying into swamps on the northwestern shores of Lake Rukwa. The main Luiche tributaries include, among others, River Nantula draining the eastern part of the sub basin, River Lukangau draining the western part, and Rivers Pande and Matusha draining the northwestern part.

6. Muze Sub-basin

Muze is the smallest sub-basin with an area of about 354 km^2 covering parts of Sumbawanga MC, Sumbawanga DC, and Nkasi districts. It is drained by River Muze which originates from the Ufipa Plateau, meanders through isolated swamps before cutting 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.

3.5 Socio-economic Importance

The Lake Rukwa basin supports a plethora of socioeconomic activities. It is a domestic water supply source for the major urban areas of Mbeya City, Sumbawanga Municipal, Mpanda Town Council, District Headquarters of Chunya, Mpanda and Mbozi, and several other urban centers and rural communities. The basin also provides water for irrigation, livestock, wildlife, mining, fishing, marine transportation, and ecological sustainability. Agriculture (including livestock keeping) is the largest and most important economic sector employing more than 80% of the population and contributing about 70% of the basin’s GDP. The major food crops include maize, potatoes, beans, and horticultural crops. The basin’s two regions (Mbeya and Rukwa) are among the top four maize producing regions (Big Four) in Tanzania. Several cash crops are also grown including cotton (in Sumbawanga and Mpanda districts), coffee (mostly in Mbozi), and tobacco (in Chunya and Mpanda districts). Other important cash crops are paddy and groundnuts.

The basin is home to the Katavi National Park, the third biggest park in Tanzania, and several Game Reserves. The Park is the core of the western Tanzanian wildlife circuit and part of the Katavi-Rukwa-Lukwati ecosystem, an area of important local and national conservation significance. The Katavi Park, together with Rukwa and Lukwati Game Reserves on its south-eastern fringes and the surrounding hunting blocks, constitutes one of the biggest and richest wildlife areas in Tanzania. Several other tourist attractions exist including: the Rungwa Game Reserve; Wildlife Open Areas of Chunya, Piti, Rungwa South, and Mzombe West; Mountains Kwimba and Mwene; natural hot springs in Ileya village; Masololo and Matundasi caves in Ngwala village; and sandy beaches on the shores of Lake Rukwa. These, coupled with its unique flora and fauna, make the basin a major potential tourist destination in Tanzania.

The basin is also endowed with significant mineral deposits, such as gold, coal, mica, iron ore, limestone, salt, and several gemstones. However, mining is carried out on a small scale, is unregulated, and is endangering the environment through pollution and contamination of water sources. Streamlining and regulating mineral exploitation would significantly increase revenue collection and also help minimize water pollution and environmental degradation. At present, the only minerals exploited in significant quantities are gold in Chunya and Mpanda, and limestone in Mbeya.

Bee keeping is also an important socioeconomic activity, especially in Chunya and Mpanda Districts. The abundance of the 'miombo' type of vegetation creates favorable conditions for beekeeping at a commercial scale. It is estimated that about 20 tons of honey and 5 tons of wax are harvested annually (Hassan *et al.*, 2001). Lack of licensing procedures makes it difficult to keep track of the beekeepers who are free to trap bees and collect honey.

Although the basin is well endowed with significant natural resources, it is still largely under-developed compared to other regions of Tanzania. Basin water use, though currently low, is expected to grow significantly in the near future due to a growing population, expansion of irrigated agriculture, and general increase in the basin's other socio-economic activities. The rising water demands are expected to exert more pressure on water resources and intensify conflicts among competing water uses. The situation is likely to be exacerbated by global climate change whose impacts are already manifesting themselves in terms of increased frequency and magnitude of extreme weather events (droughts and floods). The challenge for the basin water managers is, therefore, how to sustainably manage the growing water demands while protecting the environment. The proposed IWRMD Plan, developed through a stakeholder participatory process, provides a comprehensive framework for addressing current and future water resources management and development challenges in the basin.

4. Baseline Socio-economic Conditions

4.1 Basin Socio-economic Conditions

Detailed socio-economic surveys and assessments were conducted to establish baseline conditions and the level of dependence on the basin water resources by riparian communities. Detailed findings are presented in ***Volume II: Lake Rukwa Basin Socioeconomic Profile***. Summary findings are summarized next.

4.1.1 Population Size, Growth Rate, and Density

The Lake Rukwa Basin population is about 2,531,692 (2012 National Census), 80% of whom live in rural areas and 20% in urban areas. **Figure 4.1** shows a comparison of human population across sub-basins. Songwe sub-basin has the highest population of about 843,278 accounting for about 33% of the total basin population. Rungwa is the most sparsely populated sub-basin accounting for only about 2% of the basin population. **Figure 4.1** also shows that the population growth rate for four of the sub-basins is above the national average of 2.9%. Such growth rates are not sustainable and pose significant challenges for management and utilization of the basin's resources. This situation also creates significant challenges for service delivery as the rate of investment in socioeconomic infrastructure is very low to cope with the rapid population growth. Overall, the basin has a low population density (about 30 persons per km^2) compared to the national average of above 40 persons per km^2. Population density varies significantly between sub-basins with Luiche having the highest of about 180 persons per km^2 while Rungwa has the lowest of about 2 persons per km^2. Generally, population distribution is greatly influenced by soil fertility and conducive climatic conditions, availability of socioeconomic opportunities, accessibility to good social services, and better employment and business opportunities in urban areas. Large swaths of land are part of national parks and game reserves and are not open to human habitation.

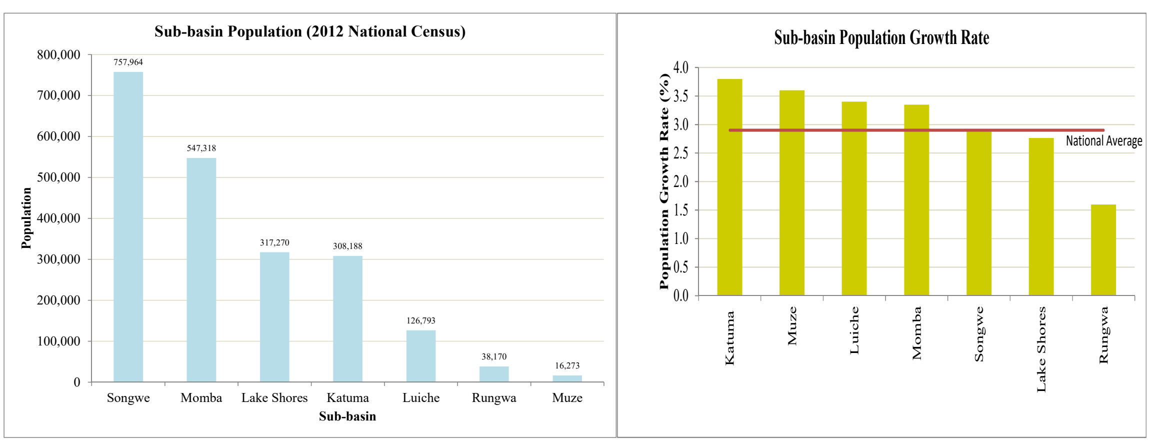

Figure 4.1: *Left:* Sub-basin Population (2012 National Census); *Right:* Population Growth Rate.

4.1.2 Education, Occupation, and Sources of Household Income

The majority of household heads in the basin are educated only up to primary level (see **Figure 4.2)**. On average, about 70% of household heads received only primary education with a small percentage of about 13% and 7% receiving secondary and post-secondary education respectively. About 10% of the household heads did not receive any education at all. Agriculture (crop farming and livestock keeping) is the leading economic activity in all sub-basins employing more than 60% of the population. Other significant employment categories are formal and self-employment (e.g., retail shops, street vending, brick and craft making, charcoal burning, mining, transportation) that on average employ about 12% and 10% of the basin population respectively. The major source of household income is sale of agricultural produce (food and cash crops; see **Figure 4.2**). About 55% of the basin households depend on agricultural produce sales as their main household income.

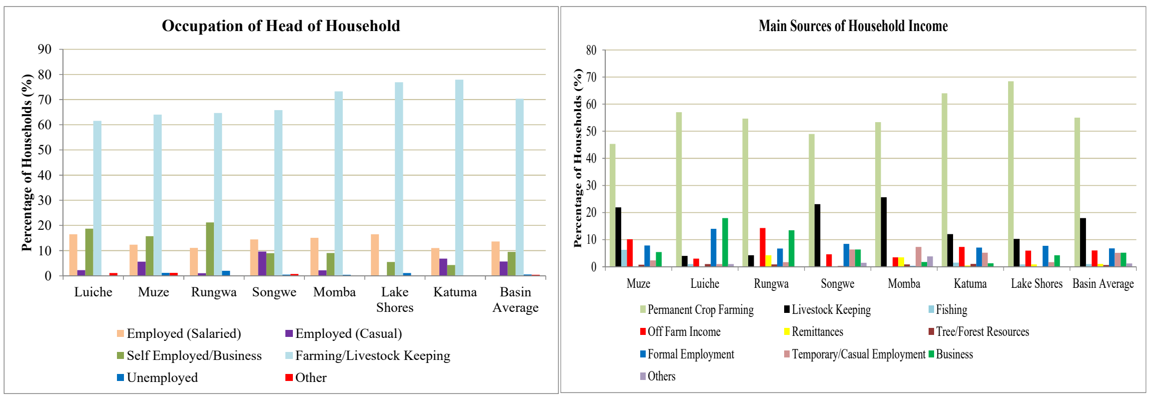

Figure 4.2: *Left*: Household Occupation; *Right*: Household Income.

4.1.3 Poverty Levels and Literacy Rates

The population below the poverty line ranges from 12.4% in Mbeya City to 44.4% in Nkasi DC. All the basin districts Mpanda TC, Mpanda DC, and Nkasi DC have a smaller percentage of the population below the poverty line compared to the national average of 34%. Poverty levels are much higher in rural areas because of fewer economic opportunities (for business and employment). According to the 2010 Demographic and Health Survey (NBS, 2010), Mbeya and Rukwa regions had literacy rates of 79% and 72 % respectively compared to the national average of about 77%. The results also show higher literacy rates among males [Mbeya (86%); Rukwa (80%)] than among females [Mbeya (72%); Rukwa (61%)].

4.1.4 Access to Social Services

Domestic Water Supply: Rural and urban water supply coverages in all the basin districts fall short of the national 2010 targets, except for Mbeya City. Access to clean drinking water in rural areas varies from about 38% in Mbeya DC to 56% in Mbeya City Council, while access in urban areas ranges between 16% in Nkasi to 95% in Mbeya City. The spatial variability in water supply coverage is mostly attributed to differences in investment patterns in the different districts over the years, but may also reflect the relative technical difficulties of developing and maintaining water supplies in different parts of the basin.

Sanitation: The majority (about 88%) of households rely on traditional pit latrines for their household sanitation. Very few households rely on other sanitation facilities such as ventilated improved pit latrines (4.5%), flush toilets (7.2%), and other facilities (0.3%). Reliance on pit latrines by the majority of basin riparians has implications for water pollution due to poor 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 90% of the basin population. It is mostly used for domestic cooking and lighting and in diverse subsistence economic activities such as brick making, pottery and curing of tobacco. Fossil fuel such as kerosene is also widely used for lighting purposes mostly in the rural areas but also in urban areas where it is used for cooking as well. Less than 5% of the basin households have access to the national electricity grid operated by TANESCO. Over-reliance on fuel wood is responsible for the wide spread deforestation observed. 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 Lake Rukwa Basin districts is very poor compared to other parts of Tanzania. Sumbawanga DC has the lowest estimated number of people per health facility (i.e., 5,066) compared to Mbozi DC and Mpanda DC with about 10,953 and 10,773 people per health facility respectively. There is also a general shortage of medical staff in all basin districts. The mean doctor/population ratio for Rukwa basin is about 1:112,359, far below the WHO recommended standard of 1:10,000 and the national average of 1:25,000. The trend is similar in all districts except Mbeya CC with a doctor/population ratio estimated at 1:19,259. The most common causes of morbidity and mortality are malaria, acute respiratory infection (ARI), anemia, pneumonia, diarrhea, urinary tract infections (UTI), skin infections, ear infections, intestinal worms, clinical AIDS, and tuberculosis. Malaria is the leading cause of morbidity and mortality in Lake Rukwa basin. Malaria prevalence is reported to be higher in rural areas (5%) than urban areas (1%), and highest in the lake zones.

4.1.5 Transport and Communication Infrastructure

Roads are the predominant mode of transport accounting for more than 90% of all goods and passenger transportation. Most roads in the basin are usable only during the dry season and become impassable during the rainy season. For example, in Rukwa region more than 50% of the roads are unusable in the wet season due to poor maintenance, lack of bridges at river crossings, and slippery surfaces. Railways are another important means of transport especially for heavy goods. The Tanzania–Zambia Railway (TAZARA) line from Dar es Salaam to Tunduma and Kapiriposhi in Zambia traverses through Mbeya region with four railway stations in the basin (Vwawa in Mbozi DC, Tunduma in Momba DC, and Uyole and Iyunga in Mbeya CC). Marine transport on Lake Rukwa is not well developed but potential exists. Transportation on the Lake is by use of boats and small canoes transporting fishermen and businessmen between different landing sites. Air transport to and from the basin was given a major boost following the recent commissioning of Songwe International Airport in Mbeya DC. The airport has daily flights to and from Dar es Salaam from where passengers can make connections to other regional and international destinations. Availability of fast, convenient, and reliable transport to and from the basin is likely to boost the tourism industry, facilitate businesses, and stimulate general economic development. Besides the international airport in Mbeya, there are five airstrips in Mbeya region (located in Chunya DC at Kiwanja, Lupa, Piti, Lila and Lukwati) and one in Mbeya CC.

Telecommunication services consist of telephones (landline and cellular), internet cafes, radio stations, television stations and postal services. Cellular phones services are provided by four major companies (Vodacom, Airtel, Tigo, and Zantel). Tanzania Telecommunications Company Limited (TTCL) is the sole provider of landline services. The basin also has a few television stations and FM radio stations serving different districts. Generally, urban areas are better served by telecommunication services than rural areas where network coverage is very poor and limited.

4.2 Water Resources Management Practices

The National Water Policy (2002) and Water Resources Management Act (2009) established a comprehensive institutional framework for water resources management and development at all levels. Specifically, the policy and legal framework entrenches the fundamental principle of devolution of water resources management functions to the lowest appropriate level. It also recognizes the hydrological basin as the most appropriate water resources planning and management unit. Implementation of the new institutional framework has been ongoing for a number of years with mixed results. The four basin water resources management levels stipulated in the law include basin water boards, catchment and sub-catchment water committees, and water user associations or groups. The intention is that eventually all become administratively and financially autonomous in the management of water resources under their respective areas of jurisdiction. Review of the experience and lessons learned in implementation of the existing water resources management framework in Lake Rukwa Basin revealed several critical gaps which have been presented in detail in ***Volume I: Lake Rukwa Basin Socioeconomic Profile***. There is general concern that all the basin management institutions have not yet developed the requisite capacity, cohesion, and coordination to ensure sustainable management and development of water resources at all relevant levels. Summary findings are presented next.

(1) Weak Mechanisms for Implementation of Policies and Enforcement of Laws

The water sector has a strong and elaborate policy, legal, and institutional framework in place. However, the main challenge is weak implementation of policies and enforcement of laws by the responsible institutions due to inadequate technical and financial resources. Without strong enforcement mechanisms, perpetrators cannot be held accountable for their actions. This serves as a disincentive to the otherwise law abiding citizens who will be discouraged from continuing to abide by the law while offenders go unpunished. There is a need to review the existing enforcement mechanisms to promote cost effective and incentive-based approaches to implementation of policies and enforcement of laws other than the existing command-and-control practices.

(2) Weak Provisions for Effective Participation of LGAs in WRM

Local Government Authorities (LGAs) have a central role to play in water resources management and development in their areas of jurisdiction. However, this role is not explicitly emphasized under the existing water resources management framework. Consequently, most LGAs regard water resources management as being the responsibility of Basin Water Boards (BWBs) and not one of their core functions, and they are currently playing a peripheral role. Given the prevailing technical and financial challenges of BWBs, water resources management functions can best be implemented when various levels of government are legally allocated distinct but mutually reinforcing roles. This will help leverage resources from LGA budgets to support implementation of water resources management related activities in their jurisdiction. The Act should also increase visibility of LGAs in the basin decision making processes by enhancing their representation on the BWBs from one representative currently to several representatives reflecting the diversity of LGAs.

(3) Inadequate Stakeholder Representation in Basin Decision Making Organs

The WRM Act No.11 of 2009 provides for establishment of 10 member BWBs and 5 member catchment/sub-catchment committees. This level of representation is quite low considering the large expanse of some of the basins/catchments and the wide diversity of stakeholder groups and interests. The law could be reviewed to provide for broader stakeholder representation. In the same spirit of fostering true stakeholder representation and participation in decision making, the current process of appointment of members of the BWB should also be reviewed, so that members are elected by the different catchment/sub-catchment forums to ensure representation of diverse and unique interests/concerns in the basin planning and decision making processes.

(4) Weak inter-sectoral Coordination and Collaboration on WRM Issues

The notion of Integrated Water Resources Management is still looked upon as a purely water sector affair and is less appreciated or even understood by other government sectors, even those with high stakes in sustainable water resources management (e.g., Agriculture, Energy, Environment, Fisheries, Livestock, Industry, and Wildlife, among others). Current practice shows that there is very little consultation and collaboration with the water sector, if any, by these sectors during preparation and implementation of their respective sector development plans. Even at basin level, joint planning for water resources management and development between the BWB and other sectors such as agriculture and land use is more theory than practice. No comprehensive mechanisms for cross-sectoral planning and collaboration are currently being rigorously followed at the basin level. As a priority, it is important for all water resources dependent sectors at all levels to embrace the principle and practice of integrated water resources planning and management for sustainable economic development.

5. Water Resources Availability Assessments

Detailed water resources availability assessments were conducted under this project and are detailed in ***Volume III: Water Resources Availability Assessments***. The key findings and conclusions are summarized next.

5.1 Climate

5.1.1 Rainfall

The basin climate exhibits marked variations at seasonal, annual, and inter-annual time scales. Climate cycles (i.e., years of high or low rainfall) occur with an average frequency of 5 to 6 years. The historical record does not show evidence of any statistically significant long term trend (increasing or decreasing) of the annual or wet season rainfall. The average wet season rainfall over the entire basin is 133.8 mm/month, but there have been years when the wet season rainfall was as low as 90 mm/month or as high as 192.5 mm/month. Average rainfall amounts vary by sub-basin, with Rungwa receiving the least (121.8 mm/month) and Momba the most (148.7 mm/month). Rainfall deficits and excesses affect all sub-basins at the same time and have the potential to magnify the basin-wide impacts of droughts and floods. The Rungwa sub-basin is most prone to severe droughts and floods. Future climate assessments show that average future rainfall is not expected to change significantly from the historical regime, except that rainfall extremes are expected to intensify in magnitude and frequency of occurrence.

5.1.2 Temperature

The average year-round temperature over the basin is 21.4 ^{o}C. The warmest average temperatures occur over Lake Rukwa and adjacent areas to the north (22–23.5 ^{o}C), and the coolest occur over the Muze sub-basin (19.4 ^{o}C). Historical temperature records show significant increasing average temperature trends for all sub-basins and all months of the year. Recent average monthly temperatures show an increase of nearly 1^{o}C over the average monthly temperatures of the 1950s, 1960s, and 1970s. Climate warming portends adverse hydrologic consequences, as it is expected to increase evapotranspiration, reduce watershed runoff, reduce groundwater recharge, increase irrigation (and other water) demands, and decrease lake levels. Future climate assessments show that temperature and potential evapotranspiration are expected to rise significantly above historical levels. Lake Rukwa Basin temperatures are projected to rise by an average of 1–5 ^{o}C over current levels by the end of the century (Interim Report II).

5.2 Surface Water Resources

The basin hydrology is characterized by an extensive network of seasonal and perennial rivers that feed and drain several small lakes and large expanses of swamps before they all discharge into Lake Rukwa, the main basin hydrological feature. Lake Rukwa is vulnerable to climate variability and change because of its shallow depth and large surface area. Existing historical data is spatially sparse over large parts of the basin, temporally intermittent, and to a large extent inadequate to support detailed hydrologic and water resources assessments. In addition, the rating curves of most river-gauging stations are outdated and need recalibration. There is an urgent need to upgrade the monitoring network to collect reliable, consistent, and contemporaneous data that can be used to monitor the hydro-climatic basin processes: river flows at several locations within each sub-basin; rainfall and evapotranspiration over the watersheds upstream of locations where river flow is measured; lake levels; lake surface area and storage; and groundwater levels.

5.3 Groundwater Resources

The general geology of the Rukwa Basin is comprised mainly of Precambrian (Archaean, Proterozoic) and Cenozoic formations. These formations crop-out over about 88% and 11% of the area, respectively. Four aquifer types exist, namely: intergranular, intergranular and fractured, fractured, and faults. The water table generally mirrors the topography and is influenced by major drainage lines. Depths to groundwater tend to become deeper toward Lake Rukwa which acts as an inland drainage 'sink' with no external drainage or outlets. There are two groundwater sinks, one in the north-west and the other in the south-east of the LRRV, which presumably correspond to the reported dual lake nature of Lake Rukwa. 57% of the existing basin boreholes have yields between 0.5 and 2.0 l/s, while 22% have low yields of < 0.5 l/s. The low yield boreholes are mostly located in the northeast around Rungwa and toward the northwest near Namanyere. Yields greater than 2.0 l/s occur in the Lake Rukwa Rift Valley (LRRV) and along the higher lying recharge area of the Ufipa Plateau. Higher yielding boreholes also occur in the southeast along the Mbeya Range.

The basin has an estimated mean recharge ranging between 0.3 to 1.6 billion m^3 per annum. This equates to an average recharge factor between 0.3 to 2.5% of MAP. Initial estimates indicate that about 580 billion m^3 of groundwater is stored in basin aquifers, 55% of which occurs in the LRRV aquifers. The total volume of groundwater that is potentially available for utilization under normal rainfall conditions (considering a wet year cycle of five years and drought index of one year) is estimated to be 9.4 billion m^3/year, and the realistically exploitable quantity of groundwater is estimated to be about 4.1 billion m^3/year. The groundwater potential is unevenly distributed with about 939 m^3/ha/yr being available in the LRRV area and about 521 m^3/ha/yr elsewhere. There are no groundwater level monitoring stations in the basin. This is a serious shortcoming for the effective management of groundwater resources. There is an urgent need to carry out a comprehensive basin-wide groundwater monitoring and characterization program to obtain aquifer parameters (e.g., hydraulic conductivity, transmissivity, and storativity) to improve the preliminary assessments of aquifer types and groundwater potential.

5.4 Water Quality

Generally, the basin surface waters and groundwaters have relatively poor physical and bacteriological quality and good chemical quality. Poor physical quality is most pronounced in surface water. There is strong seasonality in water quality with poor water quality being associated with the rainy season. Both surface and groundwater in several basin areas is contaminated with bacteria of fecal origin. The problem is most serious in surface waters, where about 75% of tested water samples had coliform counts above national standards. However, only 10% of groundwater sources exhibited this problem. Lake Rukwa is an alkaline lake with a sodium-bicarbonate water type. The pH of the lake ranges from 8.8 to 9.8; alkalinity is about 900 mg $CaCO_3$/L, and electrical conductivity ranges from 2200 to 2800 µS/cm. The lake has poor physical and bacteriological quality.

The main water quality issues in the basin include high silt loads from widespread catchment degradation; poor rural sanitation leading to physical and bacteriological contamination of surface and ground water resources; poor urban sanitation leading to heavy pollution of streams draining urban areas; high iron from suspected pipe rust; high iron occurring naturally in rock formations; high fluoride naturally occurring in groundwater sources; high levels of mineralization and hardness in groundwater; and heavy metal pollution from mining activities. Heavy metal pollution from gold mining poses the greatest threat to water quality. Artisanal mining activities increasingly mobilize heavy metals from goldfields and transport them into surface water bodies. Heavy metals are present and are likely accumulating in Lake Rukwa.

The current water quality dataset in the basin is scanty (has limited spatial and temporal coverage) and has some data quality issues. The water quality monitoring network is performing poorly in terms of the annual turnout of water samples, spatial coverage, scope of potential polluting activities monitored, and range of parameters measured. The poor performance of the water quality monitoring network is attributed to budgetary constraints, limited analytical capacity of the water quality laboratories, and inaccessibility of some water sources located in remote and protected areas. There is an urgent need to improve the capacity of the Mbeya and Sumbawanga water quality laboratories for (a) field sampling and analysis including field sampling gear (equipment for sediment transport measurement of suspended solids and bedload); (b) lake sampling; (c) reviewing the adequacy of field transportation facilities; (d) improving the analytical capability to include selected heavy metals; and € improving laboratory quality control and quality assurance systems.

6. Sectoral Water Use Assessments and Findings

6.1 Introduction

Lake Rukwa basin water demand projections for 2015 to 2035 were assessed for the following water use sectors: domestic (urban and rural), irrigation, livestock, and industrial. The detailed assessment findings are presented in a separate report volume: ***Volume III – Water Demand Projections (2015 – 2035)***. The main findings, conclusions, and recommended actions are summarized below.

The basin aggregate consumptive water demand is projected to increase from 600.42 million m^3 in 2015 to about 1298.49 million m^3 in 2035, an increase of about 116%. At the sectoral level (see **Figure 6.1**), the biggest increase in water demand is projected to be in the irrigation sector (631.7 million m^3, accounting for 90% of total basin increase). The other sectors are expected to experience much smaller increases: domestic water demand (56 million m^3, accounting for 8%); livestock water demand (8 million m^3, accounting for 1%); and industrial water demand (2 million m^3, accounting for less than 1% of total basin increase).

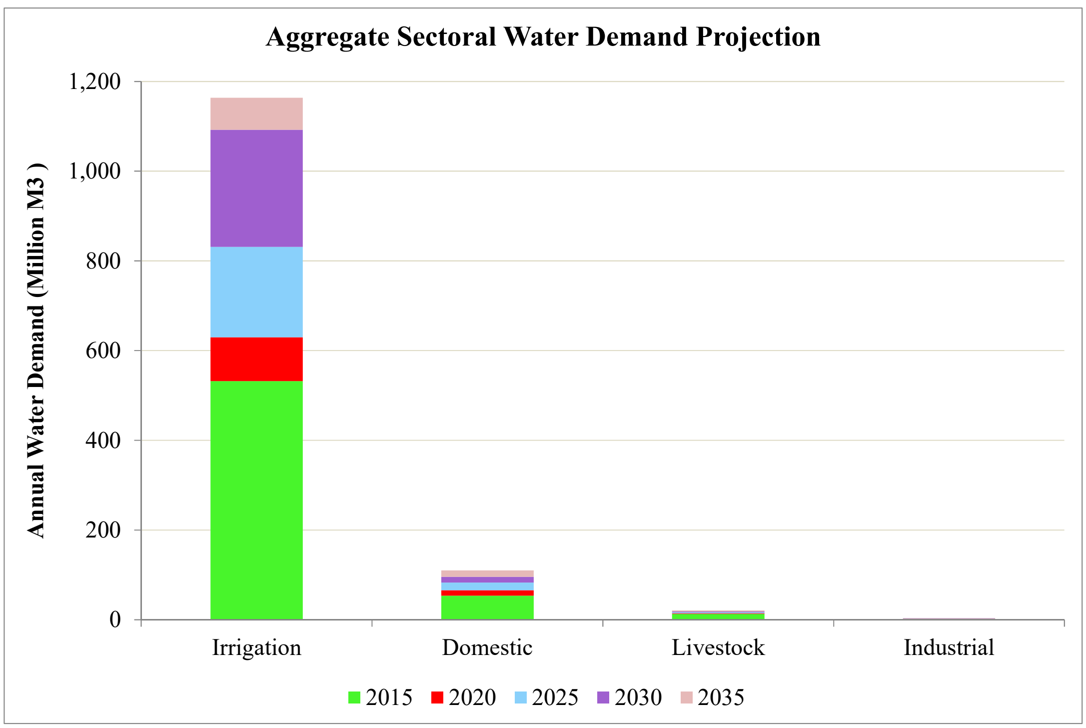

Figure 6.1: Sectoral Water Demand Projections.

6.2 Irrigation Water Requirements

Irrigation is the highest consumptive use accounting for about 90% of the total water consumed in the basin. Currently, less than 50% of the potential irrigable land is under irrigation. This implies that significant potential exists for future irrigation expansion. Additional water use will put more pressure on the available water resources and should be planned and managed carefully taking into consideration other water uses. Based on the existing irrigation development plans, the Lake Rukwa basin annual irrigation water requirements are projected to increase from about 492 million m^3 in 2012 to about 1,164 million m^3 by 2035, an increase of about 140% (see **Figure 6.2**). This is attributed to the projected increase in irrigated acreage from about 26,818 ha in 2012 to about 56,637 ha by 2035 (see **Figure 6.3**). The highest growth in irrigation water demand is likely to be observed in two sub-basins, Momba and Lake Shores. The same two sub-basins are projected to register the highest increase in irrigated area, 37% and 27% of the total basin increment by 2035 for Momba and Lake Shores respectively. This is consistent with the current national and local irrigation development plans which indicate that most of the potential medium to large scale irrigation developments are likely to be located in the two sub-basins. Of the additional 672 million m^3 of irrigation water required between 2012 and 2035, 40% of it will be required in Momba sub-basin and 6% will be required in Songwe sub-basin. This implies that although Momba is not yet categorized as a water stressed sub-basin, the situation is likely to change if the anticipated irrigation developments are implemented over the planning horizon. This uneven growth in additional irrigation water requirements highlights which specific sub-basins should be of major concern to the LRBWB for water demand growth in the medium to long term. To achieve the above irrigation targets, the government has formulated a number of strategies and plans to transform Tanzania's economy from a low productivity, agricultural based economy to a semi-industrialized economy characterized by modernized agricultural, industrial, and service sectors. Of direct relevance to irrigation development are the following strategies and plans: The Agricultural Sector Development Strategy (ASDS); Agricultural Sector Development Program (ASDP); National Irrigation Master Plan (NIMP); Kilimo Kwanza; SAGCOT; BRN; and several others. The envisaged irrigation developments and targets under each of these strategies and plans have been carefully reviewed and are the basis for the irrigation water demand projections described herein. Besides water availability, realization of the full irrigation potential is dependent on availability of irrigation water supply infrastructure to ensure adequate and reliable water supplies to all irrigable areas. Achieving targets would require significant investments in irrigation infrastructure. The three main drivers of irrigation development in the basin over the planning horizon are likely to be the BRN initiative (currently focusing on the Mpanda area), the SAGCOT initiative (in the Sumbawanga Cluster area), and Local Government Authorities.

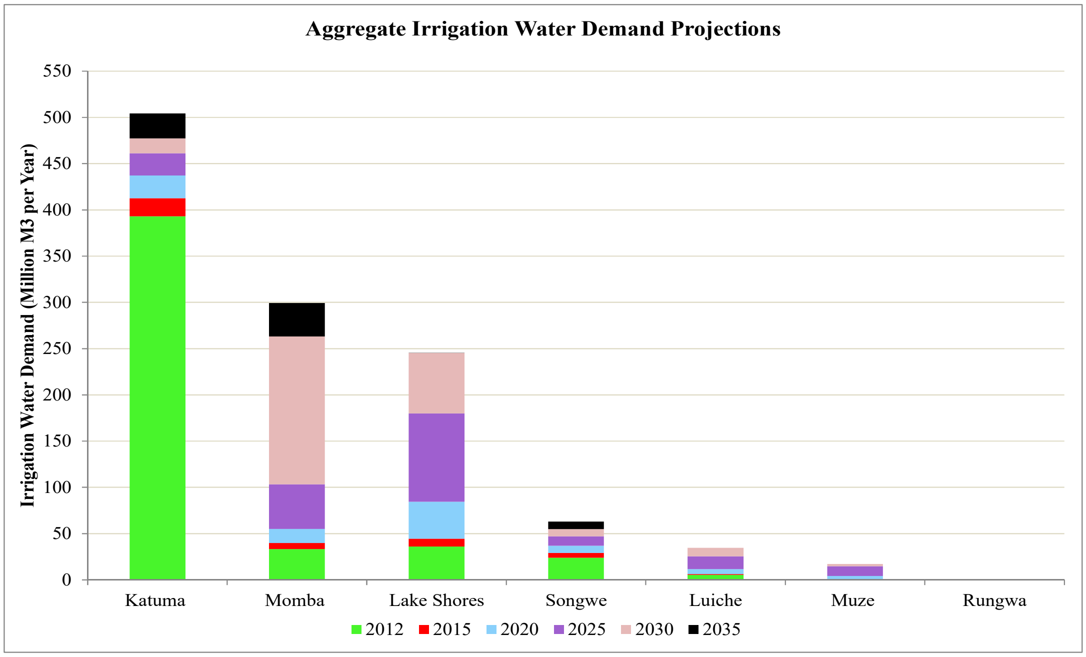

Figure 6.2: Aggregate Irrigation Water Demand Projections.

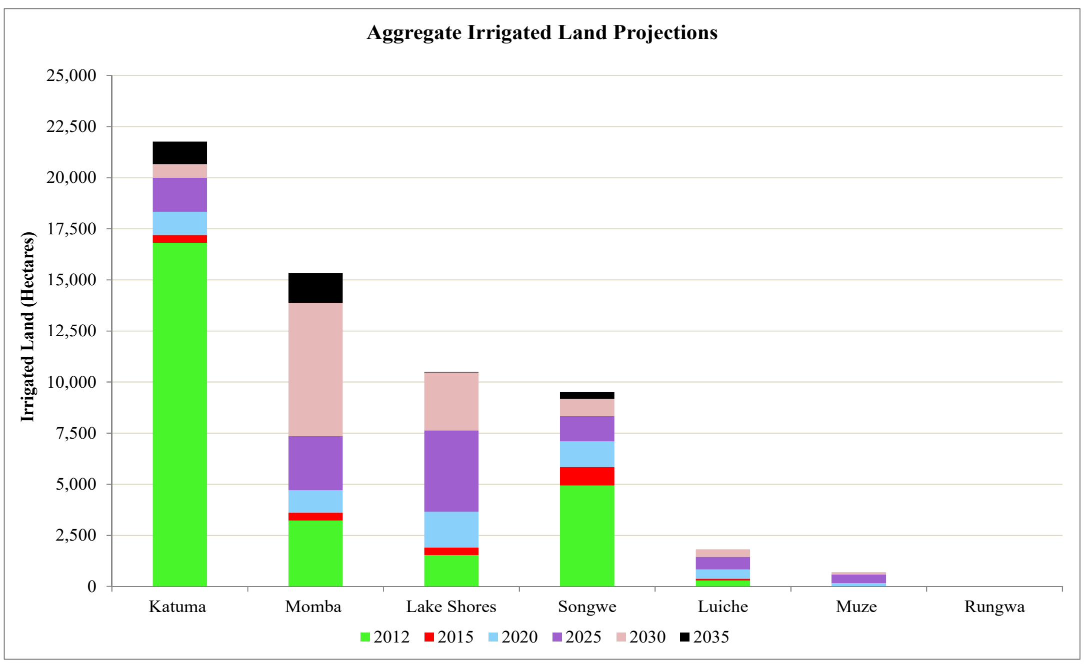

Figure 6.3: Aggregate Irrigated Land Projections.

(1) Irrigation Developments Planned under the BRN Initiative

The Big Results Now (BRN) initiative is a performance management methodology adopted by Tanzania in August 2012 to catalyze the planning, delivery, monitoring, evaluation, and implementation of national development projects prioritized under the Five Year Development Plans (FYDP). Six strategic sectors (i.e., Agriculture, Water, Energy, Education, Transport, and Resource Mobilization) were identified as National Key Result Areas (NKRAs) in early 2013.

NKRAs were prioritized for immediate implementation under the initiative. BRN focuses on key strategic projects that have the potential to stimulate economic growth and bring immediate results in the short-term to meet the Vision 2025 goals and targets. Interventions in the Agriculture NKRA are increasing agricultural productivity and investment. Resolving key sector bottlenecks, such as unlocking land to enable investment and support to small holder farmers in three major crops (rice, maize, and sugarcane) are a focus. The 2015 targets for the Agriculture NKRA include: (i) 25 commercial farming deals for paddy and sugarcane; (ii) 78 collective rice irrigation and marketing schemes; and (iii) 275 collective warehouse-based marketing schemes. Of the 78 existing smallholder rice irrigation schemes, only 7 are in the basin in Mpanda Region. These include Iloba, Kakese, Karema, Mwamapuli, Mwamkulu, Ugala, and Urwira. Interventions in these schemes focus on introducing a service provider in each target district to manage the identified schemes while building irrigator organizations' capacity over a two year period. The private service provider is expected to play a catalytic role along the agricultural production value chain to stimulate agricultural productivity. The interventions in Mpanda Region target increasing rice production from 9, 819 MT to 21,000 MT and improving yields from 3.4 MT/ha to 8 MT/ha.

(2) Irrigation Developments Planned under SAGCOT

The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) initiative is a public-private partnership launched in 2010 to facilitate developing competitive agribusiness value chains across the Southern Corridor. The Southern Corridor covers a total area of about 287,000 km^2 extending from the coastal plains through Kilombero Valley and the Usangu plains to the Southern Highlands. The initiative is envisioned to stimulate rapid growth and modernization of the agricultural sector. This growth and modernization can benefit food security, poverty reduction, economic prosperity and reduced vulnerability to climate change, thus contributing to the goals and objectives of TDV 2025. Of the six pilot clusters identified under the initiative, only one, the Sumbawanga Type III cluster, partly falls within Lake Rukwa basin. SAGCOT has set specific targets to expand the portion of irrigated area under the Sumbawanga Cluster located in Lake Rukwa basin from the current 2,528 ha to 3,075 ha by 2015; 6,639 ha by 2020; 14,751 ha by 2025; and 23,388 ha by 2030. The planned irrigation development mostly focuses on modernization of existing public irrigation schemes through rehabilitation and expansion of existing irrigation infrastructure. The above incremental irrigation developments will translate into additional irrigation water requirements of 11 million m^3 by 2015; 63 million m^3 by 2020; 164 million m^3 by 2025 and 213 million m^3 by 2030.

(3) Local Government Authorities Irrigation Development Plans

Local Government Authorities (LGAs) play a lead role implementing irrigation development initiatives. The developments are supported through the Local Government Capital Development Grant (LGCDG), District Agricultural Development Grant (DADG), District Irrigation Development Fund (DIDF), National Irrigation Development Fund (NIDF), private sector, and contributions from beneficiary farmers. Interventions under the Local government irrigation development activities mainly focus on improving existing traditional irrigation schemes through rehabilitation and expansion of existing irrigation infrastructure, including construction of rainwater harvesting and storage infrastructure. Through the Obstacles and Opportunities to Development (O&OD) process, farmers identify operational issues and constraints in existing irrigation schemes and also propose potential new irrigation sites. New sites are then screened and prioritized and included in the District Agricultural Development Plans (DADPs). LGAs through the Prime Ministers' Office (PO-RALG) request funds from the District Irrigation

Development Fund (DIDF) for construction/rehabilitation of traditional irrigation schemes in their jurisdiction. The DIDF is a funding mechanism established under the Agriculture Sector Development Program to finance district level irrigation activities on a competitive basis. The Fund is administered by the Ministry of Agriculture, Food and Cooperatives, which disburses requested funds to respective LGAs for implementation of approved activities. LGAs are responsible for outsourcing technical assistance for the preparation and implementation of the planned irrigation investments.

6.2.1 Issues and Challenges

One of the major challenges associated with irrigation water use in the basin is very low water use efficiency. Traditional irrigation schemes are the majority accounting for about 78%. Traditional schemes have inadequate and poorly constructed infrastructure which result in high water losses and, thus, low water use efficiency. A great potential for water savings exist if traditional infrastructure is replaced with improved infrastructure. Studies in other basins in Tanzania (Great Ruaha sub-basin) have demonstrated that modest improvements in traditional irrigation infrastructure can result in appreciable water use efficiency gains and reduction in irrigation abstractions (SMUWC, 2001). Water losses are not limited to traditional irrigation schemes only. Significant water loss is also experienced in schemes with improved irrigation where actual water abstractions are often more than the required or permitted allocations. In addition, canal inlets are intentionally left open longer than necessary even during the dry season, when there are no crops on the farms. Addressing this particular problem requires increased vigilance on the part of the LRBWB through periodic monitoring of water users to ensure compliance with water permit conditions. This would help to minimize wastage of water and curb illegal water abstractions.

Irrigation schemes in the basin are also marred with water use conflicts mostly arising from inadequate water supply. Three types of conflicts are usually experienced: internal conflicts between scheme members; conflicts with intruding pastoralists; and conflicts between the scheme and water users upstream/downstream of the scheme. Internal conflicts between scheme members usually occur during periods of water shortage when there is not enough water in the canals to meet all farmers' irrigation needs. In such instances, some farmers divert all the water in the primary or secondary canals adjacent to their farms, thus cutting off supply to downstream scheme members. In some organized schemes, water rationing takes place and water allocation time tables are established which require different groups of farmers to irrigate at different times depending on water availability. However, even in such cases conflicts arise when some farmers do not adhere to the agreed irrigation time table. During the dry season, pastoralists migrate from neighboring areas in search of water and pasture for their livestock. Their preferred destination is usually the flood plains and swamps where farming activities are concentrated. The livestock destroy crops and irrigation canals leading to conflicts with the farmers. Conflicts between the scheme and downstream/upstream water users normally arise when flow in the shared river/stream reduces. Upstream users usually act in a selfish manner by diverting most or all the flow in the shared river/stream, thus denying downstream users access to water. All these issues should be addressed as part of the irrigation water use management strategy.

Another challenge is inadequate involvement of the LRBWB in planning and implementing major irrigation initiatives. For example, the ambitious agricultural expansion and intensification envisioned under the different national initiatives (i.e., Kilimo Kwanza, SAGCOT, BRN, etc.) are being planned with little or no involvement of the LRBWB. The implication is that irrigation expansion plans are being made without careful consideration of current and future water resources constraints and competition with other basin water uses. The scale of investments being planned under these initiatives can only make economic sense if adequate and reliable water supplies are guaranteed to support the envisioned irrigation activities. Unfortunately, several of the areas in the Southern Corridor are already experiencing water shortage due to declines in rainfall in recent years; increased water demand in other sectors; and inadequate water storage infrastructure which are expected to worsen. It is important that those responsible for coordination of important national initiatives realize that water will be the major limiting constraint to achieving the envisaged agricultural productivity and expansion. It is, therefore, in their interest that they work closely with the LRBWB in planning for these initiatives to ensure that realistic targets are set for the maximum irrigable area under the prevailing temporal and spatial water resources constraints. A related irrigation initiative that the LRBWB should pay attention to is the ongoing rehabilitation and expansion of irrigation infrastructure with funding from the District Irrigation Development Fund. It is important that the LRBWB provides technical guidance in the ongoing and planned irrigation expansion activities to ensure orderly development and sustainable use of the basin's water resources taking into consideration all competing water uses, existing water permit allocations, and environmental flow requirements.

6.2.2 Priority Intervention Measures

The projected increase in irrigation water demand under current inefficient irrigation practices is unsustainable in the long run since several sub-basins are already experiencing water stress. Having an irrigation sector dominated by traditional irrigation schemes (78%) is totally unsustainable from a water resources management point of view. Any strategy to address the projected irrigation water demand should, as a matter of priority, first focus on improving irrigation water use efficiency before exploring options to increase irrigation water supply. Improving irrigation infrastructure presents a good opportunity for irrigation water demand management and water conservation. This intervention should begin with the already water stressed paddy growing sub-basins (most especially Katuma) and then extend to the other less stressed sub-basins. In the short to medium term, no more irrigation water abstraction permits should be issued in Katuma sub-basin until the desired irrigation water use efficiency improvements are implemented on the existing schemes. The LRBWB should continuously evaluate progress and ensure that any future new permits are only issued against water savings accruing from the efficiency improvements. Secondly, the LRBWB should institute, as one of the conditions for renewal of irrigation permits, that permit holders demonstrate good progress toward improving irrigation water use efficiency before their permit is renewed. The LRBWB should set efficiency improvement targets to be met by existing permit holders prior to permit renewal. For future new irrigation water permit applications (in all sub-basins), the LRBWB should specify that applicants have permit conditions to line all their irrigation canals; install permanent water diversion control and quantity measuring structures; construct lined return canals; and agree to a self-monitoring water abstraction program with mandatory submission of water abstraction data to the LRBWB. The irrigation use efficiency improvements should also be complemented with other water demand management measures like promotion of less water intensive crops and drought resistant cultivars.

Besides demand management, there is also potential for augmented water supplies through construction of water storage infrastructure and harvesting excess water during the wet season for use during the dry season. There is also opportunity to augment supplies through inter basin water transfer schemes. Inter basin transfers present a good opportunity for water scarce sub-basins to tap into abundant water supplies from neighboring basins to augment their available water resources. For example Katuma sub-basin, which is already water stressed, could benefit from the significant and underutilized water resources in Momba sub-basin. However, caution should be exercised before implementing such schemes to ensure that the long-term water needs and environmental requirements are not compromised. Another water supply augmentation measure is conjunctive use of surface and groundwater. Currently groundwater is being exploited on a small scale in several parts of the basin mostly for domestic consumption in rural areas. However, potential for large scale groundwater use for irrigation water supplies has not been fully explored due to scant information on aquifer potential. Groundwater in Rukwa basin is likely to be a key resource to improve the water supply coverage in many basin areas under the changing climate. Stakeholders in the irrigation sub-sector should therefore invest in groundwater investigations to identify potential aquifers for exploitation as part of their future irrigation expansion plans.

6.3 Domestic Water Requirements

Water supply coverage in Lake Rukwa Basin is generally low. The basin average water supply coverage is about 45% and 50% for rural and urban areas respectively. These figures are below the national averages and are also significantly lower than the 2010 national targets of 65% and 90% coverage for rural and urban water supply respectively. Annual domestic water demand for the basin is projected to increase from about 54 million m^3 in 2015 to about 110 million m^3 by 2035. The projections also show that domestic water demand is expected to double by 2035 in all sub-basins except Momba and Rungwa (see **Figure 6.4**). Urban water demand as a percentage of total domestic water demand is projected to grow from the current 65% to about 75% by 2035 due to the high urban population growth over the planning period. This has serious implications for service delivery in urban areas and will require increased and sustained investments in urban water supply and sewerage infrastructure. The government has put in place specific strategies and plans aimed at increasing access to adequate and reliable clean water supply and sanitation to all citizens. Specifically, the government has set planning targets to increase urban water supply services from the current 78% to 95% by 2015 and 100% by 2025. Similarly, access to safe water in rural areas is to increase from 54% to 70% by 2015 and 90% by 2025. To facilitate timely achievement of the above targets, the Ministry of Water is implementing a comprehensive Water Sector Development Program (WSDP) to accelerate the pace with which water supply and sanitation services are made available to the population. The program is specifically designed to enable the government to achieve water supply and sanitation targets set in National Strategy for Economic Growth and Reduction of Poverty (MKUKUTA II) as well as meet the Millennium Development Goals. Under WSDP, significant investments are being made towards rehabilitation and expansion of water supply infrastructure to ensure rapid expansion in improved water and sanitation coverage.

6.3.1 Issues and Challenges

One of the major challenges facing urban water supply utilities is increasing water treatment costs due to pollution and high turbidity levels in raw water. This is attributed to upstream catchment degradation resulting from widespread deforestation and poor farming practices. There are also increasing incidences of disposal of untreated effluent and solid waste into water bodies, especially in urban and peri-urban areas. These, and other uncontrolled human activities in the upstream catchment areas, negatively impact the surface water quality of rivers and streams which serve as sources for most urban water supply utilities. The increased water treatment costs are often transferred to water users as increased tariffs. These tariffs discourage water users from paying for the services. As a result users either resort to use of unsafe water sources or engage in illegal water connections.

Most urban water supply utilities do not meet water demand for reasons including inadequate capacity, low production levels, high water losses, inadequate water sources, and general deterioration of scheme infrastructure. In all the schemes, actual water production is less than the installed capacity thus implying inadequate water sources. Most of the water supply schemes do not have water treatment facilities resulting in poor water quality supplied to their customers. For several schemes existing infrastructure, such as storage tanks and pipe networks, has exceeded its design life and has extensive leakage. Several urban water supply facilities are faced with frequent pump break downs and erratic power supply negatively affecting their reliability. Addressing these challenges should form part of any strategy to improve domestic water supply coverage in the basin, more so as the utilities prepare to cope with projected increase in domestic water demand.

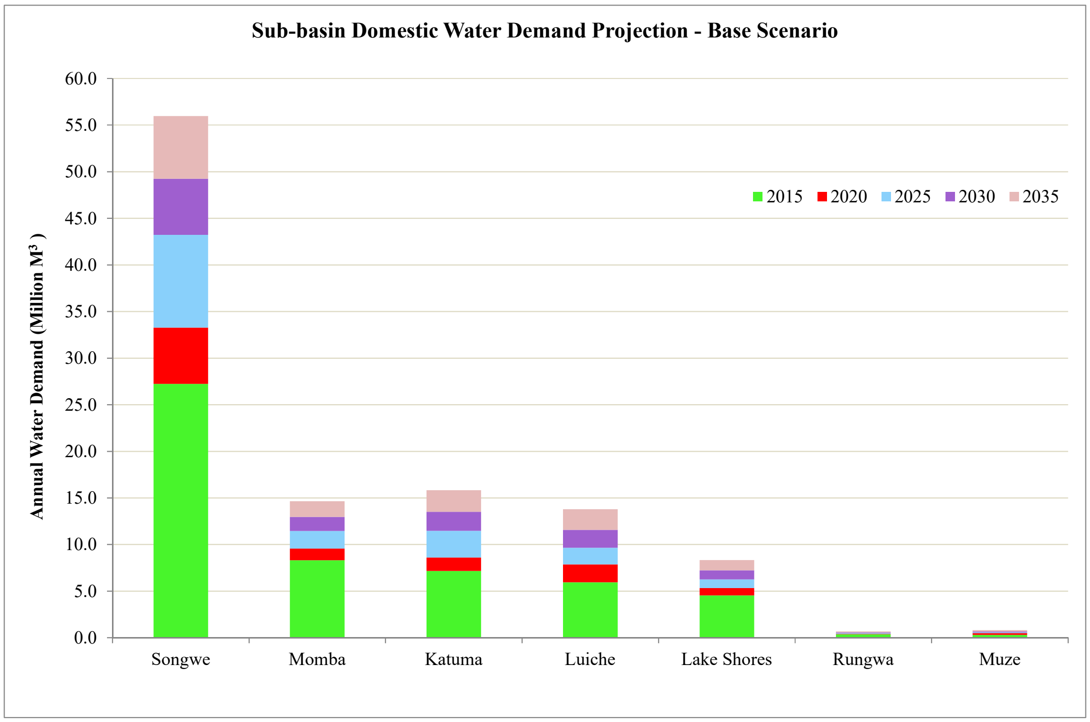

Figure 6.4: Sub-basin Domestic Water Demand Projection – Base Scenario.

6.3.2 Priority Intervention Measures

(1) *Water Demand Management*: On average, non-revenue water accounts for more than 35% of gross urban water demand. Although this is a challenge to utility managers, it also presents an opportunity for future water demand management if proactive measures are implemented to reduce water losses in urban water supply systems. For example, water demand management assessments show that implementation of modest measures (increased vigilance in detecting and fixing water leakages, increased metering, timely rehabilitation of water supply infrastructure, curbing illegal water connections, etc.) would reduce non-revenue water by 25% in 2035. This would reduce the gross basin water demand in 2035 from about 110 million m^3 to about 103 million m^3, a small (about 7%) but a potentially important water savings, especially during periods of severe water scarcity.

(2) *Water Supply Augmentation*: To cope with future water demand, the UWSAs should also consider water supply augmentation through construction of water storage infrastructure to harvest excess water during the wet season for use during the dry season. This would particularly help even out the month-to-month water deficits which cause significant disruptions in water supply services. There is also opportunity to augment supplies through inter basin water transfer schemes. For example Mbeya City, which faces severe water shortages during the dry season, could benefit from the significant and underutilized water resources in Momba sub-basin or a neighboring basin like Lake Nyasa. A specific inter basin transfer scheme that should be fast tracked and studied in detail is the proposed transfer of water from Kiwila River in Lake Nyasa basin to augment water supplies for Mbeya City. This proposal has been a subject of discussion for some time and should be carefully studied and implemented as soon as possible if found feasible. Another water supply augmentation measure is conjunctive use of surface and groundwater. Currently, potential for large scale groundwater use for urban water supplies has not been fully exploited, due to scant information on aquifer potential. However, groundwater is likely to be a key water supply sources in many basin areas in the near future. UWSAs should, therefore, invest in groundwater investigations to identify potential aquifers as part of their future water supply expansion plans.

(3) *Protection of catchments upstream of urban water supply sources*: Another intervention measure for urban water supply utilities is demarcation and protection of catchments upstream of important water sources. Study findings indicate that some observed sub-basin water scarcities can be attributed to dwindling water sources from destruction of upstream watersheds. Particularly, rampant deforestation, over grazing, and wetland degradation are responsible for destruction of important catchments and thus undermine the capacity to sustain downstream water sources. The Water Resources Management Act (2009) Section 37 (1) provides for the establishment of protected zones on land draining to or above important water sources. This activity shall involve systematic identification, survey, acquisition, and protection of catchments draining to important water sources serving large populations, e.g., urban areas. This initiative has already commenced around sources serving Mbeya City and should be expanded to other parts of the basin starting with sources supplying all major towns and urban areas. This initiative should also be complemented by intensified enforcement of Section 34 of the Act regarding prohibition of human activities near water sources.

6.4 Livestock Water Requirements

Livestock keeping is one of the major socio-economic activities in the Lake Rukwa basin. Domestic animals constitute one of the most important non-land assets owned by the majority of people in rural areas. The sector plays a major role in the rural economy and has great potential for future development. Total livestock population in the basin is approximately 3.5 million. Katuma, Lake Shores, and Songwe are the top three sub-basins with the highest cattle population. The current (2012) annual livestock water consumption for the Lake Rukwa basin is estimated to be about 12 million m^3. Katuma, Lake Shores, and Songwe sub-basins have the highest livestock water consumption accounting for about 26%, 22%, and 22% of the basin total respectively. Livestock water demand is projected to increase from 12 million m^3 in 2012 to about 21 million m^3 in 2035, an increase of about 74% (see **Figure 6.5**). The projected increase in livestock population and water demand will lead to increased pressure on the basin's natural resources and exacerbate the ongoing environmental degradation. The government, through the Livestock Sector Development Program (LSDP), has outlined comprehensive strategies to ensure sustainable livestock production in the country. The LSDP has specific provisions for addressing increasing livestock water demand through promotion of rainwater harvesting technologies, investment in construction of livestock water supply infrastructure (e.g., Charco dams, small dams, boreholes, etc.). Several other national and local initiatives are also being implemented to support sustainable growth of the livestock sector. For example, SAGCOT aims at increasing both agricultural and livestock production in the southern corridor part of which falls in the Rukwa basin. The initiative intends to enhance livestock production in the corridor through investment in modern animal production and marketing systems; promotion of better livestock feed and feeding systems; increased access to improved livestock breeds; adoption of improved range management practices; and increased access to reliable veterinary services. Specifically for the Sumbawanga Cluster, SAGCOT intends to invest in two livestock ranches, four regional markets and four units of cold storage by 2030.

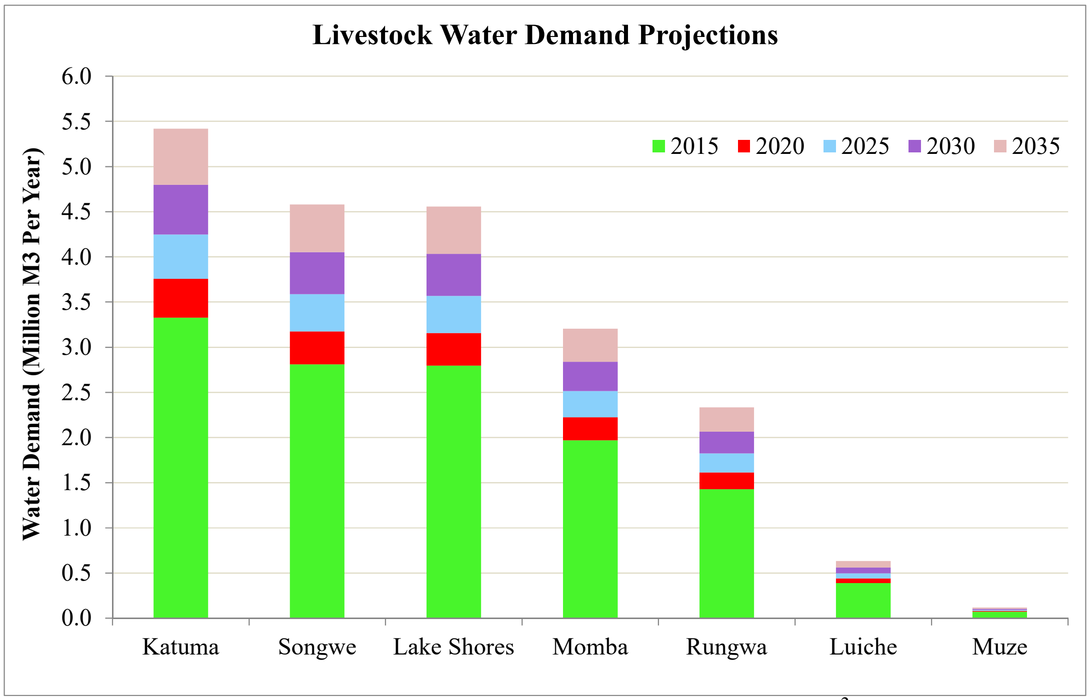

Figure 6.5: Livestock Water Demand Projection (million m^3 per year).

6.4.1 Issues and Challenges

Lack of village land use plans in most parts of the 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 basin’s natural resources. Most 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 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 all vegetation cover. Livestock encroachment on protected areas has had an adverse effect on large mammal assemblages in the Katavi National Park and Rungwe Game Reserve, causing direct grazing competition between livestock and wildlife, poaching of wildlife by pastoralists, and disease spreading from livestock to wild life.

6.4.2 Priority Intervention Measures

A holistic approach aimed at addressing all the above issues should be adopted to address the projected increase in livestock water demand. Priority focus should be on preparation of village land use plans to allow for demarcation of specific areas for livestock grazing and watering. Strict enforcement of land use plans will ensure that livestock stay away from communal lands where other socio-economic activities like farming are carried out thus minimizing conflicts between farmers and pastoralists. Another priority intervention is provision of designated livestock watering areas and facilities so that pastoralists do not water their animals directly in water sources used for other uses.

6.5 Industrial Water Requirements

The Lake Rukwa basin has very limited industrial and manufacturing activities, most of which are concentrated in Mbeya City. The top industrial water users in Mbeya City are supplied by Mbeya Urban Water Supply and Sewerage Authority (except Mbeya Cement Company which is supplied by Songwe Water Company). Because of the small number of industries currently operating in the basin, their impact in terms of water use is small compared to other water uses (e.g., irrigation). They also do no not pose serious pollution issues, although some may cause localized pollution problems if their effluent discharge is not managed well. Water use by industrial complexes usually serves more than one purpose: irrigation of farms for raw material production; direct input in the production of the industrial products; human consumption for the hundreds of workers in the industrial complexes; and waste dilution of industrial effluent at the end of the production process. Industrial water demand is projected to increase from 1.68 million m^3 in 2015 to 3.85 million m^3 in 2035. It is envisioned that most future industrial developments will be concentrated around Mbeya City and that most of the new industries will be connected to the Mbeya-UWASA network. Therefore, industrial water demand growth for Mbeya City should be taken care of as part of the urban water supply master plan. Mbeya-UWASA has already incorporated future industrial water demand in its medium to long term water supply expansion plans. The same applies to the other smaller towns of Sumbawanga and Mpanda, where current and projected industrial development is much smaller compared to Mbeya City.

6.5.1 Issues and Challenges

The biggest challenge faced by the industries is inadequate water supplies and poor raw water quality, which usually results in significant treatment costs to make it usable in the industrial production processes. Inadequate water supplies are a major constraint to the operations of most of the existing industries. For example, Tanzania Breweries Limited currently runs one production line with a water demand of 60 m^3/hr. There are plans to install a second production line to meet the growing demand and market for beer in Mbeya and surrounding regions.

However, the expansion plan is still pending due to inadequate water supply by Mbeya-UWSA. According to TBL officials, the expansion work can only be implemented if Mbeya-UWSA can guarantee additional water supplies to meet water demand for the two production lines. Similar problems are experienced by Southern Bottlers Company (SBC) Tanzania Limited. SBC receives sufficient water supply from Mbeya-UWSA for its production activities during the rainy season. However, during the dry season (especially September to December) the plant experiences periodic water shortages mostly due to mandatory water rationing by Mbeya-UWSA. In some cases, this forces the company to temporarily stop production for 1-2 days leading to significant revenue losses. The other issue with industrial water use is low water use efficiency in most existing industrial establishments. This is mostly attributed to failure to adopt water saving production technologies, but it is also due to leakages in water distribution pipe systems, lack of proper metering systems for different water use processes in the plant, negligence by workers, and delays in reporting and fixing leakages. Implementation of measures to address the above issues can result in significant water savings.

6.5.2 Priority Intervention Measures

The recommended actions for addressing industrial water demand include water demand management through improvement in water use efficiency and augmentation of water supplies. Improved water use efficiency presents the best opportunity to control industrial water demand growth in the short- to medium term. For example, Coca Cola Kwanza has started implementing water saving measures, and its target is to reduce the current per capita water use from 4.5 liters to about 3 liters of water for every liter of soft drink produced. This is less than half of the amount SBC uses (6.8 liters of water per liter of beverage produced). Water saving measures being implemented include sensitizing factory workers on efficient water use practices and water rationing during periods of scarcity. The company has also established a water management committee to oversee implementation and compliance with water use efficiency measures instituted by the plant. Signs to emphasize closing of taps while not in use have been placed in washrooms and production units at the factory. Emphasis is being placed on using less water while hand washing and cleaning. The committee is also in charge of checking for leakages and addressing them as soon as possible. Renovations have been done in washrooms to reduce water used in flush toilets and stop any leakages as well as installation of valve controls on pipes to regulate water used for cleaning purposes. The company also plans to introduce meters that measure water used per shift so that workers found wasting water are reprimanded if necessary. Plans are also underway to pave the factory compound to reduce wastage of water used in dust control. All major industries can be encouraged to follow the example of Coca Cola Kwanza and implement similar water saving measures which collectively could result in significant reductions in industrial water use. Supply augmentation measures that can be implemented to mitigate production disruptions include: construction of on-site raw water storage tanks of adequate capacity; and use of groundwater to supplement surface water supplies.

6.6 Environmental Water Requirements

Lake Rukwa Basin is home to many aquatic and terrestrial ecosystems of local, national, and global conservation significance. The basin environment and natural resources are important for supporting diverse socio-economic activities and sustaining livelihoods of the local population. Satisfying water demands for different socioeconomic sectors while also maintaining environmental flow requirements leads to a healthy and functioning ecosystem as a whole. Environmental water demands place constraints on water use which should be acknowledged by water managers and decision makers. Any decision taken on water allocation should recognize environmental flow requirements as legitimate water use to support vital ecosystem functions. It is therefore important that such decisions are informed by careful assessment and understanding of the impacts of proposed water resources developments on the environment and the potential trade-offs. However, despite their importance, the basin ecosystems are under increasing pressure from diverse human activities such as clearing of forests for agriculture and human settlement; cutting down trees for firewood, charcoal, and timber; pollution from mining activities, poor household sanitation, disposal of untreated industrial effluent, and improper use of fertilizers and pesticides. This should be a cause of major concern to decision makers in the basin as the collective impact of these activities on the environment compromises its ecological integrity and ability to render important ecosystem functions vital for sustaining livelihoods of riparian communities.

6.6.1 Issues and Challenges

The main water resources management challenge is how to meet the increasing water demands to ensure socio-economic development and poverty eradication without compromising the proper functioning of the environment. Section 6(2) of the Water Resources Management Act (2009) requires that a specific minimum river flow be reserved in all water sources for basic human needs and to protect aquatic ecosystems. The law requires that this flow reserve be given highest priority in water allocation over all other water uses. Therefore, during water allocation, the requirements of the reserve must be met before water can be allocated for other uses. For cases where water is already allocated for other uses in breach of the reserve requirement, the reserve should be met progressively over time. Unfortunately, due to weak enforcement of the law, the mandatory reserve flow is not complied with in most water allocation decisions. This is mostly attributed to lack of specific scientific data on environmental flow requirements for different river sections in the basin. Consequently, the environment takes whatever is left over after allocation to other water uses contrary to the legal provisions. This negatively impacts the ecological functioning of the water sources with severe environmental consequences.

6.6.2 Priority Intervention Measures

(1) Detailed environmental flow assessments should be undertaken for all critical river sections to establish environmental flow requirements on which to base water allocation decisions. Once EFRs have been established, enforcement and monitoring for compliance will be required. The strategy for implementation of the environmental flow requirements in water stressed sub-basins (e.g., Katuma) should follow a cautious approach starting with enforcement of lower EFRs and gradually increasing over time to the desired level. This would avoid sudden disruptions of irrigation activities and allow farmers time to adjust their irrigation water use practices and comply with the EFR constraints. It would be counterproductive to embark on rigorous enforcement of high EFR values which alienate the local community and lead to unnecessary loss of productivity. This approach would require gradual improvements in the environmental flows from the current levels to the desired environmental flow reserve. This could be done in tandem with other water supply augmentation and demand management interventions aimed at gradually reducing over reliance on heavy water abstractions from the concerned critical river sections. The LRBWB will also carry out periodic review of the environmental reserve flow for different river sections and modify them in response to increased water demands for other sectors, where necessary.

(2) Other measures that should be implemented to protect the environment include control of pollution from point and non-point sources through regulation of industrial effluent discharge to comply with standards; control of agrochemical use to minimize pollution from agricultural fields, regulation of mining activities (especially gold mining) to prevent pollution from untreated mine effluent discharge; improvements in urban and rural sanitation to reduce pollution from fecal matter; and improved watershed management to reduce soil erosion and sedimentation of water bodies.

6.7 Mining Water Requirements

The basin's water resources play a crucial role in supporting mining activities in two main ways, as a source of water supplies for the different mining processes and as recipient of effluent from the mineral processing activities. The current water used in the mining sector is very small compared to other uses like irrigation and domestic water use. However, mining activities pose a considerably bigger risk to water pollution and environmental degradation than other water use sectors. The main threat comes from unregulated use of chemicals (mercury and cyanide), especially in small scale artisanal gold mines, and poor handling and disposal of mine effluent. Unregulated mercury use in gold mining is of particular concern because of its potential health and general environmental hazards. Mining activities with respect to other minerals such as marble, limestone, and sandstone are not considered to pose a serious threat to water resources and environmental health.

6.7.1 Priority Intervention Measures

Recommended actions to address future mining water use are focused on containing the pollution attributed to mining activities. There is need to register and regulate all mining activities with regard to water use and effluent discharge. Most emphasis should be put on sensitizing, training, and equipping the small scale artisanal gold miners to enable them carry out their mining activities in an environmentally friendly manner. The National Environmental Management Council (NEMC) should increase its vigilance in registering all mining operations in the basin and monitoring their compliance with environmental laws and standards. The LRBWB should also intensify water quality monitoring of water sources in mining areas to detect deterioration in water quality.

6.8 Wildlife Water Requirements

Wildlife need water for three main uses: drinking, environmental maintenance, and primary habitat. The first is consumptive while the other two are non-consumptive water uses. Water requirements for habitat maintenance and environmental needs cover all species of animals large and small. Absence of water to maintain habitats affects food availability, changes the microclimate, and negatively affects the animals. Water availability has a strong correlation to wildlife presence and concentration in parks and game reserves. Water regimes influence the availability and spatial distribution of food and drinking water and thus determine the wildlife population dynamics and movement patterns. Generally, places with more water have more wildlife populations. Most wildlife migration and movement patterns are seasonal in response to the seasonal rainfall patterns that determine temporal and spatial distribution of water sources. During the rainy season, water and pasture are evenly distributed in the parks and game reserves and so is wild life.

6.8.1 Issues and Challenges

The main challenge is to ensure availability of adequate water supplies for wild life use during the dry season. During the dry season (May to October), most streams and rivers in the park and game reserves dry up. During this period, most wildlife concentrate close to the few available water sources including swamps and a few other water sources like springs and excavated ponds. However, these sources are not adequate to meet the water needs of the significant wildlife population. In Katuma National Park, for example, these sources have been reported to dry out with severe consequences for wildlife which is left to depend on only a few small muddy pools that remain in dry riverbeds. This water shortage is attributed to excessive water abstraction for irrigation in schemes upstream of the park. Conflicts between the park/game reserves and surrounding communities mainly escalate during the dry season due to reduction in water availability and pasture. For example, for Katavi National Park, the main water use conflict is between the park and upstream irrigators at Mwamkulu, Nkungwi and Kakese villages who abstract water to irrigate paddy farms. Paddy irrigation started in late 1990s with small farms in the Katuma River floodplains upstream of the park. In 2004 the small scale farming expanded greatly to now cover the whole floodplain. Water for irrigation has been increasingly diverted using dams on the river, and no water returns to the river. During the dry season, these small dams completely block the river flow resulting in severe water shortage for wildlife downstream in the park. This situation led to wildlife deaths in the park in 2005 when a number of hippos died due to lack of water. Following intervention by relevant authorities, a mechanism was put in place to allow TANAPA to continuously monitor upstream irrigation water withdrawals to ensure that sufficient water is left in the river for wildlife use downstream. This arrangement seems to be working except during extended drought periods when the flow in the river is too small to be shared; in this case the park could require that upstream irrigation activities stop. However, farmers are not willing to comply. TANAPA is also undertaking construction of more wildlife watering ponds inside the park and is seeking government intervention for stringent measures to ensure that upstream users of Katuma River are obliged (by law) to maintain a specified minimum flow in the river for wildlife use downstream. Increasing human activities around the park are also negatively impacting water availability in the park. These include poor agricultural practices upstream, leading to increased river siltation and reduced flow due to excessive irrigation withdrawals, and pollution of water due to increased unregulated small scale gold mining in areas north of the park. For example, Kabenga River, which feeds into Katuma River, flows through Mutisi area where there is reported wide spread use of cyanide in the ongoing gold mining activities.

6.8.2 Priority Intervention Measures

There is need for strict enforcement of the environmental flow reserve to ensure availability of water for ecological and wild life water requirements. This, coupled with other measures like construction of wildlife watering ponds inside the parks and game reserves, will help address wild life water requirements and minimize conflicts.

6.9 Fisheries Water Requirements

Fishing is a very important socioeconomic activity in the basin mostly concentrated around Lake Rukwa and the major rivers feeding it. Fisheries are an important source of food, household income, and livelihood for the poor riparian communities. River flows must be maintained to sustain fisheries and other sensitive aquatic organisms. Quantifying how much water can be abstracted without damaging the fisheries and ecological systems is therefore a very important aspect and integral part of sustainable water resources management. This flow is termed environmental flow, and for fishery purposes it is defined as that portion of river flow needed to maintain the ecosystem or protect fisheries.

6.9.1 Issues and Challenges

EFA studies are important tools in fisheries management as they can be used to assess the impact of river flow variability on fisheries productivity. Information generated from EFA studies enable fisheries biologists to estimate productivity based on the volume of water and fish catch. Using this relationship also allows computation of marginal water productivities when planning water management strategies. Unfortunately, such relationships cannot easily be derived for most of the major rivers in the basin owing to lack of adequate and reliable contemporaneous hydrological and fishery catch data. The estimation of potential yield under varying hydrological conditions is a key challenge for fisheries managers. However, once this estimate can be made, the capacity of the fishery can be deduced and its productivity under varying hydrological conditions inferred. This information is very useful for sustainable fisheries management and integrated water resources management. Such analysis would also enable water resources planners and managers to assess the impact of different upstream water uses, such as excessive upstream water abstraction for irrigation, on fisheries productivity in critical sections of the basin (rivers, wetlands, reservoirs) and therefore understand the trade-offs between the different competing water uses.

Despite its high potential, aquaculture production is still very low in the basin. The low productivity is attributed to a number of factors including: small pond size, poor management, inadequate extension services, inadequate marketing, poor transport infrastructure, and competing sources of tilapia from active lake capture fisheries. Fish farming is carried out by rural small-scale farmers in small freshwater ponds. Over 80% of the pond owners are primarily engaged in agriculture and consider fish farming as a secondary activity. Aquaculture is mostly practiced mainly in Sumbawanga MC, Mbeya DC, and Nkasi districts. Small scale fish farming is mostly popular in urban areas where the demand for fish is very high and also in areas far from Lake Rukwa and other lakes. The Government of Tanzania has developed a National Aquaculture Development Strategy (NADS). The purpose of NADS is to ensure increased fisheries production in an economically, socially, and environmentally sustainable manner.

6.9.2 Priority Intervention Measures

(1) The quantity of water available, the timing of peak and minimum flows, and water quality are all important factors to fisheries productivity and breeding. Different fish species generally use different parts of the aquatic system, including the main river channels, lakes, seasonally varying wetlands, estuaries, and near-shore marine areas. Some species use all or many of these areas and migrate between them. The environmental flow reserve must, therefore, be maintained in all water bodies to sustain fisheries and other sensitive aquatic organisms. Detailed environmental flow assessments should be carried to establish environmental flow requirements for all critical river sections in the basin. Enforcement of EFRs and monitoring their compliance will go a long way in sustaining fisheries productivity in the basin.

(2) Lake productivity processes and the health of the habitat determine fisheries production. Since fish production and sustainability depend on the health of the fish habitat, there is need to consider management of pollution and eutrophication along with fisheries management. A

number of activities in the basin including agriculture, livestock keeping, urban development, utilization of wetland resources, and mining affect the health of the fish habitat if not managed properly. Poor agricultural practices, intensive use of fertilizers and pesticides, drainage of wetlands, and rampant deforestation are examples of human activities that are detrimental to sustainable fisheries management. Pollution of water bodies as a result of the above human activities adversely affects their ecological health and productivity processes thus undermining fisheries production. Therefore, adoption of integrated watershed management and environmental conservation practices is a pre-requisite to a sustainable and vibrant fisheries industry.

(3) Water use conflicts exist between fishermen and pastoralists who graze their animals within lake peripheries thus destroying breeding grounds for fish along the shores of the Lake. There is need for preparation and enforcement of village land use plans to ensure identification of dedicated areas for livestock grazing and watering to avoid animals grazing and watering around the lake shores and destroying fish breeding grounds.

(4) Fish landing villages suffer from lack of clean water supply resulting in direct consumption of untreated lake water which leads to frequent out-breaks of water borne diseases. The problem is exacerbated by lack of good sanitation facilities at the fish landing villages. There is need for provision of adequate water supply and sanitation facilities at the fish landing villages.

(5) There is need to regulate discharge of wastewater from aquaculture ponds into neighboring water sources to prevent pollution. Fish farmers should be sensitized on modern fish farming practices to maximize benefits from aquaculture and reduce pressure on the basin's water resources due to over fishing.

6.10 Hydropower Water Requirements

Less than 5% of households in Lake Rukwa basin are connected to the national electricity grid. Some of the isolated urban areas close to the Zambia border (e.g., Sumbawanga MC) are connected to the Zambia electricity grid while others (e.g., Namanyere) are served by thermal power from generators. More than 90% of the basin population depend on firewood and charcoal as their main source of energy for domestic cooking and lighting. Fuel wood is also commonly used in other subsistence economic activities such as brick making, pottery, and curing of tobacco. Kerosene is also widely used for lighting purposes mostly in rural areas but also in urban areas, where it is used for cooking as well. Heavy dependency on fuel wood has contributed to environmental degradation due to widespread cutting of trees in most parts of the basin. There are several small-scale and mini hydropower sites that have been identified in different parts of the basin. The most notable ones include: (i) Mtembwa River at Yala Falls (30 MW); (ii) Nzovwe River at Msia village (8 MW); (iii) Churu River at Nkwilo village (1.165 MW); (iv) Kilambwa River at Kalumbaleza (1 MW); and (v) Luiche River at Uzia village (0.1 MW). These schemes have already attracted potential investors who are currently assessing their commercial viability for potential development. A few other smaller sites exist in different parts of the basin that have not yet attracted investment interest.

7. Sub-basin Water Assessments and Findings

Sustainable water resources planning and management aims to balance water availability and demand through equitable access to and efficient use of basin water resources by all stakeholders. To objectively determine this balance, quantitative information is needed to determine whether the available water resources can satisfy the demands in all sub-basins and basin-wide. The strategy for determining sub-basin water balance is thus:

(i) Assess and quantify available water resources in each sub-basin under historical and projected future climate conditions.
(ii) Assess and quantify current sub-basin water demand and use and make projections of future water demands.
(iii) Based on (i) and (ii) above, establish sub-basin spatial and temporal water deficits.
(iv) Identify appropriate intervention measures and options to address the observed and anticipated water deficits.

Based on the above strategy, detailed sub-basin water balance assessments were carried out as described in a separate report volume (***Vol V: Sub-basin Water Balance Assessments)***. The main findings and conclusions are summarized below.

7.1 Sub-basin Water Use and Demand

Detailed water demand projections were conducted and the findings are in Interim Report II, ***Volume I: Water Demand Projections***.

The Lake Rukwa Basin aggregate consumptive water demand is projected to increase from 600.42 million m^3 in 2015 to about 1298.49 million m^3 in 2035, an increase of about 116%. **Figure 7.1** and **Table 7.1** show that the biggest projected increase in water demand over the planning horizon will be in Momba (267 million m^3, accounting for 38% of total basin increase). This is mostly attributed to anticipated significant expansion in irrigated agriculture compared to other sub-basins. The other sub-basins that will experience a big increase in water demand include: Lake Shore (207 million m^3, accounting for 30% of total basin increase), Katuma (103 million m^3, accounting for 15% of total basin increase), and Songwe (67 million m^3, accounting for 10% of total basin increase). The Katuma sub-basin is projected to have the highest water demand of about 525.5 million m^3 accounting for 41% of the total basin water demand in 2035. The other sub-basins projected to have significant water demand in 2035 include: Momba (317 million m^3, accounting for 24%), Lake Shores (258.4 million m^3, accounting for 20%), and Songwe (127.4 million m^3, accounting for 10% of total basin demand).

Figure 7.2 and **Table 7.2** show that, at basin level, on average most of the water (more than 85%) is used during the period Nov – Apr (paddy growing period). During the period May – Oct, irrigation is limited to small vegetable gardens, a few small beans and maize gardens, and irrigation of the perennial crops like coffee. **Figure 7.3** shows variability in monthly water consumption patterns between sub-basins. The traditional paddy growing sub-basins experience excessive water use (more than 90% of annual total) during the paddy growing months (Nov – April) with very little water use (less than 10%) during the rest of the year. On the contrary, the non-paddy growing sub-basins (Songwe) have a fairly even distribution of monthly water use over the year. These differences in temporal water consumption patterns over the year have implications for selection of appropriate water management and allocation strategies applicable to individual sub-basins.

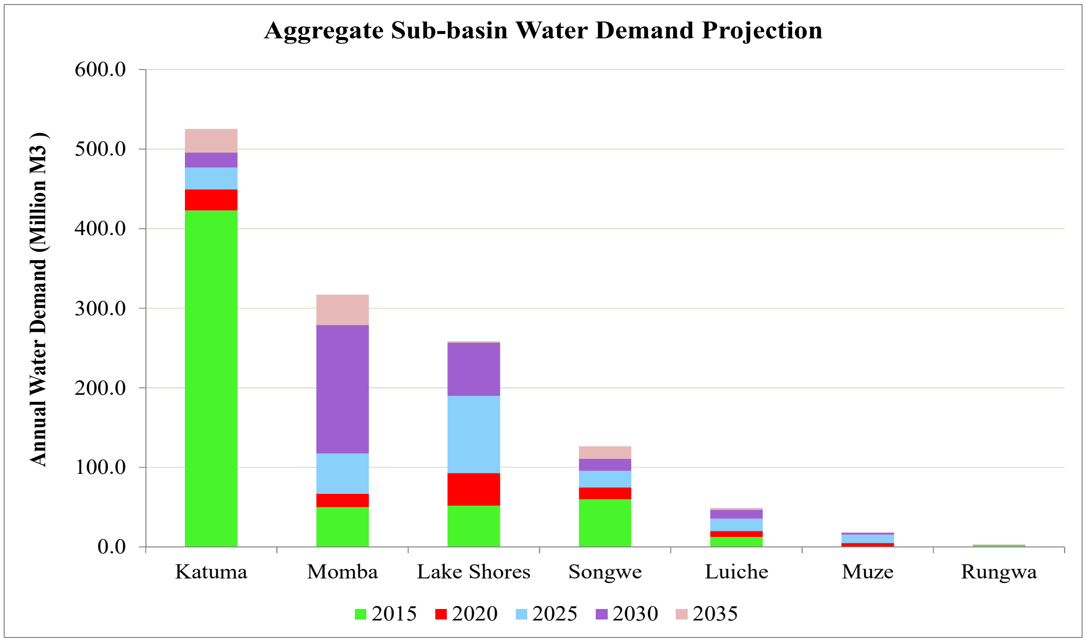

Figure 7.1: Aggregate Sub-basin Water Demand Projection.

Table 7.1: Aggregate Sub-basin Water Demand Projection.

Sub-basin	**2015**	**2020**	**2025**	**2030**	**2035**
Katuma	422.99	449.58	476.92	495.51	525.45
Momba	50.00	66.90	117.26	279.00	317.05
Lake Shores	51.85	92.89	189.74	256.58	258.40
Songwe	60.73	75.66	96.55	111.61	127.39
Luiche	12.66	20.01	35.55	46.74	49.03
Muze	0.39	4.77	15.38	18.00	18.14
Rungwa	1.80	2.05	2.34	2.66	3.03
TOTAL	**600.42**	**711.87**	**933.76**	**1210.11**	**1298.49**

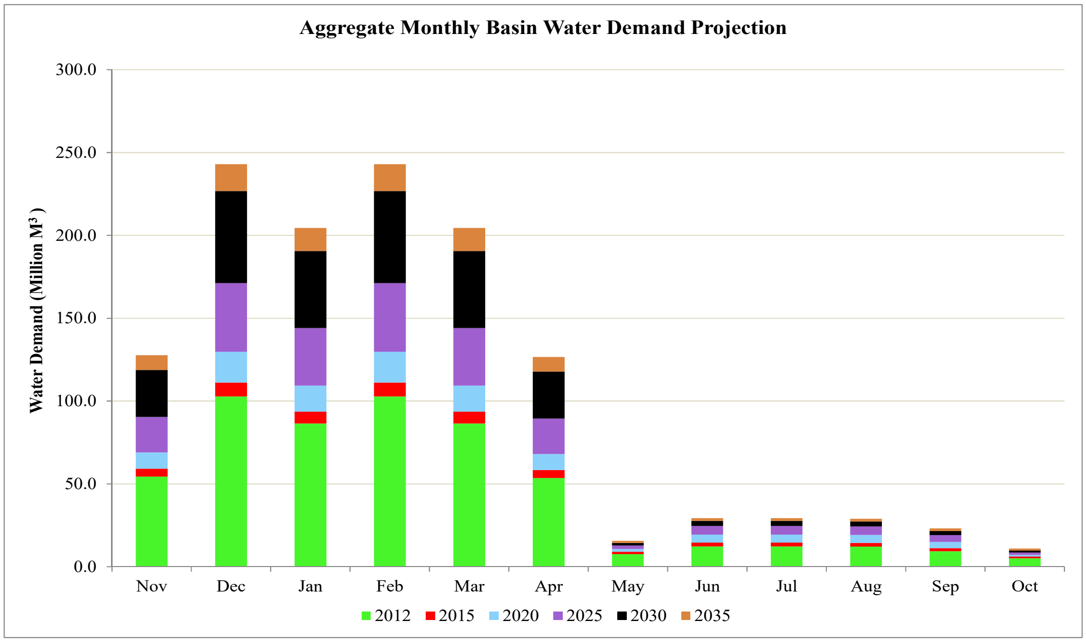

Figure 7.2: Aggregate Monthly Basin Water Demand Projection.

Table 7.2: Aggregate Monthly Basin Water Demand Projection.

	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
2012	54.43	102.79	86.48	102.79	86.48	53.65	7.63	12.24	12.24	12.12	9.45	5.24
2015	59.15	111.18	93.65	111.18	93.65	58.35	9.09	14.57	14.57	14.39	11.21	6.24
2020	68.95	129.77	109.32	129.77	109.32	68.11	10.76	19.46	19.46	19.20	14.98	7.18
2025	90.39	171.15	144.08	171.15	144.08	89.50	12.84	24.64	24.64	24.30	19.11	8.59
2030	118.82	226.74	190.65	226.74	190.65	117.87	14.40	27.75	27.75	27.35	21.62	9.75
2035	127.61	243.03	204.44	243.03	204.44	126.66	15.72	29.39	29.39	29.00	23.20	11.05

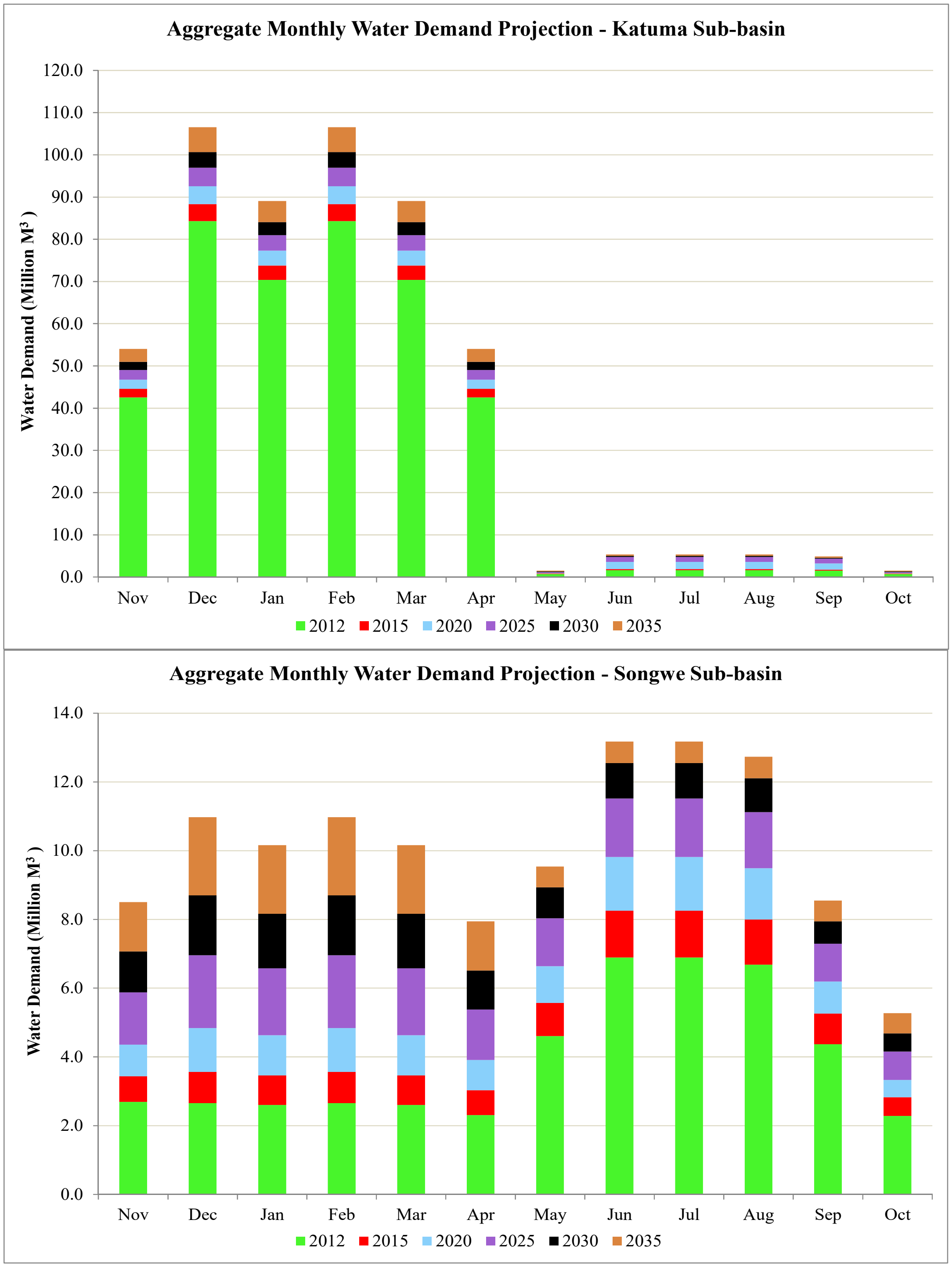

Figure 7.3: Aggregate Monthly Sub-basin Water Demand Projection

7.2 Spatial and Temporal Water Deficits and Stress

The main finding from the sub-basin water assessments is that water use and demand varies across the basin depending on the nature and intensity of socioeconomic activities. Most sub-basins have high water use and demand projections because of widespread paddy production.

Where it is significant, paddy production dwarfs all other water uses. Unfortunately, most sub-basins have taken up paddy production as a primary socioeconomic activity, placing a heavy requirement on their water resources. The only exception is the Songwe sub-basin where paddy production is not as popular as in other basin areas. Consequently, several sub-basins are already experiencing water stress even under current demand levels, with Katuma being the most stressed.

The water stress in the paddy growing sub-basins is exacerbated by the fact that paddy is produced by traditional irrigation schemes characterized by poor irrigation infrastructure and inefficient irrigation practices which result in high water losses. For many paddy schemes, the water loss exceeds 50% and is clearly unsustainable. Moreover, paddy growing sub-basins experience peak irrigation demand during the wet season. This is somewhat peculiar as in other regions high water demand usually occurs in the dry season when supply is low. Because of this, farmers develop the false sense that the activity is sustainable, as “water is usually there when they need it.” There is also little incentive to use water more efficiently during the wet season since “rain provides it for free.” Thus, a common farmer perception is that if water is not used in its entirety, it will be wasted. However, this perception is bound to change as water shortages begin to occur more and more frequently during the wet season, drawing attention to the need for more efficient irrigation practices; improvement of irrigation infrastructure; and construction of water storage reservoirs. Such measures, coupled with others, including the use of drought resistant crop varieties and diversification from paddy growing to other less water intensive high value crops, could reverse the current trend of unsustainable water demand growth.

The Songwe sub-basin, the agricultural production of which is not paddy-dominated, experiences water shortages during the dry season when supply is low. Thus, the Lake Rukwa sub-basins experience water stress at different times of the year and for different reasons. Correspondingly, individual sub-basins have unique water issues that warrant unique solutions.

Besides the projected water demand growth and its associated impacts, the legal requirement to comply with stipulated environmental flow requirements at specific river sections may require stakeholders to forego some of their water allocation expectations. The assessments also show that during prolonged drought conditions, adherence to environmental flow requirements in some of the sub-basins (especially Katuma) would result in no water allocation to other water sectors for several consecutive years. This may not be a realistic approach but serves to demonstrate the critical water stresses and risks that most sub-basins face if appropriate measures are not implemented to reverse the current inefficient water use practices. Given the significant amounts of environmental flow requirements compared to other water uses, it is important that detailed EFAs are conducted for all critical watersheds to establish accurate EFRs against which water allocation decisions shall be based. This will ensure that unrealistically high EFRs are not used as a basis to curtail water allocation to other sectors and thus stifle basin socio-economic development.

Water balance assessments also show that climate change is expected to exacerbate the basin water stress. The projected temperature increases have critical implications for basin hydrology, agriculture, and water resources, since increased evaporation losses may reduce surface water flows, soil moisture, groundwater recharge, and lake levels. Furthermore, higher future temperatures will increase crop evapotranspiration and irrigation demand.

7.2.1 Impact on Lake Rukwa Levels

Lake Rukwa, being the recipient of flows from all basin areas, is most vulnerable to the reinforcing effects of rising basin water demands, climate change, and environmental flow requirements. Climate change is expected to reduce the natural water supply to the lake while increasing water abstractions in the watersheds will only exacerbate the situation with adverse impacts on the Lake Rukwa levels. **Figure 7.4** shows that increased consumptive water use leads to lower lake levels in the long term. In reference to the natural state of the lake, the long term lake level reduction is 3.5 meters for the 2015 water demands, 5 meters for the 2025 water demands, and 7 meters for the 2035 water demands. Simulation of Lake Rukwa fluctuations show that if the basin consumptive water use had followed *any* of the projected water demand scenarios since the 1950s, lake levels would have fallen below the basin separation level at the end of 2006. Under the 2035 water demand scenario, the lake would have separated into two basins on several historical periods including the middle and late 1950s, the 1990s, and most alarmingly the entire 2003 – 2007 period. During the latter episode, the lake would have experienced its deepest drawdown approaching the northern lake basin bottom (792 masl) within 2.3 meters. Essentially, under this water demand scenario, the lake would be in a state of separation since 1993. The 2025 water demand scenario, while not as severe as that of 2035, also depletes the lake down to its separation threshold by 2011. Lastly, the current water use, while causing lake separation at the end of 2006, allows the lake to recover in the period following the drought. However, current water uses cause a perpetual lake drawdown of 2 to 3.5 meters compared to natural lake conditions.

The water balance assessments show that Lake Rukwa levels are very sensitive to basin water use and that the 2035 and potentially the 2025 water demand scenarios would render Lake Rukwa vulnerable to climate variability and change. Based on the assessment findings, there is a clear trade-off between increased water abstractions and use in the upstream basin watersheds and sustainability of the Lake Rukwa ecosystem. It has been demonstrated above that any further increase in water abstractions beyond the 2015 level will have serious consequences for the sustainability of the lake. It is, therefore, an important decision that Lake Rukwa Basin stakeholders will have to make between increased water abstractions to support basin socio-economic activities at the detriment of the lake or to cut back on water abstractions through water use efficiency improvements to ensure sustainability of the lake ecosystem. Assuming that stakeholders choose the latter option, as a short-term measure, it is recommended that a moratorium be immediately imposed on any further expansion of irrigation activities in the basin as the LRBWB works together with farmers and other basin stakeholders to improve irrigation water use efficiency (as emphasized elsewhere in this report) and reduce consumptive water use and demand in the long term. The LRBWB should only reconsider lifting the moratorium after it has convincing evidence that all the recommended interventions have been satisfactorily implemented and the intended objectives achieved.

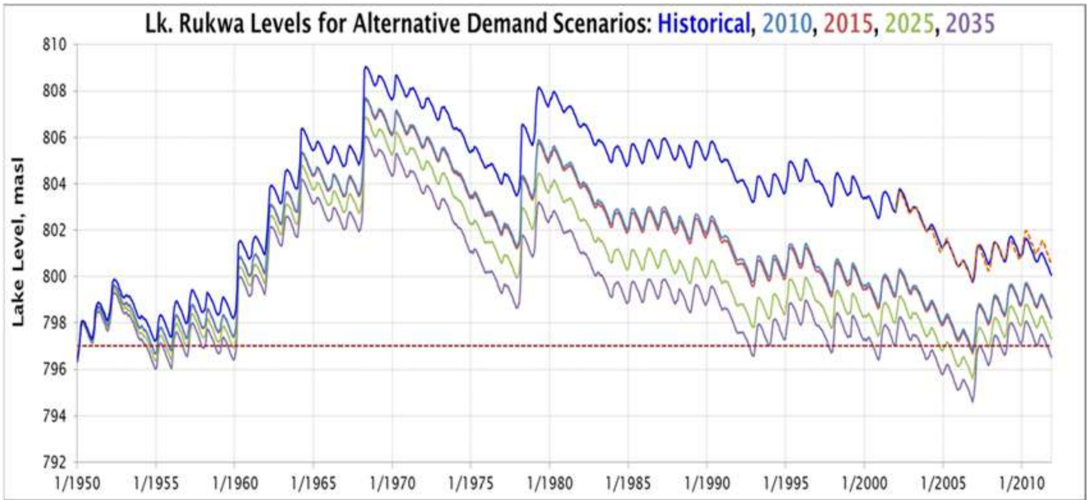

Figure 7.4: Lake Rukwa Level Assessments for Alternative Demand Scenarios.

7.3 Strategy to address the Projected Water Deficits

Sub-basin water balance assessments indicate that, at annual level, most sub-basins have adequate water resources to meet the existing and projected annual water demands. However, the biggest challenge in all sub-basins are the localized monthly water shortages especially during peak irrigation periods for the paddy growing sub-basins and during the dry season Songwe sub-basin due to the high domestic water demand for Mbeya City. All basin watersheds suffer from one or more of the following reinforcing water issues: first, is the wide spread water intensive paddy growing; second, is the poor irrigation infrastructure and on-farm irrigation water management practices; and third, is the lack of adequate water storage infrastructure. Improvements in irrigation infrastructure and on-farm water management practices could significantly reduce irrigation water use and help slow down the projected sub-basin water demand growth to manageable levels. Secondly, construction of strategic water storage infrastructure, were feasible, to harness excess runoff during the wet season could help reduce some of the projected month-to-month water deficits to within tolerable limits.

Detailed discussions of the strategies to address projected water deficits in individual sub-basins are contained in separate report volumes, i.e., **Volume II (a)** to **(f)**: *Sub-basin Water Resources Management and Development Plans*. Preliminary topographical analysis was conducted for all sub-basins to identify potential water storage sites in individual watersheds. The potential storage determination was based on 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 dams of a certain height at different locations within the sub-basin. Specific technical information was computed for each identified site including width of the dam; catchment area upstream of the dam site; and volume and surface area of the reservoir that would result by building a dam at the site. Several potential development options were also analyzed for each site by varying the dam height and width. It is important to note that the accuracy of the results and recommended potential storage options is limited by the DEM resolution and may contain some uncertainties. Thus, the values of the reservoir volume, inundated area, dam width, and upstream watershed area should be viewed as estimates that need to be refined by more detailed field data collection and analysis during the follow-up pre-feasibility studies. These caveats notwithstanding, the analysis provides fairly good guidance on the most promising dam sites and potential development options. Summary of the sub-basin specific recommended interventions is presented next.

As a general recommendation for all sub-basins, detailed studies should be conducted as soon as possible (within the first three years of implementation of the IWRMD Plan) to ascertain feasibility of the identified storage sites and develop the resources required for their construction. Construction of the dams would reduce the risk of water deficits and increase the reliability of water supply. Secondly, improvements in irrigation water supply infrastructure should commence without delay in all traditional irrigation schemes to minimize water losses and improve irrigation water use efficiency. This activity requires proper supervision and coordination from the LRBWB to ensure that targeted reductions in irrigation water use are achieved. The LRBWB should require that all existing irrigation water use permit holders commit to an agreed time-bound plan to line all their irrigation canals, install permanent water diversion control and quantity measuring structures, construct lined return canals, and implement a self-monitoring water abstraction program with mandatory periodic submission of water abstraction data to the LRBWB. Permit holders should be informed that renewal of their permit is contingent upon demonstrating substantive and verifiable progress toward improving irrigation water use efficiency in their farms. The LRBWB should work closely with the farmers and other stakeholders in setting desired efficiency improvement targets to be met by all permit holders in the basin. Thirdly, the relevant authorities (e.g., MAFC, LGA, LRBWB, etc.) should begin sensitizing farmers regarding the challenges associated with intensive paddy cultivation and work toward reducing the irrigated paddy acreage to sustainable levels. Realistic targets for irrigated paddy acreage should be agreed upon with the farmers and subsequently monitored to ensure implementation of this water conservation measure. Farmers should also be encouraged to adopt less water-intensive rice varieties (e.g., upland rice) or to diversify into other, less water-intensive crops.

Some inter-basin water transfer possibilities should also be studied further, with extra attention paid to the source watershed to ensure that its long-term water needs and environmental requirements are not compromised. Specific recommendations on water storage development options for the individual sub-basins/watersheds are discussed next.

1. Katuma Sub-basin

(1) Katuma at Sitalike Watershed

The water storage capacity required to meet the projected water demand for the Katuma at Sitalike watershed is 292 MCM. Preliminary topographical analysis conducted for the watershed revealed existence of only one potential storage site of capacity 18 MCM, surface area of about 2.36 km^2, and dam height and width of 30 m and 360 m respectively. The site is located at 30.6745 E; 6.3003 S. Detailed water resources assessments indicate some reduction in observed monthly water deficits for the period August to November but only minor reductions for December to April. This is attributed to the small size (18.0 MCM) of this storage site relative to the estimated total storage requirements for the watershed (292 MCM). The assessments also show that irrigation efficiency improvements (from 1.56 l/s/ha to 1.0 l/s/ha), while strongly recommended, cannot mitigate the observed frequency of monthly water deficits even for the 2015 water use targets. These findings underscore that the current water use situation in this watershed is unsustainable, and appropriate intervention measures should be identified and implemented urgently. Thus, notwithstanding the market incentives of paddy production, there is a limit beyond which paddy production cannot be supported by the available water resources.

This limit has already been exceeded in the Katuma at Sitalike watershed. Based on the assessment findings, it is recommended that a moratorium be imposed on any further expansion of irrigation activities in the Katuma at Sitalike watershed. The LRBWB should only reconsider lifting the moratorium after it is convinced that all the recommended interventions with regard to improvements in irrigation water use efficiency have been satisfactorily implemented and the intended objectives achieved.

(2) Msadya at Usevya Watershed

Water storage capacity required to meet the projected water demand for the Msadya at Usevya watershed is 219 MCM. Preliminary topographical analysis conducted for the watershed revealed the existence of two potential storage sites [Site 1 located at: 31.1461 E; 7.1994 S and Site 2 at: 31.1272 E; 7.1506 S]. Based on preliminary assessment, Site 1 is considered to be more attractive with potential storage capacity of 44.3 MCM, surface area of 2.32 km^2, and dam height and width of 50 m and 450 m respectively. Assessments for this site under historical hydrologic conditions (1960 to 2011) indicated significant reductions in water deficits for the period April to November but only minor reductions for December to March. The assessment also showed that combining development of this reservoir storage *and* improving irrigation water use efficiency (from 1.56 l/s/ha to 1.0 l/s/ha) would further reduce the frequency of water deficits to a reasonable level for the 2015 water demands. However, the December and January deficits under the 2025 and 2035 water demand targets remain quite high despite implementation of the two interventions. It is recommended that a moratorium be imposed on any further expansion of irrigation activities in the Msadya at Usevya watershed. This measure is necessary because the available water resources cannot reliably support the existing level of irrigation activities in the watershed unless specific interventions (i.e., increase in water storage capacity and improvements in irrigation water use efficiency) are implemented immediately. The LRBWB should only consider lifting the moratorium after it has reliable evidence that the Basin Plan interventions have been satisfactorily implemented and have the intended effect.

(3) Katuma Northeastern Watershed

Estimated storage capacity required to meet the projected water demand for the Katuma Northeastern watershed is 47.0 MCM. Preliminary topographical analysis conducted for the watershed did not identify any reasonable potential storage site. However, several small potential storage sites were identified with aggregate storage of up to 25.1 MCM. Simulation of potential reservoir development options under historical hydrologic conditions (1960 to 2011) indicated significant reduction in water deficits across all water demand targets. However, the deficits still persist across most months due to the fact that total reservoir storage (25.1 MCM) is nearly half of the storage required in this watershed (47.0 MCM). The assessments also show that developing the reservoir site *and* improving irrigation efficiency (from 1.56 l/s/ha to 1.0 l/s/ha) would further reduce (but not eliminate) water deficits, especially in March and April.

2. Songwe Sub-basin

(1) Songwe at Galula Watershed

The water storage capacity required to meet the projected water demand for Songwe at Galula watershed is 158.5 MCM. Preliminary topographical analysis conducted for the watershed revealed the existence of four potential storage sites [Site 1 located at: 33.2146 E; 8.9208 S, Site 2 at: 33.0685 E; 8.8209 S, Site 3 at: 33.0043 E; 8.8128 S, and Site 4 at: 33.2599 E; 8.8666 S.].

Based on preliminary assessment, Site 1 is considered to be most attractive with potential storage capacity of 103.0 MCM, surface area of 4.78 km^2, and dam height and width of 70 m and 450 m respectively. Detailed water resources assessments with this site indicated significant reduction in monthly water deficits across all water demand targets. For example, with the construction of this reservoir, the frequency of water deficits for the month of July, under the 2035 demand target, reduces from 96% to 4%. The simulation also shows that, irrigation efficiency improvements (from 1.56 l/s/ha to 1.0 l/s/ha) would also contribute to more drought-resilient water management. There is also potential for inter-basin water transfer to augment water supplies for Mbeya City during the dry season. A specific water transfer scheme that should also be studied in detail is a water transfer from Kiwila River in Lake Nyasa basin to Mbeya City. This project has been under consideration by Mbeya-UWSA for some time, and if it is found to be feasible (for both sub-basins), it should be given implementation priority.

(2) Lupa Watershed

Estimated storage capacity required to meet the projected water demand for Lupa watershed is 303 MCM. However, preliminary topographical analysis conducted for the watershed revealed the existence of only one medium size potential storage site [at location: 33.2543 E; 8.6250 S] with potential storage capacity of 36.9 MCM, surface area of 1.33 km^2, and dam height and width of 50 m and 450 m respectively. Detailed assessments under historical hydrological conditions (1960 to 2011) indicated significant reductions in water deficits for the period November to February but only minor reductions for March to October. This is attributed to the fairly small size (36.9 MCM) of the identified storage compared to the total storage requirements for the watershed (303 MCM). The simulation also shows that irrigation efficiency improvements (from 1.56 l/s/ha to 1.0 l/s/ha) are helpful but not sufficient to close the supply-demand gap. This is because the water used for irrigation is fairly small compared to other water uses, especially the environmental flow requirements.

(3) Songwe Eastern Watershed

The water storage capacity required to meet the projected water demand for Songwe Eastern watershed is estimated to be 42 MCM. Preliminary topographical analysis conducted for the watershed revealed the existence of two medium size potential storage sites (Site 1 at location: 33.3679 E; 8.6758 S and Site 2 at location: 33.4248 E; 8.6712 S). Both sites were found to be attractive with the following characteristics: Site 1 with potential storage capacity of 25.9 MCM, surface area of 1.59 km^2, and dam height and width of 50 m and 450 m respectively; and Site 2 with potential storage capacity of 31.3 MCM, surface area of 1.29 km^2, and dam height and width of 70 m and 450 m. Simulation of potential reservoir operation under historical hydrological conditions (1960 to 2011) indicates significant reduction in observed monthly water deficits across all water demand targets. For example with the storage reservoirs in place, the frequency of occurrence of water deficits for the month of August, under the 2035 demand target, reduces from 64% to 0%. Irrigation efficiency improvements (from 1.56 l/s/ha to 1.0 l/s/ha) are also recommended to further increase the drought immunity of the agricultural sector.

3. Momba Sub-basin

The Momba Sub-basin is generally well endowed with water resources most of which are underutilized except for the southeastern watershed where most irrigation activities are concentrated. Most sub-basin areas do not experience any water stress except for the southeastern watershed. Consequently, most of the critical interventions are aimed at addressing projected water deficits in the southeastern watershed. Construction of strategic water storage infrastructure should help even out the observed month-to-month water deficits and result in overall seasonal surpluses. The water storage capacity required to meet the projected water demand for the southeastern watershed is estimated to be about 11.63 MCM. Preliminary topographical analysis conducted for the watershed revealed only one small potential storage site (at location: 31.8642 E; 8.5994 S) with potential storage capacity of 2.3 MCM, surface area of 0.34 km^2, and dam height and width of 10 m and 450 m respectively. Detailed assessments of this reservoir site combined with irrigation efficiency improvements (from 1.56 l/s/ha to 1.0 l/s/ha) under historical hydrological conditions (1960 to 2011) indicated that some monthly water deficits (especially in January, July, August, and September) would be reduced, but those in other months (especially in November and December) would remain. Thus, additional intervention measures are needed to mitigate the stresses in these two months.

Owing to the small potential storage capacity identified in the Momba Southeastern watershed, the option of transferring water from outside the watershed (but from within the sub-basin) was considered to close the water deficit gap. Preliminary topographical analysis was conducted for the other sub-basin watersheds and indeed a large potential storage site was identified [at location: 31.5492 E; 8.9167 S] with storage capacity of up to 454.3 MCM, surface area of 21.4 km^2, and dam height and width of 70 m and 450 m respectively. This storage site has significant storage potential that would satisfy all the water requirements for the southeastern watershed if the topography allows for the construction of water transfer works. It is, therefore, the most promising option to address the water management needs of the southeastern Momba watershed, and its further technical, economic, and environmental assessment should be a Plan priority.

4. Luiche Sub-basin

The Luiche Sub-basin has sufficient water resources to meet its projected water demand growth. However, it is recommended to increase the sub-basin water storage capacity to address the projected month-to-month water deficits. A potential storage site has been identified (at location 31.5731 E; 7.8113 S) with potential storage capacity of 39.9 MCM, surface area of 1.62 km^2, and dam height and width of 70 m and 450 m respectively. Detailed assessment of this storage option under historical hydrological conditions (1960 to 2011) indicates significant reduction in monthly water deficits. For example, under the 2035 water demand target, the frequency of water deficits reduces from 96.2% to 0% and 83% to 1.9% respectively for the months of November and December. The assessment also shows that combining this storage option with irrigation efficiency improvements (from 1.56 l/s/ha to 1.0 l/s/ha) would eliminate all water deficits under all water demand targets.

5. Muze Sub-basin

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 water availability. The main challenge, however, are the projected monthly water deficits that are likely to be experienced, especially in November and December, during preparation of paddy nurseries and fields. Construction of strategic water storage infrastructure should help even out the observed month-to-month water deficits and result in overall seasonal surpluses. The water storage capacity required to meet all the projected sub-basin water demands is estimated to be about 7.67 MCM. Preliminary topographical analysis conducted for the sub-basin revealed the existence of one potential storage site (at location 31.4675 E; 7.7551 S) with storage capacity of 7.3 MCM, surface area of 0.51 km^2, and dam height and width of 40 m and 360 m respectively. Detailed assessments of this reservoir option under historical hydrological conditions (1960 to 2011) indicated significant reduction of monthly water deficits. For example, under the 2035 water demand target, the frequency of water deficits reduces from 98.1% to 0% and 84.6% to 1.9% respectively for the months of November and December. The simulation also shows that developing this storage option and improving irrigation efficiency (from 1.56 l/s/ha to 1.0 l/s/ha) would eliminate all water deficits under all water demand targets.

6. Rungwa Sub-basin

Surface water is an important water supply source for the Rungwa Sub-basin. However, its temporal variability makes it an unreliable water source during the dry season when most of the rivers dry up. A potential intervention would be construction of water storage infrastructure to harvest excess water during the wet season and use it to augment low supplies during prolonged dry periods. However, preliminary topographical analysis conducted for the sub-basin did not yield any suitable water storage site except for small micro dams.

8. Summary Findings: Issues, Challenges and Opportunities

8.1 Main Study Findings and Conclusions

The sub-basin water balance assessments reveal a number of issues that motivate potential action areas. The key summary findings are as follows:

(1) Lake Rukwa Basin lacks adequate water resources data and information. Although most of the sub-basins are gaged, flow measurements are irregular and inconsistent creating large data gaps. Groundwater data is totally lacking. In addition, there are no systematic water use or withdrawal measurements in most sub-basins. Inadequate and unreliable data present a serious challenge for water resources planning and management processes. It is important that LRBWB puts high priority on data collection and management in all basin watersheds to support more accurate water resources assessments.

(2) Most sub-basins are already experiencing water stress even under current water demand levels. Paddy production, especially in Katuma sub-basin, dwarfs all other water uses. The only exception is the Songwe sub-basin where paddy production is not as popular as in other basin areas. High water use in paddy growing sub-basins is mostly attributed to paddy production by traditional irrigation schemes characterized by poor irrigation infrastructure and inefficient irrigation practices suffering high water losses. Although at an annual level most sub-basins do not seem to experience deficits, all sub-basins are vulnerable to monthly water deficits. Without appropriate intervention measures, water deficits will grow as demands rise and will inevitably undermine the socio-economic value of all water related sectors. Structural measures like construction of water storage reservoirs could help eliminate some water deficits and restore environmental flow conditions. These should go hand-in-hand with demand management measures, especially through improvements in irrigation infrastructure and on-farm irrigation water use efficiency. Improvements in irrigation water use efficiency (through lining of irrigation canals and adoption of efficient irrigation water use practices and technologies) could reduce the current demand by half. Such interventions can most likely address the observed shortages. These measures coupled with more sustainable agronomic practices, such as diversifying from paddy growing to other, less water-intensive high value crops, could reverse the current trend of unsustainable demand growth.

(3) Lake Rukwa sub-basins experience water stress at different times of the year and for different reasons. Unlike the other sub-basins that experience most water stress during the wet season (paddy growing season), the Songwe sub-basin experiences water shortages during the dry season when supply is low. Thus, individual sub-basins have unique water issues that warrant unique solutions. Paddy growing sub-basins have to confront the challenge of inefficient irrigation as part of the strategy to address water deficits. For several of the sub-basins, structural measures like construction of water storage infrastructure could help reduce water deficits. Conjunctive use of surface and groundwater is another potential water supply augmentation measure. However, lack of data and information on the basin groundwater potential makes this option speculative and underscores the critical importance of groundwater monitoring.

(4) Although subsection 6(2) of the Water Resources Management Act (2009) prioritizes water allocation for domestic purposes first, water for environmental reserves second, and water for socioeconomic activities third, the current practice of water allocation and use in the basin does not follow the legislative mandate. Instead, the common practice is to first allocate water for all non-environmental uses and leave the residual flow for the environment. It is uncommon for current water allocation decisions to explicitly take into consideration specific EFRs. This may be attributed to the complexity of assessing EFRs and to the lack of data for developing EFRs at critical river sections. It is therefore important that comprehensive basin-wide environmental flow assessments are carried out to establish EFRs for all critical river sections. Proactive management actions should also be taken to protect these EFRs from competing water uses.

(5) The Lake Rukwa basin is vulnerable to climate change. Climate change is expected to impact the basin hydrology and water resources primarily through increased evapotranspiration from watersheds, wetlands, and lakes. Higher evapotranspiration is likely to reduce surface water flows, soil moisture, groundwater recharge, and lake levels. In addition to supply side impacts, higher evapotranspiration is likely to increase agricultural water demand (due to increased crop evapotranspiration) and possibly demand for other water uses. The water balance assessment findings highlight notable decreases in future streamflow in all major rivers in the basin. Particularly, Lake Rukwa, being the ultimate recipient of flows from all basin areas, is most vulnerable to the reinforcing impacts of climate change and increasing water demands. It is very important that climate change impacts and risks be understood and considered *proactively* in water resources planning and management decisions. A comprehensive basin climate change adaptation strategy is urgently needed to ensure that climate change issues are given due attention in all basin planning processes.

8.2 Key Basin Challenges and Opportunities

Thematic Area	Challenge	Opportunity
Water Resources Management Framework	• Weak enforcement of policies and laws. • Inadequate technical and financial resources. • Weak stakeholder coordination and collaboration mechanisms. • Inadequate lower level WRM structures (WUAs, CCs, etc.).	• Strong water related policies and laws. • Comprehensive WRM institutional structure. • Autonomous Basin Water Boards in place. • Increased government funding for WRM activities. • Five WUAs established and providing support to LRBWB on local WRM issues.
Water Resources Monitoring and Assessment	• Inadequate and poorly maintained water resources monitoring network. • Inadequate technical capacity for water resources assessments. • Inadequate databases, information systems, and technical tools.	• Existence of basic water resources monitoring network which was rehabilitated recently. • Development of Rukwa DSS to be used as information system and for technical assessments. • Availability of data from

	• Inadequate and poor quality water resources data.	public international sources (e.g., CRU) to supplement locally available data.
Water for Socioeconomic Development	• Low access to safe water for domestic use. • Inefficient water use practices, most especially in traditional irrigation schemes. • Uneven spatial and temporal water availability. • Increasing water scarcity due to climate and demand change. • Increasing water use conflicts due to water scarcity and competition among different water use interests. • Prevalence of wide spread illegal water abstractions and uses.	• Strong regulatory framework for water allocation and use. • Availability of water resources of reasonable quality and quantity to meet different socioeconomic needs. • Increased government and private sector investment in water development activities (especially domestic and irrigation water supply). • High potential for irrigated agricultural production.
Water for Environment and Biodiversity Conservation	• Widespread environment degradation due to deforestation, pollution, etc. • Specific environmental flow requirements (EFR) for critical river sections not yet established. • Weak enforcement of the environmental flow reserve as required by law. • Uncontrolled over abstractions upstream of conservation areas, e.g., in Katuma sub-basin.	• WRM Act (2009) prioritizes water allocation to the environment, only second to basic human needs. • Strong environment management policies, laws, and institutions in place.

8.3 Water Resources Problem Diagnosis

Water resources problem diagnosis is a very important step in the IWRM planning process because it identifies and conceptualizes potential intervention measures for prevailing water resources problems. Problem diagnosis provides the key ingredients for development of the IWRMD Plan. During the course of the study, several water resources findings, conclusions, and issues were extensively reviewed and discussed by basin stakeholders at different fora. Technical reports containing these findings, conclusions, and issues (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 facilitated workshops. The comments contributed by the stakeholder review process were extensive and helped focus the study on priority stakeholder interests and concerns.

This section presents the water resources problems identified and discussed in the various stakeholder fora. The discussions also involved identifying water related pressures, causes, and associated impacts. Information generated from this "pressure-impact" analysis enabled stakeholders to understand how and to what extent different socio-economic activities affect the basin's water resources and environment in general. Pressure-impact analysis is also useful in helping determine whether or not sufficient data/information exists to fully analyze the identified problems, quantify their corresponding impacts, and design appropriate intervention measures. A major stakeholder observation was that the Rukwa basin is faced with significant challenges associated with inadequate and poor quality water resources data. This observation and several other stakeholder concerns provided the basis for identifying potential basin interventions that are discussed extensively in subsequent report chapters. Several of the water related problems identified together with their potential causes and associated impacts are summarized in the matrix below.

Water Resources Problem Diagnosis Matrix

Problem	Underlying Causes	Impacts
Inadequate and/or poor quality data	• Inadequate and limited monitoring network with large unmonitored watersheds and groundwater aquifers. • Ad hoc and infrequent field data collection resulting in large data gaps. • Poor operation and maintenance of monitoring network resulting in frequent breakdown of field equipment.	✓ Poor water resources planning and management decisions. ✓ Inadequate water infrastructure designs. ✓ Inadequate water information dissemination to the public. ✓ Poor investment decisions on water related projects.
Non-compliance with water permit regulations and other provisions of the Act	• Weak enforcement capacity to crack down on illegal water abstractions and non-compliance with water permit conditions. • Inadequate awareness by water users of their rights and obligations under the Act. • Lenient penalty structure that cannot deter offenders from non-compliance with the Act. • Weak and poorly facilitated Water User Associations to monitor illegal water use. • Limited support from local community leaders in enforcement efforts either due to lack of awareness and/or motivation, and/or conflict of interest.	✓ Over abstraction of water by illegal users thus denying legal users rightful access to allocated water. ✓ Low revenue to the LRBWB since many illegal water users don't pay any water user fees. ✓ Distortion of catchment water balance since illegal abstractions are difficult to account for in the official water allocation plans. ✓ Water use conflicts between legal and illegal water users.
Water use conflicts	• Water scarcity in the basin, especially during dry periods. • Inefficient water use, especially in traditional paddy irrigation schemes resulting in farmers drawing more water than necessary. • Weak and poorly facilitated Water User Associations to monitor proper use of local water resources. • Weak enforcement capacity to crack down on illegal water abstractions and non-compliance with water permit conditions. • Lack of village Land Use Plans to guide orderly use of	✓ Reduced productivity and loss of revenue by downstream water users. ✓ Livestock and wildlife deaths and migration due to lack of water and grazing resources. ✓ Animosity between water users some of which may result in destruction of property and human deaths. ✓ Increased migration of people, especially pastoralists in search of water and pasture for their animals resulting in more

Problem	Underlying Causes	Impacts
	local land and water resources. • Uncontrolled movement of pastoralists into the basin in search of water and grazing resources.	conflicts and spread of diseases. ✓ Disruption of social order and socioeconomic activities due to insecurity.
Low safe water and sanitation coverage	• Inadequate investment in safe water supply and sanitation facilities. • Poor operation and maintenance of installed water supply and sanitation facilities resulting in low operational efficiencies and frequent facility break down.	✓ High prevalence of water related diseases resulting in high infant mortality rates, reduced productivity and unnecessary health expenses. ✓ Low productivity of women and girls who spend most of their time walking long distances to fetch water. ✓ High dropout rates of female students from school.
Inadequate awareness of water resources related issues	• Lack of access to reliable water resources data and information. • Inadequate school curriculum that does not make adequate provisions for water resources and hygiene related studies. • Inadequate technical and financial capacity to sensitize local communities on water resources related issues.	✓ Lack of interest by local communities to participate in water resources related activities. ✓ Catchment degradation and pollution of water resources. ✓ Unsustainable and inefficient domestic, industrial and irrigation water use.
Violation of minimum environmental flow requirements	• Lack of scientific data/information on required minimum environmental flow requirements for different river sections. • Lack of knowledge/awareness regarding legal requirements for minimum environmental flows. • Weak enforcement capacity to crack down on illegal water abstractions and non-compliance with water permit conditions. • Water scarcity especially during the dry season, making it difficult to enforce minimum environmental flow requirements due to competition for the little	✓ Loss of biological diversity and ecological functions of water bodies. ✓ Loss of livelihoods and incomes for households dependent on river based socioeconomic activities for their survival. ✓ Increased suffering/death of wildlife in protected areas dependent on perennial rivers/streams for their survival.

Problem	Underlying Causes	Impacts
	available water by different water users.	
Pollution of water sources/bodies	• Inadequate sanitation facilities in rural and urban areas. • Poor siting of sanitation facilities (e.g., location of shallow pit latrines near water sources). • Improper discharge of effluent from industries, abattoirs, and toilets into rivers. • Improper use of agro-chemicals. • Improper use of chemicals and uncontrolled disposal of effluent from small scale artisanal gold processing operations. • Watering of livestock in rivers. • Bathing, and washing of clothes, utensils, and chemical containers in rivers. • Lack of and/or poor solid waste disposal facilities. • Laxity in enforcement of environmental rules and regulations.	✓ Increased occurrence of water borne diseases due to consumption of poor quality water. ✓ Increased raw water treatment costs by utility companies and industries. ✓ Loss of aesthetic value. ✓ Ecological damage in rivers and wetlands. ✓ Increased water scarcity due to non-usability of heavily polluted water sources resulting in affected users looking for alternative water sources.
Inefficient water use	• Inadequate/poor irrigation infrastructure and on-farm water management practices especially in traditional paddy irrigation schemes. • Inadequate/old and poorly maintained urban water supply infrastructure resulting in high non-revenue water. • Low water tariffs resulting in wastage of water due to lack of incentives to conserve water. • Use of inefficient/water intensive industrial production technologies including limited use of recycled water.	✓ Water scarcity due to unnecessary excessive withdrawal of water resulting in water use conflicts. ✓ Low revenue from water use since a large quantity of water is wasted. ✓ Disincentive for adoption of water conservation practices since any gains are wasted by inefficient water users.
Water Scarcity	• Lack of and/or inadequate water storage infrastructure to store water during rainy season to augment low flows during the dry season. • Excessive water withdrawals by upstream water users resulting in shortages for the downstream users.	✓ Increased water use conflicts. ✓ Reduced productivity and loss of revenue due to water constraints. ✓ Increased water borne diseases and decreased quality of life.

Problem	Underlying Causes	Impacts
	• Illegal water abstractions that are not factored in the official water allocation decisions resulting in excessive water use and scarcity. • Changes in streamflow patterns due to climate warming and increased evapotranspiration. • Changes in land use patterns resulting in increased flash floods and reduced base flows to sustain dry season low flows. • Increased water demand due to increased population, climate change, and general socioeconomic development. • Inadequate water supply sources.	✓ Increased water supply interruptions in urban areas. ✓ Increased environmental degradation due to loss of biological diversity and ecological functions. ✓ Increased migration of people, especially pastoralists in search of water and pasture for their animals resulting in conflicts and spread of diseases. ✓ Increased livestock and wildlife deaths.
Heavy sediment transport in rivers	• Cutting down trees for expansion of agricultural activities and human settlements due to population pressure. • Charcoal burning and timber logging as alternative sources of household income. • Poor cultivation practices especially on steep slopes. • Uncontrolled bush burning. • Overstocking of grazing lands resulting in destruction of ground cover. • Cultivation of river banks and wetland areas resulting in destruction of buffer zones along rivers and lake shores.	✓ Deterioration in physical water quality in rivers/lakes making it unusable for some purposes like drinking. ✓ Drying up of streams and rivers due to increased flash floods and hence reduction in base flow. ✓ Destruction of ecological biodiversity due to loss of habitat for flora and fauna. ✓ Increased expenditure on raw water treatment by Urban Water Supply Authorities due to poor raw water quality. ✓ Increased siltation of natural and man-made water storage reservoirs.
Inadequate capacity for water resources assessments	• Inadequate and/or lack of appropriate water resources assessment tools and decision support systems. • Limited technical and experienced staff with the required skills to carry out high level assessments. • Inadequate reliable water resources data on which to	✓ Limited dissemination of technical information to the public. ✓ Heavy reliance and expenditure on consultants for high level technical expertise.

Problem	Underlying Causes	Impacts
	base the technical water resources assessments. • Difficulty to attract and retain high level technical staff due to low salaries compared to the private sector. • Inadequate funding to facilitate and motivate staff to undertake high level water resources assessments.	✓ Limited influence on water related planning and investment decisions in other sectors.
Inadequate water storage/supply infrastructure	• Inadequate funds for water supply infrastructure development. • Poor operation and maintenance of water infrastructure. • Inadequate technical capacity for design, construction supervision, and operation and maintenance of water supply infrastructure. • Unfavorable topography and difficult terrain for construction of certain infrastructure (e.g., dams). • Old and dilapidated infrastructure characterized by frequent breakdown.	✓ Water scarcity. ✓ Water supply interruptions. ✓ Loss of production and revenue due to water constraints. ✓ Water use conflicts. ✓ Low access to safe water coverage.
Flooding	• Catchment destruction especially cutting down trees and cultivation of hill slopes. • Climate change is likely to exacerbate severe floods.	✓ Loss of soil fertility and increased sediment loads in rivers due to soil erosion. ✓ Destruction of infrastructure, crops, farmland, and displacement of downstream communities. ✓ Waterborne diseases.
Drainage of wetlands	• Conversion of wetlands into agricultural land due to shortage of arable land. • Unsustainable harvesting of wetland products. • Disposal of excessive toxic wastes into wetlands. • Brick making. • Lack of awareness/wrong perception on importance of wetlands.	✓ Loss of wetland ecosystem (biodiversity, water supply, etc.). ✓ Loss of wetland functions (flood control, erosion control, water filtration, water storage, etc.).
River bank	• Shortage of agricultural land due to population	✓ Soil loss.

Problem	Underlying Causes	Impacts
cultivation	pressure. • Weak enforcement of river bank protection regulations and guidelines.	✓ Increased sediment loads in rivers. ✓ River bank failures and interference with natural river morphology.
Soil erosion	• Deforestation and vegetation removal. • Inappropriate land use practices. • Cultivation on steep slopes. • Inappropriately designed drainage systems.	✓ Soil/fertility loss. ✓ Increased sediment loads in rivers. ✓ Low crop yields. ✓ Loss of agricultural land.
Over-abstraction of groundwater	• Inadequate surface water sources in terms of quantity and quality. • High investment and treatment costs for surface water supply schemes. • Degradation of groundwater recharge areas.	✓ Depletion of groundwater reserves. ✓ Land subsidence due to rapidly receding water table. ✓ Drying up of rivers and streams due to reduced base flows.

9. Basin Vision, Strategic Goals and Priority Actions

9.1 Lake Rukwa Basin Vision and Mission

The Lake Rukwa Basin Vision and Mission statements define the overall strategic goal for water resources management and development. 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 IWRMD 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*)

9.2 IWRMD Plan Strategic Goal

The overall goal of the Rukwa Basin IWRMD Plan is to eradicate poverty and stimulate socioeconomic transformation through sustainable management, equitable access, and efficient use of the basin water resources. This goal is to be realized through making progressive improvements to existing water resources management and use practices with the objective of achieving sustainable balance between water availability and demand without compromising environmental integrity.

9.3 IWRMD Plan Strategic Objectives

The matrix below presents the strategic objectives and priority actions addressed by the IWRMD Plan. They describe the broad outcomes expected following implementation of the Lake Rukwa IWRMD Plan over the planning horizon (2016 – 2035). These were derived from the sub-basin specific water resources management and development plans.

Strategic Objective	Priority Actions
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 basin water demands. • Achieve sustainable water demand growth over the planning horizon. • Incorporate climate change impacts in all basin water resources planning and management decisions.
Strategic Objective 2: To ensure availability of adequate and reliable water resources data for all watersheds and aquifers.	• Upgrade and expand the existing water resources monitoring network to cover all important watersheds and aquifers. • Review and upgrade existing data processing, storage, and assessment hardware and tools.
Strategic Objective 3: To	• Undertake comprehensive annual water use surveys to identify

identify and register all basin water uses and ensure full compliance with permitting requirements.	and register all basin water uses. • Establish water abstraction and use monitoring network to quantify basin water use. • Strengthen permit enforcement and compliance monitoring mechanisms.
Strategic Objective 4: To determine and ensure compliance with the flow reserve for all basin water resources classes.	• Classify all basin water resources and establish resource quality objectives for each class. • Undertake detailed environmental flow assessments for all critical basin river sections and establish appropriate environmental flow requirements. • Determine the flow reserve for all basin water resources classes. • Monitor and ensure compliance with the flow reserve.
Strategic Objective 5: To promote integrated watershed management and environmental conservation	• Protect vulnerable watersheds and reverse basin environmental degradation. • Control pollution from point and non-point sources.
Strategic Objective 6: To strengthen the capacity for water resources management at all basin levels.	• Establish all lower level WRM entities and committees as provided for under the WRM Act (2009) and empower them to effectively undertake their mandates. • Strengthen the technical and financial capacity of the LRBWB to ensure effective and timely implementation of planned activities. Empower all key basin stakeholders to ensure their active and sustained involvement in WRM activities.

9.4 Priority Actions

The priority actions described below were derived from the sub-basin specific water resources management and development plans. They also include water resources planning and management actions that cut across all sub-basins and are intended to put in place the necessary enabling environment for successful implementation of the IWRMD Plan.

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

The overarching objective for development of the Lake Rukwa Basin IWRMD Plan is to ensure sustainable management and development of the basin water resources to benefit current and future generations. Therefore, one of the main challenges the Plan seeks to address is balancing water supply and demand to ensure that the available water resources satisfy current and future basin water demands without compromising environmental integrity. The four objectives to be achieved under this goal are discussed next.

Objective 1: To ensure availability of water resources of adequate quantity and quality to meet current and future basin water demands.

Water balance assessments conducted under the study indicate that most sub-basins are already experiencing water stress (to varying degrees) under current water supply and demand conditions. To enhance water resources availability to meet current and future water demands, there is a need to implement comprehensive structural and non-structural supply augmentation measures aimed at improving water security in different basin areas. The specific proposed actions to achieve this objective are discussed next.

Action 1.1.1: **Construct water storage infrastructure to increase basin storage capacity**.

Preliminary topographical analysis was conducted for all sub-basins and potential water storage sites identified for individual watersheds, where available. Several potential development options were also analyzed for each site by varying the dam height and width. Detailed studies should be conducted within the first three years of implementation of the IWRMD Plan to ascertain feasibility of the identified storage sites and potentially undertake construction as soon as practicable. Dam construction should be fast tracked to increase watershed storage capacity and help reduce drought vulnerability. Details of the identified potential water storage sites are contained in **Volume II (a)** to **(f)**: *Sub-basin Water Resources Management and Development Plans*. Due to scarcity of financial resources, this activity should begin with the most stressed sub-basins first (i.e., Katuma and Songwe) and then proceed to the other sub-basins. Opportunities should also be explored for investment in storage facilities that can be shared by adjacent sub-basins where the topography allows. Preference should be given to multi-purpose storage facilities that address issues of flood control, mini-hydropower generation, irrigation, and sediment control, among others. Three potential storage reservoirs have been identified in Katuma sub-basin (Ilalangulu, Katuma, and Dirifu) and prefeasibility studies have already been conducted as part of this study. Development of the three sites should be considered as a priority activity once the detailed feasibility studies confirm technical and commercial viability.

Action 1.1.2: **Conjunctive use of surface and groundwater.**

Currently groundwater is being exploited on a small scale in several parts of the basin mostly for domestic consumption. However, large scale groundwater use in irrigated agriculture, to the present day, has been limited for a number of reasons including: scant information of aquifer potential; and the potential for irrigation through surface systems has not yet been exhausted. A comprehensive groundwater monitoring program has been recommended to help develop the required understanding of the basin groundwater potential. Upon availability of adequate data, detailed groundwater assessments should be conducted to identify areas with high groundwater potential for future development and use. The outcome of the basin-wide groundwater assessments will be valuable in developing a comprehensive plan for the conjunctive use of surface and groundwater as part of the broader Rukwa Basin water security program.

Action 1.1.3: **Explore and implement inter basin water transfers to augment sub-basin water supplies as feasible and appropriate.**

Inter basin water transfers present a potential opportunity for water scarce sub-basins to augment their available water resources from adjacent/neighboring basins with abundant supplies. For example, Katuma and Songwe sub-basins could benefit from the significant water resources in Momba sub-basin and other neighboring basins. However, caution should be exercised before implementing such schemes to ensure that the long-term water needs and environmental requirements of the source basin are also sustained. Two water transfer schemes are being recommended for detailed feasibility studies. First is a water transfer from Kiwila River in Lake Nyasa basin to Songwe basin to augment water supplies for Mbeya City. This proposal has been a subject of interest by Mbeya-UWSA for some time and should be carefully studied. The second water transfer is from a potential storage site in northwestern Momba [located at 31.5492 E; 8.9167 S] to the southeastern Momba sub-basin to relieve current water stresses. This site has significant storage potential to satisfy all water requirements in the southeastern Momba watershed provided the topography would support economical construction of the associated infrastructure.

Objective 2: To achieve sustainable water demand growth over the planning horizon.

The current rate of water demand growth in all sub-basins is unsustainable given the already existing water stress. Therefore, there is an urgent need to reverse the rising water demand through retrofitting traditional irrigation schemes in ways that reduce high water losses. Other demand management measures should target reductions in water losses experienced in urban water supply systems due to old and poorly maintained infrastructure.

Action 1.2.1: **Rehabilitation and upgrading of irrigation water supply infrastructure in traditional irrigation schemes.**

Improvements in irrigation water supply infrastructure should commence in all traditional irrigation schemes to minimize water losses and improve irrigation water use efficiency. This activity requires proper supervision and coordination from the LRBWB to ensure that the intended objective of reducing irrigation water use is achieved. The LRBWB should require, as a condition for irrigation water permit renewal, that all existing irrigation water use permit holders commit to an agreed 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 implement a self-monitoring water abstraction program with mandatory periodic submission of water abstraction data to the LRBWB. Permit holders should be required to demonstrate substantive and verifiable progress toward improving irrigation water use efficiency in their farms before their permits can be renewed. The LRBWB should work closely with the farmers and other stakeholders to set desired efficiency improvement targets to be met by all permit holders.

Action 1.2.2: **Rehabilitation and upgrading of urban water supply infrastructure to reduce water losses.**

Implementation of modest measures like increased vigilance in detecting and fixing water leakages, routine maintenance and rehabilitation of water supply infrastructure, curbing illegal water connections, and increased metering could significantly reduce water losses in urban water supply systems. Reduction in urban water supply losses is achievable over the planning horizon given the ongoing investments in rehabilitation and expansion of urban water supply infrastructure under WSDP. For example, Mbeya urban water supply infrastructure has just undergone major rehabilitation and expansion under the recently concluded Mbeya urban water supply and sanitation project phase II. Similar infrastructure improvements are ongoing in the major towns and urban centers in the basin. This activity requires proper coordination from the LRBWB to ensure that the intended objective of reducing water losses in urban water supply systems is achieved. The loss reduction measures should be complemented by other demand management measures such as setting deterrent tariffs to minimize water wastage, encouraging water recycling and re-use, and water rationing.

Action 1.2.3: **Comprehensive and routine monitoring of water abstractions/use.**

Unless water managers have accurate knowledge of the water amounts being abstracted from the river and groundwater system (quantity, location, and timing), it is difficult to determine spatial and temporal deficits and pinpoint system inefficiencies. Lack of accurate and consistent water abstraction and use data is a major setback for any meaningful water supply-demand balance assessment. There are no systematic measurements of water use/withdrawals in all sub-basins. It is thus difficult to estimate actual water abstractions and accurately reconstruct unimpaired flow series at key basin nodes. There is a need to establish a comprehensive water use monitoring network to ensure routine collection of water use data. Implementation of this activity has to be undertaken in collaboration with the 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 that all water permit holders install water abstraction/use measuring devises, maintain accurate 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 inform permit holders that failure to install water abstraction/use monitoring devises or deliberate recording or submission of false data would constitute an offence carrying costly penalties. To supplement the self-monitoring program, the LRBWB should install water abstraction/use monitoring devises at a few strategic locations in the system for its own regulatory purpose.

Objective 3: Incorporate potential climate change impacts in all basin water resources planning and management decisions.

Critical review and analysis of historical climatological data shows clear evidence of a changing climate over the Rukwa Basin. Climate warming portends adverse hydrologic consequences which may have far reaching impacts on the basin water resources and dependent socioeconomic activities. It is thus imperative that all future basin developments consider the potential impacts of future climate change as well as appropriate adaptation measures.

Action 1.3.1: **Develop a comprehensive climate change mitigation and adaptation strategy and plan for Lake Rukwa basin.**

The projected climate change impacts for the basin are expected to have critical implications for hydrology, agriculture, and water resources, since increased evaporation losses may reduce surface water flows, soil moisture, groundwater recharge, and lake levels. A comprehensive climate change mitigation and adaptation strategy and plan should be developed to enable stakeholders to cope with potential future climate change impacts.

Action 1.3.2: **Develop a flood and drought forecasting and early warning system for the Lake Rukwa basin.**

Over the past decades, the basin has been experiencing increased incidences of severe floods and droughts. Occurrence of these extreme events poses a big challenge in planning and managing the basin water resources. Severe water scarcity during drought periods often results in significant loss of productivity and escalation of conflicts between competing water users. Floods on the other hand are associated with destruction of properties and human life, increased incidences of water borne diseases, severe damages of crops and rural infrastructure, and general disruption of socio-economic activities. Results from detailed climate change assessment studies indicate increased annual streamflow variability implying that the magnitude and frequency of occurrence of severe floods as well as droughts are expected to increase. It is, therefore, important to develop a comprehensive flood and drought forecasting and early warning system to enable timely implementation of drought mitigation and flood evacuation contingency measures.

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

Reliable, consistent, and contemporaneous data is needed to quantify the river flows at several locations within each sub-basin, to estimate rainfall and evapotranspiration over the watersheds upstream of the locations where river flow is measured, and to determine groundwater levels and fluxes in different basin aquifers. Despite the ongoing efforts by the LRBWB to operate and maintain a reasonable water resources monitoring network, the basin still faces considerable challenges related to the unavailability or inadequacy of water resources data. Although most of the sub-basins appear to be gaged and monitored, critical review of the available data shows large data gaps and questionable data quality (due to inconsistencies and irregularities in the current data collection and quality control procedures). Review of the existing river rating curves also revealed that most were generated 20 to 30 years ago and have not been updated or re-validated. Worse still, there is very limited understanding of the magnitude and distribution of groundwater resources in the basin. With regard to water quality monitoring, for several sites only few water quality parameters are being analyzed (an average of just 12 parameters per sample). Therefore, the available information is incomplete, making it difficult to carry out comprehensive water quality assessments for the concerned basin areas.

Besides the monitoring challenges highlighted above, the current data processing, quality control and storage mechanisms of the LRBWB are inadequate. There is no coherent database or information management system in place to ensure proper data processing, quality control, and storage. Most of the data is stored in different computers accessible to different staff. Some of the historical data is still in hard copy form and needs digitizing to ensure proper storage. Urgent measures are needed to strengthen the existing water resources monitoring network and assessment capacity to ensure sustainable water resources management and development.

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

Review of the existing monitoring network depicts uneven spatial distribution of stations with significant gaps occurring over large parts of Rungwa, Katuma, and Songwe sub-basins. The situation is worse when it comes to groundwater resources monitoring. There is currently no groundwater level monitoring. With regard to water quality, most of the currently monitored sites are concentrated in urban centers leaving large areas to the north and northeast virtually ungaged. In addition, very few of the sites have been monitored consistently over a reasonable period of time to discern any long term water quality trends. The existing monitoring network is, therefore, inadequate to meet the data and information requirements for managing the Lake Rukwa Basin. General recommendations are made below regarding potential improvements in the existing monitoring network. Detailed recommendations specific to each sub-basin are contained in **Volume II (a)** to **(f)**: *Sub-basin Water Resources Management and Development Plans* and in **Volume VI** of the Final Report.

Action 2.1.1: **Upgrade and expand existing surface water resources monitoring network.**

While significant effort was recently undertaken by the LRBWB to upgrade the existing surface water resources monitoring network, the network is spatially sparse over large basin regions and to a large extent inadequate to generate the necessary data required to support detailed hydrologic and water resources assessments. World Meteorological Organization Guidelines for hydro-meteorological monitoring network design (*WMO; Guide to Hydrological Practices, WMO-No. 168, 2008*) recommend a minimum precipitation network density of 250 km^2 per station in mountainous regions and 575 km^2 per station in interior plains. For streamflow, the recommended minimum density is 1000 km^2 per station in mountainous regions and 1875 km^2 per station in interior plains. However, for the Lake Rukwa Basin, such station densities would require very costly investments in monitoring equipment, maintenance, and operational support. The following specific intervention measures are proposed to improve the existing surface water monitoring network.

(a) **Main Rivers**: A minimal monitoring network is recommended to enable characterization of the hydro-meteorological regime in all major basin watersheds; calibrate reliable hydrologic models; and undertake comprehensive hydrological and water resources assessments. As a minimum, the proposed network for each watershed should include: (i) two streamflow gage stations, one near the river entrance to the lake and a second in the middle reaches; (ii) three rainfall stations distributed evenly to capture the orography of each main river watershed; and (iii) one meteorological station measuring evaporation and other climatic variables (e.g., temperature, solar radiation, humidity, and wind speed and direction) in the watershed interior. Due to its considerably larger size, the Rungwa sub-basin is recommended to include six rainfall and two meteorological stations.

(b) **Lake Rukwa**: As a minimum, eight rainfall stations and four meteorological stations distributed evenly around the shores of Lake Rukwa are recommended to characterize the lake rainfall and evaporation regime. Lake levels should also be monitored at two lake shore locations, one on the north and a second on the south lake basins. In view of the likely lake-aquifer interactions, several wells need to be established and monitored on a monthly (or at least a seasonal) basis at varying distances (i.e., 5, 10, 25, and 50 km) from the lake shore and along north-south and east-west transects. Such monitoring wells are particularly important within the high permeability inter granular aquifer within which the lake is embedded. These transects can be spaced at distances of 50 km for a total of five east-west and one north-south transect. The purpose of this monitoring program would be to characterize the seasonal groundwater flow direction and magnitude, and the impact of groundwater pumping on lake levels.

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

There are no groundwater monitoring stations in the basin, presenting serious challenges in the sustainable management and development of the basin water resources. There is an urgent need to establish a comprehensive groundwater monitoring network. As part of the study, a minimum monitoring network of 21 boreholes has been proposed as shown in **Figure 9.1**. The selection was based on a number of factors: coverage of main aquifers and recharge areas; close proximity to existing hydrometric/climatological stations; station accessibility; potential use of existing productive boreholes; and minimization of investment and network operation costs. The proposed stations shall be reviewed by the LRBWB and their implementation prioritized based on availability of the necessary funds. Since most of the proposed monitoring sites are based on existing boreholes which are in close proximity to hydrometric/rainfall gauging stations, visits to the stations can be combined with routine visits to the hydrometric/rainfall stations to minimize operational costs. The proposed monitoring network provides reasonable minimum coverage of major aquifer types and areas based on available data, but it will need to be reviewed and augmented with additional monitoring boreholes as more detailed information becomes available on the basin's aquifer characteristics.

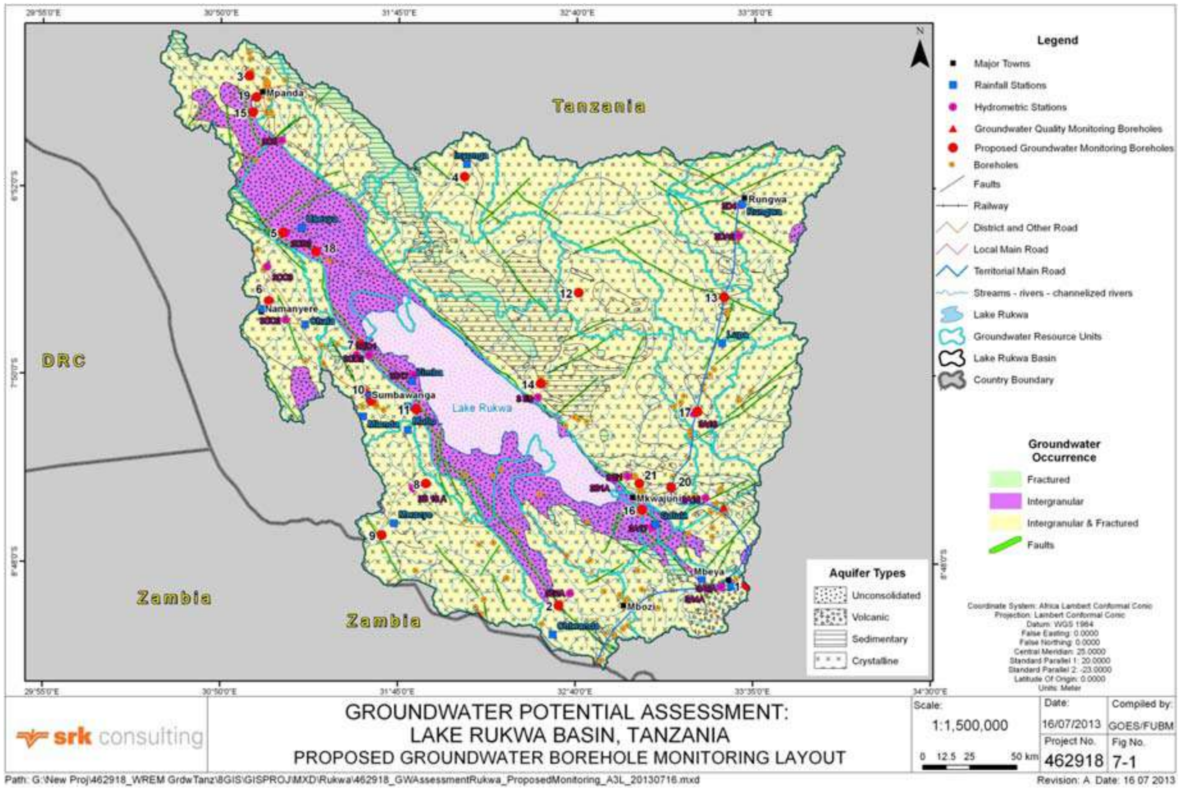

Figure 9.1: Location of proposed groundwater monitoring points.

Action 2.1.3: **Strengthen and expand the basin water quality monitoring program.**

Based on the existing water quality monitoring challenges identified during the study, the following specific intervention measures are proposed for implementation to strengthen the LRBWB water quality monitoring program.

(a) Increase spatial coverage of water quality monitoring sites to address the existing data gaps in the monitoring network, especially in the north and north-eastern basin areas.
(b) Improve the analytical capability of the Mbeya and Sumbawanga laboratories to include analysis of more water quality parameters including selected heavy metals. This support should also include strengthening the quality control and quality assurance systems for the two laboratories.
(c) Improve the capacity of the Mbeya and Sumbawanga laboratories for field sampling and analysis. This should also include procurement of field sampling gear, including equipment for the measurement of sediment transport and deposition (suspended solids and bedload) and for lake sampling.
(d) Conduct basin-wide water quality surveys to bridge data gaps and investigate heavy metal concentrations in Lake Rukwa (both water column and bottom sediments).

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

Although monitoring stations are supposed to be visited by basin staff on a regular basis to collect water resources data and carry out routine inspections and maintenance of equipment, this does not happen due to inadequate funding. The situation is worsened by frequent equipment break downs due to vandalism and poor maintenance resulting in significant data gaps. The financial resources required to operate and maintain an elaborate monitoring network in a basin as extensive as Rukwa are quite significant. Reliance on central government budget allocations alone to sustain the basin water resources monitoring operations has proved unsustainable as the funds are inadequate and rarely disbursed on time. Furthermore, the current revenue generated by the BWB from water permit fees is very small to sustain network operations. Pending availability of sufficient funding for its monitoring operations, the LRBWB should explore other potential options to ensure sustainable and consistent data collection. For example, the LRBWB should explore the possibility of training some selected members of Water User Associations to support the board in some of its monitoring activities in their areas of jurisdiction, e.g., taking the daily gage readings and relaying the information by phone text messages. LGA staff could also be involved in the monitoring activities. For example, the LRBWB could have volunteer liaison officers at ward/district headquarters to receive filled data forms from gage readers and forward them to the basin offices in Sumbawanga town or Mbeya City. Local communities neighboring the monitoring stations should be sensitized about the importance of the installed monitoring equipment and hence the need to safeguard them against vandalism.

Objective 2: Review and upgrade existing data processing, storage, and assessment tools and hardware.

Data and information are of little value without the knowledge and tools to analyze and understand their trends and implications. The Rukwa Decision Support System (DSS) developed under the project presents an excellent opportunity to address the existing data management and analysis issues. The Rukwa DSS is a comprehensive information and decision support system that brings together and facilitates the collection, storage, analysis, quality control, sharing, and use of all water related data in the basin in an integrated and user friendly fashion.

Action 2.2.1: **Conduct comprehensive follow up training in the use of Rukwa DSS.**

Although the LRBWB staff have received some training on the use of the Rukwa DSS, it is not sufficient to ensure full utilization of its functionalities. There is need for additional systematic training to develop the capacity of LRBWB and district staff to compile, quality control, archive, analyze, and share hydro-climatic data through the Rukwa DSS. Technical training of staff should be an integral part of the IWRMD Plan implementation process to ensure sustainability.

Action 2.2.2: **Upgrade basin computer hardware and software.**

The existing LRBWB computing facilities (hardware and software) are inadequate and need considerable upgrading to support high end data management and technical assessments using the Rukwa DSS.

Action 2.2.3: **Migrate all existing water resources data and information into the Rukwa DSS.**

Following completion of development of the Rukwa DSS and transfer to the LRBWB, responsible basin staff should embark on the process of populating and expanding the databases with all available and new data and information toward establishing a robust central information management system. Staff should also continue working on data quality control using the built in Rukwa DSS tools and functionalities to ensure storage of reliable and good quality data. The process of updating the old rating curves should continue using the Rukwa Rating Tool to enable generation of reliable river discharge sequences.

Action 2.2.4: **Conduct technical assessments using the Rukwa DSS and generate periodic technical reports.**

LRBWB staff should routinely use the Rukwa DSS to carry out technical assessments and generate information required for water resources planning and management processes in the basin. The DSS should also be used to generate periodic (e.g., quarterly or annual) water resources reports for dissemination to different basin stakeholder groups as part of the community outreach and sensitization program.

GOAL 3: All basin water uses registered and fully compliant with permitting requirements.

There are several competing water uses including irrigation, livestock, wild life, industrial, environmental, and domestic consumption. Effective water use monitoring and regulation is absolutely necessary to assess the integrity of the water distribution system, issue permits, and collect water use fees. Although illegal water usage is an offence under the Water Resources Management Act (2009) carrying stiff penalties, most basin areas still face the challenge of illegal water abstractions and non-compliance with water permit conditions. 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. There is an urgent need to strengthen the basin regulatory and enforcement mechanisms to ensure compliance with the law.

Objective 1: Strengthen water resources regulatory and enforcement mechanisms.

Although regulation of water use is one of the primary functions of the LRBWB, the board still faces the challenge of inadequate capacity (technical and financial) to monitor the vast number of water users. Monitoring water usage and enforcing compliance with water permit conditions for the thousands of water users is a challenge that requires full cooperation from the water users themselves and the local communities. It is therefore important that formation of lower level water resources management structures and sensitization of local communities are considered as priority intervention measures in the IWRMD Plan to strengthen the regulatory capacity of the LRBWB. The strategy should also include 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 BWB to routinely review and update the Water Permit Register to ensure timely follow up with pending applications and those that require renewal.

Action 3.1.1: **Conduct comprehensive annual surveys of all 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 staff are required to regularly traverse large distances in the Lake Rukwa Basin to reach all water users and validate their legal standing. Thus, this kind of activity cannot be planned as a routine undertaking because of budgetary constraints. Continuing to voice complaints about the budgetary constraints is not a viable solution either. Other creative ways of performing this function should be explored. For example, the LRBWB could engage all key basin stakeholders in a discussion to plan an annual basin event dubbed "*Operation zero tolerance for illegal water use in Rukwa Basin.*" This 'community policing' activity could attract corporate sponsorship and leverage support and resources from several sources other than leaving all funding responsibility to the LRBWB. Under such an arrangement, the LRBWB would play a coordination role and leverage the strength of the different stakeholders toward successful water management. The process would also be viewed by all stakeholders as being transparent and become less susceptible to manipulation by powerful interest groups (e.g., big commercial irrigation farmers, politicians, etc.). Being an annual event would ensure adequate planning and resources mobilization for its effective implementation. In the final analysis, comprehensive permit compliance monitoring should go beyond a few under-facilitated BWB staff and instead become a community responsibility jointly planned with the involvement of all key stakeholder agencies (including police, Local Government Authorities, local leaders, Water User Associations, Water User Groups, NGOs, and CBOs, among others). The BWB should ensure that the annual survey is as detailed as possible to capture and verify the bulk of the required monitoring information during the annual survey, and accordingly update the water permit database. The annual event could be supplemented by a few targeted routine enforcement activities by BWB 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 Mbeya) is the logistical constraints of the water permit application process, e.g., the requirement to travel long distances to Mbeya City to follow up 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 years pending issuance of the water permit. These procedural issues serve as a disincentive to water permit applicants and thus exacerbate illegal water use. It is important that the LRBWB expedites 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 difference in a short time as more resources are sought to address the 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 permit applications is a complex process that requires careful consideration of all potential impacts of the intended water abstraction and use on downstream water users including the environment. This kind of assessment cannot be carried out through a simple visual inspection of the proposed water abstraction site and spot measurement of the stream flow at the time of inspection. There is need to develop appropriate technical tools that can be used for objective and technically defensible assessments of permit applications and ensure consistency in the allocation decisions. Such tools can be incorporated in the Rukwa DSS and help give credibility to the permitting process and instill stakeholder confidence in the water allocation decisions.

GOAL 4: Environmental Flow Requirements determined for all critical river sections and compliance enforced.

Determination and consideration of environmental flow requirements (EFRs) in water allocation decisions is not optional and can no longer be ignored. The environment is a legitimate water user, albeit a silent one, whose needs must be considered and fulfilled in all water allocation decisions. It is, therefore, important that detailed environmental flow assessments be conducted to establish appropriate EFRs for all critical river sections in the basin.

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. Unfortunately, specific EFRs have not yet been determined for all critical sub-basin river sections. It is, therefore, important that the desired EFRs are 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 to establish applicable EFRs.**

As part of the study, detailed environmental flow assessment was conducted for two sub-basin watersheds (Katuma at Sitalike and Songwe at Galula). This exercise should be conducted for all critical basin river sections to establish appropriate 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.

Pollution from point and non-point sources is a major concern as it renders some of the available water resources unusable. Several basin rivers, especially Songwe, Momba, Luiche, and other small streams have been observed to carry significant sediment load, especially during the rainy season, most of which is deposited in the vast wetlands but some finds its way into Lake Rukwa. This is attributed to the widespread deforestation in the catchment, especially in Mpanda, Chunya, and Sumbawanga districts, 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. Pollution of water sources from mercury used in gold processing has been reported in in Mpanda and Chunya districts. There is also concern that some of the mercury ends up in Lake Rukwa since the rivers passing through the mineral fields discharge into the lake. Lake Rukwa is already experiencing water quality problems manifested through increased eutrophication and algal blooms in the recent past. If action is not taken soon enough to reverse this trend, the lake biodiversity and thriving fisheries industry could be in jeopardy. Poor sanitation due to low latrine coverage and increasing use of agrochemicals are other causes of pollution of surface and groundwater.

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

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

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

Study findings indicate that some of the observed sub-basin water scarcities can be attributed to dwindling water sources due to destruction of upstream watersheds. Particularly, rampant deforestation, over grazing, and wetland degradation are responsible for destruction of important catchments thus undermining their capacity to sustain downstream water sources. The Water Resources Management Act (2009) Section 37 (1) provides for the establishment of protected zones on land draining to or above important water sources. This activity shall involve systematic identification, survey, acquisition, and protection of catchments draining to important water sources serving large populations, e.g., urban areas. This initiative has already commenced around sources serving Mbeya City and should be expanded to other parts of the basin starting with sources supplying all major towns and urban areas. This initiative should also be complemented by intensified enforcement of Section 34 of the Act regarding prohibition of human activities near water sources (i.e., 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 the establishment of groundwater controlled areas for purposes of water supply and commercial, industrial or agricultural development. The groundwater controlled areas shall be identified following the detailed groundwater assessment and mapping exercise that shall identify areas of high groundwater potential.

Action 5.1.3: Promote sustainable management and utilization of basin forestry resources.

This will focus on reversing the current trend in basin deforestation through implementation of a 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 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 exploitation of forest resources. Local communities will also be encouraged to participate in the management of forests within their vicinities through development of comprehensive community based forest management plans.

Action 5.1.4: Promote sustainable management and utilization of basin wetland resources.

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

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

Action 5.2.1: Improve facilities for management and disposal of municipal wastewater and solid waste in urban and peri-urban areas.

Environmental sanitation and the management of solid and liquid wastes in urban areas is generally poor and is characterized by piles of uncollected garbage (with a high content of organic matter); illegal emptying of septic tanks and domestic wastewater into storm water drains; open defecation; and discharge of untreated solid and liquid wastes from cottage industries and car garages into nearby streams. The result is heavy contamination of water sources located within or near neighborhoods. These activities result in contamination of water sources used for urban water supply thereby requiring costly water treatment. This problem is most pronounced in the major urban areas especially Mbeya City, Mbozi DC, and Sumbawanga Town Council. Mbeya City is the only major urban areawith a conventional sewerage system. The other major urban areas (Sumbawanga Town, Mpanda Town, Vwava, Mbalizi, Mlowo, Namanyere, Tunduma, and Chunya) rely mostly on on-site sanitation (septic tanks and pit latrines). The poor siting of the sanitation facilities results in untreated sewage being discharged into neighboring surface water sources. Thus, there are compelling public and environmental health reasons for increased investment in conventional sewerage systems and appropriate solid waste management facilities for all major urban areas to improved sanitation and control pollution of water sources.

Action 5.2.2: Control discharge of untreated industrial effluent into water sources.

Most big industries are connected to the Mbeya Urban Water Supply and Sewerage Authority (Mbeya-UWSA) network which supplies them with raw water and is also a recipient of their effluent discharge. Those that discharge their effluent directly into neighboring water bodies are required to apply for wastewater discharge permits. Only Mbeya Cement Factory has been issued a wastewater discharge permit to date. LRBWB Staff are required to visit the industries regularly and inspect their water abstraction and effluent discharge activities to ensure that they comply with permit conditions. However, this is not occurring regularly as required due to financial constraints. Industries are also monitored by the National Environment Management Council (NEMC) for compliance with existing environmental laws. NEMC officials are required to visit all major industrial establishments and undertake environmental audits to ensure compliance with environmental management plans. However, NEMC seldom visits all the industries due to inadequate technical and financial resources. There is need for strict enforcement of wastewater discharge permits for all applicable industrial establishments and routine monitoring to ensure compliance with effluents discharge standards.

Action 5.2.3: Regulate and control pollution from mining activities.

Mining activities pose a considerably more serious risk to water pollution and environmental degradation than other water use sectors in the basin. The main threat comes from unregulated use of chemicals (mercury and cyanide), especially in artisanal gold mines, and poor handling and disposal of mine effluent. Unregulated mercury use in gold mining is of particular concern because of its potential health and general environmental hazards. There is need to register and regulate all mining activities with regard to water use and effluent discharge. Most emphasis should be put on sensitizing, training, and equipping the small scale artisanal gold miners to enable them to carry out their mining activities in an environmentally safe manner.

Action 5.2.4: Regulate and control pollution from agrochemical use.

Agrochemicals can be a big source of non-point pollution if not applied in a controlled manner. Except for a few medium to large scale commercial farms, agrochemicals are not widely used in the basin. However, there is need for increased vigilance to monitor agrochemical usage to ensure proper use and pollution minimization. There is need for extension workers to sensitize farmers on proper handling (storage and application) of agrochemicals to minimize misuse.

Action 5.2.5: Improve sanitation and hygiene in rural households.

Between 15–40% of rural households in the basin have no sanitary facilities and practice open defecation. Of those that have facilities, close to 98% use the traditional pit latrine, which if poorly located or constructed, can lead to contamination of nearby water sources with fecal bacteria and pathogens. This situation, combined with generally poor excreta management and hygiene practices in homes, leads to widespread pollution of unprotected surface and subsurface sources. One of the consequences of this problem is the high incidence of water borne diseases in the region. Diarrhoea—a common water borne diseases—ranks among the top five causes of illness and death in the basin districts. The most affected areas are the districts of Mbeya Rural, Sumbawanga Rural, and Chunya. The government is promoting improved sanitation practices by sensitizing local communities on the importance of good household sanitation and hygiene and demonstrating innovative and cost-effective approaches. For example, Mpanda Town Council is implementing a Community Led Total Sanitation (CLTS) program as one of its strategies to improve household sanitation in the district. The sanitation sensitization campaigns also involve forming school sanitation clubs and staging sanitation and hygiene school competitions. At the community level funds are availed to train local artisans in sanitation technologies and construct demonstration facilities; help construction of community (schools, health centers, etc.) sanitation facilities; and support communities improve existing latrines. There is need to replicate these interventions to other basin areas to improve sanitation levels and reduce pollution of water bodies from poor disposal of fecal matter.

GOAL 6: Strong and efficient water resources management institutions established at all basin levels.

The four basin water resources management levels stipulated in the Water Resources Management Act (2009) include basin water boards, catchment and sub-catchment water committees, and water user associations. The intention is that eventually all will be administratively and financially autonomous in managing water resources under their respective areas of jurisdiction. Review of the existing water resources management institutions in Lake Rukwa basin highlights a number of weaknesses and shortcomings. There is general concern that all the basin management institutions have not yet developed the requisite capacity, cohesion, and coordination to ensure sustainable management and development of water resources at all relevant levels. Inability of the LRBWB to establish and sustain operations of lower level water resources management structures has significantly slowed progress of water resources management in the local areas. The impact is the observed low levels of public awareness regarding water resources management issues and high levels of illegal water abstraction and use.

Action 6.1: Establish all lower level WRM institutions and committees as provided for under the WRM Act (2009) and empower them to effectively undertake their mandates.

Action 6.2: Strengthen the technical capacity of the BWB to ensure effective and timely implementation of its planned activities.

Action 6.3: Empower all key basin stakeholders to ensure their active and sustained involvement in WRM activities.

10. Strategic Action Plan and Budget

10.1 Strategic Action Plan

The Lake Rukwa 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 of implementing the 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 performance. The SAP is presented in the matrix below. The detailed Logical Framework Analysis for the SAP is presented in **Annex A**.

Lake Rukwa Basin Strategic Action Plan

FIVE YEAR PHASE	Jul 2015 - Jun 2020					Jul 2020 - Jun 2025					Jul 2025 - Jun 2030					Jul 2030 - Jun 2035					Lead Implementing Agencies
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
PROGRAM 1: Basin Water Security Enhancement Program																					
COMPONENT 1: Water Resources Infrastructure Development																					LRBWB, LGAs, WUAs
OBJECTIVE: To enhance basin water storage and supply capacity																					
TASK 1.1.1: Basin-wide rapid assessment and ranking of potential inter basin water transfer schemes and storage sites																					
TASK 1.1.2: Prefeasibility studies of priority potential inter basin water transfer schemes and storage projects																					
TASK 1.1.3: Feasibility studies of priority potential inter basin water transfer schemes and storage projects																					
TASK 1.1.4: Construction of priority inter basin water transfer schemes and storage projects																					
COMPONENT 2: Climate Change Assessment and Adaptation Study																					LRBWB
OBJECTIVE: To assess climate change impacts on the basin's water resources and socioeconomic sectors and develop an adaptation strategy																					
TASK 1.2.1: Conduct detailed climate change impact assessment study for the basin and develop a comprehensive basin-wide climate change mitigation and adaptation strategy and plan																					
TASK 1.2.2: Develop a basin flood and drought forecasting and early warning system																					
COMPONENT 3: Technical Support for Water Use Efficiency Improvement																					LRBWB, LGAs, WUAs, SAGCOT, BRN, UWSAs
OBJECTIVE: To provide technical support for water use efficiency improvements in traditional irrigation schemes and urban water supply authorities																					
TASK 1.3.1: Provide technical assistance to Irrigation associations in planning and implementation of irrigation water supply infrastructure improvements																					
TASK 1.3.2: Monitoring and evaluation of water use efficiency improvements in irrigation and urban water supply systems.																					
PROGRAM 2: Basin Environmental Flow Reserve Compliance Program																					LRBWB, WUAs
OBJECTIVE: To ensure compliance with environmental flow reserve for all water resources classes.																					
TASK 2.1: Basin-wide classification of water resources and establishment of resources quality objectives																					
TASK 2.2: Conduct basin-wide environmental flow assessments and determine the environmental flow reserve to be used in water allocation decisions																					
TASK 2.3: Enforcement and monitoring compliance with the environment flow reserve																					

Lake Rukwa Basin Strategic Action Plan(continued)

FIVE YEAR PHASE	Jul 2015 - Jun 2020					Jul 2020 - Jun 2025					Jul 2025 - Jun 2030					Jul 2030 - Jun 2035					Lead Implementing Agencies
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
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																					LRBWB, WUAs
TASK 3.1.1: Establish a basin-wide groundwater resources monitoring network																					
TASK 3.1.2: Upgrade and expand existing surface water resources monitoring network																					
TASK 3.1.3: Upgrade and expand water quality monitoring network																					
TASK 3.1.4: Coordinate establishment of water abstraction/use monitoring network																					
TASK 3.1.5: Conduct routine and timely collection of water resources data.																					
COMPONENT 2: Strengthen water resources assessment																					LRBWB
TASK 3.2.1: Conduct basin-wide groundwater resources assessment and mapping																					
TASK 3.2.2: Conduct basin-wide water quality baseline survey																					
TASK 3.2.3: Transfer all historical data into Rukwa DSS database to create a central unified database for the basin																					
TASK 3.2.4: Conduct routine water resources assessments using Rukwa DSS and disseminate periodic reports to stakeholders																					
PROGRAM 4: Water Permit Enforcement and Compliance Monitoring Program																					LRBWB, WUAs
OBJECTIVE: To register all 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																					

Lake Rukwa Basin Strategic Action Plan (continued)

FIVE YEAR PHASE	Jul 2015 - Jun 2020					Jul 2020 - Jun 2025					Jul 2025 - Jun 2030					Jul 2030 - Jun 2035					Lead Implementing Agencies
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
PROGRAM 5: Integrated Watershed Management and Environmental Conservation																					LRBWB, LGAs, WUAs, UWSAs, Miners, Industries, Farmers
OBJECTIVE: To ensure that all vulnerable watersheds are protected and basin environmental degradation reversed.																					
TASK 5.1: Identify, demarcate, and protect watersheds upstream of major water supply sources.																					
TASK 5.2:Identify, demarcate, and protect recharge areas for important groundwater supply aquifers.																					
TASK 5.3: Provide technical and financial support for catchment afforestation activities in critical watersheds.																					
TASK 5.4: Provide technical and financial support for wetland restoration and conservation activities in critical watersheds.																					
TASK 5.5: Construct appropriate facilities for management and disposal of municipal waste water and solid waste in urban and peri-urban areas.																					
TASK 5.6: Regulate and control discharge of industrial effluent into water sources.																					
TASK 5.7: Regulate and control pollution from mining activities.																					
TASK 5.8: Regulate and control pollution from agrochemical use.																					
TASK 5.9: Support and promote improved sanitation and hygiene in rural households.																					
PROGRAM 6: Basin Human and Institutional Capacity Development Program																					LRBWB, MoW
OBJECTIVE: To ensure efficient service delivery and timely implementation of LRBWB planned activities.																					
TASK 6.1: Establish all lower level basin water resources management entities and empower them to play an effective supportive role to the BWB																					
TASK 6.2: Conduct training needs assessment and provide appropriate training to BWB staff to ensure effective and timely implementation of planned activities																					

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

10.2 Budget Estimates

The total estimated budget required for implementation of the Lake Rukwa Basin IWRMD Plan over the period 2016 to 2035 is about 176.68 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 10.1** and **Figure 10.1** show the budget estimates by program area. Program 1 (Water Security Enhancement) has the highest budget allocation (55%) because of the high capital costs associated with construction of water storage and supply infrastructure. **Figure 10.2** shows budget distribution across sub-basins. Katuma and Songwe sub-basins together account for about two-thirds of the total budget (66%) which reflects the existing challenges the two sub-basins are facing and the significant resources required to address them. **Figure 10.3** shows budget distribution across implementation phases. Phase 1 activities account for the highest percentage of the budget (30%) 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 10.2**.

Table 10.1: Budget Estimates by Program.

	Rukwa IWRMD 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	27.10	20.60	21.60	24.60	**93.90**
PROGRAM 2: Environmental Flow Assessment and Monitoring Program	4.14	1.60	1.60	4.14	**11.48**
PROGRAM 3: Water Resources Monitoring and Assessment Program	8.94	2.80	3.34	3.40	**18.48**
PROGRAM 4: Water Permit Enforcement and Compliance Monitoring Program	2.94	2.80	2.84	2.80	**11.38**
PROGRAM 5: Integrated Watershed Management and Environmental Conservation Program	5.30	5.30	5.30	5.30	**21.20**
PROGRAM 6: Human and Institutional Capacity Development Program	5.24	5.00	5.00	5.00	**20.24**
TOTAL	**53.66**	**38.10**	**39.68**	**45.24**	**176.68**

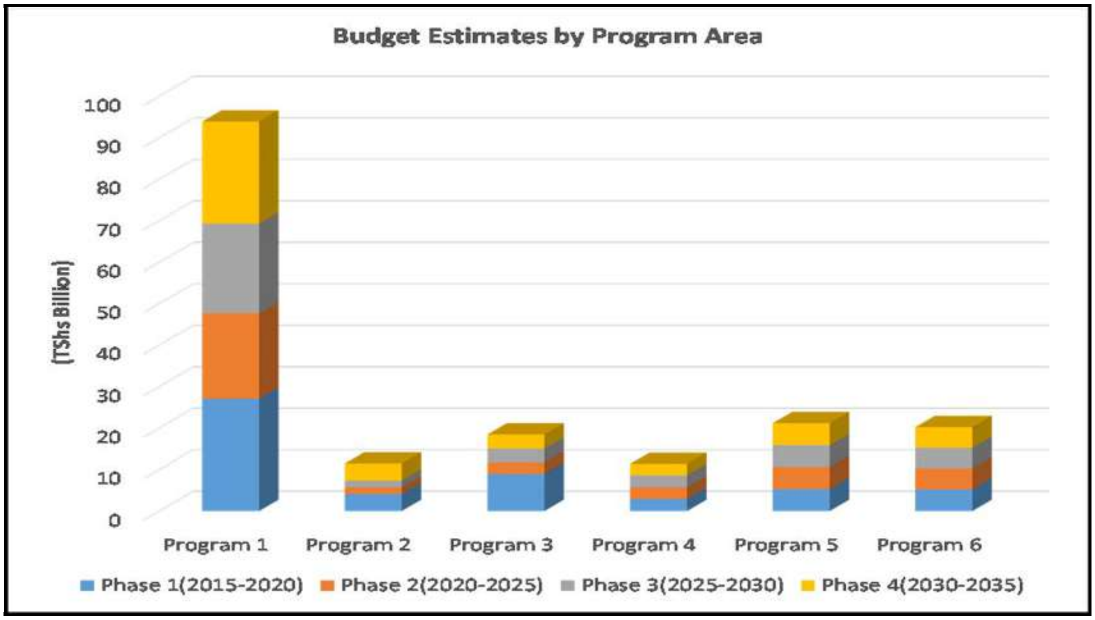

Figure 10.1: Incremental Program Budget Estimates.

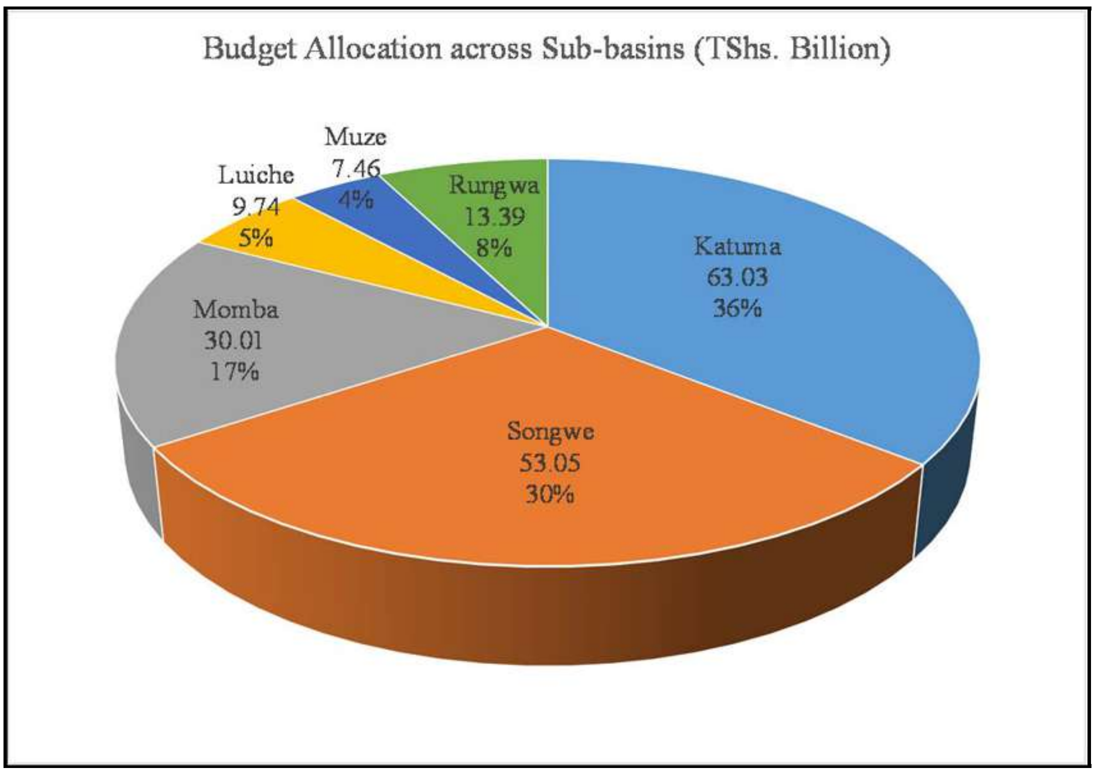

Figure 10.2: Sub-basin Budget Allocation.

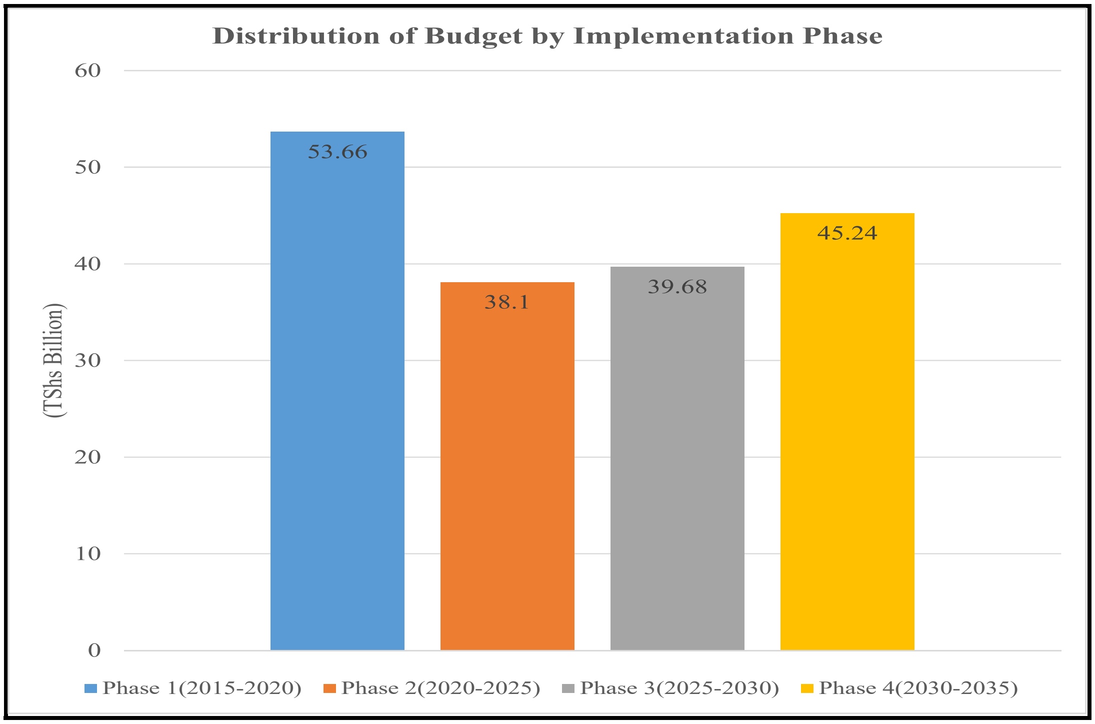

Figure 10.3: Distribution of Budget Estimates by Implementation Phase.

Table 10.2: Budget Estimates for Lake Rukwa Basin IWRMD Plan Implementation.

	Rukwa IWRMD PLAN BUDGET ESTIMATES (TShs. Millions)			
	Jul 2015 - Jun 2020	**Jul 2020 - Jun 2025**	**Jul 2025 - Jun 2030**	**Jul 2030 - Jun 2035**
PROGRAM 1: Basin 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.	15,000	10,000	10,000	10,000
Strategic Action 1.1.2 : Assess potential for and construct inter-basin water transfer schemes to increase sub-basin water supply capacity.	10,000	10,000	10,000	10,000
Strategic Action 1.1.3 : Assess potential for and construct medium to large scale groundwater supply schemes to increase sub-basin water supply capacity.	-	-	1,000	4,000
COMPONENT 2: Climate Change Assessment and Adaptation Study				
Strategic Action 1.2.1 : Conduct detailed climate change impact assessment study for the basin and develop a comprehensive basin-wide climate change mitigation and adaptation strategy and plan	500	-	-	-
Strategic Action 1.2.2 : Develop a basin flood and drought forecasting and early warning system	1,000	-	-	-
COMPONENT 3: Technical Support for Water Use Efficiency Improvement				
Strategic Action 1.3.1 : Provide technical assistance to Irrigation associations in planning and upgrading of irrigation water supply infrastructure and monitor water use efficiency improvements.	400	400	400	400
Strategic Action 1.3.2 : Provide technical assistance and monitor water use efficiency improvements in Urban Water Supply Authorities	200	200	200	200
Program 1 Sub-total	***27,100***	***20,600***	***21,600***	***24,600***
PROGRAM 2: Basin Environmental Flow Reserve Compliance Program				
Strategic Action 2.1 : Basin-wide classification of water resources and establishment of resources quality objectives	500	-	-	500
Strategic Action 2.2 : Conduct basin-wide environmental flow assessments and determine the environmental flow reserve to be used in water allocation decisions.	2,040	-	-	2,040
Strategic Action 2.3 : Conduct routine field visits to check compliance with environmental flow reserve and apprehend violators.	800	800	800	800
Strategic Action 2.4 : Conduct regular public awareness raising campaigns on the importance of maintaining environmental flow reserve and consequences of violations.	800	800	800	800
Program 2 Sub-total	***4,140***	***1,600***	***1,600***	***4,140***
PROGRAM 3: Water Resources Monitoring and Assessment Program				
COMPONENT 1: Strengthen water resources monitoring network				
Strategic Action 3.1.1 : Rehabilitate and expand surface water resources monitoring network to cover all important basin watersheds.	3,200	1,000	1,000	1,000
Strategic Action 3.1.2 : Establish network of groundwater level monitoring boreholes to cover all major basin aquifers.	4,200	-	1,000	1,000
Strategic Action 3.1.3 : Establish additional water quality sampling sites to cover all important pollution prone basin areas.	100	-	-	100
Strategic Action 3.1.4 : Conduct routine and consistent network visits for data collection and equipment maintenance.	800	800	800	800
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.	200	200	200	200

	Rukwa IWRMD PLAN BUDGET ESTIMATES (TShs. Millions)			
	Jul 2015 - Jun 2020	Jul 2020 - Jun 2025	Jul 2025 - Jun 2030	Jul 2030 - Jun 2035
COMPONENT 2: Strengthen water resources assessment capacity				
Strategic Action 3.2.1 : Establish comprehensive central database for the basin based on the Rukwa DSS information management system.	40	-	40	-
Strategic Action 3.2.2 : Transfer all historical data into Rukwa DSS database to create a central unified database for the basin.	-	-	-	-
Strategic Action 3.2.3 : Conduct routine training for data entry staff to ensure proper maintenance of the database.	200	200	200	200
Strategic Action 3.2.4 : Conduct basin-wide groundwater resources assessment and mapping	-	500	-	-
Strategic Action 3.2.5 : Conduct basin-wide water quality baseline survey	100	-	-	-
Strategic Action 3.2.6 : Conduct routine water resources assessments using Rukwa DSS and disseminate periodic reports to stakeholders	100	100	100	100
Program 3 Sub-total	***8,940***	***2,800***	***3,340***	***3,400***
PROGRAM 4: Water Permit Enforcement and Compliance Monitoring Program				
Strategic Action 4.1 : Conduct annual basin-wide water use surveys to locate, verify, map, register and regularize all water withdrawals, waste water discharges and hydraulic infrastructure.	1,000	1,000	1,000	1,000
Strategic Action 4.2 : Conduct routine processing of new water permit applications and renewals.	200	200	200	200
Strategic Action 4.3 : Establish comprehensive water permit database based on the Rukwa DSS information management system.	40	-	40	-
Strategic Action 4.4 : Develop technical tools for evaluation of water permit applications and compliance monitoring	100	-	-	-
Strategic Action 4.5 : Undertake routine update of the water permit database.	-	-	-	-
Strategic Action 4.6 : Conduct routine field visits to check compliance with permit conditions and apprehend illegal water users.	800	800	800	800
Strategic Action 4.7 : Conduct regular public awareness raising campaigns on the dangers of illegal water abstraction and non-compliance with permit conditions.	800	800	800	800
Program 4 Sub-total	***2,940***	***2,800***	***2,840***	***2,800***
PROGRAM 5: Integrated Watershed Management and Environmental Conservation Program				
Strategic Action 5.1 : Identify, demarcate, and protect watersheds upstream of major water supply sources	1,000	1,000	1,000	1,000
Strategic Action 5.2 : Identify, demarcate, and protect important groundwater recharge areas.	1,000	1,000	1,000	1,000
Strategic Action 5.3 : Provide technical and financial support for catchment afforestation activities in critical watersheds	2,000	2,000	2,000	2,000
Strategic Action 5.4 :Provide technical and financial support for wetland restoration and conservation activities in critical watersheds	500	500	500	500
Strategic Action 5.5: Construct appropriate facilities for management and disposal of municipal waste water and solid waste in urban and peri-urban areas	-	-	-	-
Strategic Action 5.6 : Regulate and control discharge of industrial effluent into water sources.	100	100	100	100
Strategic Action 5.7 : Regulate and control pollution from mining activities.	500	500	500	500
Strategic Action 5.8: Regulate and control pollution from agrochemical use.	200	200	200	200
Strategic Action 5.9: Support and promote improved sanitation and hygiene in rural households.	-	-	-	-
Program 5 Sub-total	***5,300***	***5,300***	***5,300***	***5,300***
Strategic Action 6.1 : All basin areas appropriate for establishment of lower level water resources management entities identified and local communities engaged and sensitized on the importance and process of establishment of the structures.	240	-	-	-
Strategic Action 6.2 : Local communities facilitated in establishment of the appropriate lower level structures and sensitized and trained on their sustainable operations.	4,000	4,000	4,000	4,000
Strategic Action 6.3 : All vacant positions in approved LRBWB staff structure filled.	-	-	-	-
Strategic Action 6.4 : Conduct training needs assessment and provide routine training to BWB staff to ensure effective and timely implementation of planned activities	1,000	1,000	1,000	1,000
Program 5 Sub-total	***5,240***	***5,000***	***5,000***	***5,000***
GRAND TOTAL	**53,660**	**38,100**	**39,680**	**45,240**

11. ANNEX A: IWRMD Plan Logical Framework Analysis

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
IWRMD PLAN MISSION A prosperous basin community sustainably managing and utilizing its water resources for wealth creation, socioeconomic transformation, and environment conservation.	➢ Percentage of basin population living below the poverty line. ➢ Basin GDP.	➢ National Bureau of Statistics. ➢ Regional and District Socio-economic Profile Reports.	➢ Water is the major constraint to basin socioeconomic development.
STRATEGIC GOALS: **GOAL 1:** Sustainable balance between water supply and demand achieved by 2035.	➢ Percentage of annual sub-basin water demands not satisfied by available water resources.	➢ LRBWB Reports.	➢ Adequate and reliable data available to conduct sub-basin water balance assessments and determine deficits.
GOAL 2: Adequate and reliable water resources data available for all basin watersheds and aquifers by 2035.	➢ Percentage of watersheds and aquifers with inadequate and/or poor quality data.	➢ LRBWB Reports.	➢ Required funding available for network upgrade and expansion.
GOAL 3: All basin water abstractions registered with 100% compliance to permit conditions by 2025.	➢ Percentage of water abstractions not registered and/or not complying with permit conditions.	➢ LRBWB Reports.	➢ LRBWB has sufficient technical and financial resources to enforce water permit compliance. ➢ Cooperation from stakeholders to report illegal water abstractions.
GOAL 4: Flow reserve maintained in all basin rivers all year round by 2035.	➢ Percentage of time per year that flow reserve requirements are breached.	➢ LRBWB Reports.	➢ LRBWB has required funds to conduct environmental flow assessments for all critical sites. ➢ LRBWB has sufficient technical and financial capacity to monitor compliance with environmental flow requirements.
GOAL 5: Integrated watershed management and environmental	➢ Percentage of basin area implementing integrated	➢ LRBWB Reports.	➢ Cooperation from local communities to implement

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
conservation achieved by 2035.	watershed management and environmental conservation practices.		integrated watershed management activities.
GOAL 6: Fully established and operational basin water resources management framework in place by 2035.	➢ Percentage of basin management structure not in place and/or not operational.	➢ LRBWB Reports.	➢ LRBWB has sufficient funds to facilitate establishment and operations of the institutions.
EXPECTED OUTPUTS **OUTPUT 1:** Sub-basin water deficits eradicated.	➢ Additional sub-basin water storage capacity constructed. ➢ Additional water supplied from inter-basin water transfer schemes constructed. ➢ Additional water supplied from medium to large groundwater schemes. ➢ Percentage reduction in annual sub-basin water demand as a result of water use efficiency improvements especially in traditional paddy irrigation schemes. ➢ Basin climate change adaptation strategy developed and implemented.	➢ LRBWB Reports ➢ District Development Reports ➢ Irrigation development project reports (SAGCOT, BRN, etc.).	➢ Adequate funding available for construction of water storage and inter-basin water transfer infrastructure. ➢ Potential storage sites of adequate capacity are available in most sub-basins. ➢ Adequate potential for inter-basin water transfer exists. ➢ Adequate groundwater potential exists to support medium to large scale groundwater pumping to augment surface water supplies in stressed basins. ➢ Adequate funding available to finance rehabilitation and upgrading of irrigation water supply infrastructure to reduce water losses and reduce demand.
OUTPUT 2.1: Water resources monitoring network (surface and groundwater; quantity and quality) upgraded and expanded to cover all important basin watersheds and aquifers.	➢ Number of existing hydrometric stations rehabilitated/upgraded. ➢ Number of new hydrometric stations constructed. ➢ Number of existing climate/ rainfall stations rehabilitated/ upgraded. ➢ Number of new climate/rainfall	➢ LRBWB Reports.	➢ Adequate funding available for rehabilitation and expansion of monitoring network. ➢ Potential sites for construction of new stations are accessible with no encumbrances.

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
	stations established. ➢ Number of groundwater level monitoring boreholes drilled. ➢ Number of additional water quality sampling sites established.		
OUTPUT 2.2: Water resources monitoring network properly operated and maintained.	➢ Number of operational stations visited routinely. ➢ Number of data records collected from water resources monitoring networks as a percentage of the target collection.	➢ LRBWB Reports.	➢ Adequate funding and staff available for effective operation and maintenance of the monitoring network.
OUTPUT 2.3: Comprehensive and up to date water resources database maintained.	➢ Number of monitoring stations with up to date data records. ➢ Number of data records entered into database as percentage of target.	➢ LRBWB Reports.	➢ The LRBWB shall adopt the Rukwa DSS as the central repository of water resources data and information for the basin. ➢ LRBWB will procure appropriate computing facilities on which to install and operate the Rukwa DSS.
OUTPUT 3: All basin water users registered and in possession of valid water permits and fully complying with permit conditions.	➢ Number of permits issued and/or renewed. ➢ Number of illegal and /or non-compliant water users reported and/or apprehended.	➢ LRBWB Reports.	➢ LRBWB has adequate funding to conduct regular compliance monitoring to curb illegal water abstraction and use. ➢ Local communities are willing to cooperate and report illegal water users in their neighborhoods to the LRBWB for follow up.

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
OUTPUT 4: Flow reserve established for all critical river sections in the basin and fully complied with.	➢ Basin water resources classified. ➢ Number of sites for which environmental flow assessments have been conducted and EFRs determined. ➢ Number of EFR compliance trips undertaken. ➢ Number of EFR non-compliance cases reported.	➢ LRBWB Reports.	➢ LRBWB has sufficient funds to conduct detailed environmental flow assessments for all critical river sections in the basin. ➢ LRBWB has sufficient technical and financial resources to enforce and monitor compliance with the environmental flow reserve.
OUTPUT 5.1: All vulnerable watersheds protected and basin environmental degradation reversed.	➢ Number of catchments upstream of important water sources demarcated and protected. ➢ Area of forest coverage planted. ➢ Area of wetlands conserved.	➢ LRBWB Reports.	➢ LRBWB has sufficient funds to protect identified watersheds. ➢ Cooperation from local communities to plant trees and protect wetlands.
OUTPUT 5.2: Pollution from point and non-point sources controlled.	➢ Number of conventional sewerage treatment plants constructed. ➢ Number of solid waste management and disposal facilities constructed. ➢ Percentage of industries with on-site effluent pretreatment facilities. ➢ Percentage of industries issued with wastewater discharge permits. ➢ Number of mining entities issued with wastewater discharge permits. ➢ Percentage of farmers trained in proper use of agrochemicals. ➢ Percentage of households with improved household sanitation facilities.	➢ LRBWB Reports.	➢ UWSAs have adequate funds to finance construction of necessary facilities. ➢ Cooperation from industries and mining entities. ➢ Cooperation from farmers regarding proper use of agrochemicals. ➢ Local communities willing to adopt improved sanitation technologies.

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
OUTPUT 6: All basin water resources management institutions established and fully functioning.	➢ Number of Water User Associations, Catchment Committees/Councils, and Sub-catchment Committees/Councils established and/or fully operational. ➢ Number of vacant positions in established LRBWB staff structure. ➢ Number of staff trained to improve their performance skills.	➢ LRBWB Reports.	➢ LRBWB has adequate funding to establish all lower level water resources management structures and facilitate their operations. ➢ LRBWB has sufficient funds to recruit new staff to fill vacant positions and provide the necessary incentives to minimize staff turnover.
<u>ACTIVITIES/PROCESSES</u>			
OUTPUT 1: Sub-basin water deficits eradicated.			
<u>Output 1.1</u>: Sub-basin water storage and supply capacity enhanced.			
***Strategic Action 1.1.1*:** Assess potential for and construct surface water storage infrastructure to increase sub-basin water storage capacity.	➢ Consultancy Services. ➢ LRBWB Staff time. ➢ Contractor.	➢ Consultancy Report. ➢ LRBWB Reports.	➢ LRBWB has adequate funds to hire consultancy services for the different technical and prefeasibility studies.
***Strategic Action 1.1.2*:** Assess potential for and construct inter-basin water transfer schemes to increase sub-basin water supply capacity.	➢ Consultancy Services. ➢ LRBWB Staff time. ➢ Contractor.	➢ Consultancy Report. ➢ LRBWB Reports.	➢ Adequate and reliable data available for use in the technical and prefeasibility studies.
***Strategic Action 1.1.3*:** Assess potential for and construct medium to large scale groundwater supply schemes to increase sub-basin water	➢ Consultancy Services. ➢ LRBWB Staff time. ➢ Contractor.	➢ Consultancy Report. ➢ LRBWB Reports.	➢ Adequate and reliable groundwater data available to assess groundwater potential. ➢ Adequate funds for consultancy

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
supply capacity.			services to carry out groundwater assessments and mapping.
<u>Output 1.2</u>: Sub-basin water demand growth reduced and effectively managed.			
***Strategic Action 1.2.1*:** Rehabilitate and upgrade water supply infrastructure in traditional paddy irrigation schemes to improve irrigation water use efficiency and reduce water demand.	➢ Consultancy Services. ➢ LGA staff time. ➢ LRBWB Staff time. ➢ Irrigation Association Members' time. ➢ Contractor.	➢ Consultancy Reports. ➢ LRBWB Reports. ➢ LGA Reports. ➢ SAGCOT Reports. ➢ BRN Reports. ➢ Project Completion Reports.	➢ Irrigation associations and LGAs prioritize the activity and have adequate funds for its implementation. ➢ Activity prioritized for funding under SAGCOT and/or BRN.
***Strategic Action 1.2.2*:** Rehabilitate and upgrade urban water supply infrastructure in in major basin urban areas to reduce water transmission and distribution losses and reduce water demand.	➢ Consultancy Services. ➢ UWSA staff time. ➢ LRBWB Staff time. ➢ Contractor.	➢ Consultancy Reports. ➢ LRBWB Reports. ➢ UWSA Reports. ➢ Project Completion Reports.	➢ Urban Water Supply and Sanitation Authorities prioritize the activity and have adequate funds for its implementation.
***Strategic Action 1.2.3*:** Implement other water demand management measures in urban areas (including water recycling and re-use, tariff increase to reduce water wastage, etc.) to reduce water use.	➢ UWSA staff time. ➢ LRBWB Staff time.	➢ LRBWB Reports. ➢ UWSA Reports.	➢ Urban Water Supply and Sanitation Authorities prioritize the activity and have adequate funds for its implementation.
OUTPUT 2: Adequate and reliable data available for all important watersheds and aquifers in the basin.			
Output 2.1: Water resources monitoring network (surface and groundwater; quantity and quality) upgraded and expanded to cover all important basin watersheds and aquifers.			

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
***Strategic Action 2.1.1*: Rehabilitate and expand surface water resources monitoring network to cover all important basin watersheds.**	➢ LRBWB Staff time. ➢ Contractor.	➢ LRBWB Reports. ➢ Construction Completion Reports.	➢ LRBWB has adequate funds to rehabilitate and expand monitoring network.
***Strategic Action 2.1.2*:** Establish network of groundwater level monitoring boreholes to cover all major basin aquifers.	➢ LRBWB Staff time. ➢ Contractor.	➢ LRBWB Reports. ➢ Construction Completion Reports.	➢ LRBWB has adequate funds for drilling groundwater monitoring wells.
***Strategic Action 2.1.3*:** Establish additional water quality sampling sites to cover all important pollution prone basin areas.	➢ LRBWB Staff time. ➢ Mbeya and Sumbawanga Water Quality Lab Staff time.	➢ LRBWB Reports.	
Output 2.2: Water resources monitoring network properly operated and maintained.			
***Strategic Action 2.2.1*:** Conduct routine and consistent network visits for data collection and equipment maintenance.	➢ LRBWB Staff time.	➢ LRBWB Reports.	➢ LRBWB has adequate funds and staff for routine data collection trips.
***Strategic Action 2.2.2*:** Conduct routine training for technicians and gage readers to ensure collection of reliable data and proper maintenance of monitoring equipment.	➢ LRBWB Staff time.	➢ LRBWB Reports. ➢ Specific Training Reports.	➢ LRBWB has adequate training budget.
Output 2.3: Comprehensive and up to date water resources database maintained.			
***Strategic Action 2.3.1*:** Establish comprehensive central database for	➢ LRBWB Staff time.	➢ LRBWB Reports.	➢ LRBWB has adequate funds to procure suitable computing

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
the basin based on the Rukwa DSS information management system.			facilities for installation and operation of Rukwa DSS.
***Strategic Action 2.3.2*:** Undertake routine data entry into the database and perform data quality checks.	➢ LRBWB Staff time.	➢ LRBWB Reports. ➢ Quarterly Database Status Reports.	
***Strategic Action 2.3.2*:** Conduct routine training for data entry staff to ensure proper maintenance of the database.	➢ LRBWB Staff time.	➢ LRBWB Reports. ➢ Specific Training Reports.	➢ LRBWB has adequate training budget.
OUTPUT 3: All basin water users registered and in possession of valid water permits and fully complying with permit conditions.			
Output 3.1: All water users identified, registered, and issued with water permits.			
Strategic Action 3.1.1: Conduct annual basin-wide water use surveys to locate, verify, map, register and regularize all water withdrawals, waste water discharges and hydraulic infrastructure.	➢ LRBWB staff time. ➢ Staff travel allowances. ➢ Flow measurement equipment. ➢ Water quality field equipment.	➢ LRBWB Reports. ➢ Basin annual water use survey report.	➢ LRBWB has adequate funds for implementation of activity.
***Strategic Action 3.1.2*:** Conduct routine processing of new water permit applications and renewals.	➢ LRBWB staff time.	➢ LRBWB Reports.	
Output 3.2: Comprehensive and up to date water permit database maintained.			
***Strategic Action 3.2.1*:** Establish comprehensive water permit database based on the Rukwa DSS information management system.	➢ LRBWB staff time. ➢ Database computers. ➢ Rukwa DSS Software.	➢ Physical inspection and verification of database existence. ➢ Printouts from permit database.	➢ LRBWB has adequate funds to procure suitable computing facilities for installation and operation of Rukwa DSS.

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
***Strategic Action 3.2.2*: Undertake routine update of the water permit database.**	➢ LRBWB staff time.	➢ LRBWB Reports. ➢ Quarterly water permit database status reports.	
Output 3.3: Full compliance with water permit conditions achieved.			
***Strategic Action 3.3.1*:** Conduct routine field visits to check compliance with permit conditions and apprehend illegal water users.	➢ LRBWB staff time. ➢ Staff travel allowances.	➢ LRBWB Reports. ➢ Quarterly compliance monitoring reports.	➢ LRBWB has adequate funds and staff for routine compliance monitoring trips.
***Strategic Action 3.2.2*:** Conduct regular public awareness raising campaigns on the dangers of illegal water abstraction and non-compliance with permit conditions.	➢ LRBWB staff time. ➢ Staff travel allowances.	➢ LRBWB Reports.	➢ LRBWB has adequate funds and staff for awareness activities.
OUTPUT 4: Environmental flow reserve established for all critical river sections in the basin and fully complied with.			
Output 4.1: Environmental flow reserve determined for all water resources classes.			
***Strategic Action 4.1.1*:** Undertake basin water resources classification.	➢ LRBWB Staff time. ➢ Consultancy Services.	➢ Consultancy Reports. ➢ LRBWB Reports.	➢ Adequate funds available to pay for Consultancy services for water resources classification.
***Strategic Action 4.1.2*:** Conduct detailed EFA to determine environmental flow reserve for all water resources classes.	➢ Consultancy Services. ➢ LGA staff time. ➢ LRBWB Staff time. ➢ WUA Staff time.	➢ Consultancy Reports. ➢ LRBWB Reports.	➢ Adequate funds available to pay for Consultancy services for EFA.
Output 4.2: Full compliance with environmental flow reserve.			
***Strategic Action 4.2.1*:** Conduct routine field visits to check compliance with environmental flow reserve and apprehend violators.	➢ LRBWB staff time. ➢ Staff travel allowances.	➢ LRBWB Reports. ➢ Quarterly compliance monitoring reports.	➢ LRBWB has adequate funds and staff for routine compliance monitoring trips.

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
***Strategic Action 4.2.2*: Conduct regular public awareness raising campaigns on the importance of maintaining environmental flow reserve and consequences of violations.	➢ LRBWB staff time. ➢ Staff travel allowances.	➢ LRBWB Reports.	➢ LRBWB has adequate funds and staff for awareness activities.
OUTPUT 5: Integrated watershed management and environmental conservation achieved.			
Output 5.1: Vulnerable watersheds protected and basin environmental degradation reversed. ***Strategic Action 5.1.1*:** Identify, demarcate, and protect watersheds upstream of major water supply sources. ***Strategic Action 5.1.2*:** Identify, demarcate, and protect important groundwater recharge areas. ***Strategic Action 5.1.3*:** Provide technical and financial support for catchment afforestation activities in critical watersheds. ***Strategic Action 5.1.4*:** Provide technical and financial support for wetland restoration and conservation activities in critical watersheds.	➢ LGBWB Staff time. ➢ LGA Staff time. ➢ LRBWB Staff time. ➢ LGA Staff time. ➢ LGBWB Staff time. ➢ LGBWB Staff time.	➢ LRBWB Reports. ➢ LRBWB Reports. ➢ LRBWB Reports. ➢ LRBWB Reports.	➢ LRBWB has adequate funds to protect identified watersheds. ➢ LRBWB has adequate funds to support afforestation activities. ➢ Cooperation from local communities to plant trees. ➢ LRBWB has adequate funds to support wetland restoration and conservation activities. ➢ Cooperation from local communities to conserve wetlands.
Output 5.2: Point and non-point pollution controlled. ***Strategic Action 5.2.1*:** Construct appropriate facilities for	➢ LRBWB Staff time. ➢ UWSA Staff time.	➢ LRBWB Reports. ➢ UWSA Reports.	➢ UWSAs have the necessary funds to construct the facilities.

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
management and disposal of municipal waste water and solid waste in urban and peri-urban areas.	➢ Consultants.	➢ Consultant's Reports.	
Strategic Action 5.2.2: Regulate and control discharge of industrial effluent into water sources.	➢ LRBWB Staff time.	➢ LRBWB Reports.	➢ Cooperation from industries.
Strategic Action 5.2.3: Regulate and control pollution from mining activities.	➢ LRBWB Staff time. ➢ LGA Staff time.	➢ LRBWB Reports.	➢ Cooperation from miners.
Strategic Action 5.2.4: Regulate and control pollution from agrochemical use.	➢ LRBWB Staff time. ➢ LGA Staff time.	➢ LRBWB Reports. ➢ District Reports.	➢ Cooperation from farmers.
Strategic Action 5.2.5: Support and promote improved sanitation and hygiene in rural households.	➢ LRBWB Staff time. ➢ LGA Staff time.	➢ LRBWB Reports. ➢ District Reports.	➢ Cooperation from local communities to adopt improved sanitation practices.
OUTPUT 6: All basin water resources management institutions established and fully functioning.			
Output 6.1: All lower level basin water resources management entities established and fully operational. ***Strategic Action 6.1.1***: All basin areas appropriate for establishment of lower level entities identified, local communities sensitized and facilitated in establishment and operation of their entities.	➢ DFT Staff time. ➢ LRBWB Staff time.	➢ LRBWB Reports.	➢ Local communities willing to participate in water resources management activities. ➢ LRBWB has adequate funds and staff to support establishment of lower level basin structures.
Output 6.2: LRBWB approved staff structure fully operational. ***Strategic Action 6.2.1***: All vacant positions in approved LRBWB staff structure filled.	➢ LRBWB Staff time.	➢ LRBWB Reports.	➢ LRBWB has adequate funds for staff recruitment.

NARRATIVE	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
***Strategic Action 6.2.2*:** Routine training of LRBWB staff to improve their performance skills.	➢ LRBWB Staff time.	➢ LRBWB Reports. ➢ Specific Training Reports.	➢ LRBWB has adequate training budget.

12. References

Baker, N.E., and E.M. Baker (2002): Important Bird Areas in Tanzania: A first inventory. (Dar es Salaam, Tanzania)

Hassan, S.N. and V.G. Ndibalema (2001): Apiculture: A Case Study of Lake Rukwa Basin, Tanzania.

National Census (2012): 2012 Population and Housing Census of Tanzania. National Bureau of Statistics, Ministry of Finance, Tanzania.

Nicholson, S. E., (1999): Historical and Modern Fluctuations of Lakes Tanganyika and Rukwa and their Relationship to Rainfall Variability, *Climatic Change*, 41, 53-71.

Seegers, L., (1996): The Fishes of the Lake Rukwa Drainage. Annales du Musée Royal de l'Afrique Central, Sciences Zoologiques, 287" Tervuren, Belgium.

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

WMO 2008: Guide to Hydrological Practices, WMO-No. 168.