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Lake Rukwa Basin IWRMD Plan: Final Report
Volume VI: Lake Rukwa Basin Monitoring Plan

by

WREM International Inc.
Atlanta, Georgia, USA

May 2016

Lake Rukwa Basin Integrated Water Resources Management and Development Plan

Final Report: Volume VI

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Disclaimer

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

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Preamble

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

A brief description of these reports is provided below.

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

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

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

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

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

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

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abreviations

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

1. Introduction

Adequate good quality data is crucial for sustainable management and development of the Lake Rukwa basin water resources. Without it, system responses to natural inputs and management interventions cannot be reliably understood and anticipated. And, without such confident knowledge, water resources management interventions and developments are often nothing more than high risk investments prone to creating more problems than solutions. This is the reason why routine collection of water resources data is one of the primary functions of the Lake Rukwa Basin Water Board (LRBWB).

Development of the Lake Rukwa Basin IWRMD Plan is tightly knit to the available climatic, hydrologic, and water resources data. This data supported the development of hydrologic and river models, and enabled detailed technical assessments leading to the specific water management recommendations comprising the Plan. In turn, the Plan development process also revealed existing data gaps and areas where improved monitoring would help mitigate underlying uncertainties and improve planning confidence. Thus, the guiding principle of the proposed monitoring recommendations was to design a monitoring network with the data end-use in mind—namely, a monitoring network that is responsive to specific basin planning and management data needs.

Network design adopted a watershed-based approach to ensure a cohesive monitoring network where rainfall, climatic, streamflow, groundwater, and water quality data collection is well coordinated to support integrated basin assessments. Monitoring recommendations are provided for the near- to mid-term (2016 – 2025) as well as for the long-term (2025 – 2035). The criterion that determines which of the two groups a station should belong is whether its data is needed to inform IWRMDP interventions recommended for the mid- or the long-term.

The report goes beyond data monitoring recommendations and also outlines a general data and information management strategy, in which data and other information is collected, quality controlled, archived in a central database, and subsequently disseminated to users who wish to use it for various purposes. The premise of this discussion is that raw data does not in itself have any societal or environmental value, but it becomes valuable only when it is actually *used* to serve worthy societal, economic, and environmental causes. The report also points out how the current lack of easy access to adequate good quality data and information, if not promptly addressed, could be a major barrier toward realization of the goals and objectives of the Lake Rukwa Basin IWRMD Plan.

Chapter 2 of the report discusses the existing monitoring network. Chapters 3, 4, and 5 include detailed recommendations for the establishment of hydro-climatic, groundwater, and water quality monitoring networks respectly. Lastly, Chapter 6 addresses relevant data and information management issues.

2. Existing Water Resources Monitoring Network

The existing water resources monitoring network for the Lake Rukwa Basin consists of twenty six (26) hydrometric stations, nine (9) meteorological stations, twenty (20) manual rainfall stations, and eighteen (18) water quality monitoring stations. In addition to the above, several other rainfall stations exist in different basin areas that are operated by other agencies and institutions, including the Tanzania Meteorological Agency, Agricultural Research Institutions, Church Missions, and schools. No groundwater level monitoring stations and water abstraction/use monitoring stations have been established todate. **Figure 2.1** depicts the uneven spatial distribution of the existing monitoring stations with significant gaps occurring over large basin areas, especially in the protected areas of Katavi National Park and the three game reserves of Lukwati, Uwanda, and Rungwa. More detailed information on the existing stations including their operational status is provided in **Annex A**.

Though most of the sub-basins are gaged, flow measurements are irregular and inconsistent creating large data gaps. In addition to hydrologic data scarcity and gaps, there are no systematic measurements of water withdrawals and consumptive use levels in most sub-basins. This makes the estimation of actual water abstractions and the reconstruction of unimpaired (natural) flow series tentative at best. A related challenge is that in most sub-basins, only a limited portion of the sub-basin is monitored, usually the upstream watershed. Such information can only provide a partial picture of what might be taking place in the downstream basin areas. Lastly, the rating curves at most river-gauging stations are outdated and need systematic re-calibration.

Thus, the existing monitoring nework is clearly inadequate to support water resources planning and management as mandated by Tanzanian law. Sustainable basin development and management simply cannot occur without extensive and strategic investments in a comprehensive water resources monitoring network. The LRBWB has already started to remedy the present situation by undertaking an extensive rehabilitation program of the water resources monitoring network. Most of the existing hydrometric stations have been rehabilitated and are now fully operational. New staff gauges have been installed and benchmarks revalidated. Rehabilitation of meteorological stations was also undertaken and to date fences and gates for eight stations have been repaired and rain gauges installed. However, despite these commendable network rehabilitation efforts, significant monitoring gaps remain and need to be addressed. Furthermore, once they come on line, monitoring stations are subject to chronic budgetary constraints for their continuing operation and maintenance.

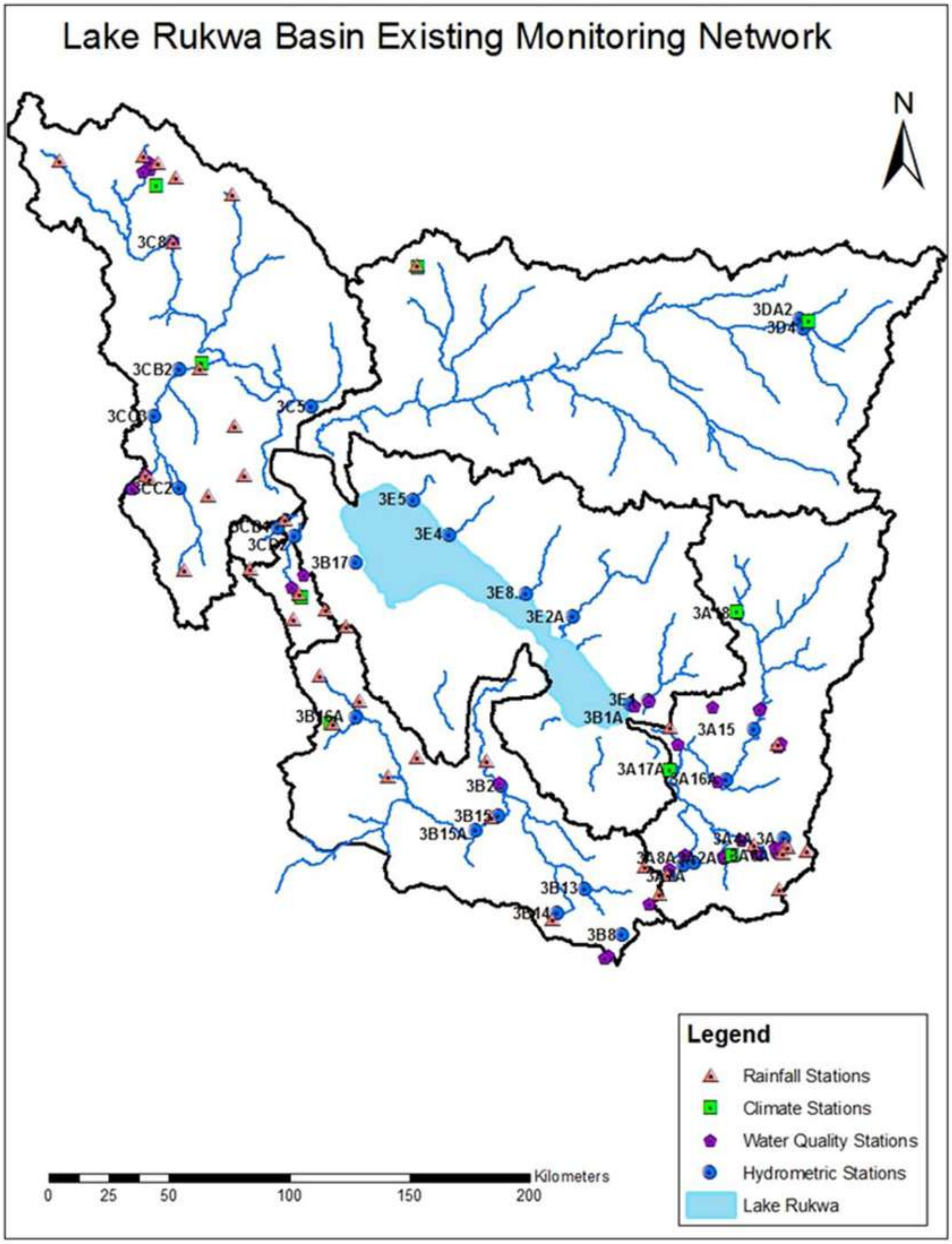

Figure 2.1: Lake Rukwa Basin Water Resources Monitoring Network.

3. Proposed Surface Water Monitoring Network

3.1 Criteria for Network Redesign

General guidelines for the density of precipitation, climatic, and streamflow stations have been promulgated by the World Meteorological Organization (*WMO-No 168, Guide to Hydrological Practices, 2008*). These guidelines are reiterated in **Figure 3.1** together with the station density they imply for the Lake Rukwa Basin. The figure shows that these guidelines would require very significant station numbers, especially in mountainous areas where the quantities being measured are markedly variable.

Thus, while the WMO recommended network density would be desirable, it is viewed as a long-term (aspirational) goal. We suggest instead that a more realistic, stage-wise monitoring investment approach be adopted, based on the basin information needs in the short-, medium-, and long-term. Priority data needs were identified based on the modeling experience undertaken to support the development of the Lake Rukwa Basin Integrated Water Resources Management and Development Plan (IWRMDP). This modeling experience includes the development of hydrologic and river/lake management models for the main sub-basins as well as basin wide.

The guiding principle of the monitoring recommendations proposed herein is to adopt a *watershed-based approach* for the design of the hydro-climatic monitoring network. The important implication of this approach is that rainfall, climatic, and streamflow monitoring networks are not designed independently of one another; rather, their design is coordinated to support the development of valid watershed models for the basin watersheds.

Area in km^2 per station			
Physiographic Unit	**Precipitation Stations**	**Climatic Stations**	**Streamflow Stations**
Mountains	250	5,000	1,000
Plains	575	50,000	1,875
Monitoring parameters	Rainfall	Temperature; Evaporation; Humidity; Wind Speed/Direction; Solar Radiation	Water Level; Discharge

Type of station	**Physiographic unit**	**Required number of stations per cell of size 2,500 km^2**
Precipitation	Mountains	10
Precipitation	Plains	5
Climatic	Mountains/plains	2*
Streamflow	Mountains	3
Streamflow	Plains	2
*2 climatic stations are required for every 4 grid cells		

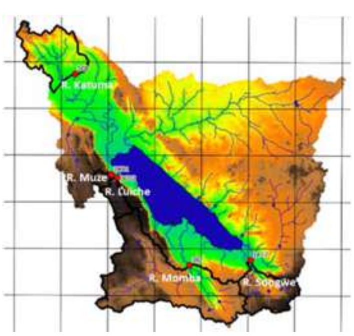

Figure 3.1: General criteria for the density of precipitation, climatic, and streamflow stations (WMO, 2008)

3.2 Recommended Hydro-climatic Monitoring Network

Review of the existing surface water resources monitoring network revealed significant gaps, with large basin areas currently not monitored. Most of these areas fall within protected areas (i.e., National Parks, Game Reserves, and Forest Reserves) that are currently inaccessible due to their conservation status. To establish and operate monitoring stations in such areas, special access arrangements will have to be made between the LRBWB and the relevant authorities responsible for management of the conservation areas, i.e., TANAPA, Wildlife Department, Forest Department, LGAs, and others. It is important that such special arrangements be indeed made to allow LRBWB staff access to the protected areas to at least establish and operate a minimal water resources monitoring network in the affected sub-basins.

A number of new additional stations are being proposed to fill the observed gaps in the existing monitoring network. It is also recognized that investments in new stations would require significant financial resources which may not be readily available in the short-term. It is, therefore, envisioned that the proposed network expansion shall take place over a longer time period, while a short-term goal to address the most urgent monitoring needs. Urgent monitoring network priorities include: (a) updating and re-validation of rating curves for the existing hydrometric stations; (b) consistent and timely collection of data from the existing stations; and (c) routine inspection and maintenance of monitoring equipment to minimize data gaps due to equipment breakdown and vandalism. Once these urgent needs are addressed and a systematic and consistent data collection, quality control, and archiving system is put in place, the LRBWB can consider expansion of the network to address other existing gaps. The recommended sub-basin specific monitoring networks are presented next.

3.2.1 Katuma Sub-basin

The recommended hydro-climatic monitoring network for the Katuma sub-basin is shown in **Figure 3.2**. In addition to the four operational hydrometric stations (i.e., Katuma River at Sitalike, **3C8**; Mfwizi River at Paramawe, **3CC3**; Mfwizi River at Ntatumbila,**3CC2**; and Msadya River at Usevya, **3CB2**), three new hydrometric stations are proposed in the following river sections:

- On Katuma River downstream of Iloba and Nkungwi traditional irrigation schemes to monitor and regulate upstream irrigation water withdrawals to ensure availability of adequate flows for downstream uses, especially in the Katavi National Park.
- On Msaginya River downstream of Urwira, Usense, and Ikondamoyo traditional irrigation schemes to monitor and regulate irrigation water withdrawals in the upstream areas; and
- On the downstream end of the Katuma River to monitor and quantify the aggregate sub-basin discharge into Lake Rukwa.

One additional climate station is also proposed for installation in the southern part of the sub-basin where no climatic measurements are currently collected.

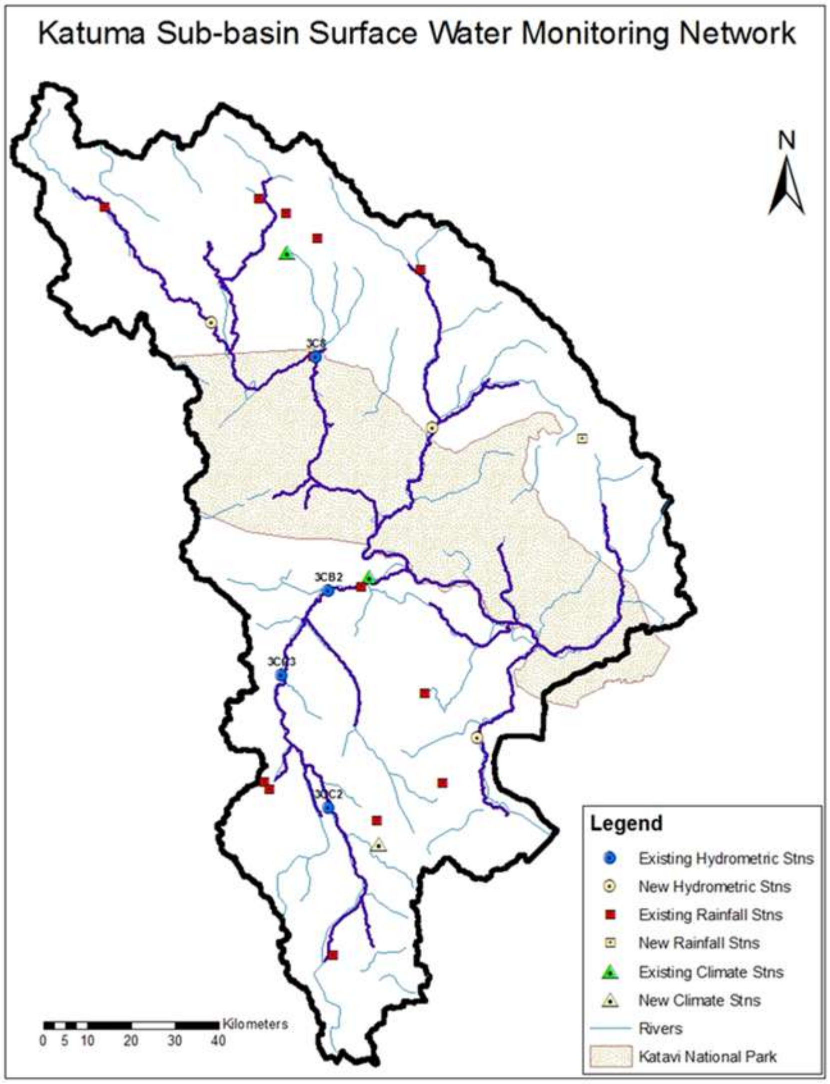

Figure 3.2: Recommended Katuma Sub-basin Surface Water Monitoring Network.

3.2.2 Songwe Sub-basin

The recommended hydro-climatic monitoring network for the Songwe sub-basin is shown in **Figure 3.3**. Two new hydrometric stations are recommended for construction on two main tributaries of the Lupa River—one upstream in Lupatingatinga and another on Shongo River downstream of Ifumbo, Simboya, and Ikukwa traditional irrigation schemes—to monitor and regulate irrigation water withdrawals in the upstream watershed areas. Three additional rainfall stations are also recommended to cover the northeastern sub-basin areas.

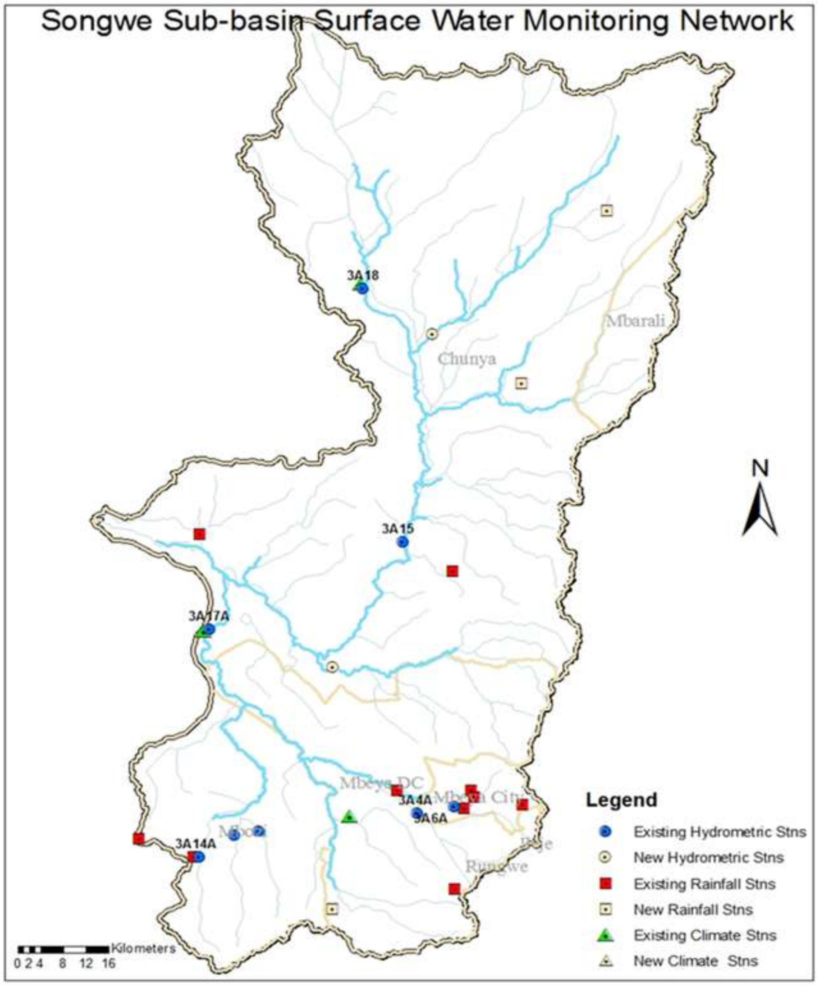

Figure 3.3: Recommended Songwe Sub-basin Surface Water Monitoring Network.

3.2.3 **Momba Sub-basin**

The recommended hydro-climatic monitoring network for the Momba sub-basin is shown in **Figure 3.4**. One hydrometric station is proposed on Saesi River to monitor transboundary flows from the upstream watershed in Zambia. Data from this station will particularly be very useful when Tanzania decides to engage Zambia on the joint management of this transboundary river. Two additional climate stations and two rainfall stations are also proposed to fill the existing gap in climatic/rainfall data coverage.

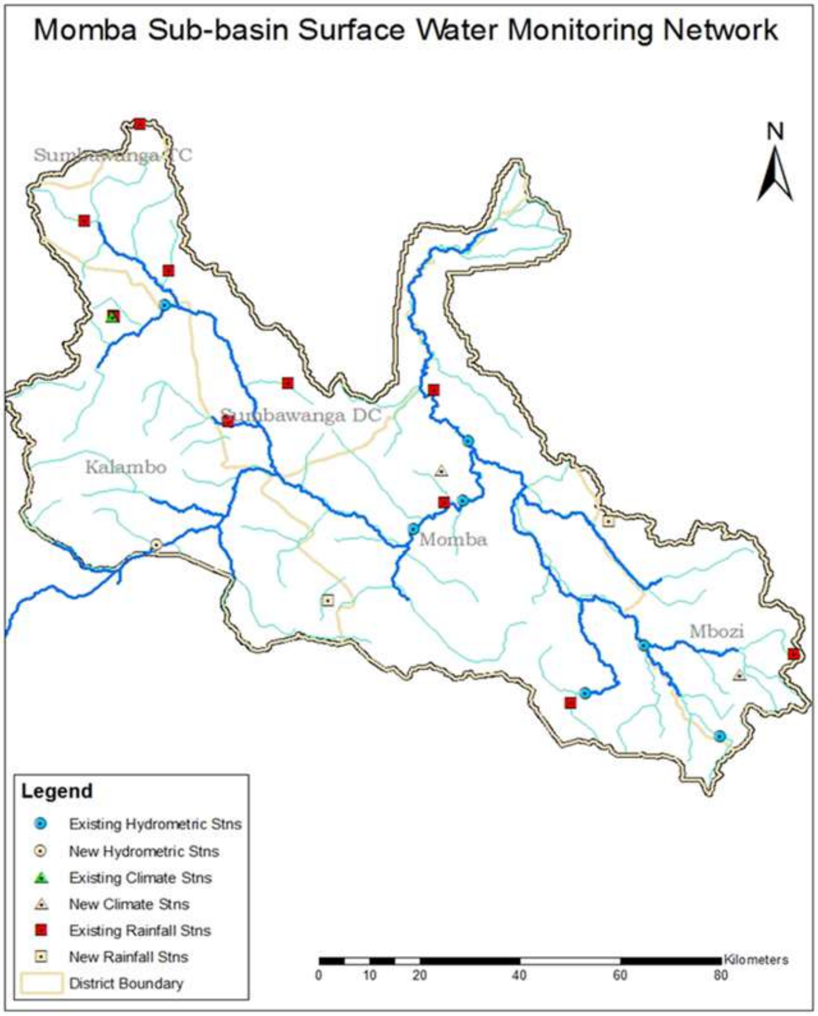

Figure 3.4: Recommended Momba Sub-basin Surface Water Monitoring Network.

3.2.4 Luiche Sub-basin

The existing Luiche sub-basin surface water monitoring network (**Figure 3.5**) consists of one hydrometric station (i.e., Luiche River at Uzia, 3CD2), one climate station, and four rainfall stations. This hydro-climatic network is considered adequate for the fairly small Luiche sub-basin (913 km^2). Of the four rainfall stations, only one is new.

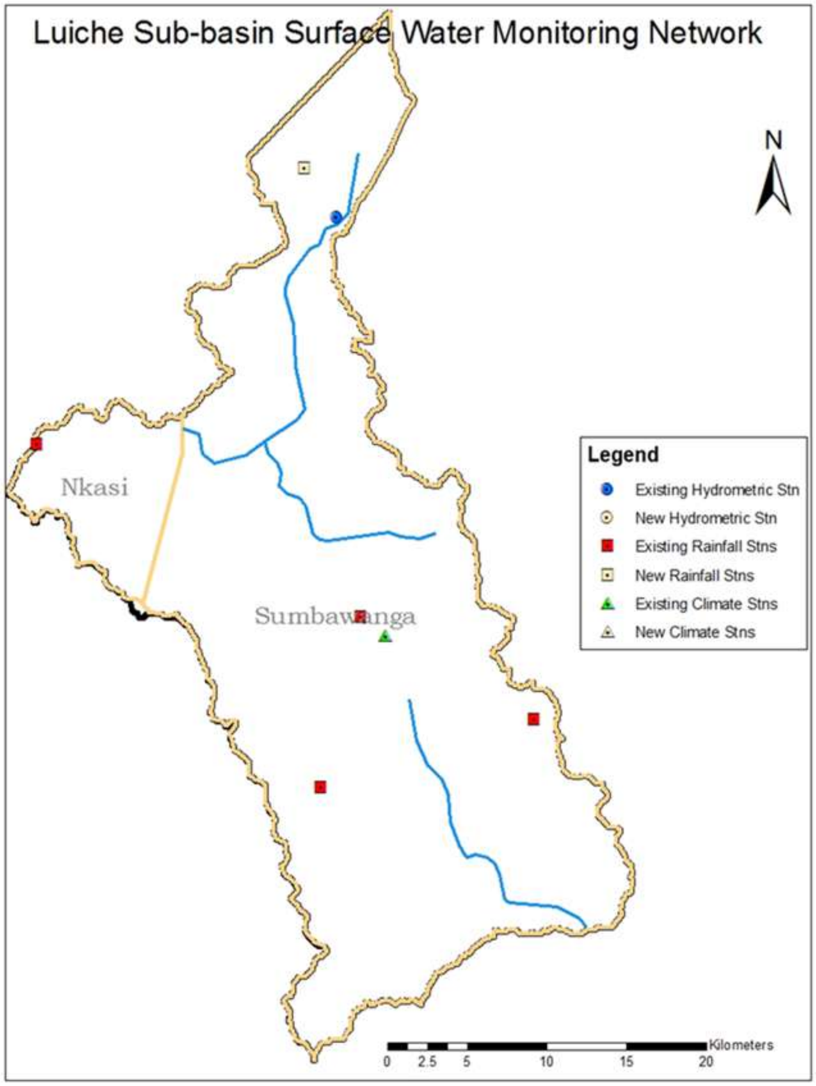

Figure 3.5: Recommended Luiche Sub-basin Surface Water Monitoring Network.

3.2.5 Muze Sub-basin

The Muze sub-basin surface water monitoring network (**Figure 3.6**) consists of one hydrometric station (i.e., Muze River at Muze, 3CD1) and one rainfall station located at the downstream end of the sub-basin. There is no climate station to facilitate collection of climatic data. One climate station and at least one rainfall station are recommended to be added to the network to fill this gap, particularly as it pertains to the upstream sub-basin areas.

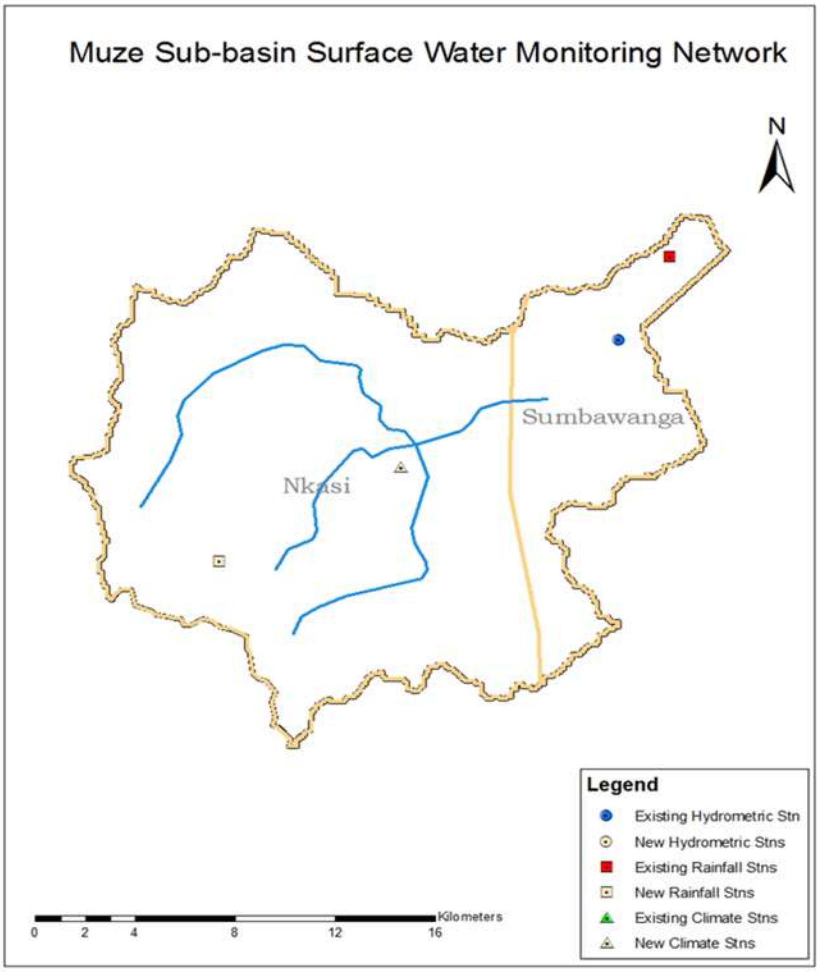

Figure 3.6: Recommended Muze Sub-basin Surface Water Monitoring Network.

3.2.6 Rungwa Sub-basin

The existing Rungwa sub-basin surface water monitoring network (**Figure 3.7**) consists of only two hydrometric stations (i.e., Musa River at Musisi, **3DA2**, and Rungwa River at Itigi Road Bridge, **3D4**), two climate stations, and one rainfall station. This level of monitoring is inadequate to meet the data and information requirements for a sub-basin the size of Rungwa (21,640 km^2). Furthermore, because the two existing hydrometric stations are located at the head waters, this leaves most of sub-basin ungauged. This is partly due to the protected areas (i.e., game reserves and forest reserves) that cover the middle sub-basin reaches.

A hydrometric station is urgently needed close to the outlet of this sub-basin to provide data on the aggregate outflow into Lake Rukwa. Additional stations in all major sub-basin watersheds should be established over time as more access is gained to the protected areas. In the short- to medium-term, it is recommended that five hydrometric stations, two climate stations, and at least five rainfall stations are established to fill the existing monitoring needs in the Rungwa region.

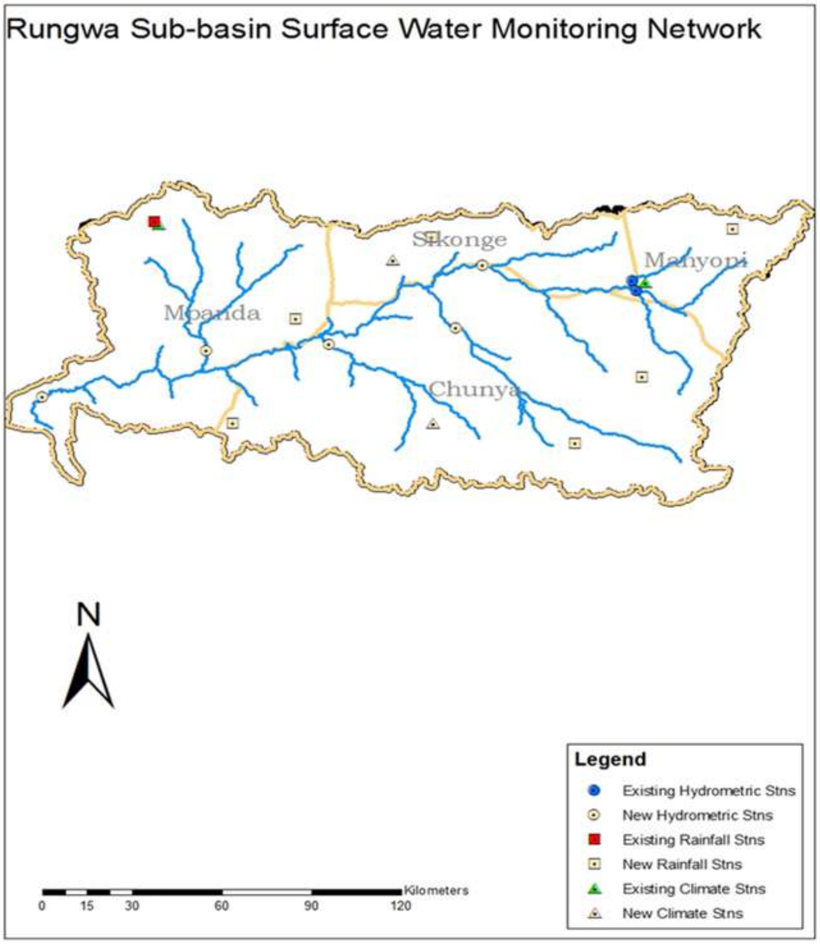

Figure 3.7: Recommended Rungwa Sub-basin Surface Water Monitoring Network.

4. Proposed Groundwater Monitoring Network

There are no groundwater table monitoring stations in the Lake Rukwa Basin. Only six groundwater *quality* monitoring stations exist, but they are unevenly distributed and their data records are sporadic and inconsistent. Establishment of a comprehensive groundwater monitoring network is a monitoring priority for the Lake Rukwa Basin IWRMD Plan.

4.1 General Considerations for Monitoring Network Design

Design of an effective groundwater monitoring program requires clear definition of the purpose and goals of such a program. A suitable and sustainable ground water monitoring network and program is one that:

- Is practical and affordable;
- Targets the main aquifers and recharge areas;
- Makes maximum use of existing wells/boreholes; and
- Gives preference to wells/boreholes in close proximity to existing climatological/hydrometric stations.

4.2 Proposed Groundwater Monitoring Network

A preliminary basin groundwater monitoring network comprising of 21 boreholes is proposed for implementation (see **Figure 4.1** and **Table 4.1**). The network provides reasonable minimum coverage of major aquifer types in the basin but will need to be reviewed and augmented with additional monitoring boreholes as more detailed data becomes available on the basin aquifer characteristics. The network design was based on consideration of several important factors including coverage of main aquifers and recharge areas; close proximity to existing hydrometric/climatological stations; accessibility; potential use of existing productive boreholes; and minimizing investment and network operation costs. Detailed discussion of the network design process is contained in **Interim Report I**, **Volume II**: *Water Availability Assessments*.

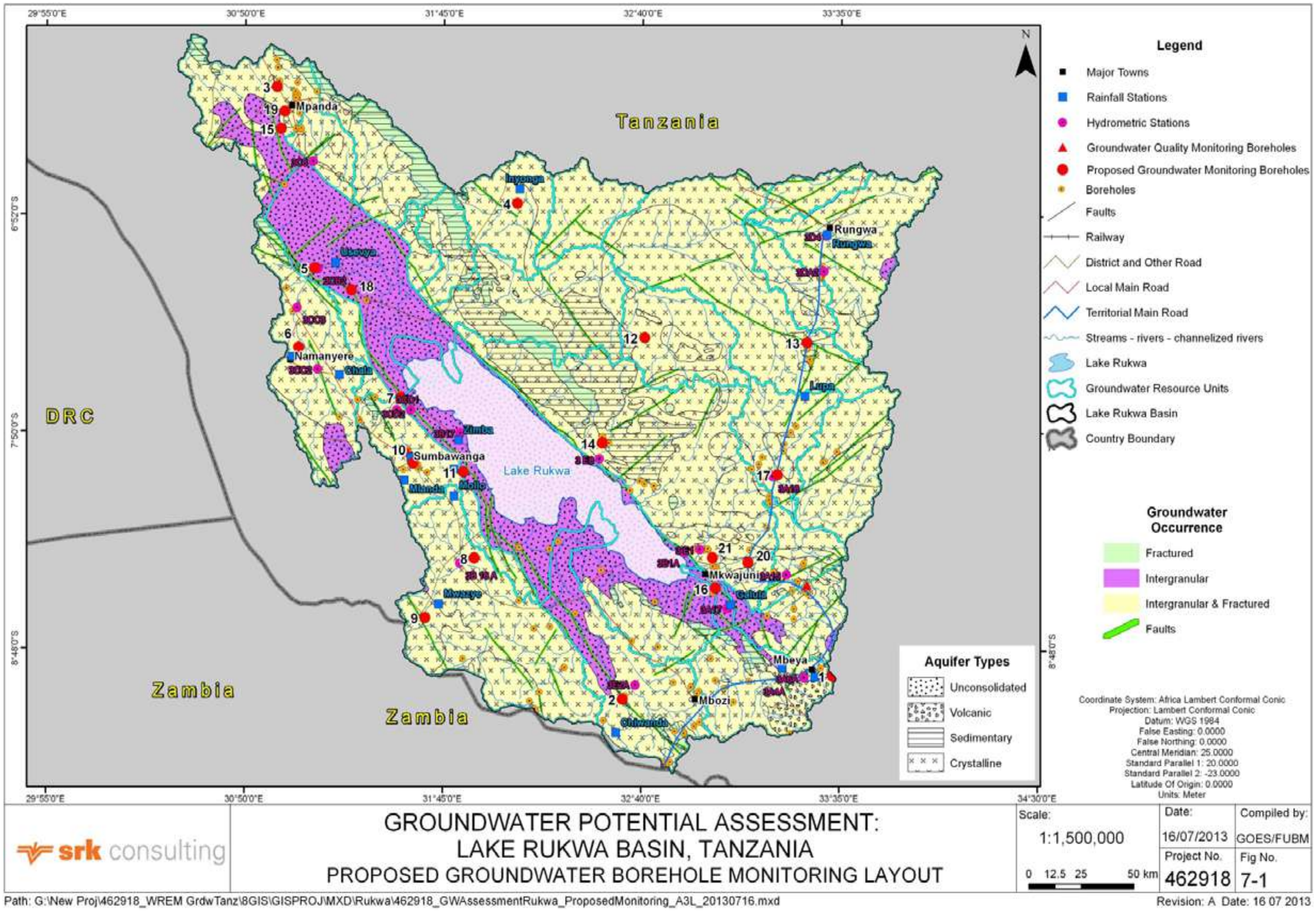

Figure 4.1: Location of proposed groundwater monitoring points.

Table 4.1: Proposed Groundwater Monitoring Stations for the Lake Rukwa Basin.

ID	Borehole Name	Borehole No.	Y	X	Aquifer Type	Location	District
1	Uyole	521/2004	9 014 654.761	560 610.787	Intergranular and fractured	Near Mbeya in the volcanic rocks	Mbeya Urban
2	Chindi A (Namlinda)	125/2009	9 002 913.000	453 914.000	Fault	Along the Ufipa fault west of Mbozi	Mbozi
3	Kabungu SS	449/2008	9 303 552.000	276 408.000	Intergranular and fractured	Near town of Mpanda	Mpanda
4	Ilela SS	457/2008	9 246 705.000	399 443.000	Intergranular and fractured	Near the Inyonga rainfall station	Mpanda
5	Kibaoni Pinda SS	458/2008	9 214 300.000	296 211.000	Intergranular	Near the Usevya rainfall station along the Ufipa fault in the Rift Valley	Mpanda
6	Lunyala II Kafiko SW	653/2008	9 175 078.000	288 211.000	Intergranular and fractured	Near the Namanyere rainfall station	Nkasi
7	Majengo BH		9 150 624.000	340 468.000	Fault	Along the Ufipa fault	Sumbawanga
8	Ikozi Village		9 071 926.301	378 324.983	Intergranular and fractured	Near 3B 16A Hydrometric station	Sumbawanga
9	Mwimbi Village		9 042 446.916	353 359.824	Intergranular and fractured	Near Mwazye rainfall station	Sumbawanga
10	Lwiche Bank		9 118 423.293	346 741.165	Intergranular and fractured	Near the Sumbawanga rainfall station	Sumbawanga
11	Songambele 'A' 1 BH		9 114 229.216	372 483.772	Intergranular	Near the Mollo rainfall station	Sumbawanga
12	Kapalala A	82/2011	9 180 752.000	464 614.000	Intergranular and fractured	Southwest of Rungwe, no other boreholes in close proximity	Chunya
13	Bitimanyanga A		9 178 650.000	547 286.000	Fault	North of the Lupa rainfall station	Chunya
14	Gua Kakoma		9 128 790.000	443 214.000	Intergranular and fractured	North of the 3 E8 Hydrometric station	Chunya
15	Mpalangombe BH	16/2009	9 282 856.000	278 598.000	Intergranular	South of Mpanda	Mpanda
16	Centre Ves2	612/2011	9 057 607.000	501 060.000	Fault	Near Galula rainfall station near the town of Mkwajuni	Chunya
17			9 113 505.000	532 457.000	Intergranular and fractured	Kagera	Chunya
18	Mwamapuli		9 203 488.678	314 873.253		Planned irrigation area	Mpanda
19	Kakese		9 291 528.523	280 453.379		Planned irrigation area	Mpanda
20	Chunya		9 070 279.718	517 509.705		Makongolosi gold mine	Chunya
21	Saza		9 072 504.489	499 549.847		Saza gold mine	Chunya

4.3 Implementation Plan

Groundwater assessments conducted under the project highlighted the paucity of information on key aquifer parameters and hydraulic properties, especially Storativity (*S*), but also Transmissivity (*T*) and Hydraulic Conductivity (*K*). Preliminary estimates of groundwater potential and recharge were made based on empirical methods that need re-calibration with adequate good quality field data. It is thus proposed that the groundwater monitoring program be implemented in two main phases: (a) a short (up to six months) intensive phase of groundwater surveying and assessment to fill identified data gaps with respect to aquifer characteristics and (b) a long-term phase of regular groundwater level and quality monitoring. Details of the two phases are discussed next.

4.3.1 Phase 1: Short-term Interventions

Specific short-term interventions with respect to groundwater monitoring and assessment are as follows:

(1) Carry out a preliminary survey (hydrocensus) of groundwater sources (wells, boreholes, springs) so that a more comprehensive and up-to-date database can be compiled. Specific tasks to be undertaken as part of the survey include, among others:
   - Carry out a pumping test program in the various aquifer types/GRUs and analyze results to obtain T and S parameters;
   - Compare these parameters with the default values used in the preliminary assessments under the study and make corrections as necessary to firm-up the preliminary estimates of the basin groundwater resources.

(2) Complete the hydrocensus of all groundwater sources (wells, boreholes, and springs) so that a comprehensive and up-to-date database can be compiled.

(3) Decide on what equipment will be deployed at the monitoring stations, e.g., data loggers (recommended for the short term boreholes selected), telemetry, or manual water level recorders. Obtain and install the requisite equipment. And construct robust housings for monitoring stations to thwart/discourage vandalism.

(4) Identify suitable laboratories and ensure that they are ready and equipped to deal with the water samples that will be submitted and have adequate QA/QC checks and procedures.

(5) Draw-up a monitoring protocol detailing all steps of the monitoring routine starting from preparations for fieldwork and covering field measurements, chain of custody for and analysis of samples, data handling, and station maintenance.

(6) Establish a suitable database and populate with the recorded data on a quarterly basis.

(7) Define key parameters (excluding hydrological parameters) to be monitored on a continuous basis, by means of data loggers (including water levels and electrical conductivity). These records should be backed up by quarterly manual measurements in April, July, October, and January when the logger data are downloaded, and the loggers should be re-calibrated as necessary.

(8) Take water samples for laboratory analysis at the end of the dry and rainy seasons and analyze for macro-chemistry and selected trace elements, e.g., fluoride. Do once-off sampling and analysis for environmental isotopes ^{16}O, ^{18}O, ^{2}H and ^{3}H to assist in recharge estimates and conceptualization studies.

(9) Hold workshops to educate staff (formal and informal) on groundwater occurrence and processes, and the social, economic and ecological benefits of the systematic management of aquifers and abstraction/monitoring points. Train staff in how to take measurements and samples so that a database of credible measurements is built up. Key times for manual control measurements and sampling are the end of the dry season (September) and the end of the wet season (May).

(10) Identify and train local communities in monitoring and the benefits accruing from it to reduce the risk of vandalism of monitoring stations.

(11) Secure adequate funding for the medium term monitoring program.

4.3.2 Phase 2: Medium to Long-term (up to 2035) Interventions

It is assumed that by this time, adequate funding will have been secured to expand the coverage and scope of the monitoring program. Below are the proposed actions to consolidate the monitoring network:

(1) Continue and expand on training programs to increase staff capacity.

(2) Expand the network by installing purpose-drilled boreholes. Carry out scientific test pumping of these boreholes to establish aquifer firm hydraulic parameters such as *T* and *S*. Install suitable monitoring equipment.

(3) Carry out maintenance of monitoring stations as required.

(4) Audit the monitoring program, data bases, personnel and laboratories.

(5) Carry out statistical analysis of the data to establish trends.

(6) Compile bi-annual reports and act on any negative trends that are apparent, e.g., falling groundwater levels and/or degrading water quality.

(7) Use monitoring data as input into catchment and regional water balance assessments and numerical flow models to provide a continual improvement in the confidence levels of predictions. Update the provisional groundwater resource potential estimates contained in the IWRMD Plan.

(8) Provide feedback to authorities, water users and communities on the condition of the groundwater resources.

5. Water Quality Monitoring Network

The existing water quality monitoring network consists of a total of 36 stations consisting of 13 stations for surface water quality monitoring, 11 stations for groundwater quality monitoring, 10 stations for drinking water quality surveillance, and 2 stations for pollution monitoring. The distribution of existing stations by sub-basin is Songwe (22), Katuma (5), Momba (4), Luiche (5), Muze (0), Rungwa (0) and Lake Shores (0). For a more detailed discussion on the existing water quality monitoring network, the reader is referred to **Interim Report I**, **Vol. II**: *Water Resources Availability Assessment*.

5.1 Recommended Water Quality Monitoring Program

5.1.1 Network Design Considerations

The existing water quality monitoring network was re-designed to achieve the following objectives:

(a) More even spatial distribution of monitoring stations.
(b) Coverage of all sub-basins.
(c) Coverage of all major surface water systems.
(d) Coverage of all major aquifer systems.
(e) Coverage of major pollution hotspots.
(f) Adequate points for assessment of water utility operations (with respect to water quality management).
(g) Integration between hydrometric and groundwater monitoring networks on one hand, and the water quality monitoring network on the other. Thus, most of the new stations proposed for inclusion on the water quality network are existing hydrometric or the proposed groundwater monitoring network.
(h) A network size that provides adequate information to aid decision making and yet can operated affordably.

The network re-design involved changing the distribution of sampling points and proposing revisions to the existing sampling frequency and monitoring parameters. Some of the existing monitoring stations (those considered redundant or adding little value) have been recommended for removal from the network, while a number of new ones are being proposed for inclusion to the monitoring network.

5.1.2 Proposed Monitoring Network

The re-designed monitoring network comprises 48 stations of the following types:

- Twenty six (26) surface water quality monitoring stations;
- Six (6) groundwater quality monitoring stations;
- Eight (8) drinking water quality surveillance stations; and
- Eight (8) pollution monitoring stations.

The relatively high number of stations is due to the unique basin topography resulting in several isolated river systems discharging into a common terminus—Lake Rukwa. This set up dictates that each river system should have a reasonable number of water quality stations for monitoring trends within the sub-basin. One important factor considered in the network re-design is integration of the different basin monitoring networks (i.e., surface water, groundwater, and water quality). Consequently, fifteen of the proposed twenty-one new surface water quality stations are to be situated at existing hydrometric stations. Two new groundwater quality monitoring stations are to be located at two of the proposed groundwater monitoring stations, while three of the seven new pollution monitoring stations are to be located at proposed groundwater monitoring stations. The revised water quality monitoring network is shown in **Table 5.1**, and the stations slated for discontinuation are shown in **Table 5.2.**

Table 5.1: Recommended Water Quality Monitoring Stations for the Lake Rukwa Basin.

Sub-basin	No.	Monitoring Station	Status	Monitoring objective
Songwe	1	Imeta River near Mabatini Road Bridge	Existing	Surface water quality monitoring
	2	Lupa River at Lupatingatinga Bridge(Stn. No. 3A18)	Existing	Surface water quality monitoring
	3	Mbalizi River at Namwinga	Existing	Surface water quality monitoring
	4	Sisimba Stream near Mabatini Road	Existing	Surface water quality monitoring
	5	Songwe Zira River after confluence with Zira River	Existing	Surface water quality monitoring
	6	Myovisi River at Great North Road (Stn. No. 3A8A)	New	Surface water quality monitoring
	7	Songwe River at Galula Bridge (Stn. No. 3A17A)	New	Surface water quality monitoring
	8	Lupa River at Darajani (Bridge on Chunya-Makongolosi Road)	New	Surface water quality monitoring
	9	Zira River at Mkwajuni Road Bridge	New	Surface water quality monitoring
	10	Songwe River at Lusungwe Road Bridge (Great North Road)	New	Surface water quality monitoring
	11	Chunya Kidole Kati Borehole (Chunya Town Water Supply)	Existing	Groundwater quality monitoring
	12	Centre Ves 2 borehole in Galula goldmine (No. 612/2011)	New	Groundwater quality monitoring
	13	Mlowo River at intake for water supply	Existing	Drinking water quality surveillance
	14	Nzovwe River at pump house	Existing	Drinking water quality surveillance
	15	Sisimba River, intake at Sisimba Water Treatment Plant, Mbeya City	New	Drinking water quality surveillance
	16	Clear Water Well at Sisimba Water Treatment Plant, Mbeya City	New	Drinking water quality surveillance
	17	Autrad Mining Company Shaft Art 25 (Makatangombe Chunya Shaft)	Existing	Impact of gold mining
	18	Borehole at Saza goldmine (located at UTM 36 M 499549 Easting; 9072504 Northing)	New	Impact of gold mining; ground water quality monitoring
	19	Kaloba Wastewater Outlet No. 1 (Mbeya City)	New	Point pollution monitoring
	20	Imeta River downstream of waste stabilisation ponds (Mbeya City)	New	Point pollution monitoring

Sub-basin	No.	Monitoring Station	Status	Monitoring objective
	21	Effluent discharge point - Coca Cola Factory (Mbeya City)	New	Point pollution monitoring
	22	Effluent discharge point - Pepsi Cola Factory (Mbeya City)	New	Point pollution monitoring
Katuma	1	Msadya River at Usevya (Stn. No. 3CB2)	New	Surface water quality monitoring
	2	Katuma River at Sitalike (Stn. No. 3C8)	New	Surface water quality monitoring
	3	Mfwizi River at Ntantumbila Road bridge (3CC2)	New	Surface water quality monitoring
	4	Katuma (Kavuu) River and Kavuu Road Bridge	New	Surface water quality monitoring
	5	Water supply borehole in Namanyere Town	Existing	Groundwater quality monitoring –drinking water quality surveillance
	6	Milala Dam at water supply intake	Existing	Drinking water quality surveillance
	7	Water Distribution Point at Maji Yard, Mpanda Town	Existing	Drinking water quality surveillance
	8	Kakese borehole (located at UTM 36 M 280453 Easting; 9291528 Northing)	New	Pollution impact from irrigation scheme
	9	Mwawampuli borehole (located at UTM 36 M 314873 Easting; 9203488 Northing)	New	Pollution impact from irrigation scheme
Luiche	1	Luiche River at Uzia (Stn. No. 3CD2)	New	Surface water quality monitoring
	2	Sumbawanga Hospital Borehole	Existing	Groundwater quality monitoring
	3	Wipanga stream at water supply intake	Existing	Drinking water quality surveillance
	4	Water distribution point at Rukwa School	Existing	Drinking water quality surveillance
Muze	1	Muze River at Muze (Stn. No. 3CD1)	New	Surface water quality monitoring
Momba	1	Mpemba River at Kombe (Stn. No. 3B13)	New	Surface water quality monitoring
	2	Samvya River at Yunga (Stn. No. 3B16A)	New	Surface water quality monitoring
	3	Mtembwa River at Chipoma (Stn. No. 3B15)	New	Surface water quality monitoring
	4	Momba River at Tontela (Stn. No. 3B2)	New	Surface water quality monitoring
	5	Borehole 265 in Tunduma Town	Existing	Groundwater quality monitoring/ drinking water quality

Sub-basin	No.	Monitoring Station	Status	Monitoring objective
				surveillance
Rungwa	1	Musa River at Musisi (Stn. No. 3DA2)	New	Surface water quality monitoring
	2	Kapalala A Borehole	New	Ground water quality monitoring
Lake Shores and Open Lake	1	Luika River at Saza-Gua Road Bridge (Stn. No. G/S 3E1)	New	Surface water quality monitoring
	2	Lukwati River at Nkunda Hill on the Saza-Gua Road (G/S 3E8)	New	Surface water quality monitoring
	3	Kikamba River at Kipalala on the Saza-Gua Road (Stn. No. 3E2A)	New	Surface water quality monitoring
	4	Lake Rukwa - Southern Basin offshore point	New	Surface water quality monitoring
	5	Lake Rukwa - Northern Basin offshore point	New	Surface water quality monitoring

Table 5.2: Existing Water Quality Monitoring Stations Recommended for Discontinuation.

Sub-basin	No.	Monitoring Station	Monitoring objective
Songwe	1	Mbalizi River 50 m downstream after confluence with Nzovwe River	Surface water quality monitoring
	2	Nsungwe Stream 100 m upstream of confluence with Songwe River	Surface water quality monitoring
	3	Songwe River 100 m upstream from confluence with Nsugwe River	Surface water quality monitoring
	4	Songwe River 50 m before confluence with Nsalala River	Surface water quality monitoring
	5	Songwe River before confluence with Zira river	Surface water quality monitoring
	6	Zira-Lupa River after confluence with Lupa River	Surface water quality monitoring
	7	Autrad Mining Company Shaft Art 13, Chunya	Ground water quality monitoring
	8	Autrad Mining Company Shaft Art 26, Chunya	Ground water quality monitoring
	9	Borehole MB 2567/2009, Chunya Town	Ground water quality monitoring
	10	Chunya Chokaa Water supply borehole	Drinking water quality surveillance
	11	Makongolosi Water Distribution Point (borehole water supply)	Drinking water quality surveillance
	12	Mlowo River at Mlowo mission pump house	Drinking water quality surveillance

Sub-basin	No.	Monitoring Station	Monitoring objective
	13	Imeta River at Itende Concrete Bridge	Pollution Impact monitoring
Katuma	1	Mpanda River	Surface water quality monitoring
	2	Rukwa School Water Distribution Point	Drinking water quality surveillance
Momba	1	Haloli Stream	Surface water quality monitoring
	2	Borehole (No number)	Groundwater quality monitoring
	3	Borehole 158	Groundwater quality monitoring
Luiche	1	Artesian borehole	Groundwater quality monitoring
	2	Magereza Borehole	Groundwater quality monitoring

5.1.3 Revised Sampling Frequency and Monitoring Parameters

Given the considerably large basin size and poor accessibility of some areas, it would be very costly to visit all water quality monitoring stations often. A realistic sampling frequency is proposed that seeks to strike a balance between providing adequate information on water quality trends and operational sustainability. The recommendation is for stations to be visited at least two times a year (once in the wet season and once in the dry season). Where necessary, adhoc visits to specific monitoring stations can be arranged as and when the need arises.

The parameters recommended to be analyzed at the different types of water quality monitoring stations are shown in **Table 5.3**. These parameters have been carefully selected to suit the monitoring objectives. The selected physical, chemical, and bacteriological parameters are recommended for analysis in every sample of water taken. With respect to metals, it is recommended that analysis be performed once a year for pollution samples, once every three years for surface and groundwater samples, and as necessary for drinking water quality surveillance. The lower frequency for metals analysis is due to high laboratory analysis costs. For drinking water sources (especially piped systems), it is assumed that comprehensive water quality analysis (including heavy metal analysis) has been performed at the design stage of the water supplies, and that heavy metals are not a problem (otherwise the water supplies should not have been built in the first place). In very few cases, particularly in cases related to pollution, it may be necessary to include one or two additional unique parameters. As an example, the monitoring stations downstream of Kakese and Mwamampuli irrigation schemes should include analyses for pesticide residues.

Table 5.3: Water Quality Parameters Selected for Monitoring.

No.	Group	Parameter	SW & GW	Drinking WQ Surveillance	Pollution
	Parameters to be analyzed in the field				
1	Physical Parameters	Colour	✓	✓	✓
2	Physical Parameters	Odour	✓	✓	✓
3	Physical Parameters	Electrical Conductivity	✓	✓	✓
4	Physical Parameters	pH	✓	✓	✓
5	Physical Parameters	Temperature	✓	✓	✓
6	Physical Parameters	Dissolved Oxygen	✓*	✓*	✓
7	Physical Parameters	Dissolved Carbon Dioxide	✓*	✓*	
8	Physical Parameters	Turbidity	✓	✓	✓
9	Chemical Parameters - General	Phenolphthalein Alkalinity	✓	✓	✓
10	Chemical Parameters - General	Total Alkalinity	✓	✓	✓
11	Chemical Parameters - Cations	Iron (II)	✓	✓	✓
12	Bacteriological Parameters	Total Coliforms	✓	✓	✓
13	Bacteriological Parameters	Faecal Coliforms	✓	✓	✓
	Parameters to be analyzed in the laboratory				
14	Physical Parameters	Total Suspended Solids	✓	✓	✓
15	Physical Parameters	Total Dissolved Solids	✓	✓	✓
16	Chemical Parameters - General	BOD			✓
17	Chemical Parameters - General	Chemical Oxygen Demand			✓
18	Chemical Parameters - General	Total Hardness	✓	✓	✓

No.	Group	Parameter	SW & GW	Drinking WQ Surveillance	Pollution
19	Chemical Parameters - General	Carbonate Hardness	✓	✓	✓
20	Chemical Parameters - General	Non Carbonate Hardness	✓	✓	✓
21	Chemical Parameters - Cations	Calcium	✓	✓	✓
22	Chemical Parameters - Cations	Total Iron	✓	✓	✓
23	Chemical Parameters - Cations	Sodium	✓	✓	✓
24	Chemical Parameters - Cations	Potassium	✓	✓	✓
25	Chemical Parameters - Cations	Magnesium	✓	✓	✓
26	Chemical Parameters - Cations	Manganese	✓	✓	✓
27	Chemical Parameters - Cations	Ammonium Nitrogen			✓
28	Chemical Parameters - Cations	Total Nitrogen			✓
29	Chemical Parameters - Anions	Chlorides	✓	✓	✓
30	Chemical Parameters - Anions	Carbonates	✓	✓	✓
31	Chemical Parameters - Anions	Fluorides	✓	✓	✓
32	Chemical Parameters - Anions	Bicarbonates	✓	✓	✓
33	Chemical Parameters - Anions	Nitrites	✓	✓	✓
34	Chemical Parameters - Anions	Nitrates	✓	✓	✓
35	Chemical Parameters - Anions	Orthophosphates	✓	✓	✓
36	Chemical Parameters - Anions	Total Phosphorus	✓	✓	✓
37	Chemical Parameters - Anions	Sulphates	✓	✓	✓
38	Metals	Aluminum	✓***		✓**
39	Metals	Cadmium	✓***		✓**
40	Metals	Chromium (VI)	✓***		✓**
41	Metals	Copper	✓***		✓**
42	Metals	Mercury	✓***		✓**
43	Metals	Lead	✓***		✓**
44	Metals	Zinc	✓***		✓**
45	Metals	Barium	✓***		✓**

* Surface water only (O_2) and groundwater only (CO_2)
** Once a year
*** Once every three years

5.2 Minimum Water Quality Monitoring Network

The water quality monitoring network recommended in the previous section is the ideal optimum network for the basin to be realized in the long term (2035). However, with the current budgetary constraints, it may not be practical to operate such an extensive monitoring program. Therefore, a minimum affordable monitoring program is proposed for the short term, as the LRBWB builds technical and financial capacity to implement the optimum water quality monitoring program. The recommended minimum monitoring network comprises 22 high priority sites (see **Table 5.4** for details) that should be fully operational within the first five years of the IWRMD Plan implementation. This network will then form the skeleton around which the full monitoring program can be rolled out by 2035.

Table 5.4: List of High Priority Stations.

Sub-basin	No.	Monitoring Station	Monitoring objective
Songwe	1	Songwe River at Galula Bridge (Stn. No. 3A17A)	Surface water quality monitoring
	2	Lupa River at Darajani (Bridge on Chunya-Makongolosi Road) (UTM 36 M 536872 Easting; 9064351 Northing)	Surface water quality monitoring
	3	Centre Ves 2 borehole in Galula goldmine (612/2011)	Groundwater quality monitoring
	4	Sisimba River, intake at Sisimba Water Treatment Plant, Mbeya City	Drinking water quality surveillance
	5	Clear Water Well at Sisimba Water Treatment Plant, Mbeya City	Drinking water quality surveillance
	6	Borehole at Saza goldmine (located at UTM 36 M 499549 Easting; 9072504 Northing)	Impact of gold mining; ground water quality monitoring
	7	Effluent discharge point - Coca Cola Factory	Pollution Monitoring Point
	8	Effluent discharge point - Pepsi Cola Factory	Pollution Monitoring Point
	9	Kaloba Wastewater Outlet No. 1 (Mbeya City)	Pollution Monitoring Point
	10	Imeta River 100 m downstream of waste stabilisation ponds (Mbeya City)	Pollution Monitoring Point
Katuma	1	Katuma River at Sitalike (Stn. No. 3C8)	Surface water quality monitoring
	2	Katuma (Kavuu) River and Kavuu Road Bridge	Surface water quality monitoring
	3	Water Distribution Point at Maji Yard, Mpanda Town	Drinking water quality surveillance
	4	Kakese borehole (located at UTM 36 M 280453 Easting; 9291528 Northing)	Pollution impact from irrigation scheme ground water quality monitoring
	5	Mwawampuli borehole (located at UTM 36 M 314873 Easting; 9203488 Northing)	Pollution impact from irrigation scheme; ground water quality monitoring
Luiche	1	Luiche River at Uzia (Stn. No. 3CD2)	Surface water quality monitoring
	2	Sumbawanga Hospital Borehole	Groundwater quality monitoring
Momba	1	Momba River at Tontela (Stn. No. 3B2)	Surface water quality monitoring
Muze	1	Muze River at Muze (Stn. No. 3CD1)	Surface water quality monitoring
Lake Shores	1	Luika River at Saza-Gua Road Bridge (Stn. No. G/S 3E1)	Surface water quality monitoring
	2	Lake Rukwa - Southern Basin offshore point	Surface water quality monitoring
	3	Lake Rukwa - Northern Basin offshore point	Surface water quality monitoring

5.3 Cost Effective Monitoring Measures

Network operational costs were taken into consideration in re-designing the recommended water quality monitoring network. A number of cost-cutting measures were considered during network re-design to help minimize investment and operational costs. These included, among others: reduction in sampling frequency; carefully defining parameter suites to eliminate redundancy; and definition of a minimum network. Other cost-cutting measures that should be considered include:

- Include a clause in the Water Use Permit of operators of major hydraulic structures (hydropower dams, irrigation headworks, multipurpose dams), to make monthly analysis of suspended solids and share the data with the LRBWB. Likewise, the discharge permits of industrial firms and municipal authorities could include a condition for self-monitoring and submission of copies of the collected data to LRBWB on a monthly or quarterly basis.
- Integration of all LRBWB network operations so that staff going on routine visits to surface and groundwater stations could be trained in water quality sample collection so that they

come back with water samples which are then submitted to the laboratory for analysis. In this way, no separate trips will be required for visits to water quality stations that are part of the surface water and groundwater monitoring networks.

- Use of portable water quality testing kits, such as those manufactured by HACH and LaMotte, that have high accuracy and precision, reasonable detection limits, do not require very high skills to operate, and do not require major modifications to laboratory infrastructure.

Table 5.5 provides estimates of annual costs for laboratory analysis of water quality samples based on the recommended parameter suites and sampling frequencies. These figures are considered manageable for the LRBWB.

Table 5.5: Estimates of Annual Cost for Water Quality Analysis, TShs.

	Surface Water	Ground Water	Drinking WQ Surveillance	Pollution Impact	Annual Cost WQ Analysis
The minimal monitoring network					
No. of Stations	10	2	3	7	
Average year: physico-chemical and bacteriological analysis for surface and ground samples; physico-chemical and heavy metal analysis for pollution samples	4,160,000	512,000	1,248,000	1,982,885	7,902,885
Once every three years: physico-chemical, bacteriological and heavy metal analysis for surface and ground samples; physico-chemical and heavy metal analysis for pollution samples	6,560,000	807,385	1,968,000	1,982,885	11,318,269
The full monitoring network					
No. of Stations	26	6	8	8	
Average year: physico-chemical and bacteriological analysis for surface and ground samples; physico-chemical and heavy metal analysis for pollution samples	10,816,000	1,536,000	3,328,000	2,266,154	17,946,154
Once every three years: physico-chemical, bacteriological and heavy metal analysis for surface and ground samples; physico-chemical and heavy metal analysis for pollution samples	17,056,000	2,422,154	5,248,000	2,266,154	26,992,308

Notes:

1. Rates for physico-chemical analysis used are for the Water Quality Division of the MoW. These are the lowest rates for physico-chemical analysis in the country. It costs 208,000 TShs. to analyse each surface and groundwater sample (32 parameters each), and 251,000 TShs. to analyse one pollution sample (32 parameters).
2. Rates for heavy metals are from the water laboratory of the Department of Water Resources Engineering, College of Engineering and Technology, University of Dar Es Salaam. They represent the average rates for heavy metal analysis in the county. It costs 240,000 TShs. to analyse heavy metals in each sample (8 parameters).

6. Data and Information Management

6.1 The Value of Good Data and Information Management

Well-designed monitoring systems and the routine acquisition of observational data are *fundamental* and *necessary* for the sustainable management of natural resources. But, they are not sufficient. By itself, raw data does not have any societal or environmental value, other than providing employment to those who collect it. Data becomes valuable only when it is actually *used* to serve worthy societal, economic, and environmental causes.

All too often, regulatory and management agencies focus on the labour intensive task of acquiring raw data but fail to manage it in ways that facilitate its beneficial use. Evidence of this failing abounds throughout the institutional system and has many frustrating manifestations, drawbacks, and costs including the following:

- Agency mandates with respect to data collection are vague, overlapping, and uncoordinated.
- Data of the same type is often independently collected by multiple agencies, government levels, private sector stakeholders, and academic institutions. Moreover, the same data is often collected using different monitoring systems and protocols, may be checked for errors through ad-hock quality control procedures (if any), and is archived in different forms from anecdotal testimonies of staff who have been there for a long time, to hard copies, and occasionally, to digital spreadsheets.
- Data accessibility is at the discretion of its custodian, and it is never free. Sometimes the price of data is a standard fee per bundle (set by the custodian), and sometimes the price is much higher paid in having to dedicate significant efforts (from weeks to months) to visit multiple agencies and institutions in different districts, cities, and towns, searching through, copying, digitizing, and error checking poorly organized data archives.
- Information about data (i.e., metadata) typically resides with a select few agency technicians, engineers, and managers who, over their years of service, developed a special interest and made it their duty to preserve the provenance of various data sets and technical documents. These are very special people, but they are fast disappearing (through promotion and retirement), without the means and the opportunity to pass their knowledge and information on to the institution they served. This loss of institutional memory impacts the quality of institutional services and has real societal costs.
- Different government departments commission technical studies using different data sets and methods, reach different conclusions, and develop contradictory positions about the *same* resource. The question of whether there is enough water to support agricultural development in a particular region of the Lake Rukwa Basin deserves to have the *same* answer regardless if it is asked at the Ministry of Agriculture, the Ministry of Water, or the affected Local Governments. Yet, the answers to these questions are not always consistent as they are derived based on different sets of operating facts.

Tanzania has quietly entered into a new era of water management where the past practices of uncoordinated sectoral interventions can no longer be an option. From now on, integrated management (meaning integrated data, assessment methods, institutional efforts, and investments) is not just a fashionable approach to sustainable development; it is the *necessary* approach to sustainable development. The WSDP effort to develop IWRMD plans for each basin is a first bold step in this direction. The next step is to bring about a cultural change in the way institutions perceive the need to work together, and the way water stakeholders appreciate that their desire to satisfy their interests may impact the interests of others and, collectively, harm the common natural resources on which they all depend. This transformative process can be facilitated by removing barriers that currently discourage it. To this end, we submit that a major such barrier is the lack of easy access to integrated good data and information. The following section conceptualizes a systematic data and information management process that can help remove this barrier.

6.2 Integrated Data and Information Management

Figure 6.1 conceptualizes an information management process by which basin data and information is collected, quality controlled, archived in a central database, and subsequently disseminated to users who wish to use it for various applications. The components of this process can be implemented in many different ways depending on the nature of the system, the available resources (related to personnel, equipment, and budgets), and the institutional capacity to leverage modern information technologies. While the individual components are certainly important, the institutional commitment to the existence and functioning of the entire process is even more critical.

The natural custodian of all Lake Rukwa Basin data and information services is the Lake Rukwa Basin Water Board (LRBWB) who should have the full responsibility of implementing and managing the data and information acquisition, archival, and dissemination process. Relevant modalities of operationalizing the process are discussed next, along with some new contributions made by the IWRMDP project and some outstanding needs.

- The main data and information categories in basin management are related to surface water (SW), groundwater (GW), water quality (WQ), and water use (WU). Data in each category are collected by different LRBWB divisions headed by a qualified engineer or scientist trained in the respective area. The data collection process is usually carried out by technicians adequately trained for this task. The data collection process is different for each data type, and for this reason, customized and clear protocols need to exist and be followed by each data collection division.
  Outstanding Process Needs: There is need to develop customized data collection templates containing the information cells that should be filled out by the data collection staff. These should be developed for each data category to ensure standardization of the information collected, recorded, and archived. If used consistently, these templates would address the common problems of missing and inconsistent information in data records.

- Data quality control should occur immediately after each field visit, and should be a joint effort by the division head and the technical staff who collected the data. After resolving any data accuracy, completeness, and consistency issues that might arise, the spreadsheets containing the newly collected data can be uploaded to the respective SW, GW, WQ, or WU database along with any relevant information about the data values or the data collection process (metadata).
  IWRMDP Project Contribution: The IWRMDP project has developed customized databases for each data category. Each database already contains all available data compiled under the IWRMDP project. Moreover, each database runs on personal computers under WINDOWS and has (i) a user-friendly interface facilitating data import,

editing, archiving, management, and export; and (ii) selected application tools to convert the raw data into other useful information. An example of the latter is a new river gage rating curve tool developed to automate the process of converting river stages to discharges. This tool first guides the user through constructing and archiving rating curves for each cross-section and historical period, and subsequently uses them to convert stages to discharges for all periods with stage measurements. The databases and the tools are also part of the Rukwa DSS which includes many other models and applications. The stand-alone database versions were developed to facilitate the information management process in **Figure 6.1**.
Outstanding Process Needs: Through their visualization options and data analysis tools, the databases can help identify potential data errors and thus assist the quality control process. However, each data category has its own specific criteria of detecting erroneous data. A useful addition to the databases would be to develop customized tools that incorporate the unique error detection criteria for each data category. This can be accomplished through close collaboration of the modeling team and the division staff.

- The next step in the information integration process is to upload the new data in the integrated database system. At any given time, the integrated database contains all data and information officially vetted in all data categories. It is important that there is one central server housing the integrated database, and that each update of the integrated database becomes the official version from which data is disseminated to any government or private data user. Because of this formal requirement, only a few authorized individuals should have permission to upload data to (and therefore alter) the integrated database. These individuals could be the division heads, or an information technology (IT) professional reporting directly to the Basin Water Officer. New database releases should be a formal process, and data provided to users should clearly reference the database release version from which it came. The server housing the integrated database can be as simple as a personal computer or as sophisticated as a network of interlinked computer servers maintained by an IT team.
  Outstanding Process Needs: While individual, stand-alone databases have been developed under the IWRMDP project for each data category, there is currently no integrated database containing the data in all categories that can serve the purpose of disseminating data to interested users. The creation of such a general purpose database is fairly straightforward given the groundwork already performed. However, a more significant effort would be needed to create suitable web-based interfaces that enable the database to receive new data and to respond to data requests. It is recommended that both functionalities be web-based (and not of a client-server type) to ensure that the processes of adding new data to the database or disseminating data from the current database release are consistent, standardized, and immune to human error.

- Once the integrated database and associated web-based interfaces are on-line, users can query and receive data through the web interface. A user may be some private engineering firm commissioned to design a water distribution system, or the LRBWB staff needing to use the data to evaluate issuing a permit. Users must have tools suitable for their own specific applications, but they can now be assured to have easy access to integrated and consistent data sets, and operate from the same base of facts.
  IWRMDP Project Contribution: The IWRMDP project has created the Rukwa DSS which includes a suite of modelling and assessment tools useful in basin planning and management applications. These tools have been delivered to LRBWB, but they may also be useful to other users too.

Outstanding Process Needs: (i) LRBWB would derive value by the development of a general purpose permitting tool which standardizes the technical investigations pertaining to the permitting process. The permitting process currently relies in part on subjective evaluations and may lead to inconsistent outcomes. As the basin earnestly engages in the development of its water and land resources, the permitting process will become an important regulatory instrument to ensure that these investments are indeed sustainable. (ii) In addition to its value associated with planning and management applications, the Rukwa DSS is also a unique training tool in the fairly uncharted area of integrated water resources management. With sufficient training, LRBWB staff can become confident developing and adding their own customized application tools, and, in so doing, begin to build up the declining institutional memory and capacity.

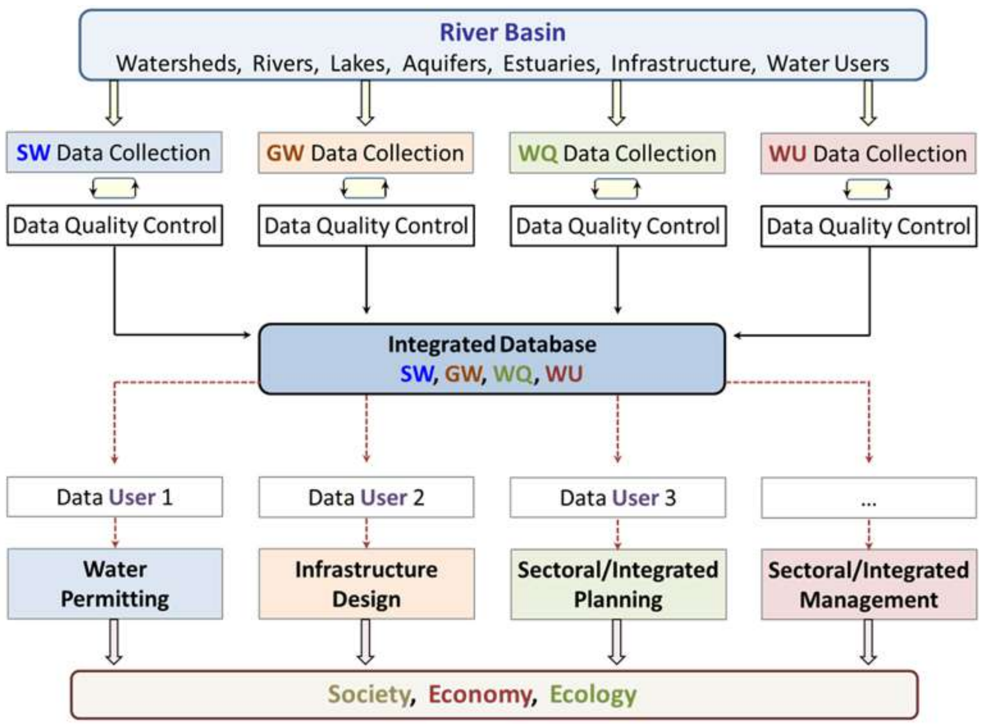

Figure 6.1: Integrated data and information management concept.

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Annex A: List of Existing Lake Rukwa Basin Monitoring Stations

Lake Rukwa Basin Hydrometric Stations					
Sub-basin	**Code**	**River**	**Location**	**Data available**	**Status**
Songwe	3A15	Lupa	Itigi Road Bridge	_	Rehabilitated
	3A18	Lupa	Lupatingatinga	1975 - 2012	Operational [Rehabilitated]
	3A4A	Mbalizi	Great North Road	1964 - 2010	Not Operational
	3A8A	Myovisi	Great North Road	1956 - 2011	Operational [Rehabilitated]
	3A6A	Nzovwe	Great North Road	1964 - 2011	Operational [Rehabilitated]
	3A7A	Ruanda	Great North Road	1958 - 2012	Operational [Rehabilitated]
	3A17A	Songwe	Galula	1974 - 2012	Operational [Rehabilitated]
	3A2A	Songwe	Iwe	1956 - 1993	Closed
	3A	Sisimba	Water Supply	1991 - 2009	Closed
	3A14A	Mlowo	Great North Road	1964 - 2011	Operational [Rehabilitated]
	3A16A	Lupa	Lupa Market	_	Closed
Katuma	3CC2	Mfwizi	Ntatumbila	1975 - 2013	Operational [Rehabilitated]
	3CC3	Mfwizi	Paramawe	1975 - 1993	Rehabilitated
	3CB2	Msadya	Usevya	1975 - 1996	Rehabilitated
	3C8	Katuma	Sitalike	1975 - 1994	Rehabilitated
	3C5	Lukima	US Rungwa Village	_	Closed
Momba	3B16A	Samvya	Yunga	1979 - 2013	Operational [Rehabilitated]
	3B8	Mpemba	Great North Road	1957 - 1998	Rehabilitated
	3B13	Mpemba	Kombe	1974 - 1997	Rehabilitated
	3B15	Mtembwa	Chipoma	1974 - 2012	Operational [Rehabilitated]
	3B15A	Mtembwa	Luasho	1978 - 2002	Closed
	3B2	Momba	Tontela	1974 - 1999	Rehabilitated
	3B14	Muko	Kaziala	1974 - 1982	Closed
Luiche	3CD2	Luiche	Uzia	1975 - 2012	Operational [Rehabilitated]
Muze	3CD1	Muze	Muze	1975 - 2013	Operational [Rehabilitated]
Rungwa	3DA2	Musa	Musisi	1978 - 2012	Operational [Rehabilitated]
	3D4	Rungwa	Itigi Road Bridge	2011 - 2012	Rehabilitated
Lake Shores	3B17	Lake Rukwa	Zimba	1976 - 1977; 2010 - 2012	Operational [Rehabilitated]
	3B1A	Lake Rukwa	Mbangala	1971 - 2011	Operational [Rehabilitated]
	3E2A	Kikamba	Kapalala	1975 - 1995	Rehabilitated
	G/S 3E1	Luika	Gua Road Bridge	2012 - 2013	Rehabilitated
	G/S 3E8	Lukwati	Nkunda Hill	1975 - 1987	Rehabilitated
	3E5	Yeye	Kolole	_	Closed
	3E4	Wuku	Mkamba	_	Closed

Lake Rukwa Basin Climate/Rainfall Monitoring Stations						
Sub-basin	**Code**	**Station**	**Location**	**Data Available**	**Status**	**Operator**
Songwe	98.3309	Galula Met. Station	Galula	1977 - 2013	Not Fully Operational [Rehabilitated]	Maji
	98.3318	Lupatingatinga Met. Station	Lupatingatinga	1976 - 2012	Not Fully Operational [Rehabilitated]	Maji
	99.3325	Isangati Primary School	Mbeya	1971 - 2012	Operational	Maji
	98.3321	Utengule/Usongwe Pri. Sch	Mbeya	1972 - 2011	Operational	Maji
	98.3320	Mbeya Maji Depot	Mbeya	1959 - 2012	Operational	Maji
	98.3324	Mwambani Mission	Mkwajuni	_	_	Mission
	98.3325	Uyole MARTI	Mbeya	_	Operational	Kilimo
	98.3302	Chunya Kilimo	Chunya	_	_	Kilimo
	98.3300	Mbeya Bomani	Mbeya	_	Closed	Kilimo
	98.3301	Mbeya Airport Met. Station	Mbeya	_	Operational	TMA
	99.3208	Mlowo Mission	Mlowo	_	_	Mission
	99.3210	Igamba	Igamba	_	_	Kilimo
	98.3317	Nzovwe Mission	Mbeya	_	_	Mission
Katuma	96.3006	Katuma Primary School	Katuma	_	_	Private
	96.3100	Uruwira Mission	Uruwira Mission	_	_	Private
	96.3104	Milala Primary School	Milala	_	_	Private
	96.3105	Mpanda Boma	Mpanda Boma	_	_	Maji
	96.3106	Katavi National Park	Sitalike	_	Operational	Private
	96.3107	Nsimbo	Nsimbo	_	_	Private
	96.3108	Magamba Met Station	Mpanda [Magamba]	_	Not Fully Operational [Rehabilitated]	Maji
	97.3102	Kate Mission	Kate	_	_	Private
	97.3104	Mamba Mission	Mamba	_	_	Private
	97.3106	Chala Mission	Chala	1986 - 1993	Not Operational	Private
	97.3113	Usevya	Usevya	_	Not Operational	Maji
	97.3117	Usevya Met. Station	Usevya	1977 - 2013	Not Fully Operational [Rehabilitated]	Maji
	97.3127	Maji Yard Namanyere	Namanyere	1993 - 2013	Operational	Maji
	97.3127	Namanyere Primary School	Namanyere	1985 - 1992	Closed	Maji
	97.3126	Mfinga Primary School	Milepa	1985 - 1992	Not Operational	Maji
Momba	98.3131	Kitete Primary School	Katazi	1984 - 1989	Not Operational	Maji
	96.3002	Mwazye	Mwazye		Not Operational	Maji
	98.3112	Mwazye Primary School	Mwazye			Private
	98.3115	Mwazye Met. Station	Mwazye S.S	1977 - 2012	Not Fully Operational [Rehabilitated]	Maji
	98.3117	Kaengesa Mission	Kaengesa			Private
	98.3120	Mpui Primary School	Mpui			Private
	98.3121	Mollo Prison Farm	Mollo	1984 - 2003	Not Operational	Maji
	98.3202	Mkulwe Mission	Mkulwe			Private
	98.3207	Laela Mission	Laela	1989 - 2009	Totally Vandalised	Maji
		Mfuto Primary School	Mbeya	2011 - 2012	Operational	Maji
	99.3209	Chiwanda Mission Pri Sch	Chiwanda	1965 - 2012	Operational	Maji
	99.3205	Mbimba Research Station	Mbimba		Operational	TCRI
Luiche	98.3127	Mlanda Primary School	Milanzi	1984 - 1989	Not Operational	Maji
		Sumbawanga Met. Station	Regional Block	1989 - 2012	Not Fully Operational [Rehabilitated]	Maji
	97.3120	Maji Depot Sumbawanga	Sumbawanga	1975 - 2013	Operational	Maji
	97.3103	Malonje Farm	Malonje [Mollo]	_	_	Private
	97.3116	Nkundi State Farm	Nkundi	_	_	Private
Muze	97.3109	Muze	Muze		Closed [Operationed before 1984]	Maji
Rungwa	96.3200	Inyonga	Inyonga	_	_	_
	96.3202	Inyonga Met. Station	Inyonga	1977 - 2009	Not Operational	Maji
	96.3301	Rungwa Met. Station	Rungwa	2000 - 2013	Not Fully Operational [Rehabilitated]	Maji
Lake Shores	97.3105	Zimba Met. Station	Zimba	1977 - 2013	Not Fully Operational [Rehabilitated]	Maji
	97.3111	Mbizi Forest Reserve	Mbizi	_	_	Private
	97.3115	Zimba (Mtowisa)	Zimba	_	Not Operational	Maji
		Milepa	Milepa	_	Not Operational	Maji
	97.3200	Gua Kijijini	Gua	_	Not Operational	Maji
		Gua Primary School	Gua	_	Operational [Re opened 2009]	Maji
		Shanta Luika Gold Mine	Saza	_	Operational	Private
	98.3126	Mawenzusi Primary School	Mollo	1984 - 1993	Not Operational	Maji
	98.3113	Kafkola	Kafkola Camp	_	_	Private

Lake Rukwa Basin Water Quality Monitoring Stations		
Sub-basin	**Station**	**Sampling Point**
Songwe	Borehole MB 2567/2009	Chunya town BH
	Borehole	Makongolosi Chunya Dp
	Autrad Mining Company Shaft Art 25	Makatangombe Chunya Shaft
	Autrad Mining Company Shaft 26	Makatangombe Chunya Shaft
	Autrad Mining Company Shaft Art 13	Makatangombe Chunya Shaft
	Zira Lupa River	Zira after confluence with Lupa River
	Songwe River	Songwe before confluence with Zira River
	Songwe Zira River	Songwe after confluence with Zira River
	Lupa_River	Lupatingatinga village bridge
	Mlowo River	Mission waterpump Station
	Mlowo River	Intake
	Songwe River	50m after confluence with Nsalala River
	Songwe River	100m up stream from confluence with NsungweStream
	Nsungwe Stream	100m up stream before confluence with Songwe River
	Mbalizi River	Nsalala
	Mbalizi River	50m down stream after confluence with NzovweRiver
	Nzovwe River	Pump House Station
	Imeta River	Itende Concrete Bridge
	Sisimba Stream	Near Mabatini Road
	Imeta River	Near Mabatini RoadBridge
	Chunya KidoleKati	
	Lupatingatinga	Lupa River
	Chunya Chokaa	Watersupply BH
Katuma	Namanyere	Water supply BH
	Katuma	River
	Milala Dam	Intake
	MajiYard	DP
	Mpanda River	Company
	Ntatumbila	River
Momba	Momba	River
	Haloli Stream	Intake
	Borehole	Tunduma BH
	Borehole 158	Tunduma BH
	Borehole 265	Tunduma BH
Luiche	Artesian	BH
	Magereza	BH
	Hopital	BH
	Wipanga	Stream Intake
	Rukwa School	DP
Muze		
Rungwa		
Lake Shores	Luika	Gua Bridge