COMPLETION OF TECHNICAL ASSISTANCE IN ENVIRONMENT AND NATURAL L RESOURCES MANAGEMENT

AKAGERA UPPER CATCHMENT (NAKU)

26/11/2020

CATCHMENT MANAGEMENT PLAN

LEFT EMPTY INTENTIONALLY

(1) EXECUTIVE SUMMARY

INTRODUCTION:

The purpose of this study was to develop a Catchment Management Plan for the Nile Akagera Upper Catchment (NAKU). Catchment planning is an important tool for integrated water resources management (IWRM) and for management of related land and natural resources. It is generally based on hydrological boundaries, i.e. drainage network that guide the water flows. A catchment is an area of land where precipitation falls, collects and drains off into a single outlet, such as a river, lake, or other body of water. A catchment includes all surface water emanating from rainfall-runoff within these boundaries and that runs downhill towards the shared outlet. It also includes those groundwater bodies that are wholly or partly within the same area, especially those that contribute to surface water flow. Catchments also contain people and businesses, such as industry, agriculture, etc., and these are all also affected by and have an impact on water resources within the catchment area. The strong relationships between land, water, people (stakeholders) and the economy within a catchment, call for an integrated management thereof.

NAKU catchment plan was developed by taking into consideration national orientations as articulated in the National Strategy for Transformation (NST1), Vision 2050, and the Nation's Green Growth and Climate Resilience Strategy (GGCRS). The catchment plan development was done in a very participatory manner involving all relevant stakeholders. The process was driven from REMA with strong support from Rwanda Water Board as the coordinating organization. Partner ministries, local authority District and Sector were adequately involved.

METHODOLOGY:

The process of developing strategies and plans to govern natural resources within a catchment is known as catchment management planning. The principles of integrated catchment management planning can be applied to the different scales of catchment units, namely catchment, sub-catchment, micro-catchment and village-level. The Catchment Management Plan (CMP) is the main output of the catchment management planning process at the broadest scale. The CMP records a vision for the catchment and formalises the current and future trends of the various resources such as water, land, environment and social economic factors in terms of that vision. The CMP then provides additional details with regard to the specific implementation of options for improved catchment management and the development of the main natural resources while still promoting and achieving national growth and development objectives. The CMP states how issues and concerns will be addressed through agreed management strategies within a specified time period, and outlines an associated legislative, procedural and technical framework for implementation. The plan reflects national policies as well as stakeholder commitments. It needs to be granted legal status, either as a contract or as a legal proclamation, if it is to be implemented. In this regards the CMP typically includes a detailed implementation plan (IP) and a Monitoring and Evaluation Plan (MEP). The IP allocates responsibility for implementation and is used to inform the District Development Plan (DDP) that can be implemented with support from the relevant Catchment Committee (CC), various national and local level government and relevant Non-Government Organizations (NGOs) and Community Based Organisations (CBOs) in the catchment.

In accordance toTR90 – Catchment Plan & SEA development manual the catchment planning process is conducted in 6 main steps as follows:

(1) Integrated situation analysis
(2) Vision development
(3) Integrated planning
(4) Sector and agency planning
(5) Coordinated implementation
(6) Joint monitoring

INTEGRATED SITUATION ANALYSIS

Integrated Situation Analysis was conducted in order to understand the status, conditions, trends and key issues affecting people, ecosystems, and institutions in the catchments under consideration at any level (local, national, regional, international). The situation analysis is importance as it leads to (i) clearly identifying the needs and concerns of beneficiaries and their livelihoods, (ii) ensure a catchment plan is appropriate to the situation, (iii) assess situational factors that will influence catchment plan implementation and effectiveness, (iv) problem and situational analysis helps to determine real - as opposed to apparent - development needs. In addition, it helps to bond program participants together by identifying a variety of issues that may need to be dealt with. This will lead to identifying existing problems that require attention. A problem is usually not the absence of a solution but an existing negative state. The negative states will be prioritized and the way forward of addressing it will result in a catchment management plan. The situation analysis would also have helped in identifying existing and ongoing interventions.

Integrated Situation Analysis was done through a review of existing information, identification and consultation with key stakeholders, a catchment tour visiting identified problem areas as well as projects already implementing improved catchment management practices, and culminated in stakeholder workshops to discuss and evaluate the critical issues as well as to identify possible improved catchment management practices. A household survey, with permission of NISR, of over 600 households was conducted across the catchment area to determine baseline information for future monitoring. Members of the catchment Task Force were involved in workshop and validation processes. In addition, meetings and consultations were held with each District and Sector offices in the catchment.

Nile Akagera Upper is catchment is one of the nine level 1 catchment located in the Kagera sub-basin of Rwanda and it is located downstream of NNYU, NAKM and NNYL. NAKU has a total area of 3053 km^2 and its represents 12.6% of the total surface area of Rwanda (26,338 km^2 including water bodies), It is a transboundary catchment, shared between Rwanda and Burundi. Nine District has their territory in NAKU Catchment, they are: Bugesera, Gasabo, Kamonyi, Kayonza, Kicukiro Kirehe, Ngoma, Nyarugenge, and Rwamagana, with 63 Sector having all or part of their territory in the catchment. All the 63 Sectors were visited during data collection. Integrated Situation Analysis reveal some hydrographic characteristic of NAKU catchment are shown in the table below:

Months	Flow (TCM) for existing conditions in Sub-catchments							
	Sub-catchment 1	Sub-catchment 2	Sub-catchment 3	Sub-catchment 4	Sub-catchment 5	Sub-catchment 6	Sub-catchment 7	Total NAKU
January	9,719	3,819	14,397	6,917	1,587	3,566	1,268	41,273
February	8,118	2,902	11,120	5,125	1,555	3,494	1,243	33,558
Match	8,533	2,343	9,188	4,624	2,539	5,706	2,029	34,962
April	14,213	4,874	19,127	9,374	3,827	8,601	3,059	63,074
May	13,711	5,642	21,078	9,259	2,451	5,509	1,960	59,610
June	2,524	1,070	4,077	1,813	259	583	207	10,533
July	1,650	693	2,654	1,176	85	191	68	6,517
August	1,520	526	1,875	778	280	629	224	5,832
September	1,422	168	731	667	545	,224	435	5,192
October	3,455	493	1,906	1,335	1,277	2,871	1,021	12,358
November	9,410	3,026	12,243	7,076	2,087	4,691	1,668	40,200
December	10,923	3,997	15,372	6,960	1,733	3,895	1,385	44,265
Total	85,198	29,553	113,769	55,103	18,224	40,960	14,569	357,375

NAKU catchment is by pollution from domestic waste, solid waste, and sediment resulting from soil erosion from the upstream catchments and within the catchment itself. The catchment has 39,569 ha of wetlands of which 2,554ha (6.5%) is still in natural condition. The most significant wetland in the catchment is the Gashora-Mugesera-Rweru complex which includes several lakes along the eastern flank of the Akagera River. The Gashora-Mugesera complex was proposed for Ramsar Status. The wetland complex is of specific concern, as a remaining natural wetland habitat it is under pressure for conversion to irrigated agriculture, while it is also listed as one of the country's most important wetland areas. This is due to its importance for ecosystem service support to people, ecological function (acting like a sponge holding water in the catchment and side lakes to be released during dry periods and improving water quality) and biodiversity support, providing habitat to more than 16 vulnerable IUCN and CITES-listed species. This wetland complex is already threatened as portions of it have been cut-off and drained for wet field rice cultivation.

There are several existing wet field rice cultivation projects scattered throughout the catchment. International research has shown a direct link between wet field rice cultivation and the increased occurrence of malaria. This was confirmed by the Districts during the stakeholder workshop.

The catchment area was historically dominated by savannah woodlands and forests, but has undergone significant change to open the land for population redistribution and farming. Of the 8,314.23ha of tree cover left in the catchment 23.6% is still natural and the remaining is plantation, agroforestry and woodlot. There are no forest reserves within the catchment but there are two areas of natural forest, the Karama Natural Forest (also called Isar Karama) and the Gako Military Zone forest. Activities of forest regeneration and vegetation cover should be prioritised to contribute towards improving soil stability, reducing soil erosion, increasing carbon sequestration, and replenishing fuel wood and forest ecosystem services.

Part of the catchment is characterised with steep slopes, and part of the catchment has a gentler terrain. The soils of catchment area are prone to soil erosion from high runoff, poor vegetation cover and poor farming practices. The implementation of progressive and radical terraces has contributed to reducing soil erosion and stabilising slopes, while increasing the area for cultivation. The roll out of terracing should be continued and expanded. The Crop Intensification Programme should be expanded and enhanced to focus on soil fertility. Implementation of techniques for runoff management along roads and pathways should be prioritised, especially to reduce runoff rate, and promote runoff harvesting.

After agriculture (and trade), construction, transport and manufacturing are the main employment sectors in the catchment. Although currently low in formal employment, there is extensive tourism potential within the catchment and this should be explored further and formalised. In particular, the relocation of Rwanda International Airport to Bugesera District strategically supports the growth of tourism, especially avitourism in the catchment.

The water balance for the catchment was calculated for existing conditions 2020 as well as for future conditions (2030 and 2050) under different scenarios of population growth and climate change, summarised in the tables above. In all scenarios (both population growth and climate change) water availability is higher than water demand at each sub catchment for all 12 months. This suggests that there is currently no need to construct major water storage schemes. However, there is a need for more localised access to water supply such as water kiosks and boreholes. The groundwater of the catchment is underutilised and not well explored. Further studies in the productive potential of groundwater should be investigated. There is capacity for further rainwater harvesting within the catchment. The consultancy has developed a detailed rainwater harvesting calculation model which can be applied to specific sites to inform the required storage capacity for the differing site characteristics. Furthermore, a detailed environmental flow assessment for the Akagera river as a system should be conducted, and the recommendations from this incorporated into the models developed for the different catchments.

CONSISTENCY ALIGNMENT WITH EXISTING LEGAL FRAMEWORK, POLICIES, STRATEGIES, AND PROGRAMMES

The catchment plan covers a wide array of policy fields and tries to provide an integrated approach to sustainable economic development (green growth) of the catchment. To avoid conflicts with other relevant policy documents from the Government of Rwanda (laws and regulations, policies, strategies, and major programmes) and maximise synergies, a thorough analysis and alignment has been made of existing policy documents. This was done in two phases. An in-depth analysis was made of numerous key documents. This included the national development framework (EDPRS2, Vision 2020 and the seven-year Government Programme 2010-2017) and the very important Green Growth and Climate Resilience Strategy (GGCRS); and relevant policies, strategies, programmes, and plans in the water sector and water related sectors (irrigation, water supply and sanitation, housing, local government, tourism, gender, etc). SWOT analyses were conducted to arrive at recommendations for the catchment plan, but also for future updates or revisions of the analysed documents. In 2017-2018 a new national development framework was introduced the National Strategy for Transformation (NST1), the seven-year Government Programme for 2017-2024 comprising the completion of Vision 2020 and beginning of Vision 2050. Together with GGCRS this provided the starting point for a new set of Sector Strategy Plans (SSPs) and District Development Strategies (DDSs), all incorporating a set of national Cross Cutting Areas (CCAs). Catchment Plans were situated in the middle, bridging the gap between national sector strategies and district strategies, optimising integration at catchment level and pro-actively optimising alignment between all three spatial scales (national, catchment, district). The alignment process further culminated in the integration of catchment plans and catchment restoration opportunities in the greening of DDSs, conducted by MINALOC in 2018. By also aligning logical frameworks of all concerned documents, an integrated intervention logic with aligned framework of indicators was developed for the catchment plan, allowing for spatial aggregation at the geographic scale of individual projects, cells, sectors, districts, catchments, provinces, and the nation. The aligned indicators also allow for bottom-up aggregation of sectoral interventions throughout the country and assessing the contribution to NST1 targets.

All the Districts have identified unplanned or informal settlements as a critical issue. This results in poor waste management (solid and liquid) and issues of flooding. Rwanda and the Nile Akagera Upper Catchment has a high population growth rate and an existing high population density. As the population continues to grow, there will be more pressure on access to land, water and services and resultant issues of waste management and rapid urban growth. It is critical that land use plans are developed and are implemented and adhered to, in order to ensure the sustainable growth and development within the catchment area.

Encroachment into the river bank and wetland buffer areas due to demand for land, access to water for irrigation or just public access pathways has been raised by all Districts within the Catchment. Enforcement of the buffers and rehabilitation where these have been damaged or removed should be prioritised.

VISION FOR THE CATCHMENT

The next step in compiling this plan involved stakeholder engagement to develop a vision and goals and objectives for the catchment management plan. During the stakeholder workshop on 13 and 14 September 2017, the vision for the catchment was proposed by the stakeholders:

A sustainable catchment that supports economic growth and welfare

Where:

Sustainable relates to the state of the catchment and ecosystem functions to sustain the current and future generations.

Ensuring sustainable water resources management is not limited to the construction of water related infrastructure, but also ensuring that the use of- and impacts to- the water resources are managed sustainably. Therefore, activities identified in the Catchment Management Plan include soft-issues as well. Therefore, the achievement of the Vision will be through three strategic goals:

Goal 1: Improved access to clean water by 2030

Goal 2: Full restoration of the Nile Akagera Upper Catchment by 2030

Goal 3: Improved Social Welfare by 2030

The goals are supported through objectives and target activities. These are summarised below.

Goal 1:	**Improved access to clean water by 2030**		
access clean water	**Objective 1.1.**	**Reduce Pollution by 30% by 2030**	
		Target 1.1.1	Runoff management
		Target 1.1.2	Pollution management plan and guidelines implementation
		Target 1.1.3	Buffer enforcement
		Target 1.1.4	Hyacinth Removal
	Objective 1.2	**Improve access to water**	
		Target 1.2.1	Rain water harvesting
		Target 1.2.2	Investigate groundwater potential
	Objective 1.3	**Watershed protection**	
		Target 1.3.1	Slope stabilization
		Target 1.3.2	Increased vegetation cover

Goal 2:	**Full restoration of the Nile Akagera Upper Catchment by 2030**	
Protected	**Objective 2.1.**	**Promote biodiversity protection**
	Target 2.1.1	Declare Gashora-Mugesera-Rweru Wetland as a Ramsar Wetland
	Target 2.1.2	Sustainable wetland utilisation and rehabilitation
	Target 2.1.3	Develop Ecotourism
	Objective 2.2	**Reforestation & Afforestation**
	Target 2.2.1	Reforestation and afforestation (natural forest, plantation, agroforestry)
	Objective 2.3	**Improved mine management**
	Target 2.3.1	Improved quality of mine discharge
	Target 2.3.2	Establish a Mines Rehabilitation Fund
	Objective 2.4	**Reduce Soil erosion**
	Target 2.4.1	Improved Monitoring and Enforcement
	Target 2.4.2	Improved Awareness / Education in Natural Resources Management

Goal 3:	**Improved Social Welfare by 2030**	
Welfare	**Objective 3.1**	**Improve Food Security**

Target 3.1.1	Increase levels of soil fertility
Target 3.1.2	Develop terracing on slopes
Target 3.1.3	Appropriate crop selection
Target 3.1.4	Expand and enhance Crop Intensification Programme
Target 3.1.5	Access to markets
Target 3.1.6	Improve Irrigation Efficiency
Objective 3.2	**Planned settlements**
Target 3.2.1	Implement land use plans
Target 3.2.2	Implement model villages
Target 3.2.3	Implement wastewater treatment plants
Target 3.2.4	Implement solid waste management
Target 3.2.5	Establish reuse and recycle programmes throughout the catchment
Objective 3.3	**Improve health**
Target 3.3.1	Reduce Spread of Malaria
Target 3.3.2	Improved domestic water quality

CATCHMENT MANAGEMENT STRATEGY

Step 3 of the planning process compiled the vision and goals into a strategy. A strategy for the catchment management plan was developed taking into consideration the District Development Plans of the participating Districts as well as identified opportunities proposed by the stakeholders during the stakeholder workshop, and consultation processes.

Economic growth is a national objective in order to elevate the country to a middle-income country. This can be achieved in different regions of the country through the adoption of the most appropriate strategy for each region. The Gashora-Mugesera wetland, located in Bugesera and Ngoma District, is a proposed Ramsar Wetland of International Importance. It provides habitat for an array of threatened bird species amongst others. The Bugesera District is already internationally known for its abundance of bird life. Birdwatching tourism (avitourism) has become a large industry and is the largest niche revenue-source within the eco-tourism industry. The annual spend of wildlife watchers (primarily bird watchers) in the US alone is about the same as the entire GDP of Costa Rica, according to a United States Fish and Wildlife survey. In poor countries such as Guyana, the bird tour industry has been actively developed by organizations including USAID, as an important alternative to less environmentally-friendly economic ventures such as deforestation and subsistence farming. Tourism is supported by several service industries including the provision of accommodation (hotels, lodges, camps), guiding, food, drivers, curios, etc., which provide off-farm employment opportunities. The proposed relocation of the Kigali International Airport to the Bugesera District would support the opportunity to develop tourism within the Akagera Upper Catchment.

The economic growth strategy proposed for this catchment area, is *the rehabilitation and protection of Gashora-Mugesera wetland for the growth and expansion of the tourism sector*. This is compatible with the District Development Plans of the districts within the catchment area in terms of the expansion of tourism activities within these districts and specifically their objective to increase the number of hotels.

The rehabilitation of the Gashora-Mugesera wetland will also secure the natural storage of water within the catchment area, which in turn contributes to water security during dry months, a serious requirement in terms of climate change resilience. The Nile Akagera Upper Catchment is at risk of drought, and the topography of the catchment does not lend itself to the construction of a large dam for water storage to meet demands during the dry months.

IMPLEMENTATION PLAN

A detailed implementation plan outlining targets and activities to achieve the goals of the vision has been developed as step 4 in the planning process. The plan includes indicators/outputs to monitor that the targets are being implemented, and indicative phasing and costing, as well as identifying the lead institution responsible for implementing the different activities. Where appropriate, specific districts and/or Sectors have been identified or recommended for prioritisation of activities. Indicators to monitor and evaluate the implementation of the plan have been included into the National M&E Framework. The plan should be reviewed and updated every 5-10 years.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AOGCM	Atmosphere-Ocean General Circulation Models
CBO	Community Based Organisation
CMC	Catchment Management Committee
CMP	Catchment Management Plan
CWMO	Catchment Water Management Officer
KCMP	Kigali City Master Plan
DDP	District Development Plan
DEM	Digital Elevation Model
EAC	East African Community
EIA	Environmental Impact Assessment
EDPRS 2	Economic Development Poverty Reduction Strategy - 2
EIGE	European Institute for Gender Equality
GIS	Geographical Information System
GoR	Government of Rwanda
IMCE	Integrated Management of Critical Ecosystems Project
IP	Implementation Plan
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
IWRM	Integrated Water Resources Management
IWRMP	Integrated Water Resources Management Planning
LVEMP II	Lake Victoria Environmental Management Project Phase II
M&E	Monitoring and Evaluation
MEP	Monitoring and Evaluation Plan
MIDIMAR	Ministry of Disaster Management and Refugee Affairs
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Finance and economic Planning
MININFRA	Ministry of Infrastructure
MINIRENA[1]	Ministry of Natural Resources
MIS	Management Information System
MoE	Ministry of Environment
NGO	Non-Governmental Organization

[1] At the time of writing this report the Ministry was MINIRENA and is thus referred to as MINIRENA in this report. It is acknowledged that the Ministry has split into Ministry of Land and Forestry and Ministry of Environment. At the time of writing this report the status of RWB has continued to be referred to as RWB under the Ministry of Environment.

NISR	National Institute of Statistics of Rwanda
NTS	National Transformation Strategy (2017-2024)
OECD	Organisation for Economic Co-operation and Development
NWCC	National Water Consultation Commission
RAB	Rwanda Agricultural Board
RCP	Representative Concentration Pathway
REMA	Rwanda Environment Management Authority
RBMAPG	Rwanda Board of Mining, Petroleum and Gas
ROAM	Restoration Opportunities Assessment Methodology
RNRA	Rwanda Natural Resources Authority
RWB	Rwanda Water and Forestry Authority
SDG	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SMA	Soil Moisture Assessment method
TCM	Thousand Cubic Metres
UNFCCC	United Nations Framework Convention on Climate Change
WASAC	Water and Sanitation Corporation
WIC	Water Inter-Ministerial Committee
WRI	World Resources Institute

GLOSSARY OF TERMS

Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.
Catchment	The area of land that contributes water to a particular river. Includes the natural resources, people and land use activities on the area of land.
Climate Change	Climate Change A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.1 See also Climate variability and Detection and attribution.
Climate Variability	Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). See also Climate change.
Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.
Ecosystem function	Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem; in other words, what the ecosystem does. The products of ecosystem functions are the goods and services humans use on a daily basis e.g. clean air, food, timber, etc.
Erosion	The action of surface processes (water or wind) that remove earth materials from one location and transport it to another. Rainfall, and the resulting runoff from rainfall, produces soil erosion. The different forms of soil erosion are: splash, sheet, rill and gully erosion. The impact of a falling raindrop creates splash erosion - once surface runoff occurs, loosened soil particles, termed sediment, will be transported. Sheet erosion is the transport of sediment by overland flow, with rill erosion occurring as concentrated flow paths. Gully erosion occurs as a certain threshold is reached and flow paths become deeper channels.

Forest	Forest patches in savannah landscapes: the natural forests in the savannah and gallery-forest of the Akagera National Park and remnants of gallery-forests and savannahs of Bugesera, Gisaka and Umutara; • Tree plantations: plantations dominated by exotic species (*Eucalyptus sp*, *Pinus sp*, *Grevillea robusta*); • Other trees and shrubs outside natural forests and tree plantations, including tree stands scattered on Farmlands (agroforestry) and serving to prevent erosion.
Gender roles	A gender role is a set of societal norms determining the types of behaviours which are generally considered acceptable, appropriate or desirable for people based on their actual or perceived gender or sexuality, i.e. Gender roles refer to society's expectations for how men and women should act.
Governance	The way government is understood has changed in response to social, economic, and technological changes over recent decades. There is a corresponding shift from government defined strictly by the nation-state to a more inclusive concept of governance, recognizing the contributions of various levels of government (global, international, regional, local) and the roles of the private sector, of nongovernmental actors, and of civil society.
Land use and land use change	Land use refers to the total of arrangements, activities, and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction, and conservation). Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of the climate system and may thus have radiative forcing and/or other impacts on climate, locally or globally.
LIDAR	stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. This is used to create a Digital Elevation Model (DEMs).
Mitigation (of climate change)	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Pollution	The Organic Law (Organic Law 04/2005, 2005) defines pollution as the contamination caused by waste, harmful biochemical products derived from human activities that may alter man's habitat and cause adverse effects on the environment like man's social wellbeing, animals, flora and fauna and the world he or she lives in.

	The law describes three types of pollution namely: Marine (water) pollution; Atmospheric pollution; and Transboundary pollution.
Runoff	That part of precipitation that does not evaporate and is not transpired, but flows through the ground or over the ground surface and returns to bodies of water. See Hydrological cycle.
Sedimentation	(Refer to Erosion above) Once loosened soil is picked up by either wind or water, it is termed “sediment”. In terms of soil erosion, sediments collected by the flow of water may be transported by rolling or sliding along the floor of a river (bedload) or by suspension in the moving fluid (suspension) before being deposited. A catchment may be made up of a patchwork of sediment source zones (source of sediment) and sink zones (sediment deposition areas), with sediment spending most time in storage. Management of sedimentation therefore needs to be at the catchment scale to effectively manage the irregular pattern of sources and sinks throughout the catchment.
Soil moisture	Water stored in or at the land surface and available for evapotranspiration.
Watershed	A catchment boundary is called a watershed, which is usually on the highest point between 2 catchments e.g. on top of a ridge, hill or mountain. A watershed divides the pathways that water will follow/drain into the catchments on either side of it. A watershed is therefore referred to as the source area of catchments.

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND AND CONTEXT

A catchment is basically the topographical space through which water flows across the land and drains into a common body of water, whether a stream, river, lake, or ocean. The boundary of a catchment follows the highest ridgeline around the stream networks and meet at the bottom or lowest point of the land where water flows out of the divide, the outlet of the watercourse. Catchment comprise of all the natural and artificial environment and the interaction between them within the divide. The health of a catchment is directly linked with the quantity and quality of water resources in it, which direct and indirectly affect the livelihood of all the communities in the catchment. This gives a clear indication of why it is necessary to manage our catchment to ensure sustainable development.

Rwanda has taken a strategic decision to continue pursuing a green growth approach to development and in addition the Vision 2050 of the government of Rwanda aspires to take the country beyond high income to high living standards by the middle of the 21st century. Pursuing this goal will come up with various developmental activities in our catchments. To ensure sustainable development in the country planning processes should take into consideration the state of our catchments. In addition, there are currently some environmental and climate change issues in Rwanda the key among them include land degradation, deforestation, dependency on biomass for fuel, soil, water and air pollution, a lack of environment-friendly transport systems, vulnerability of natural ecosystems, lack of low-carbon materials for housing and green infrastructure etc. On the other hand, Rwanda is considered as water stress less than 700 cubic meters per capita per year of renewable water resources. These mentioned issues necessitate the need for proper catchment management which is done though appropriate catchment planning. Catchment planning and management seeks to ensure the wise and effective use of water and land resources, and in particular, the quantity, quality and timing of water flows. The typical characteristic of catchment planning is given in Box 1.1.

> Box 1.1 Typically characteristics of catchment planning process is:
> - an iterative and adaptive process;
> - a holistic process;
> - geographically defined;
> - integrated with other planning processes; and
> - a collaborative and participatory process

Currently, climate change is negatively affecting local communities in Rwanda due to unreliable rainfall resulting in flooding events in the central and north-western highlands, and droughts in the eastern and southern lowlands. Consequently, major development sectors in Rwanda are affected by climate change, including agriculture, hydropower generation and water. Thus, such effects lead to reduced agricultural production because of soil erosion, reduced soil fertility and moisture and water availability; decreased agricultural yields because of crop damage from flooding, landslides, droughts; and decreased quality and quantity of water as a result of flooding and droughts.

The Rwanda's catchment including wetland and ecosystems provide a wide range of services. These include provisioning and regulating services such as water provisioning and flood mitigation respectively. Thus, these ecosystems significantly contribute to the resilience of local communities to adverse effects of climate change. However, these ecosystems are at risk. The most prevalent threat is unsustainable use of wetland and catchment ecosystems by local communities, leading to their degradation and thereby reducing their capacity to provide their ecosystem services. Consequently, the vulnerability of local communities in Rwanda to the adverse effects of climate change is increased and there for call for catchment management planning. Basically, watershed management planning pursues to answer the following questions:

Box 1.0 Questions to be answered by watershed management planning

- What is the present condition?
- What are the historical trends and will they continue?
- What is the desired future condition?
- What strategies and actions will be used to get to the desired future condition?
- What monitoring and evaluation is necessary to confirm the intended outcomes?
- How will the principles and practice of adaptive management be used to improve processes and outcomes?

This catchment plan is intended to provide sustainable management of Nile Akagera Upper (NAKU) catchment. This catchment plan was developed by taking into consideration national orientations as articulated in the National Strategy for Transformation (NST1), Vision 2050, and the Nation's Green Growth and Climate Resilience Strategy (GGCRS) and their link to Sustainable Developments Goals (SDGs) of he United Nations. Intensive stakeholders' consultation was conducted during it development. The organisations involved include: Rwanda Environmental Management Authority (REMA) Rwanda Water Board (RWB) and its Water Resources Management Department (WRMD. Consultation was conducted with the relevant authorities of all the districts that within the catchments as well as randomly selected individuals in the catchment.

The aim of this project is to collate current knowledge on status and health of the environment within NAKU catchments that include forest, savannah, and wetland ecosystems in Rwanda, to develop systematic mapping and monitoring tools to identify basin management needs and track progress towards addressing them, to develop an understanding of the drivers of their degradation, and to prepare a plan based on the results of the analyses and in response to climate threats, in collaboration with appropriate government agencies. Analysis of drivers will focus on agricultural activities; eutrophication and pollution; infrastructure development; wetland overharvesting/ overexploitation; emergent invasive species; loss of indigenous species (fauna and flora); alteration of biogeochemical cycles.

1.1 INSTITUTIONAL EMBEDDING

The management of water resources is one of the fundamental principles of the Republic of Rwanda as indicated by several policies and laws related to the protection of water resources and environment in general. There is a solid support of implementation of Integrated Water Resources Management in Rwanda by the National Water Resources Management policy (2011) and the Water Law (2018). The overall goal of the National Water Resources Management Policy is to manage and develop the water resources of Rwanda in an integrated and sustainable manner, so as to secure and provide water of adequate quantity and quality for all social and economic needs of the present and future generations, with the full participation of all stakeholders in decisions affecting water resources management. Rendering to international best management practice (BMP) in IWRM the quoted goal this goal infers into the development of catchment plans in a participatory manner, and the subsequent implementation of the plans in an as-much-as-possible decentralised process. Catchment planning is an important instrument that could make substantial contribution to the to the achievement of the objectives and goals of Vision 2020, the National Strategy for Transformation (NST1: the 7 Year Government Plan 2017-2024) and Vision 2050, of the Government of Rwanda, including the implementation of the Green

Growth and Climate Resilience Strategy (GGCRS) of Rwanda (Government of Rwanda, 2011) and other relevant sectorial policies, plans, and programmes. NST1, GGCRS, SSPs, CCAs, Catchment Plans, DDSs, and their annual implementation plans, budgets, and Imihigos, are intrinsically linked, as visualised in Figure 2.

FIGURE 1- 1 EMBEDDING OF CPS IN NST AND GGCRS FRAMEWORK

Article 10: of the Law N°49/2018 of 13/08/2018 determining the use and management of water resources Rwanda established that there should be water resources management committee at catchment level composition, responsibilities, organization and functioning of the water resources management committee at catchment level are determined by a Ministerial Order. The Ministerial Order has been drafted and is waiting for Cabinet Approval. The drafted Ministerial Order highlighted the responsibility of the Catchment Committee as follows:

(1) Provide the general orientation for the catchment management plan and advise on the measures to be provided for in the plan;
(2) Support the Authority in the development of the catchment management plan;
(3) Provide information on water users and stakeholders within the catchment;
(4) Identify the issues and priorities to be addressed by the catchment management plan;
(5) Provide information on water bodies at risk of depletion, flooding or water quality degradation;
(6) Support the Districts to align District development strategies with the Catchment Management Plan;
(7) Support Districts and other partners in the development of Catchment Management Plan, annual implementation plans and joint performance contracts on topics pertaining to water resources management and water use;
(8) Monitor and evaluate the implementation of the catchment management plan;
(9) Monitor the compliance of water use permits on ground and advise the Authority accordingly;
(10) Contribute to disputes settlement among water users;
(11) Advise on any issue as requested by the Authority.

The Catchment Committee is composed of the following members from each District within the catchment:

1. The District Vice Mayor incharge of economic development
2. A representative of water user permit holders within catchment from each of the following categories:
    a. Domestic water supply

   b. Irrigation
   c. Livestock
   d. Mining
   e. Coffee washing
   f. Power plant
   g. Aquaculture
3. Representative of non-govermental organization operating in water
4. Representative of private sector

Atleast 30% of the catchment committee members must be woment.

Here a brief introduction on policies, laws and institutional frameworks related to water resources and catchment management is provided and the brief focus but not limited to:

- the Constitution of Rwanda of 2003 as revised in 2015,
- the Seven Years Government Program: National Strategy for Transformation, NST 1 (2017-2024)
- the Vision 2020
- Economic Development Poverty Reduction Strategy (EDPRS 1 and extended to EDPRS 2)
- The seven years (2010-2017) programme of the Government of Rwanda (2010)
- Rwanda National Water Resources Master Plan (2014)
- Law n°48/2018 of 13/08/2018 on environment
- Law n°49/2018 of 13/08/2018 determining the use and management of water resources in Rwanda
- National Policy for Water Resources Management (MINIRENA, 2011)

1.1.1 CONSTITUTION OF RWANDA AS AMENDED IN 2015

The articles 22 and 53 of the constitution of Rwanda stipulate that every Rwandan has a right to live in a clean and healthy environment and the state has to ensure the protection, promotion and protection of the environment. In this fundamental law of the state, the country is prohibited to sign any agreements permitting the importation, transiting or dumping of toxic wastes susceptible to damage or deteriorate environment on its territory. In order to enforce this, the Ministry of Environment which deals with putting in place all laws and policies related to the management of water resources in Rwanda established the Ministry of Environment which deals with putting in place all laws and policies related to the management of water resources in Rwanda was establishrd. Under the Ministry of Environment, a Water Resources Board was established by Law No 72/2019 of 29/01/2020 with the mission to ensure the availability of enough and well managed water resources for sustainable. It duties among others include implementation of policies and laws related to the management, exploitation and protection of water resources in Rwanda.

1.1.2 THE SEVEN YEARS GOVERNMENT PROGRAM: THE NATIONAL STRATEGY FOR TRANSFORMATION, NST 1 (2017-2024)

In NST 1 (Prime Minister Office, September 2017), the Government of Rwanda intends to achieve economic growth and development founded on private sectors, knowledge and Rwanda's Natural Resources. In water resources management, the GoR targets to reach 100 % of access to potable water and adequate sanitation from 84% (2017), this is now revised to 2024. It is also highlighted in this programme the reinforcement of Water Users Associations. However, NST 1 envisages to put in place the policies and strategies of sustainable utilisation of the natural resources and protection of the environment.

1.1.3 RWANDA VISION 2020

Rwanda vision 2020 represents ambitious aspiration of the Rwandans to transform the country into middle-income nation. The country plans to invest in the protection and efficient management of water resources which will allow to provide potable water to 100% of the population by 2020 from 74.2% in 2010. The quality of water resources has been also taken into account in this vision, whereby the provision of adequate sewerage and waste disposal facilities to urban and rural dwellers of the country was envisaged.

To achieve the Vision 2020, the mid-term programmes were developed such EDPRS 1 (2008-2012) and EDPR2 (2013-2018) and the seven years programme of Government of Rwanda-7YP (2010-2017) which all has been complemented.

1.1.4 NATIONAL POLICY ON WATER RESOURCES MANAGEMENT (WRM)

In order to achieve a continuous and consistent management of the sub-sector of water resources management in Rwanda, a National Policy on WRM was developed in 2011, following the principle of the National Water Law gazetted in 2008 (MINIRENA 2011). As in vision 2020, the National Strategy for Transformation (NST 1), EDPRSs 1 and 2, 7YP, and the national policy and strategy for water supply and sanitation services (MININFRA, 2016a, b, c) have prioritised increase to water supply and sanitation services across the country. It was expected that much pressure on exploitation of water resources (groundwater abstraction, surface water, rainwater harvesting and hydro-electricity production, etc) is inevitable. Thus, to achieve all those ambitious targets above-mentioned, a national policy on WRM was put in place aiming to manage water resources in order to meet growing demands in water supply, owing to population growth and subsequent pollution of water.

1.1.5 THE ENVIRONMENT LAW 2018

The Law N°49/2018 on Environment in its chapter III section 2 articles 11 and 12 talk to about water resource. It explained water resources as Rivers, streams, underground water, springs, ponds, swamps and lakes are part of the State's public domain and that it uses is governed by law. It also indicated the water resources must be protected from any source of pollution. Swamps with permanent water and full of swamp vegetation must be given special protection considering their role and importance in the reservation of the biodiversity

1.1.6 THE WATER LAW 2018

In 2018, the Law N°49/2018 determining the use and management of water resources in Rwanda was gazetted. According to Water Law 2018 water resources are used and managed in accordance with the following principles:

(2) prevention of pollution with priority to source;
(3) precaution, according to which activities considered or suspected to have negative impacts on water resources shall not be implemented even if such impacts have not yet been scientifically proved. Scientific uncertainty must not be taken into consideration for the benefit of destroyers of water resources, instead it may be used in conservation of water resources;
(4) integrated management of water resources within catchment, taking into account the interests of all water users, land and other natural resources and related ecosystems;
(5) participation, according to which all interested stakeholders, including water users through their representatives, are entitled to participate in water resources management and planning;
(6) "user-pays and polluter-pays" principles, according to which the user of water and the polluter must support a significant part of expenses resulting from measures of prevention, of pollution reduction and restoration of the water resources in quality and in quantity;
(7) subsidiarity, whereby development and protection of water resources is planned and implemented at the lowest appropriate level

The responsibilities of Rwanda Water Board are the following:

(1) to implement national policies, laws and strategies related to water resources;
(2) to advise the Government on matters related to water resources;
(3) to establish strategies aimed at knowledge based on research on water resources knowledge, forecasting on water availability, quality and demand;
(4) to establish strategies related to the protection of catchments and coordinate the implementation of erosion control plans;
(5) to establish floods management strategies;
(6) to establish water storage infrastructure;
(7) to establish water resources allocation plans;
(8) to establish water resources quality and quantity preservation strategies;
(9) to control and enforce water resources use efficiency;
(10) to examine the preparation of roads, bridges, dams and settlements designs in order to ensure flood mitigation and water storage standards;
(11) to monitor the implementation of flood mitigation measures and water storage during the implementation of roads, bridges and settlements' plans;
(12) to cooperate and collaborate with other regional and international institutions with a similar mission.

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(18) to establish water storage infrastructure;
(19) to establish water resources allocation plans;
(20) to establish water resources quality and quantity preservation strategies;
(21) to control and enforce water resources use efficiency;
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(23) to monitor the implementation of flood mitigation measures and water storage during the implementation of roads, bridges and settlements' plans;
(24) to cooperate and collaborate with other regional and international institutions with a similar mission.

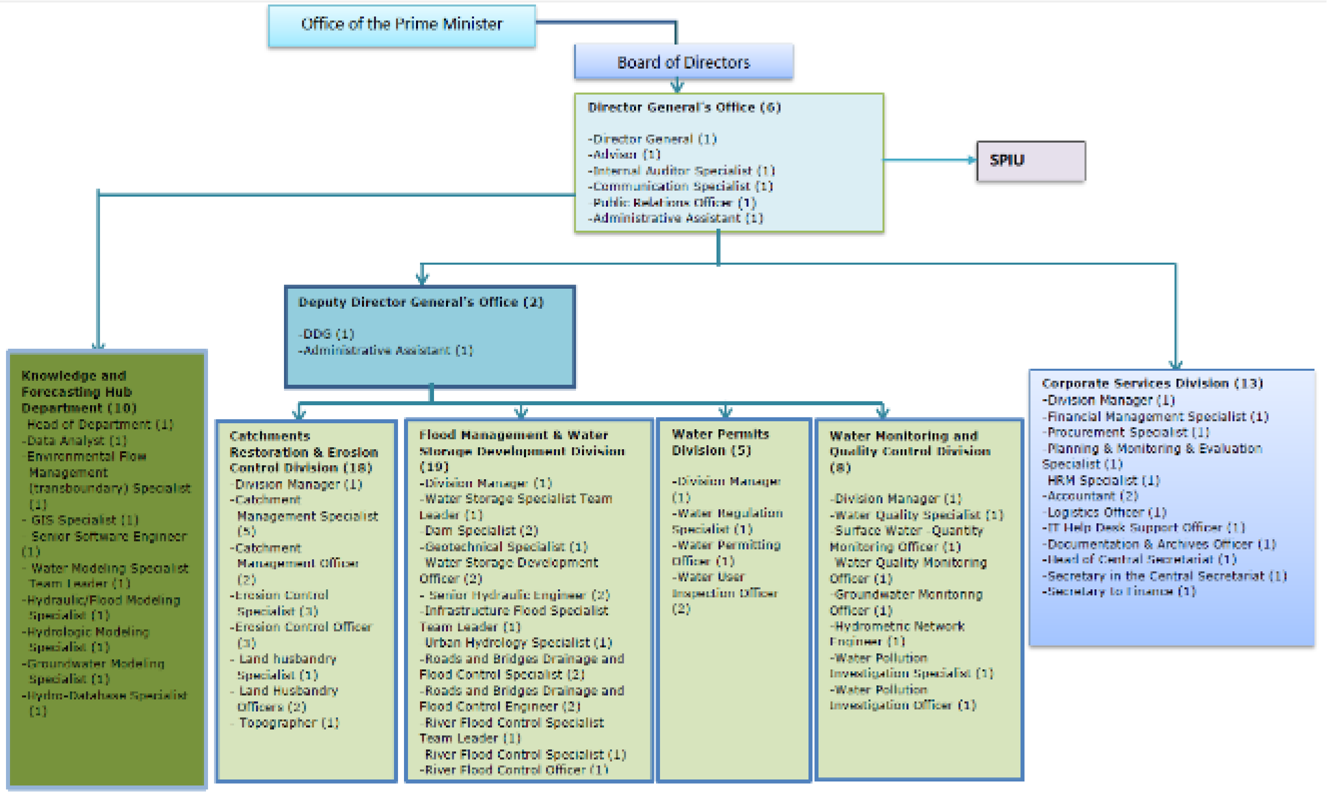


FIGURE 1- 2 EARLIER PROPOSED STRUCTURE OF RWANDA

METHODOLOGY

The process of developing strategies and plans to govern natural resources within a catchment is known as catchment management planning. The principles of integrated catchment management planning can be applied to the different scales of catchment units, namely catchment, sub-catchment, micro-catchment and village-level. The Catchment Management Plan (CMP) is the main output of the catchment management planning process at the broadest scale. The CMP records a vision for the catchment and formalises the current and future trends of the various resources such as water, land, environment and social economic factors in terms of that vision. The CMP then provides additional details with regard to the specific implementation of options for improved catchment management and the development of the main natural resources while still promoting and achieving national growth and development objectives. The CMP states how issues and concerns will be addressed through agreed management strategies within a specified time period, and outlines an associated legislative, procedural and technical framework for implementation. The plan reflects national policies as well as stakeholder commitments. It needs to be granted legal status, either as a contract or as a legal proclamation, if it is to be implemented. In this regards the CMP typically includes a detailed implementation plan (IP) and a Monitoring and Evaluation Plan (MEP). The IP allocates responsibility for implementation and is used to inform the District Development Plan (DDP) that can be implemented with support from the relevant Catchment Committee (CC), various national and local level government and relevant Non-Government Organisations (NGOs) and Community Based Organisations (CBOs) in the catchment. The typical process of catchment planning is illustrated in Figure 1 2.

The first step of the planning process, once the planning process has been initiated, is to determine the current state of the catchment. This is used as a baseline from which to develop and promote development scenarios, and the baseline against which implementation of the Catchment Management Plan can be measured. This report is the Draft Catchment Management Plan of the Nyabarongo Valley Catchment.

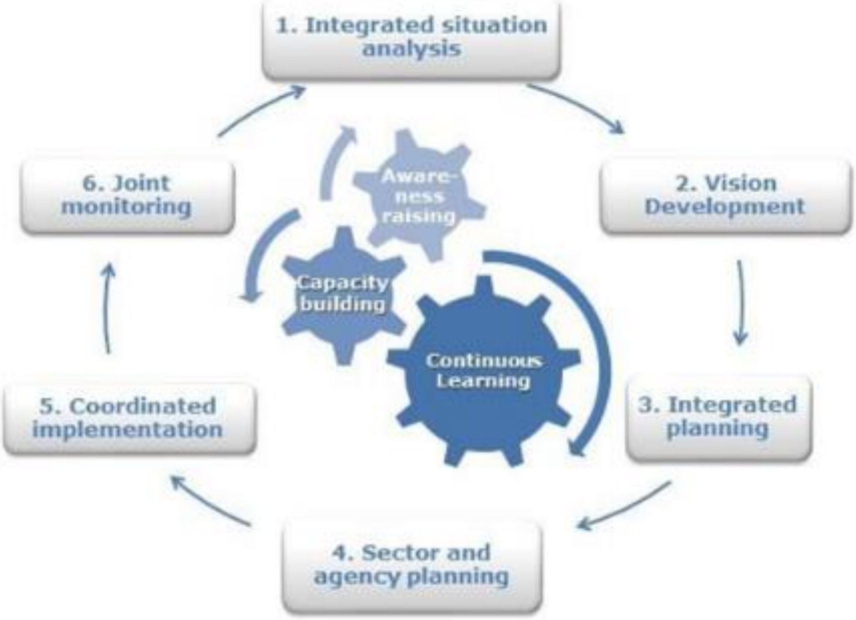


FIGURE 1- 3 TYPICAL CATCHMENT PLANNING PROCESS

However, the development of catchment management plan ends at the middle of the cicle with the development of implementation plan (see Figure 1.4). The steps of development of the catchment management plan are explained in Box 1.2.

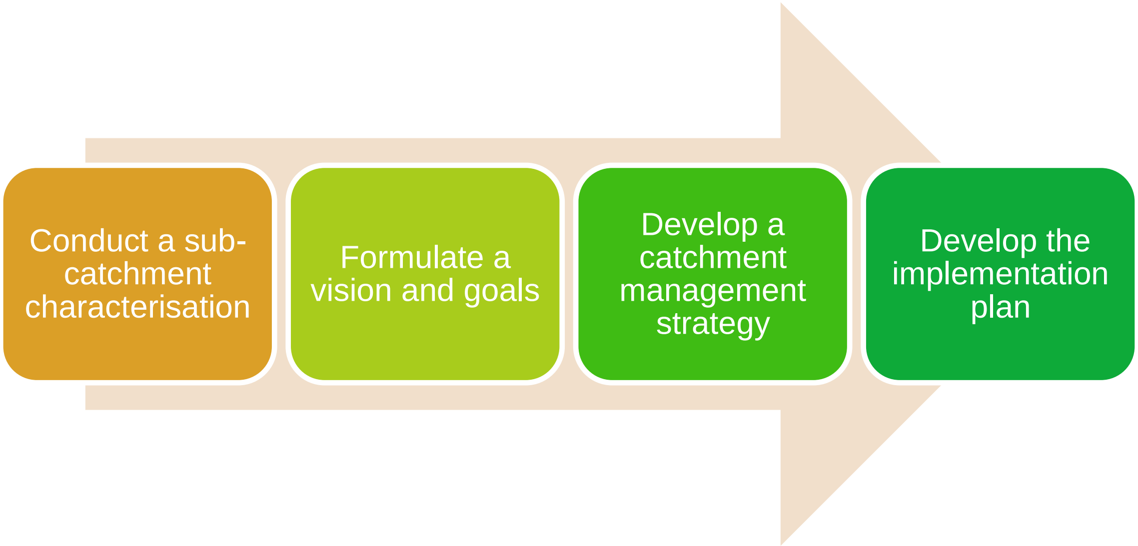


FIGURE 1- 4 STEPS IN THE DEVELOPMENT OF THE CATCHMENT MANAGEMENT PLAN.

Box 1.2 Steps of development of the catchment management plan

Step 1: Integrated Situation Analysis.

This step provides for gaining an understanding of current situation of the catchment. This also provides to determine future water availability, quality and use in the catchment, as well as identifying and prioritizing the key challenges and opportunities.

As per the approved methodology, critical issues in the catchment were identified through a review of existing information, identification and consultation with key stakeholders, a basin tour visiting identified problem areas as well as projects already implementing improved catchment management practices, and culminated in a stakeholder workshop to discuss and evaluate the critical issues as well as to identify possible improved catchment management practices. Information was collected from various stakeholders, projects and review of documents. A household survey, with permission of NISR, of over 625 households was conducted across the catchment area to determine baseline information for future monitoring. As well as a meeting and consultation with each District and Sector office in the catchment.

Step 2: Vision Development

This involves determining the desired state of the catchment over the long term, together with goals (preliminary objectives) and principles to achieve this over time. This should be developed in a participatory approach with stakeholders in the catchment.

During the catchment planning process, a stakeholder engagement workshop was held on 11 and 12 September 2017 at Splendid Hotel in Muhanga. The aim of the workshop was to engage with stakeholders from the catchment area to identify and prioritize issues within the catchment and develop a vision and goals or desired state of the catchment, and to select the Catchment Task Committee. A follow up consultations was conducted with the Districts in March and May 2020.

Step 3: Integrated Planning

This includes specifying a coherent suite of strategic objectives and outcomes related to water management, development, protection and use, disaster management and institutional development, designed to achieve the vision.

Incorporating the vision, goals and objectives determined through the stakeholder engagement process, as well as the information provided from the catchment situation analysis, a catchment management strategy is proposed in this CMP.

Step 4: Development of the implementation plan

The main activity at this point is defining the actions needed to give effect to the catchment strategy and that should ultimately achieve the vision and objectives, as well as who is responsible for the actions, the indicative phasing and costing for the actions.

To give effect to the proposed strategy, and for the achievement of the goals, objectives and ultimately

Primary and secondary data were used for the implementation of the methodology. Primary data are based on the field data collection including: visits, observations, interviews and discussions. While the secondry data were obtained from relevant institutions as organisations Table 1-1.

TABLE 1- 1 SOURCES OF DATA SETS AND ADMINISTRATIVE AUTHORITIES

Process	Source of raw data	Raw data set/time series
Atmospheric conditions	Meteo Rwanda	Precipitation, Evaporation and Temperature

Surface water	RWB	Water levels and Discharges
Ground water	RWB/3rd party	Groundwater depth
		Discharge (pumping test)
		Water quality
		DEM, Soil, Lithology, Land cover/use
Infrastructures	REG	Hydropower facilities
Measurement stations	RWB	description/state
Boreholes	RWB/3rd party	description/state
Population	NISR/2012 census	2012 population/sector
Abstraction-Retention	RWB/3rd party	

Source: Adapted from the National Water Resources Master Plan (2014)

1.1.7 EXTIMATION OF EXISTING WATER DEMAND

Another important aspect of the development of this catchment management plan is the estimation of current and future water demand. In order to conduct water balance at the NAKU level 1 catchment scale, water consumption was assessed for existing and future conditions using in 14 sectors in accordance with the database of the Rwanda Water Resources Board (RWB) as follows:

TABLE 1- 2 MAJOR WATER USERS CONSIDERED IN ESTIMATION OF WATER DEMAND

S/N	Water User	Data Source
1	Domestic Water Supply	WASAC Ltd and RWB, WARwanda, LWIR
2	Large Irrigation schemes (≥10 ha)	RAB, RWB, MINAGRI, and JICA
3	Coffee washing stations	NAEB and RWB
4	Livestocks	MINAGRI, RWB, NISR
5	Mining companies (Sites)	RWB and RMB
6	Industries/Factories	RWB, NAEB and MINICOM
7	Fish ponds	RWB and MINAGRI

Below is the description of the methodology for each water use and users:

Domestic Water Supply (DWS):
Domestic Water Supply (DWS) was calculated by using three main factors as considered by WASAC for their water supply projections and associated investment plans. These main factors include; urban water supply, rural water supply and small-scale industrial facilities.

In this context, DWS was calculated at the sector scale by using data sets available on the website of NISR, data provided by WASAC through RWB. The specific calculations delivered as part of this project included:

- Population projections between 2030-2050, by using the statistical trends developed by NISR for the period between 2012-2030.

- Consumptive demand (l/person/day) for urban and rural water supply for existing conditions 2020 and the years 2025, 2030, 2035, 2040, 2045 and 2050, as agreed with RWB.
- Three population growth development scenarios of Low, Medium and High based on the growth rate developed by NISR by considering national development mechanisms.
- Population growth data was based on the reference year of 2012 and estimate for 2020 from NISR and projection for the years of 2025, 2030, 2035, 2040, 2045 and 2050 for the three population growth development scenarios of low, medium and high growth. The division between urban and rural population was reflected through urban and rural population data sets available for the reference year of 2012 at the sector-scale. Details of the projections of these population data are presented in Annexure D.

The demand for Domestic Water Supply potable water supply of the urban and rural population (in litre/person/day) for the years 2020, 2030, and 2050, as provided by WASAC, is summarized as follows:

TABLE 1- 3 DEMAND FOR DOMESTIC WATER SUPPLY IN URBAN AND RURAL AREAS, RWANDA

2020		2030		2050	
Urban	Rural	Urban	Rural	Urban	Rural
100	30	120	40	150	40

The procedure for estimating domestic water supply is presented in Box 1.3

> Box 1.3: Procedure for estimating of demand for domestic water supply
>
> **Step 1:** Existing Rural and Urban population (as of 2012) were collected from NISR data sets at the Sector scale.
>
> **Step 2:** Future population forecasts (up to 2032) were collected from NISR data sets at the Country scale.
>
> **Step 3:** Low, Medium and High population growth rates scenarios were collected from NISR data sets
>
> **Step 4:** Statistical tools (regression analysis) were used to extrapolate the population forecasts of NISR up to 2050 for all population scenarios of Low, Medium and High. The population trends at the country scale was assumed to represent the population trends at the Sector scale.
>
> **Step 5:** Water consumption by Urban and Rural populations for existing and future conditions (2020, 2030 and 2050) were collected from WASAC.
>
> **Step 6:** Existing and Future conditions DWC values were calculated at the Sector scale

Note: This method includes the water taken from public borehole and springs

Irrigation Water Demand

Irrigation Water Demand (IWD) was calculated by referencing data sets, documents and irrigation feasibility reports provided mainly by RAB and MINAGRI (Irrigation Master Plan, 2020) and water permit from RWB. The most important aspects included;

- identification of agricultural command areas for both existing conditions and future projections; and
- determination of representative crop water demand values and associated irrigation water consumption values.

Irrigation water consumption is the amount of water to be withdrawn from surface and/or groundwater resources, which is not met through precipitation. Therefore, calculation of representative values for both the precipitation and crop water requirement are critical to result in representative values for irrigation water consumption. In order to ensure validity and representativeness of these data sets;

- precipitation data sets were derived from grid-based data sets and rainfall records collected from Meteo Rwanda, which also served as the basis of calculations for surface water resources; and
- crop water requirements were derived from the feasibility reports provided by MINAGRI.

It is important to note that crop water requirements (in m^3/ha) were grouped at the level 1 catchment scale and one representative set of crop water requirement was used base on the catchment here NAKU.

> Box 1.4 Procedure for estimating of water demand for irrigation:
>
> Step 1: Existing and Planned Irrigation command areas were collected from MINAGRI, RAB and JICA
>
> Step 2: Existing year 2020 reflect the same command areas. Areas under development reflect up to 2030 and year 2050 reflect irrigation areas under "planned"
>
> Step3: The corresponding crop water requirements (m^3/ha) were collected from the feasibility reports documented by MINAGRI, RAB and JICA
>
> Step 4: Irrigation requirements were calculated by considering three main factors: Effective

NOTE: Irrigation water use for the year 2020 for irrigation was taken from the updated water users and uses study of 2020 available at the the database of the Rwanda Water Resources Board

Coffee Washing Station Water Consumption

The data sets for coffee washing station water consumption (CWWC) collected through National Agricultural Export Development Board (NAEDB) were the main driver of the water consumption values. In this context, the following data sets were collected;

- Location of coffee washing stations at the sector scale
- Water consumption trends at these locations in the context of conventional seed washing systems and eco-flex systems
- Growth potential of the coffee washing stations.

It was noted by NAEDB that all coffee washing stations will be operating in eco-flex mode by 2030.

> Box 1.5 Procedure for estimating of water demand for Coffee Washing Station:
>
> Step 1: Locations of Coffee Washing Station were collected from NAEDB
> Step 2: Water requirements of cherries were collected from NAEDB and international best practices
> Step 3: Watering technology (conventional vs. eco-flex) were collected from NAEDB
> Step 4: Future development plans were collected from NAEDB

Industry Water Demand

The industrial water demand (InWD) values reflect consumption values driven by large-scale organized industrial zones. In this context, these facilities are not accounted by the small-scale industrial consumption supplied by WASAC which are considered under DWS.

In this context, the organized industrial zones and associated water consumption values were derived through meetings and consultations with the experts of the Ministry of Trade and Industry.

The existing conditions data sets were subject to a reality check to reflect capacity of the existing conditions infrastructure (mainly waste-water treatment facilities) in the neighborhood of these large-scale organized industrial zones.

Box 1.6 Estimation of Industrial Water Demand:

Step 1: Locations of Existing and Future Industrial facilities were collected from MINEACOM

Step 2: Existing and Future development plans for these facilities were collected from MINEACOM

Step 3: Planned water consumption values for these facilities were collected from MINEACOM

Livestock Water Demand

The livestock population and distribution at the district scale is critical to calculate associated livestock water consumption (LWDemand) accurately. In this context, total number of livestock (including cattle, goat, sheep, pig, chicken and rabbit) and "historical trend" during the period of 2008-2014 was obtained from MINAGRI. This key historical trend was used as the basis of estimating total livestock values in future years (2020, 2030 and 2050).

Water Consumption of respective livestock types are summarized below. It is important to note that approximately 40% of cow population represent local-breed, and approximately 60% of cow population represent import-breed, which consume higher amount of water resources.

TABLE 1- 4 SPECIFIC WATER DEMAND PER LIVESTOCK CATEGORY (IN L/HEAD/DAY).

Category of Livestoke Period of the year	Cow-local	Cow-import	Goat	Sheep	Pig	Chicken	Rabbit
January-May and September-December	45	97	5	3	22	0.55	0.55
June-August	70	110	10	5	35	1	1

Box 1.7 Estimation of Livestoke Water Demand:
Step 1: Livestock type and number were collected from MINAGRI and reports by NISR
Step 2: Water consumption of livestock and local vs import percent were collected from MINAGRI
Step 3: District specific data were collected from District representatives.

presented in the NIRAS for water consumption values at representative mining locations.

Box 1.8 Estimation of Mining Water Demand:

Step 1: Locations of Mining Concessions were collected from RMPGB

Step 2: Existing water consumption within level 2 catchments were collected from NIRAS report.

Step 3: Production capacity of these facilities were collected from the former Ministry of Natural Resources web-site.

Step 4: Statistical process (linear regression) was used to calculate corresponding water

Fish Ponds Water Consumption

The data sets collected for fish pond water consumption (FpWC) from MINAGRI was the major driver of calculations for fish ponds. It is important to note that there is a potential plan to shift the location of these ponds from designated inland locations to designated locations within lakes and reservoirs. In that future setting, fish pond will not abstract water from service facilities.

The calculations were based on the following steps:
Step 1: Locations of Fish ponds were collected from MINAGRI
Step 2: Surface area and depth requirements (to maintain fishery services) were collected from MINAGRI
Step 3: Water requirements were customized to reflect wet and dry periods
Step 4: It was assumed that existing conditions are valid for future conditions water consumption.

Total Catchmen Water Consumption

Total catchment water demend was then estimated by summing up the indivial category of uses and users. The total water to be withdrawals is estimate with the eqution 1.1.

$$TW_t = \sum_{i=1}^{i=I} \quad DMC_{it} + IR_{it} + MG_{it} + CWS_{it} + LS_{it} + IF_{it} + PF_{it} + \cdots, \qquad \text{equ. 1.1}$$

Where:

TW_t is total water withdrawals in catchments in terms of million cubic meters per day (MCD) during calendar year t, and I is the total number of the sub-catchments level 2.5 in this case 7 for NAKU catchment. $DMC_{it} -$ Domestic Water Consuption, IRit- Irrigation Water Use, MGit- Mining Water Use, CWSit –Water Use by Coffee Washing Stations, LSit- Livestock Water Use, IFit- Water use by Industries and Factories that are not supplied by WASAC, FPit – Water Use by Fish Ponds.

Modelling and projection of water demand

Modelling water demand and availability using WEAP Model take into consideration the followings:

i. 7 level 2.5 sub-catchment
ii. 7 types of water use and users
iii. 3 population growth scenarios (Low, Medium and High)
iv. 2 Climate change scenarios (RCP4.5 and RCP8.5)
v. 7 different years, Current Account Year 2020 and projection years 2025, 2030, 2035, 2040, 2045 and 2050
vi. Number of results handles N=(7x7x3x2x6) +1= 1,765 results
vii. Comberting available data from diffirent levels: country, districts, sectors to data on level 2.5 catchment for all the 7 types of water users.

Two Representative Concentration Forcing RCP4.5 and RCP8.5 were selected for climate change scenarios to represent two extreme climate change situations. This gives an opportunity to understand the possible range of impact of climate change in term of water demand and availability in the catchment. The different RCPs and other climate change models are shown in Table 1-5.

TABLE 1-5 PARAMETERS AND RULES FOR EXTENDED CONCENTRATION PATHWAYS (SOURCE: VAN VUUREN ET AL. 2011)

Parameter	ECP	Generic rule
CO_2 and other well-mixed GHGs	ECP8.5	Follow stylized emission trajectory that leads to stabilization at 12 W/m^2
	ECP6 ECP4.5	Stabilize concentrations in 2150 (around 6.0 W/m^2) Stabilize concentrations in 2150 (around 4.5 W/m^2)
	ECP3PD	Keep emissions constant at 2100 level
	SCP6to4.5	Return radiative forcing of all gases from RCP6.0 to RCP4.5 levels by 2250
Reactive gases	All ECPs	Keep constant at 2100 level
	SCP6to4.5	Scale forcing of reactive gases with GHG forcing
Land use	All ECPs	Keep constant at 2100 level

The water resources modelling in WEAP model is conducted in the sequence shown in the figure 1.5 below.

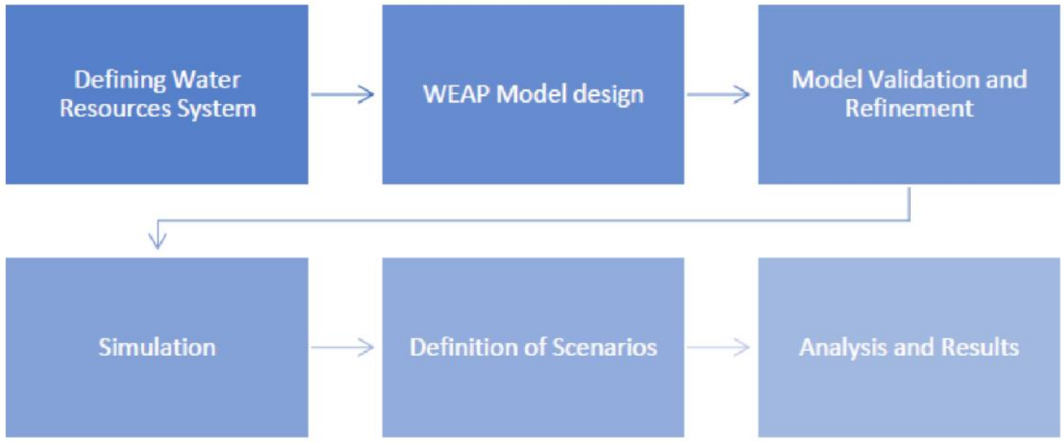


FIGURE 1- 5 SEQUENCE OF WATER RESOURCES MODELLING IN WEAP MODEL

1.1.8 ESTIMATING SOIL EROSION

In this study erosion mapping was conducted with the help of the Catchment Restoration Opportunities Mapping Decision Support System (CROM DSS) of the Rwanda Water Resources Board. Erosion mapping in CROM DSS was conducted with the help of RUSLE model.

The CROM DSS is accompanied by catchment restoration classification matrix (Table 1-6), used to support decision making on which measures to implement, provides multiple options per class. It does not prescribe which option should be implemented at any location. Rather, this decision is made in the local detailed consultation and decision-making process of Micro-Catchment Action Planning.

TABLE 1- 5 CROM DSS CLASSIFICATION OF CATCHMENT RESTORATION OPPORTUNITIES PER CLASS ACCORDING TO SOIL DEPTH AND LAND SLOPE

Land slope ↓	Soil depth ↓	
	2: (> 0.5 m)	3: (< 0.5 m)
1: (0-6%)	**Class I** ▪ Agroforestry + contour ploughing + alley cropping with grass strips.	**Class VI** ▪ Agroforestry + contour ploughing + alley cropping with grass strips; ▪ Forestation where soil depth is too limited and unsuitable for crops; ▪ Perennial crops, coffee, tea, banana, fruit trees.
2: (6 - 16%)	**Class II** ▪ Progressive terraces (reinforced by agroforestry hedges and grass strips); ▪ Perennial crops, coffee, tea, banana, fruit trees.	**Class VII-a** ▪ Progressive terraces (reinforced by agroforestry hedges and grass strips); ▪ Perennial crops, coffee, tea, banana, fruit trees; ▪ Forestation where soil depth is too limited and unsuitable for crops.
3: (16 - 40%)	**Class III** ▪ Bench terraces (option only in case of suitable, stable parent material / geology; avoid introducing landslide risks); ▪ Progressive terraces (reinforced by agroforestry hedges and grass strips); ▪ Perennial crops, coffee, tea, banana, fruit trees.	**Class VII-b** ▪ Progressive terraces (reinforced by agroforestry hedges and grass strips); ▪ Forestation where soil depth is too limited and unsuitable for crops; ▪ Perennial crops, coffee, tea, banana, fruit trees.
4: (40- 60%)	**Class IV** ▪ Narrow cut terraces (option only in case of suitable, stable parent material / geology; avoid introducing landslide risks); ▪ Progressive terraces (reinforced by agroforestry hedges and grass strips); ▪ Forestation (Biological measures);	**Class VIII-a** ▪ Forestation (Biological measures) + trenches / ditches.

	■ Perennial crops, coffee, tea, banana, fruit trees.	
5: (> 60)	**Class V** ■ Forestation (Biological measures) + trenches / ditches; ■ Perennial crops, coffee, tea, banana, fruit trees.	**Class VIII-b** ■ Natural vegetation.

1.2 JOINT CATCHMENT PLAN IMPLEMENTATION

This catchment plan was developed in an integrated manner, using a participatory approach with key stakeholders in the catchment as a requirement for both IWRM and SEA principles. The development of catchment plans relates to Steps 1-3 of the planning cycle (Figure 1). Step 4 (sector and agency planning) refers to mandated entities, preparing the implementation of their own elements of catchment plans: special attention and time was given to ensure optimal inclusion of existing and planned programmes, and projects of plan partners at central and local level. Whereas the preparation of the projects of plan partners is largely their own internal process, implementation of Step 5 needs to be well coordinated. Different projects, carried out in the same sub-catchment, may have multiple interactions because they use the same land and water resources.

To this end, the Catchment Committe will need to assume a coordination role, in close collaboration with designated representatives of the projects-implementing partners. Similar collaboration between the Catchment Committe and the national plan partners is required in the joint monitoring and evaluation of catchment plan implementation (Step Six), also for the timely development of the subsequent catchment plan for 2024-2030.

1.3 PLAN STRUCTURE

The structure of this catchment plan generally follows the steps of the IWRM cycle in Figure 1.

Chapter 2 describes the characterisation of the NAKU Catchment. The chapter describes the key characteristics of the catchment including natural resources and economic activities. It also provides information on the current and future water demands and water balance, as well as challenges identified within the catchment area that should be addressed through the Catchment Management Plan.

Chapter 3 of the Report sets out the Catchment Management Plan. The chapter presents the vision, goals and objectives, as well as the catchment strategy which drivers the water management scenario. The chapter also presents the proposed strategic measures and water allocation plan.

Chapter 4 sets out the proposed institutional arrangements for the implementation of the Catchment Management Plan.

Chapter 5 presents the detailed implementation plan and monitoring and evaluation for the plan.

Chapter 2 INTEGRATED SITUATION ANALYSIS

2.1 CATCHMENT CHARACTERIZATION

1.2.1 INTRODUCTION TO CATCHMENT CHARACTERIZATION

In catchment characterization important catchment characteristics need to be identified for management & planning of catchment. Important characteristics of catchment can be broadly categorized into:

(1) Climate (Precipitation, Evaporation, Wind, Relative humidity etc.),
(2) Physiography (Size and shape of watershed, Elevation, Slope and aspect)
(3) Geology (Drainage features [pattern, density, etc.], Parent rock types igneous, sedimentary, metamorphic),
(4) Soil (Soil depth, Soil type, Soil infiltration capacity, Soil erosiveness etc.)
(5) Land use and land cover (Land use types [forest, grassland, agriculture, urban, etc.], government private industrial), Ownership pattern (government, private, – Forest land conditions Major forest types [Rangeland condition and types, Agricultural practices, Road networks and condition, Recreational use (resort, wildlife, fish resource, etc.)]
(6) Catchment hydrology (Erosion conditions along streams, Floods and Stream flow [quantity and quality])
(7) Socio-economic features/catchment use (Water use and needs [sources of water, domestic use, irrigation, industrial, power generation, etc.], Water use problems [erosion, flooding, siltation, water supply, water quality, etc.], income generation activities associated with watershed management

Catchments are delineated based on hydrological characteristics, i.e. where water flows within a geographic space, and therefore do not align with regular Administrative boundaries. In this case a catchment is comprised, wholly or partially, of the Administrative Districts and Sectors. The whole area of a specific District or Sector may not fall entirely within one or the same catchment, but could fall within 2 or even 3 different catchment areas.

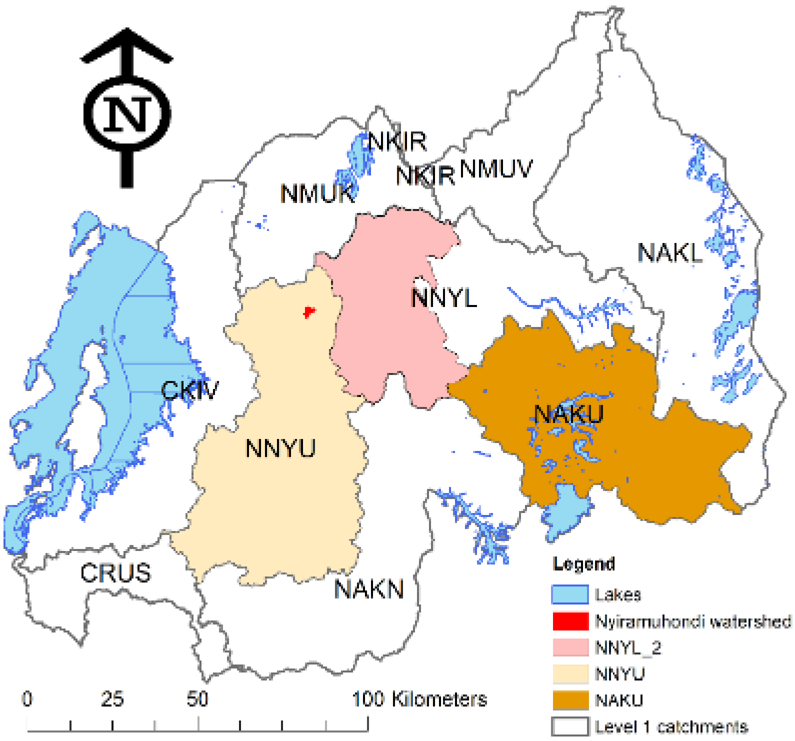
1.2.2 INTRODUCTION TO NAKU CATCHMENT

Nile **AK**agera **U**pper (NAKU) catchment is one of the nine level 1 catchment of Rwanda. As the name suggest it is located within the Nile Basin of Rwanda. It drains the area from the confluence of Nyabarongo NNYL and Akanyaru NAKN rivers down to the Rusumo Falls. NAKU has a total area of 3053 km^2 and its represents 12.6% of the total surface area of Rwanda (26,338 km^2 including water bodies). It ranks fifth in size among level 1 catments (see Figure 2.1). It is a transboundary catchment, with Burundi and Tanzania downstream. Nine District has their territory in NAKU Catchment, they are: Bugesera, Gasabo, Kamonyi, Kayonza, Kicukiro Kirehe, Ngoma, Nyarugenge, and Rwamagana, with 63 Sector having all or part of their territory in the catchment Figure 2.2. NAKU catchment has the majority of its territory 2,756.42 sq km (90.20%) located in the Eastern Province, 298.92 sq km (9.78%) in the city of Kigali and 0.39 sq km (0.013%) in the southern province. All the 63 Sectors were visited during data collection. It is important to include the Districts and Sectors that fall within the catchment area in the catchment planning process, as the outputs of the CMP will have direct bearing on these administrative areas. The District Development Strategy (DDS) of the member Districts of the

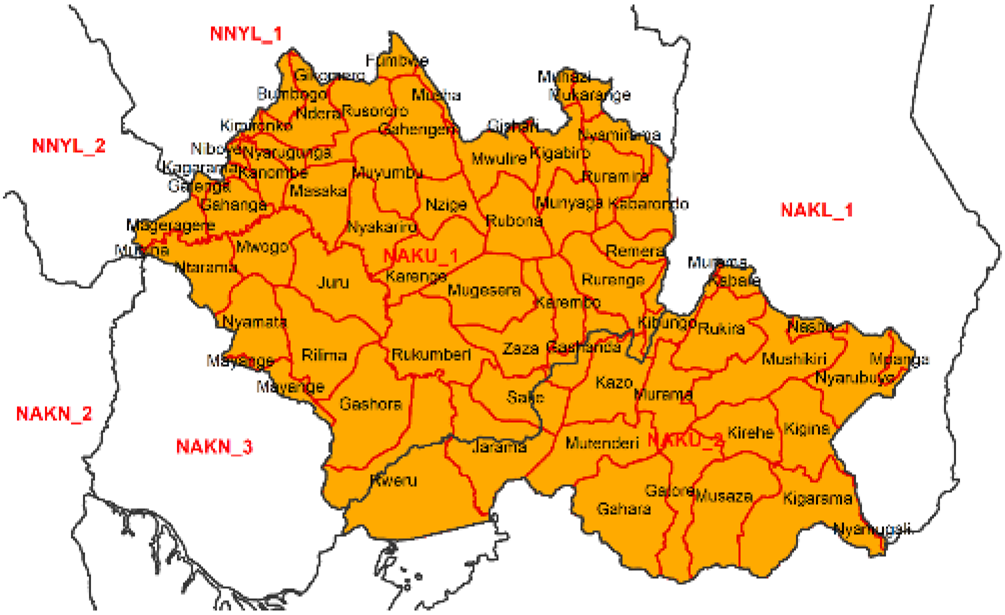
Catchment area have been and was considered in compiling the Akagera Upper CMP. Applicable activities from the CMP will need to be incorporated into the updated DDSs of the member Districts. The location of NAKU catchment in Rwanda is shown in Figure 2-1. NAKU catchment is made up of two level 2 catchments which are (i) Akagera Upper 1 (NAKU_1) with an area of 1,888 km² and it is upstream of the Lake Rweru is totally located in Rwanda and (ii) Akagera Upper 2 (NAKU_2) with a total area of 1,165 km² in Rwanda. This is transboundary catchment shared with Burundi. Some of the surface characteristics of NAKU catchment according to RoR, (2014) are:

- Land area of the catchment within Rwanda: 2,941 km²
- Surface area of the series of lakes (in Rwanda): 112 km²
- Surface area of Lake Rweru: 123 km² (of which 34 km² in Rwanda)
- Total area of the NAKU catchment within Rwanda: 3,053 km²
- Upstream area from Akanyaru catchment (Rwanda & Burundi): 5,328 km²
- Upstream area from Nyabarongo catchment: 8,601 km²
- Catchment area in Burundi and Tanzania (Lake Rweru and Ruvubu River): 13,714 km²
- Grand total of the Upper Akagera at Rusumo Falls: 30,696 km².

Akagera River within NAKU catchment has high sinuosity that explained by it meandering nature as it paths through very flat floodplain that is flooded annually over its entire width.



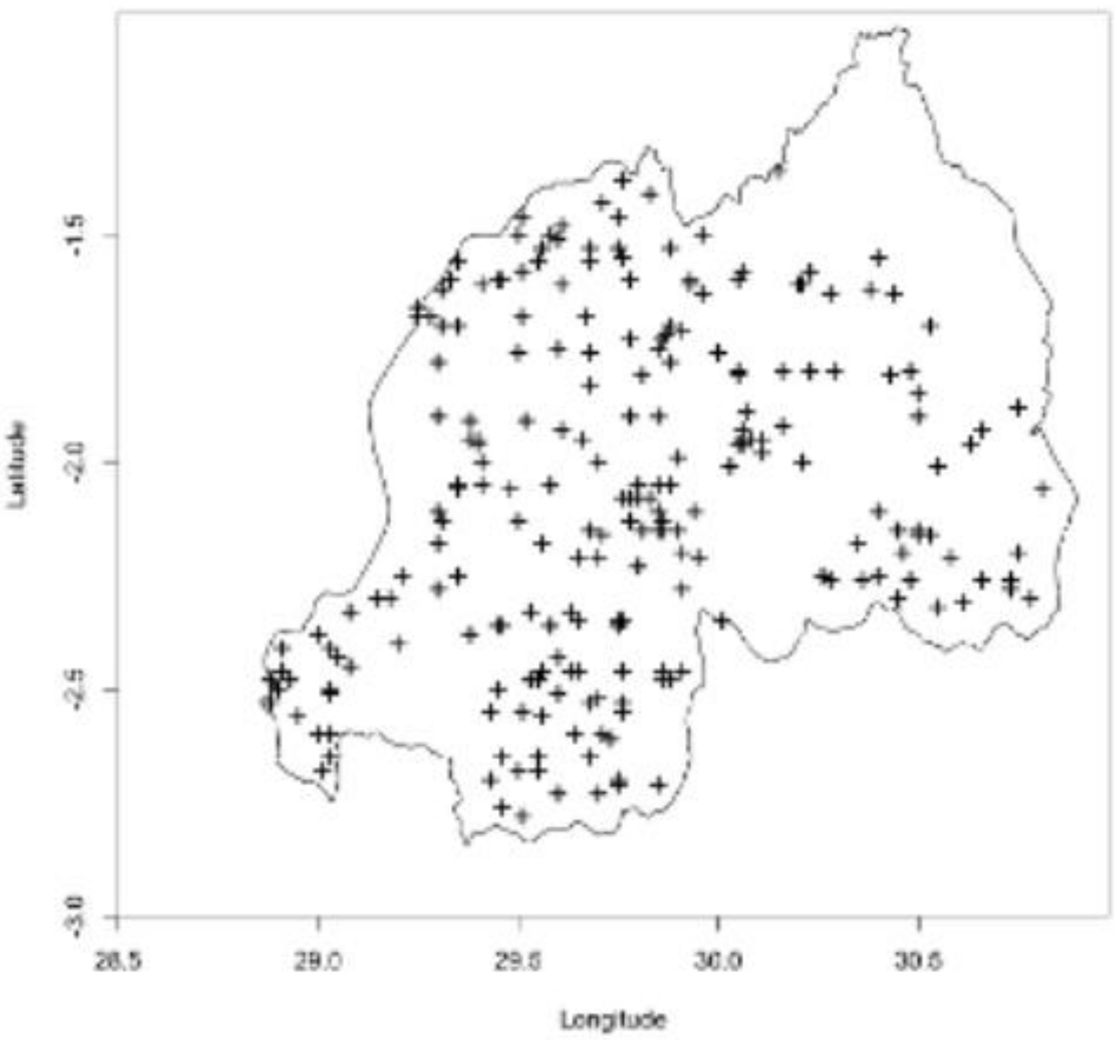
FUGURE 2- 1 LEVEL 1 CATCHMENTS AND THE LOCATION OF NAKU CATCHMENT IN RWANDA



FUGURE 2- 2 SECTORS WITHIN NAKU CATCHMENTS

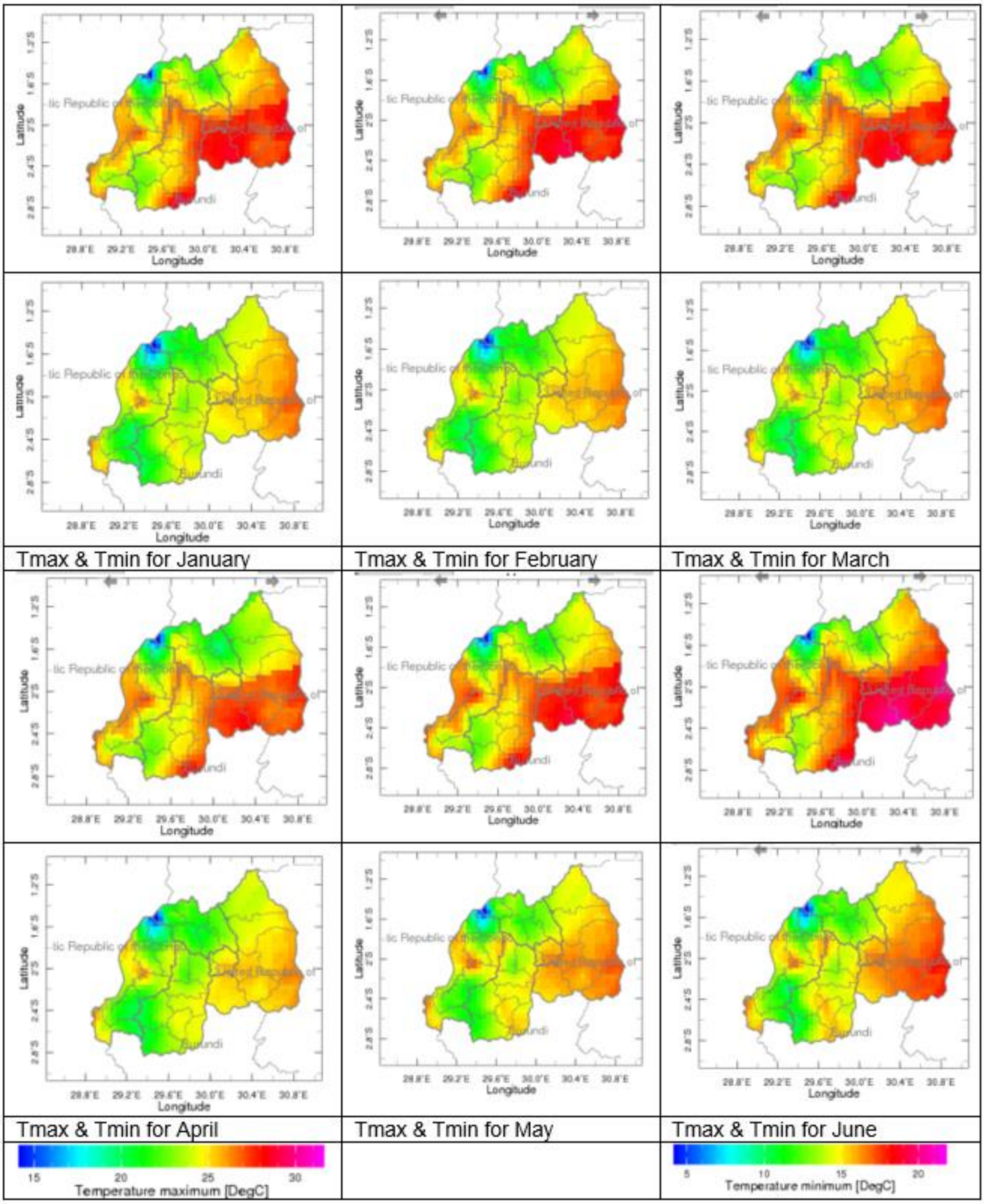
1.2.3 CLIMATE OF NAKU CATCHMENT

This section provides an overview of the climate of the NAKU catchment. Climate means the usual condition of the temperature, humidity, atmospheric pressure, wind, rainfall, and other meteorological elements in an area of the earth's surface for a long time. Rwanda has a temperate tropical highland climate, with lower temperatures than are typical for equatorial countries due to its high elevation. The online meteorological data from the meorological stations around the country Figure 2-3 made available by Rwanda Meteo was used to analysed inter relationship between temperature and rainfall in the catchment.

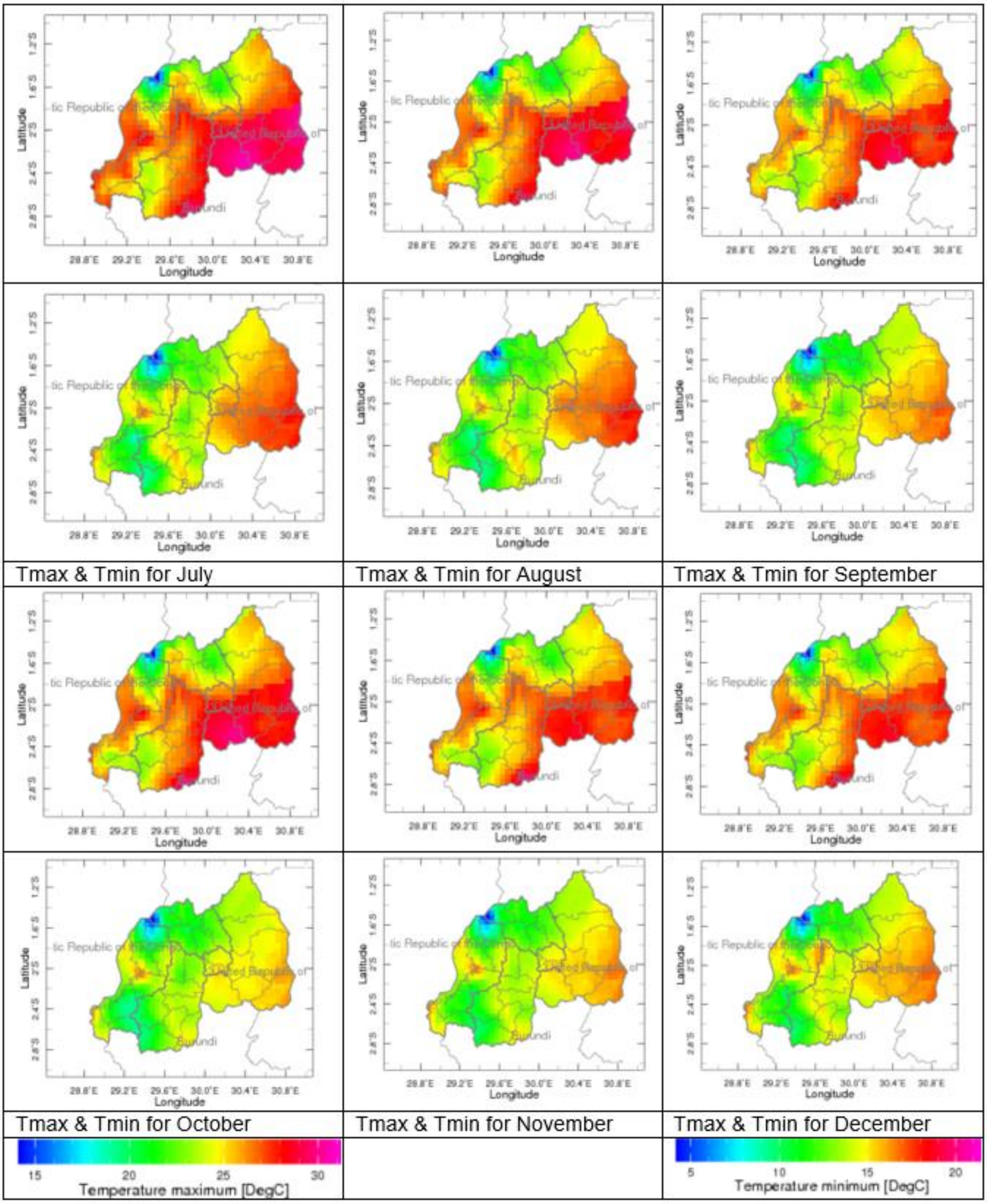


FUGURE 2- 3 DISTRIBUTION OF METEOROLOGICAL STATIONS IN RWANDA

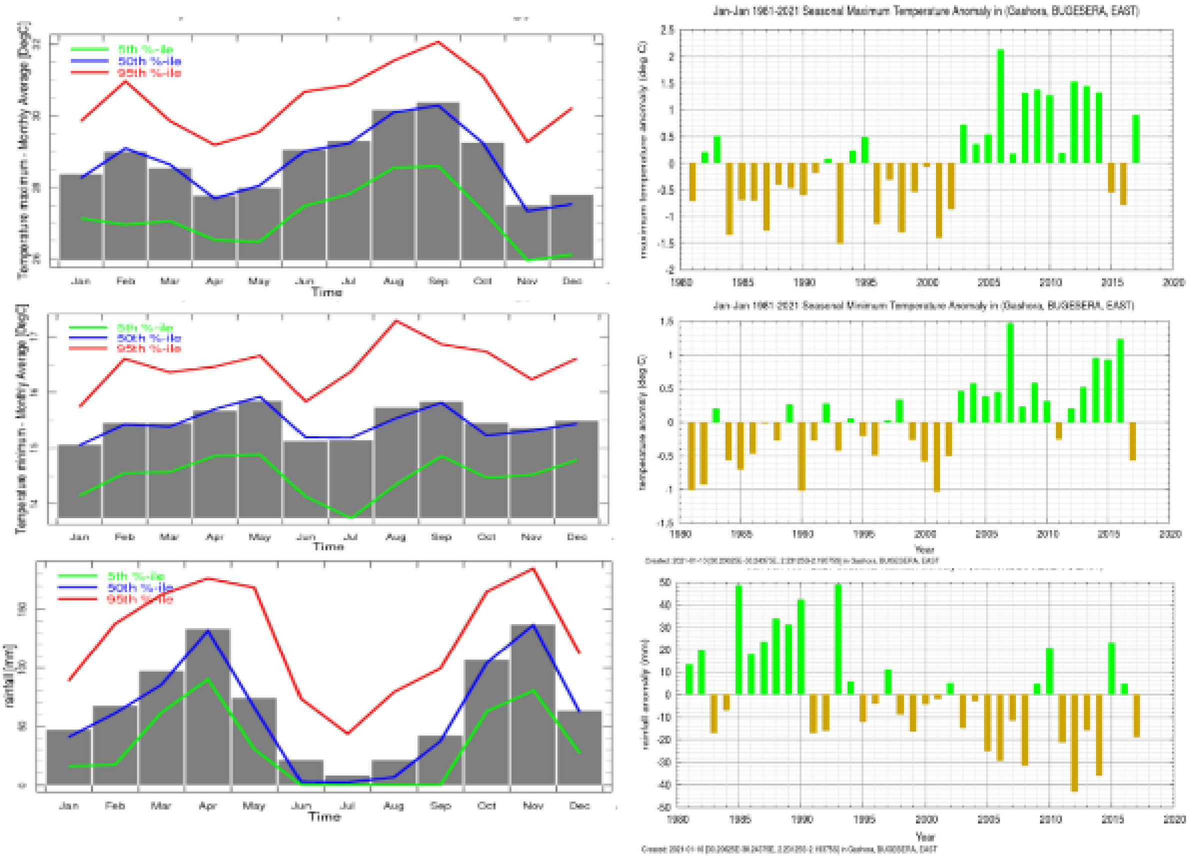
Minimum and maximum temperature data for the period from 1981 to 2017 was used to generate mean maximum and minimum temperature distributions withing Rwanda for 12 months (January – December) Figure 2-4 and Figure 2-5. Based on those Figures it be be seen that NAKU catchment is located within the Eastern Rwandan dry and hot lowland climate zone with temperature ranging from 14 - 32^{O}C with average of about 17 ^{O}C. The monthly mean maximum and mean minimum temperature, rainfall and their abnomalies within the NAKU catchment are shown from Figure 2-5 to 2-10. The catchment enjoys bimodal rainfall with an annual mean of about 925 mm. The mean monthly relative humidity in the catchment varies from 60% to about 80% Figure 2-11 and wind speed in Figure 2-12.



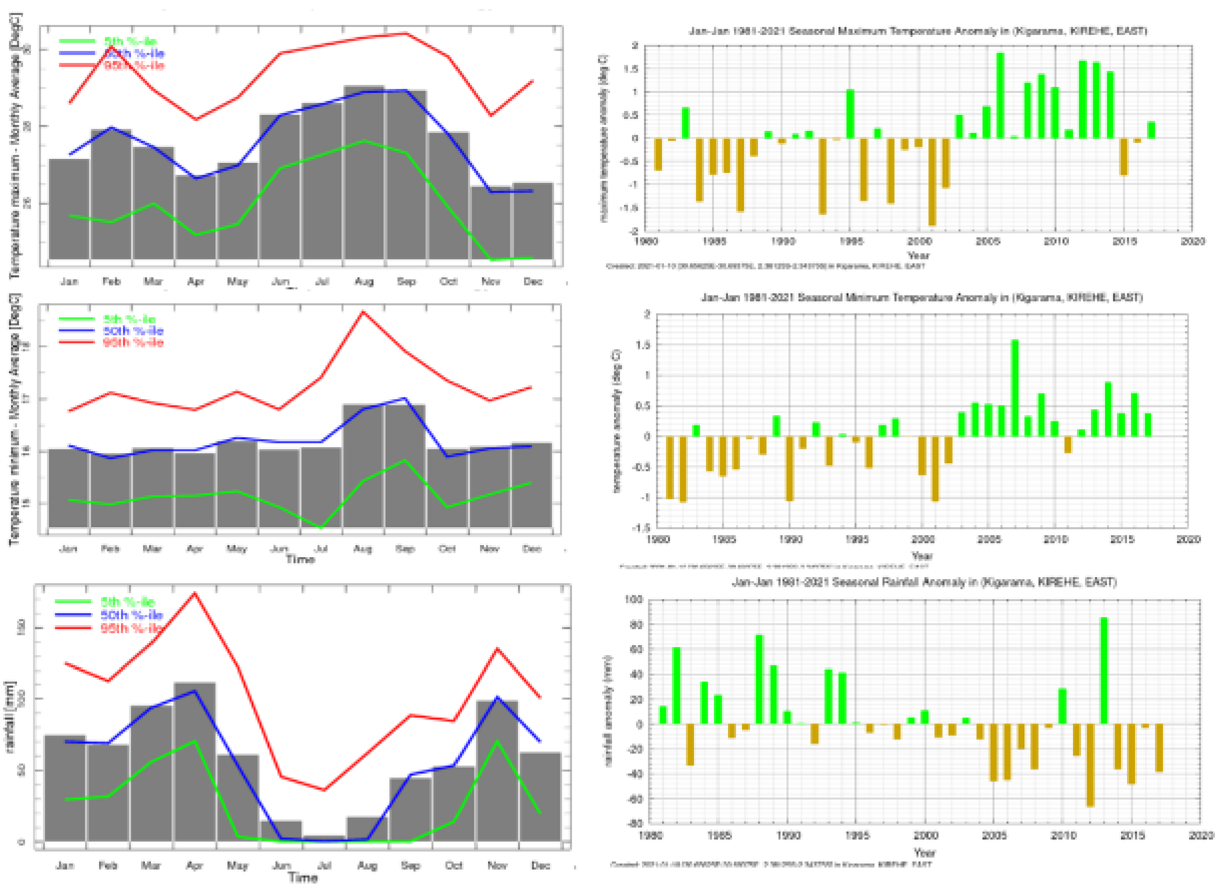
FUGURE 2- 4 VARIAVILITY OF TMAX & TMIN WITHIN RWANDA FROM JANUARY TO JUNE



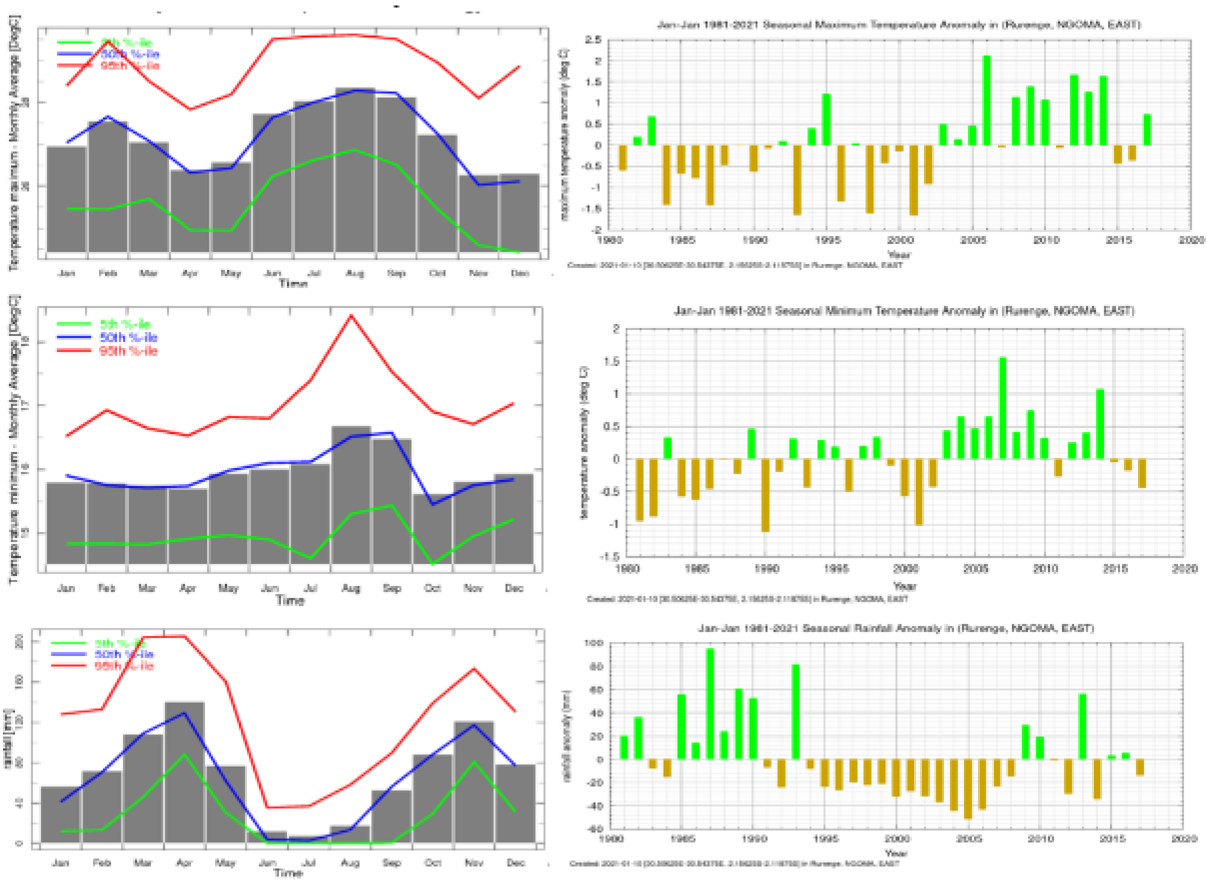
FUGURE 2- 5 VARIAVILITY OF TMAX & TMIN WITHIN RWANDA FROM JULY TO DECEMBER



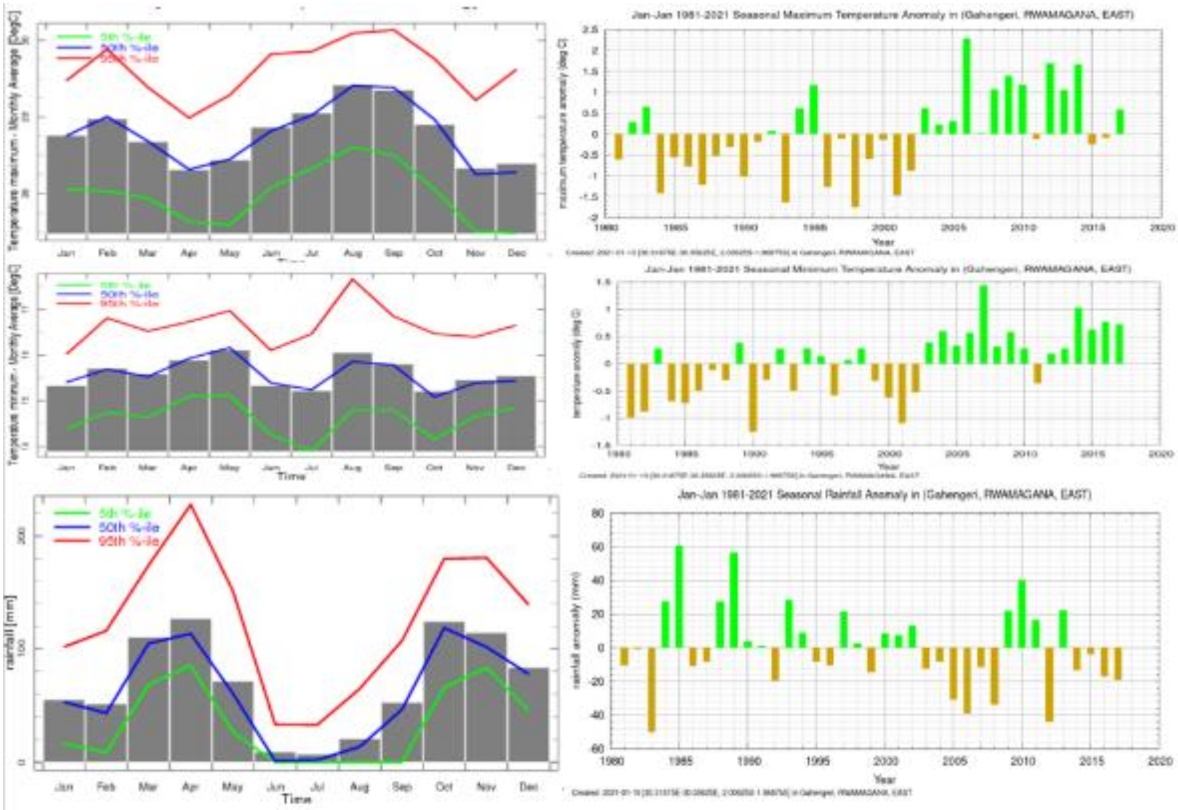
FUGURE 2- 6 TMAX & TMIN, RAINFALL AND THEIR ANOMALIES AT GASHORA BUGESERA



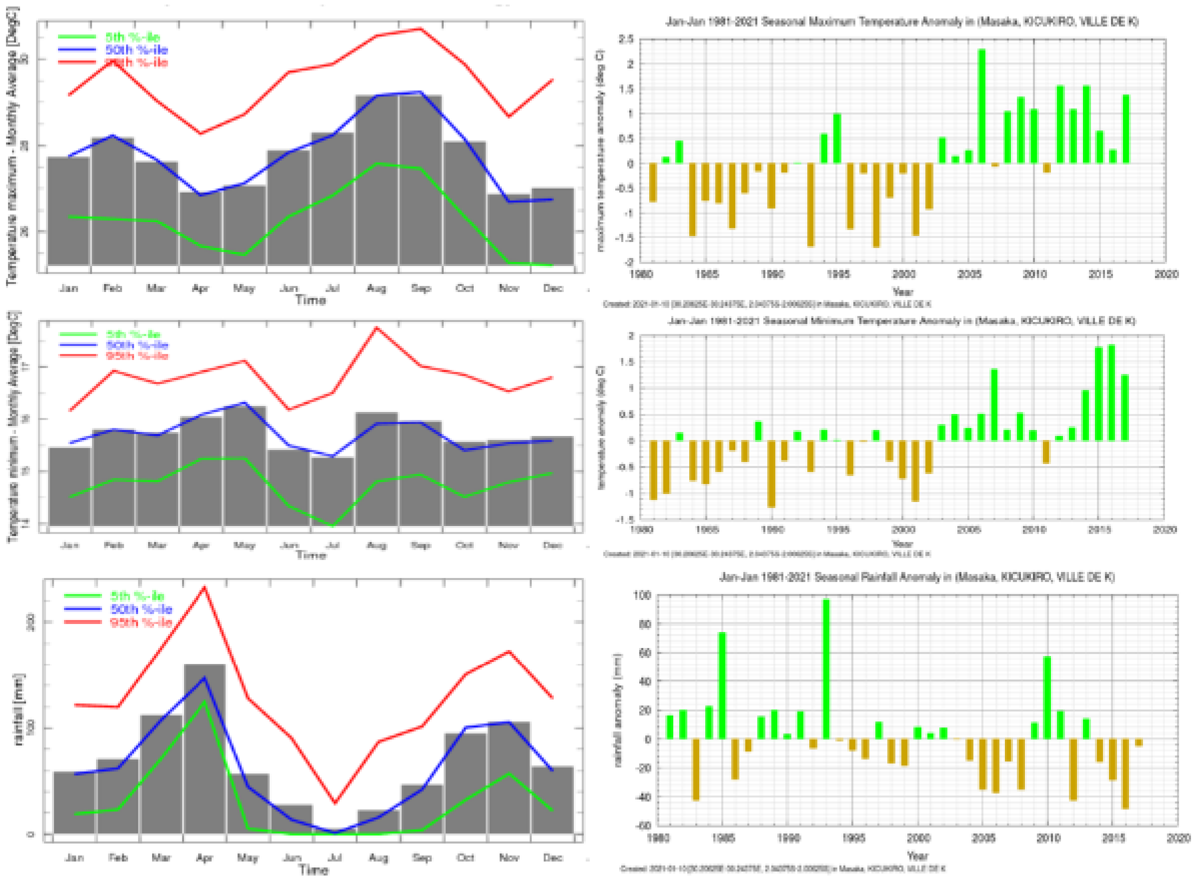
FUGURE 2- 7 TMAX & TMIN, RAINFALL AND THEIR ANOMALIES AT KIGARAMA, KIREHE



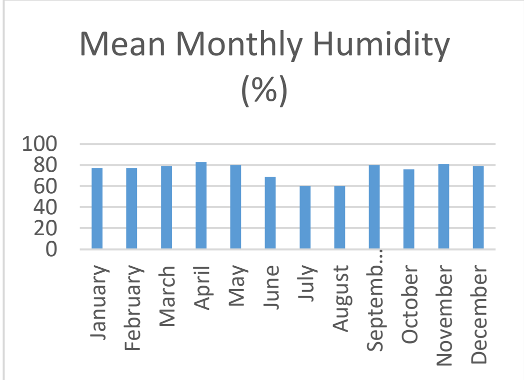
FUGURE 2- 8 TMAX & TMIN, RAINFALL AND THEIR ANOMALIES AT RURENGE, NGOMA



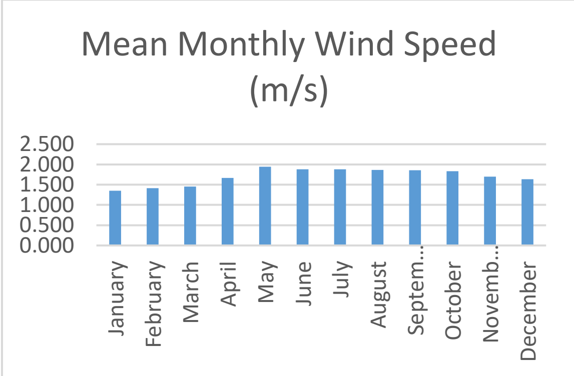
FUGURE 2- 9 TMAX & TMIN, RAINFALL AND THEIR ANOMALIES AT GAHENGERI, RWAMAGANA



FUGURE 2- 10 TMAX & TMIN, RAINFALL AND THEIR ANOMALIES AT MASAKA, KICUKIRO



FUGURE 2- 11 HUMIDITY



FUGURE 2- 12 WIND SPEED

For all the selected locations-

1. From 1981-2000 the value of both Tmax & Tmin are below long-term mean temperature, while rainfall is above long-term mean.
2. From 2000-2017 the value of both Tmax & Tmin are above long-term mean temperature, while rainfall is below long-term mean.
3. For the last 20 years there is decrease in the mean annual rainfall and the trend is not a continuous one. We are observing meteorological drought

Conclusions

1. The changes could be due to cycliness of the climate which is about 60 years in the case of Rwanda. If this is true we expect lower temperature after 2050 and consequently rise in the rate of population growth, except if control is put in place.
2. The changes could also be due to global warming in that case it could be concluded that this started around the year 2000
3. The observed extremes in NAKU catchment e.g. floods are due to human activities that could include: urbanization, poor agricultural practices, and deforestation

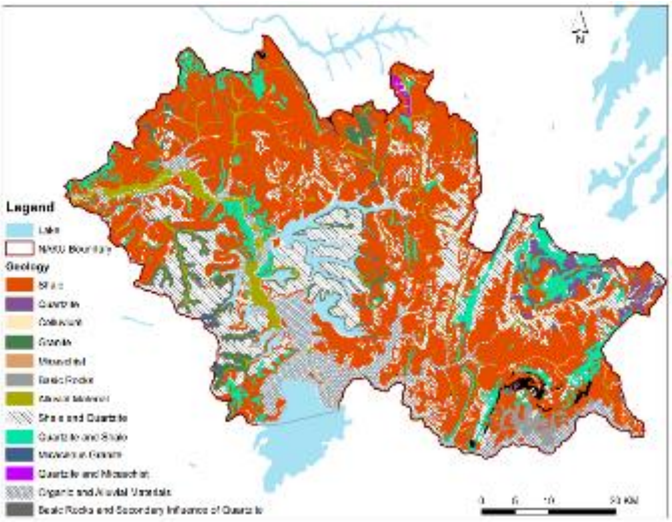
Recommendations:

1. There is need to appropriately managed upstream catchments (NNYU, NNYL, NMUK, and NAKN) through training of the farmer on best agricultural practices through IWRM approach, control domestic runoff through rainwater harvesting, reduce the number of people defending on agriculture through creating off-farm income generating activities.
2. Ensure implementation of the family planning programme to control rapid population growth.

1.2.4 GEOLOGY, SOIL, TOPHOGRAPHY & ECOLOGY

1.1.1.1 GEOLOGY:

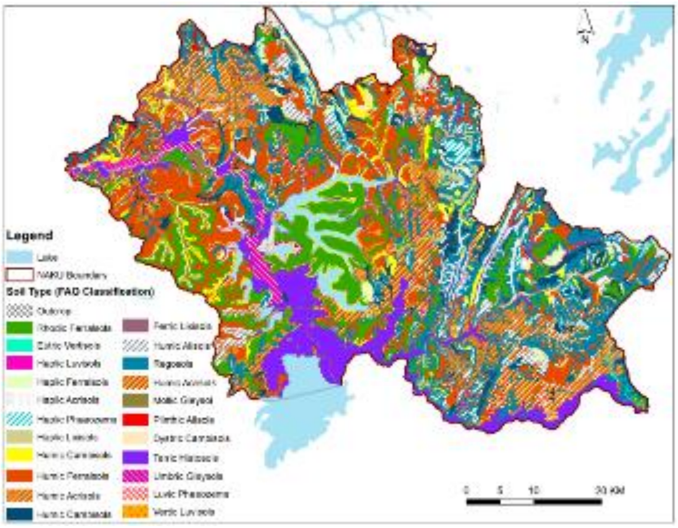
The lithology of NAKU is dominated by shale and shale quartzite basement aquifers with other lithology classes including shale, granite, colluvium, and alluvial material in valley bottoms (see Figure 2.13). The distribution of the lithology of NAKU catchment is made up of with granite and pegmatite in the east, shale in the center, and quartzite and quartz rich schist in the east. Alluvial material is found in the water cause located in the center and the west of the catchment. While the Akagera floodplain contains extensive areas of peat. Some volcanic and basalt material are found near the outlet of the catchment. The above mentioned characteristics determines the groundwater potential of the catchment. Aquifers associated with quartzite and schist have average storage and transmission properties, hence groundwater recharge rates, base-flow and recession characteristics are expected to exhibit average values. Quartzite and alluvial material are generally interesting for groundwater exploitation however, need detail investigation.



FUGURE 2- 13 GEOLOGICAL CHARACTERISTICS OF NAKU

1.1.1.2 SOIL:

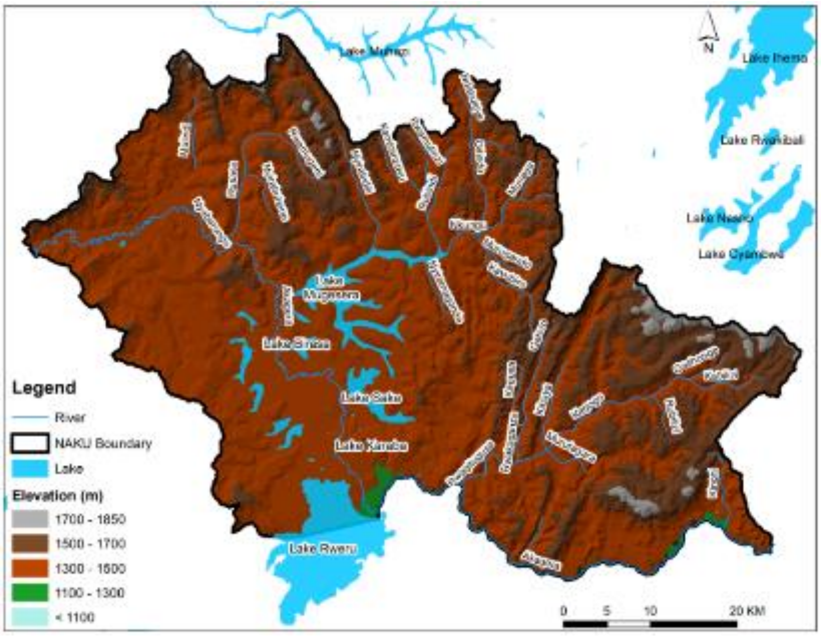
The soil classes for the NAKU catchment are presented in FIGURE 2.14. Some of the dominant soil classes include the ferralsol with a complement of the 'nitosol - acricol alisol - lixisol' class. The cambisol, clay soils with low infiltration rate and mineral soils conditioned by flat topography classes make up most of the remaining area. Especially the lower reach of the Akagera floodplain presents histosols. There are some very small areas with andosols. Except for clay and mineral sols conditioned by flat topography infiltration rates of these soils are generally high.



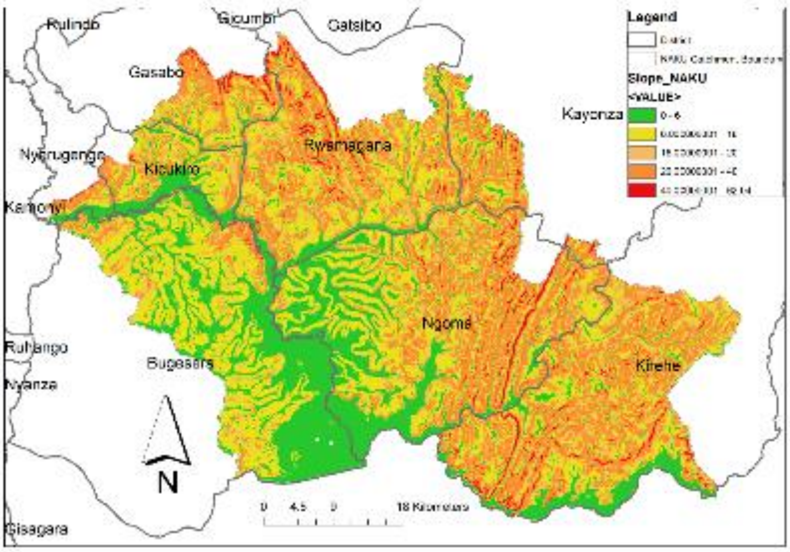
FUGURE 2- 14 SOIL TYPE FOR NAKU CATCHMENT

1.1.1.3 TOPHOGRAPHY AND SLOPES:

Topography and slopes are important factors as per as the movement of run-off is concern. It is also closely connected to flood and erosion. NAKU catchment is relatively flat with slopes ranging from majority of its territory having a slope ranging from 1100 to 1850 m above sea level, with the majority of the territory within the slope range of 1300 t0 1500 m **FIGURE 2.15**. Topography, slopes and the cultivation method, determine the management practice such as terracing. The landform of the main drainage network in the north of the NAKU catchment is on sloping land with a gradient of 10 to 30 percent, moving from medium-gradient hill to valley floor. In the south of the catchment there is level land with a gradient below 10 percent made of dissected plain to plain landforms at the catchment outlet, **FIGURE 2-16**. In particular, the hillslopes in the north of the catchment (within Rwamagana, Kicukiro, Gasabo Kayonza and Kirehe Districts) will require additional mechanical and biological inputs due to the increased slope of the land and inherently erodible soils. The southern regions of the catchment are less steep, towards the catchment outlet the organic soils (peat) (within Bugesera, Ngoma, and Kirehe Districts) need to be managed effectively.



FUGURE 2- 15 TOPOGRAPHY OF NAKU CATCHMENT

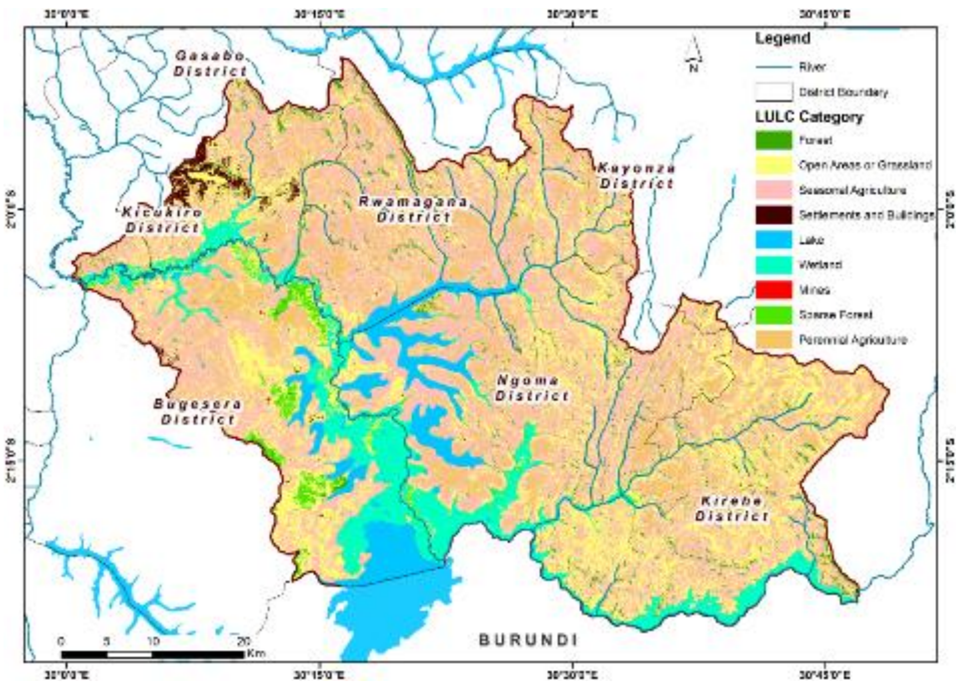


FUGURE 2- 16 SLOPE CATEGORY FOR THE CATCHMENT (SOURCE: USGS SRTM ONE ARC-SECOND)

1.2.5 LAND USE AND LAND COVER:

The resource controlling primary productivity for terrestrial ecosystems can be defined in terms of land: the area of land available, land quality and the soil moisture characteristics. Land cover and land use represent the integrating elements of the resource base. Changes in land cover and land use affect the global systems (e.g., atmosphere, climate and sea level) or they occur in a localized fashion in enough places to add up to a significant total. Land cover is the expression of human activities and as such changes with alterations in these. Hence, land cover is a geographical feature which may form a reference base for applications ranging from forest and rangeland monitoring, production of statistics, planning, investment, biodiversity, climate change, to desertification control. People have reshaped the earth continually but the present magnitude and rate are unprecedented. Nowadays it is realized that it is very important to know how land cover has changed over time, in order to make assessments of the changes one could expect in the (near) future and the impact these changes will have on peoples' lives. As people are the main users of the land, it is important for any system to be oriented towards them.

The Rwanda landcover map for 2018 was used to develop the LULC map of NAKU catchment **FIGURE 2.17** and **TABLE 2-1**. The map indicates that most of the catchment area is covered with seasonal agriculture, with the hillslope areas having areas of sparse to moderate forest. The land cover of the catchment is dominated by rainfed agriculture with, especially in the east significant areas of natural open land, forest plantation and built up area in small sections throughout the catchment and a larger domain for the city of Kigali. The western part of the Akagera floodplain is used for irrigated / agricultural wetland with the central and eastern part, due to humidity preserved as natural wetland. NAKU catchment is located mostly in the Eastern Province and the City of Kigali with only very little area of the catchment in the Southern Province. The Eastern Province is a drought prone area, and as such the land use focuses on the seasonality of rainfall, and encroaches into the wetland areas. Due to water requirements during the dry seasons cultivation extends nearer the wetland areas. Apparently, these same areas become flooded during the rainy season. There are floodplain wetlands associated with the Akagera River, as well as unique Lakes. Papyrus from the wetland is used as mulch for crops and as crafts. There is limited grazing and presence of non-invasive alien vegetation. Forests and trees provide a canopy of protection from intense rainfall, and the tree roots act to stabilise the soil to reduce soil erosion. Removal of forested areas removes this protective covering and exposes soils to erosion.



FUGURE 2- 17 LANDCOVER FOR THE NAKU CATCHMENT

TABLE 2- 1 AREA COVERAGE OF EXISTING LULC IN NAKU CATCHMENT

S/N	LULC Category	Area (Ha)	Area (%)
1	Seasonal Agriculture	125,442.7	40.9
2	Perennial Agriculture	38,263.0	12.5
3	Dense Forest	8,711.9	2.8
4	Sparse Forest	5,254.2	1.7
5	Open Areas or Grassland	87,081.4	28.4
6	Settlements and Buildings	2,437.2	0.8
7	Waterbody	13,996.8	4.6
8	Wetland	25,282.0	8.2
9	Mines	3.2	0.0

1.1.1.4 FOREST:

Across Rwanda 29.2% of the total dry land area is forest. Of this 60% is plantations and woodlots while only 40% is natural forest (REMA, 2015). The Eastern part of the country historically was dominated with savannah woodlands and forests. However, since 1994 this area has undergone significant land-use change and the area has been opened up for population re-distribution and farming. “For the case of Eastern Province, the main landscape was initially dominated by savannas. Very recently, a very large part of that landscape has been converted to agriculture and husbandry farms. The most destructive land use type remains conversion to agriculture while husbandry farms can allow persistence of some forms of biodiversity.” (NUR, 2011) “The forest ecosystems, which occupied 30% of the total surface of the country in 1930 was reduced to 8.9% by the year 2000. This severe loss of forests has remarkably led to more than 90% decline of fauna species in Akagera National Park. The analysis of deforestation has revealed some associated consequences on regulating services where a monthly temperature increase of 0.5°C and a monthly decrease of 10 mm in rainfall has been remarked in the study period of 1970 to 2010” (Habiyaremye *et al.,* 2011). It is known that fragmentation is more problematic in areas with extensive and rapid land use change due mainly to agriculture under the tropics and where protected area networks underrepresent natural landscape heterogeneity (NUR, 2011). Impacts associated with the recent deforestation include “soil degradation, erosion, landslides, reduced water quality, and a loss of biodiversity (Kanyamibwa, 1998; Partow et al., 2011; Plumptree et al., 2001)” (Ordway, 2015).

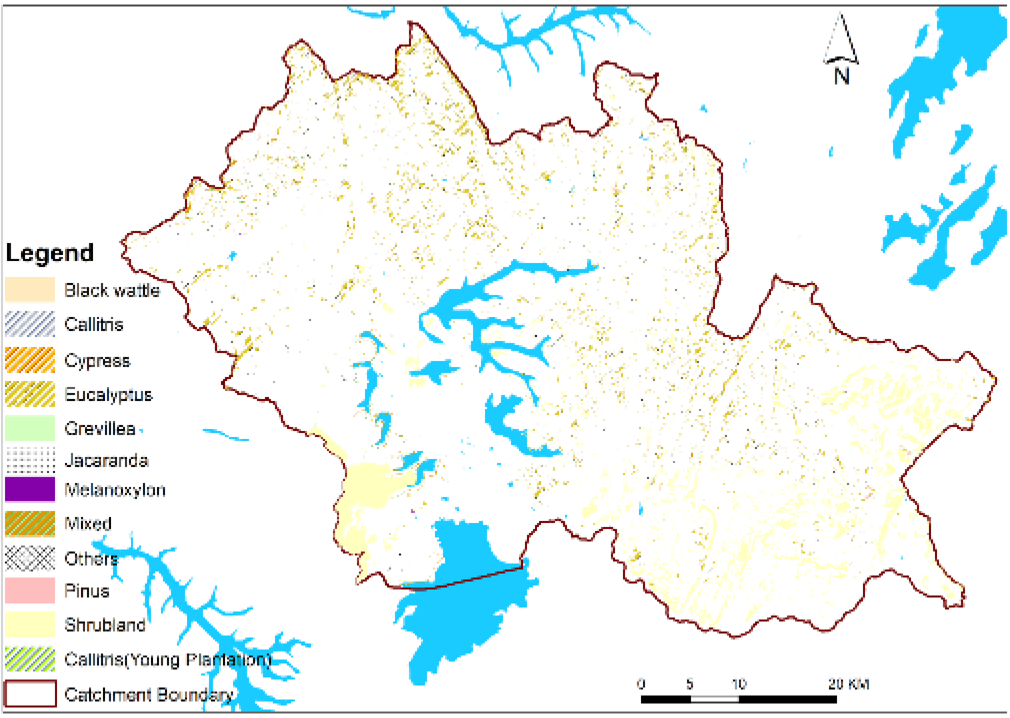
The land-use of the Akagera Basin are predominantly agriculture, grassland and forest. With the Akagera catchment being dependant on the creation of surface water storage for sustaining its dry season flow, the erosion protection measures should be reinforced, especially in catchments that generate the inflow of the future reservoirs, such as the Mugesera / Rweru Wetland Complex within the Akagera Upper Catchment.

Although there are no national forest reserves within the Akagera Upper Catchment, there are two forests of significance in the Bugesera District, Gashora and Mayange Sectors, as well as afforestation projects and agroforestry projects are being implemented within the member Districts.

Through the District Development Strategies (DDS) and consultations with the Districts and Sectors within the Catchment, deforestation has been identified by the majority as being a direct issue or a cause of another issue in particular soil erosion. During Catchment Management Planning workshop on 14 September 2017 and during field work between September to November, 2020, all Districts identified the need for reforestation and afforestation activities within the catchment.

There is high competition between forestry and other land use activities especially agriculture and settlement expansion resulting in deforestation. Natural forests have been cleared either for firewood/charcoal, to expand agricultural areas or for expansion of settlements. Where forestry has been replaced this has been done through plantation or woodlots. Unfortunately, the loss of natural forests results in the loss of indigenous species and provision of habitat for native species as well as the loss of other forest based ecosystem services such as runoff mitigation, higher rate of carbon storage, whereas the plantation and woodlots are planted with alien and invasive species such as *Eucalyptus, Pinus, Acacia mearnsii or Grevillea.* While these later species are fast growing they are not indigenous and do not provide the necessary habitat for biodiversity or the forest-based ecosystem services to the same degree as natural forests. These species, especially the Eucalyptus and Pine alter the soil conditions preventing the regrowth of understory forest structures, and can contribute to further soil erosion as a result. The lack of soil cover contributes to increased runoff from the land which in turn contributes to soil erosion and flooding damage to adjacent land.

Of the 32 species of invader plants identified in the Assessment of impacts of invasive alien species (REMA, 2016) 20 are species invading natural forests.



FUGURE 2- 18 MAP OF TYPE AND LOCATION OF FORESTS WITHIN THE AKAGERA UPPER CATCHMENT

As the Eucalyptus, Pines and Grevillea are fast growing species they are used for woodlot plantations and can be harvested for timber and fuelwood. However, as they are very water-thirsty species they should be planted away water from waterbodies such as springs, river banks and wetlands. On occasion, they may be used to dry out areas prone to flooding or waterlogging.

In particular *Grevillea robusta* is used as a species for agroforestry practices due to its quick growing nature and for nitrogen fixing in cultivated soils, refer Figure 2-12. It should be noted that it is a common allergen causing skin irritation and inflammation of eyelids.

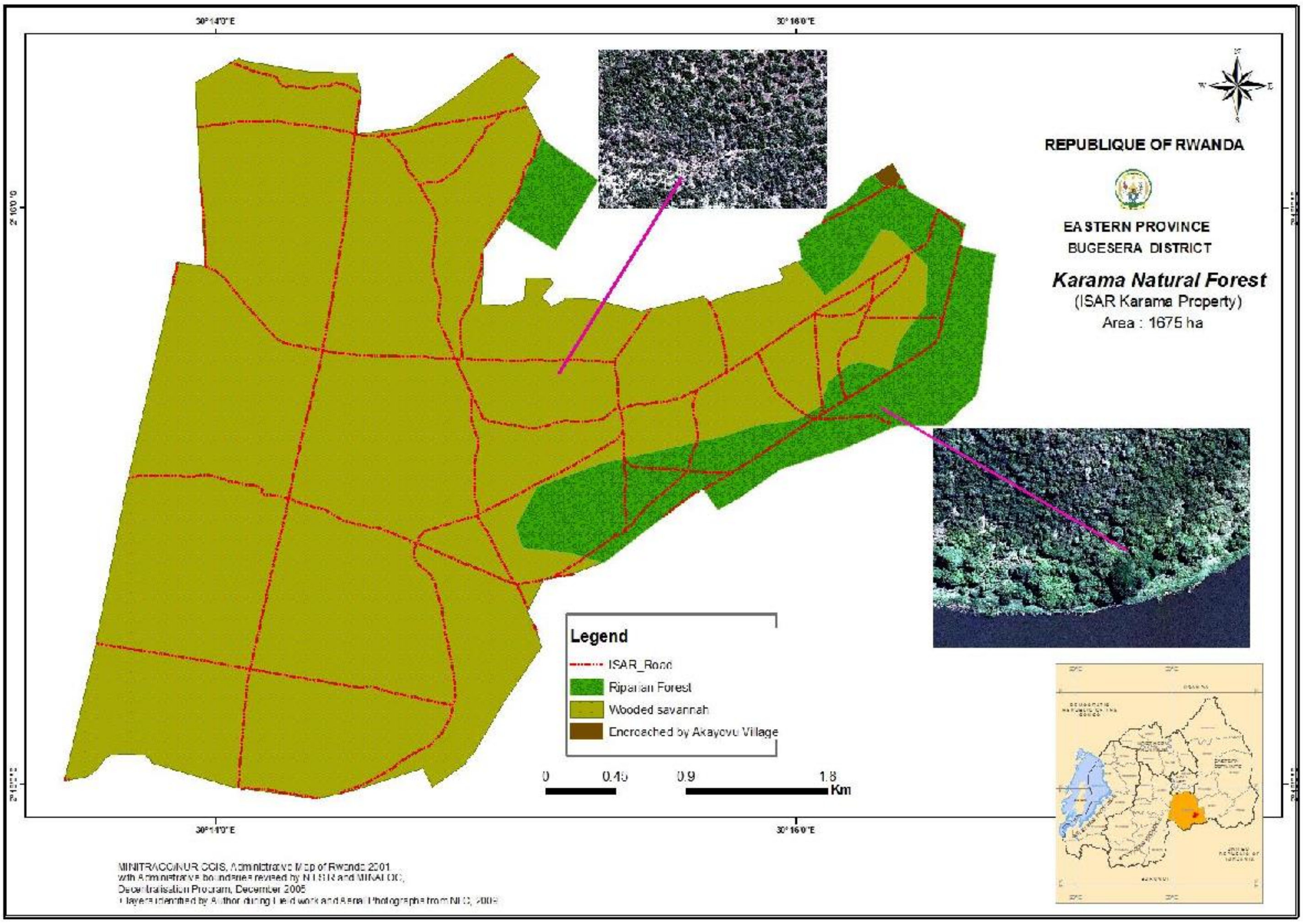
FUGURE 2- 19 EXAMPLE OF GREVILLEA ROBUSTA USE IN AGROFORESTRY IN BUGESERA DISTRICT.

Trees are used in agroforestry practices to provide nitrogen fixing to cultivated soils to replenish nitrogen in the soils, as well as to provide fruit and shade. As the trees are planted sporadically or in single-windrows they do not provide any forest ecosystem function and therefore agroforestry trees are not included in natural forest area calculation, afforestation or forest regeneration projects.

Within the Nile Akagera Upper Catchment there are no National Protected Forest Reserves, but there are two natural forest that should be conserved, Karama Natural Forest in Gashora Sector, and Gako Military Zone Forest in Mayange Sector both in Bugesera District. Although there are several plantations within the catchment, these are Alien species and do not contribute towards forest-based biodiversity.

2.1.1.1 KARAMA NATURAL FOREST

According to NUR (2011), Karama Forest (commonly known as ISAR KARAMA Forest) is located in Gashora Sector within Bugesera District in the Eastern Province. It is shared between Mwendo and Ramiro Cells, at an altitude of 1337m. Karama Forest is a natural dry forest characterized by diversified habitats, Figure 2-13. The main patterns are composed of xerophytic plants and tiger bushes. The forest is bordered by Kirimbi and Gaharwa Lakes in the South-eastern side, where the gallery forest is dominant. This forest makes part of the Bugesera savanna relicts and is adjacent to Gako military domain, separated by the tarmac road in the West. The forest covers about 80% of the total area (about 1000 ha), while 20% is used for agroforestry, husbandry, agriculture, etc. The forest is under the management RAB KARAMA where different research activities of agriculture and cattle breeding are conducted.



FUGURE 2- 20 MAP OF KARAMA FOREST (SOURCE: NUR, 2011)

According to the NUR (2011) Report, Karama forest is rich in plant diversity dominated by trees and shrubs of *Rhus natalensis*, *Grewia similis*, *Grewia bicolor*, *Acokanthera schimperi*, *Vepris nobilis*, *Afrocanthium lactescens*, *Psydrax schimperiana*, *Euphorbia candelabrum*, *Osyris lanceolata*, *Olea europea* var. *Africana*, *Pappea capensis*, *Euclea schimper*, *Haplocoelum foliorosum*, *Ozoroa insignis*, *Dichrostachys cinerea*, *Strychmos lucens*, *Markhamia obstusifolia*, *Boscia angustifolia* var. *corymbosa*, *Acacia hockii*, *Acacia gerardii*, *Capparis tomentosa*, *Carissa eduli*, *Maytenus senegalensis*, *Lannea fulva*, *Combretum molle*, *Gardenia ternifolia*, *Flacourtia indica*, *Scutia myrtina*, *Ximenia caffra* (preferred edible fruit tree), *Kigelia africana, ….* Most of these species are used for various purposes particularly in traditional medicine.

This forest is also rich in orchid species among which *Microcoelia* is the dominant genera. Some herbaceous species characteristics of low altitude savannas and xerophyllous forest are also abundant. Some of them are *Themeda triandra*, *Hyparrhenia filipendula*, *Sporobolus pyramidalis*, *Loudetia simplex, Asparagus africanus, …* Alongside the Kirimbi Lake, many species of *Cyperus sp*. are observed.

Concerning the wild fauna, the forest is home to mammals like rabbits, *Chlorocebus aethiops* and *Herpestes ichneumon.*

Karama forest plays an important role as a refuge to many grassland and woodland snakes. These include *Naja nigricollis, Naja melanoleuca, Vipera aspic* and *Opheodrys vernalis*. On the side of the lakes, there live also snakes related to areas of permanent water like *Python sebae*.

Some bird species were also recorded (*Ceuthmochares aereus*, *Streptopelis senegalensis*, *Lamprotornis purpuropterus*, *Francolinus nobilis*, *Bulbucus ibis*, *Pycnonotus barbatus*, *Ceryle rudis* and *Cossypha caffra*).

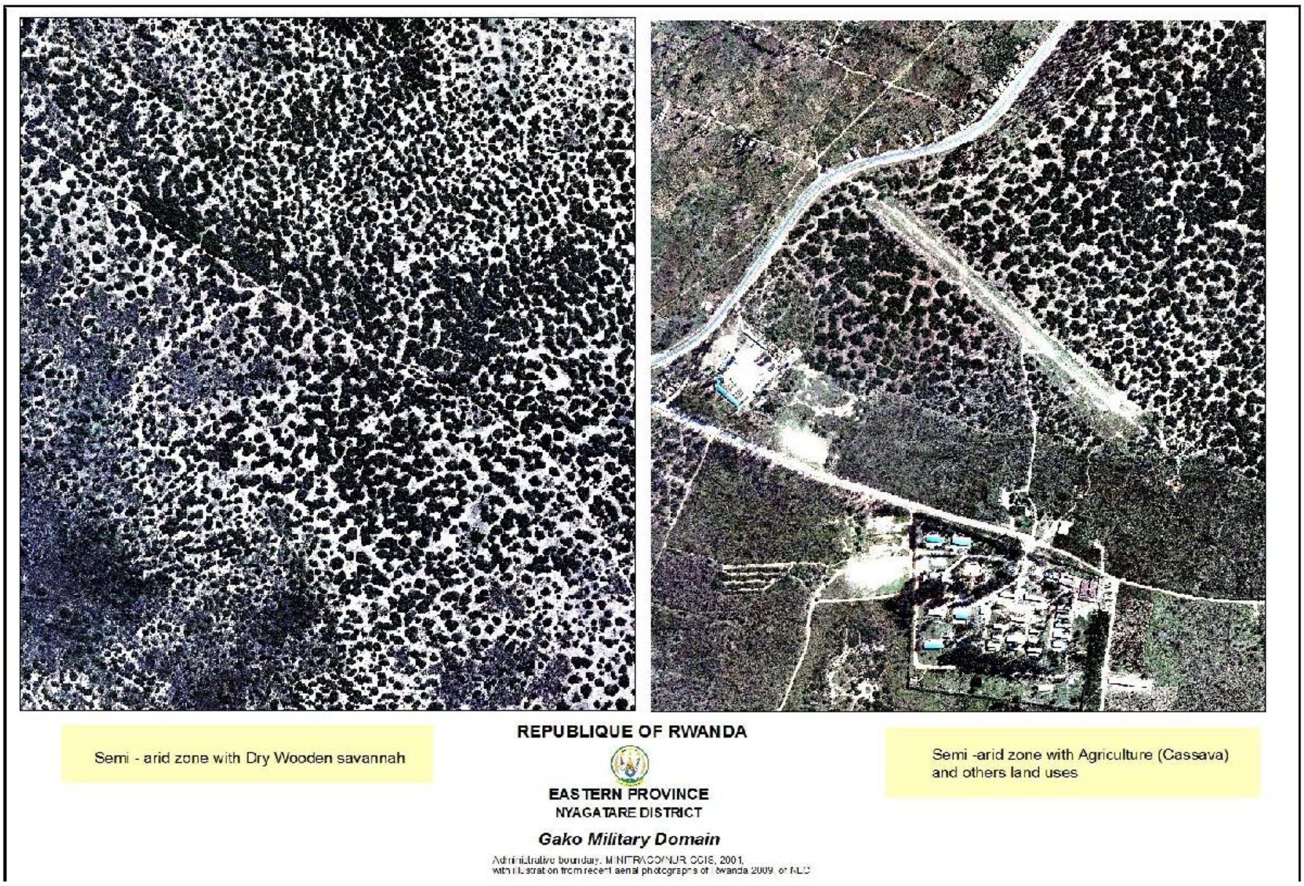
The ecosystem functions of Karama forest play a big role by providing edible and medicinal plants. Indeed, several plant species that it hosts are used to manufacture drugs by traditional healers to cure certain particular affections of which bites of the snakes relatively frequent in this area.

Furthermore, the forest plays a paramount ecological role in preventing erosion and eutrophication of surrounding aquatic systems. It also contributes in climate mitigation by reducing evaporation on water surface. The forest also serves as food source and habitat for different animal as well as bird nests for bird species. Karama contributes in general in the maintenance of the ecological balance of the Bugesera region (rainfall regulation, soil cover and improvement).

NUR (2011) identified that among the threats posed to this ecosystem, the population pressure which rely highly on the forest for their subsistence ranks the first. Some of activities are agriculture, hunting, firewood collection, charcoal making that lead to the forest degradation. The agro-pastoral encroachment and fire wood collection are the predominant challenges to this ecosystem. To prevent these threats, RAB is currently delimitating the forest by establishing a buffer zone. The institution contributes also in sensitizing people about its protection. It was observed, however, that the poaching activities are far from stopping, which might be due to the big size of the forest and limitations of controlling encroaching activities (an example is that people continue to cut trees and burn charcoals).

2.1.1.2 GAKO MILITARY ZONE FOREST

Located in Bugesera District, Mayange Sector in the Eastern Province, Gako military domain, Figure 2-20, shares the same topographic, ecological and biodiversity features with the neighbouring Karama natural forest. Indeed, these two natural forests look pretty alike besides that Gako is bigger than Karama in terms of area, and of course flora and fauna diversity. As a military domain, the rate of deforestation an encroachment is lower.



FUGURE 2- 21 GAKO MILLITARY DOMAIN FOREST (SOURCE: NUR, 2011)

1.2 NATURAL RESOURCES OF THE AKAGERA UPPER CATCHMENT

1.2.1 WATER RESOURCES

1.2.1.1 POLICY FRAMEWORK

1.1.1.1.1 NATIONAL POLICY FOR WATER RESOURCES MANAGEMENT 2011

National Policy for Water Resources Management (2011) - The National Policy for Water Resources Management (2011) is a revised version of the policy on Water and Sanitation formulated in 2004. The policy of 2004 was revised to address the pressures of rapid urbanisation, changing demands for water uses, degradation of watersheds from unsustainable and inappropriate land use practices, and the uncertainties of climate change (Byers et al., 2014). According to the 2011 policy, the vision of the current Water Resources Management Policy is to have a water resources sub-sector governed by a policy, legal and institutional framework that promotes sustainable use of water resources and which contributes meaningfully to the socio-economic development of Rwanda. Within the strategic plan developed in support of this policy (2011-2015) the value and risks of wetlands were defined. The water resources of Rwanda will be conserved, protected and managed in order to secure and enhance its availability for, and utility to, the present and future generations. For this purpose, the Government shall:

1. Monitor and assess water resources to understand the water balance and to support water accounting, identify the spatial and temporal occurrence and distribution in the country;
2. Formulate a water resources management strategy addressing, inter alia, watershed protection and provides mechanisms for the designation of special conservation and or protection zones;
3. Promote water conservation techniques and technologies, including rainwater harvesting, water recycling and other appropriate technologies.

In particular, the compilation of the Akagera Upper Catchment Management Plan contributes to achieving point two.

1.1.1.1.2 NATIONAL WATER RESOURCES MASTER PLAN, 2014

The Rwanda NWRS Master Plan 2014 is the development of a Master Plan for sustainable water resources development, utilization and management in the country. The Masterplan shall be a blueprint for a process of sustainable water, land and related resources development and management with the aim to maximize economic and social welfare in an equitable manner while safeguarding the environment.

In the process of compiling the Akagera Upper Catchment Management Plant, the NWRS Master Plan is used as the blueprint. The specific catchment characteristics will inform the development of the plan such that it is catchment specific, however the NWRS will provide the guiding principles.

1.2.1.2 CATCHMENT WATER RESOURCES

The water resources available at level 1 catchment scale for Akagera Upper was calculated by considering the Surface Water resources and Ground Water resources. The main characteristics of SW and GW systems are defined in Section 2.3.1.4 and 2.3.1.5, respectively.

1.2.1.3 HYDROLOGY OF THE CATCHMENT

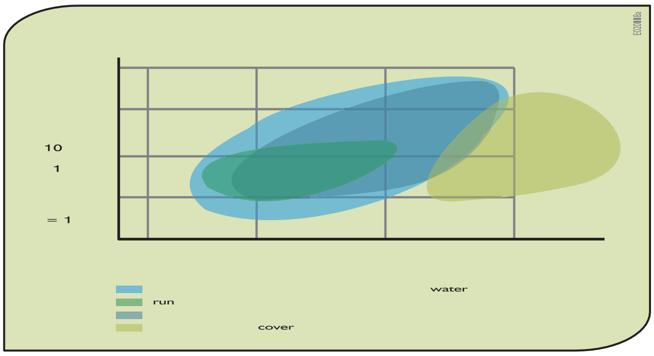
Once the temporal and spatial scales are defined, it will be important to evaluate specific components of the hydrologic cycle. The main components of the hydrological cycle, identifying the processes that are either inputs, such as precipitation, evaporation and air temperature, and those that are modelled, such as infiltration, transpiration, percolation, and surface and groundwater runoff.

In the context of Level-1 catchment:

- Meteorological data sets (i.e., precipitation and temperature) are being collected by Meteo Rwanda, and
- Hydrometric data sets (i.e., flow rate and stage) are being collected by RWB.

In order to build a catchment management model by integrating multiple river basin processes, it is important to structure spatial and temporal scales that characterize these processes. Precipitation, which is the source of virtually all freshwater in the hydrological cycle, is typically highly variable and uneven in its distribution over time and space. Similarly, the rates of evaporation and transpiration vary considerably according to climatic and land-cover conditions. The relative magnitudes of the fluxes associated with individual components of the hydrological cycle, such as evapotranspiration, may differ significantly even at small spatial scales such as a micro-catchment, an agricultural field and a woodland.

Figure 2-7 shows the ranges of spatial and temporal scales usually considered when modelling the processes taking place in the three major river basin components – watersheds, surface water bodies and groundwater aquifers. It is important to note that “monthly” temporal scale will suffice the requirements of the surface water and groundwater processes within the LEVEL 1 catchment Akagera Upper.



Source: UNESCO, 2005

FUGURE 2- 22 SPATIAL AND TEMPORAL SCALES OF VARIOUS RIVER BASIN PROCESSES

It is important to express these processes quantitatively by using representative data sets. Some of the critical data sets and associated administrative authorities are summarized in methodology section.

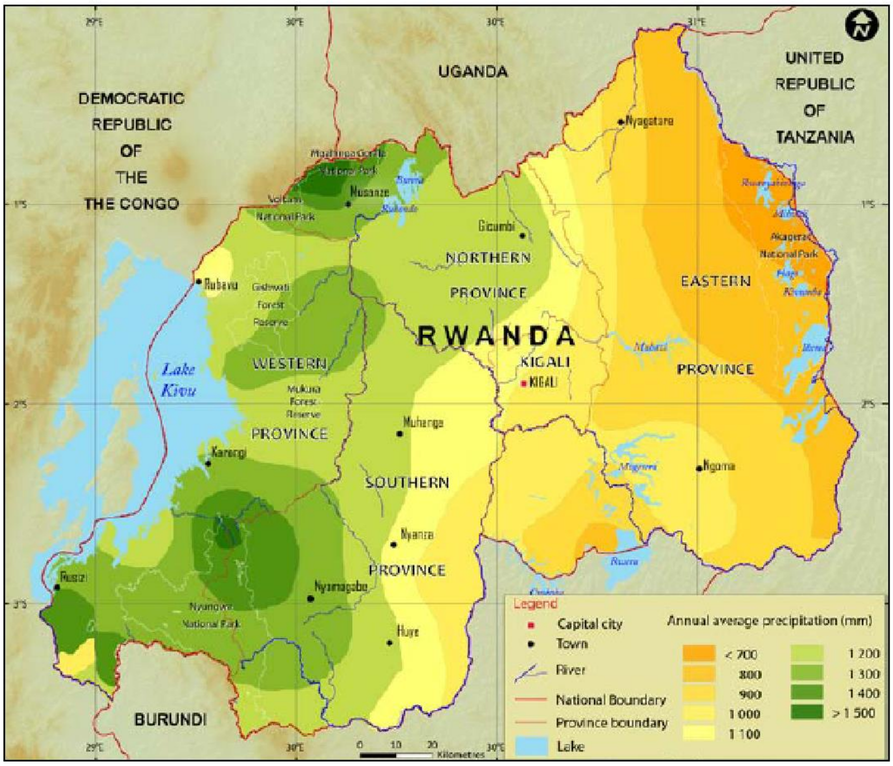
1.1.1.1.3 PRECIPITATION

Rwanda is entirely situated within the equatorial zone, but it enjoys a moderate tropical climate due to its high altitude, which ranges from 900 m to 4,500 m above mean sea level (AMSL). There are two rainy seasons, a short one in October and November and a longer one from February to May. The rainfall classification for the catchment is depicted in **Figure 2-8**.

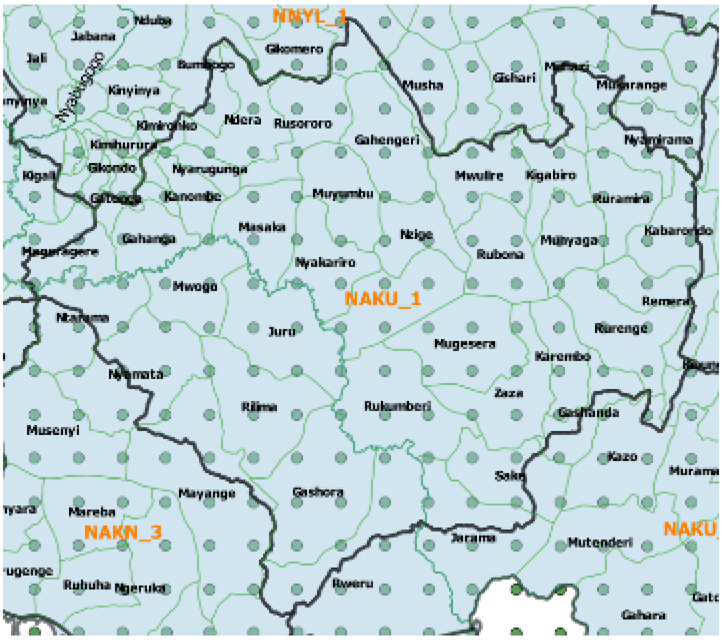
The precipitation data sets have been evaluated by using two-products generated by Meteo Rwanda:

- ❖ Station based measurements (at monthly scale) represent long-term trends in precipitation
- ❖ Grid based data sets (at monthly scale) represent spatial changes in precipitation within Level-1 catchment. The grid data sets are specifically important to evaluate the impacts of geographical conditions on the amount of rainfall.

Both of these data sets have been evaluated to understand the changes in precipitation at respective points (using station based data sets) and within the level-1 catchment (using grid based data sets). The impacts of climate change on the precipitation trends are documented in **Annexure A**.

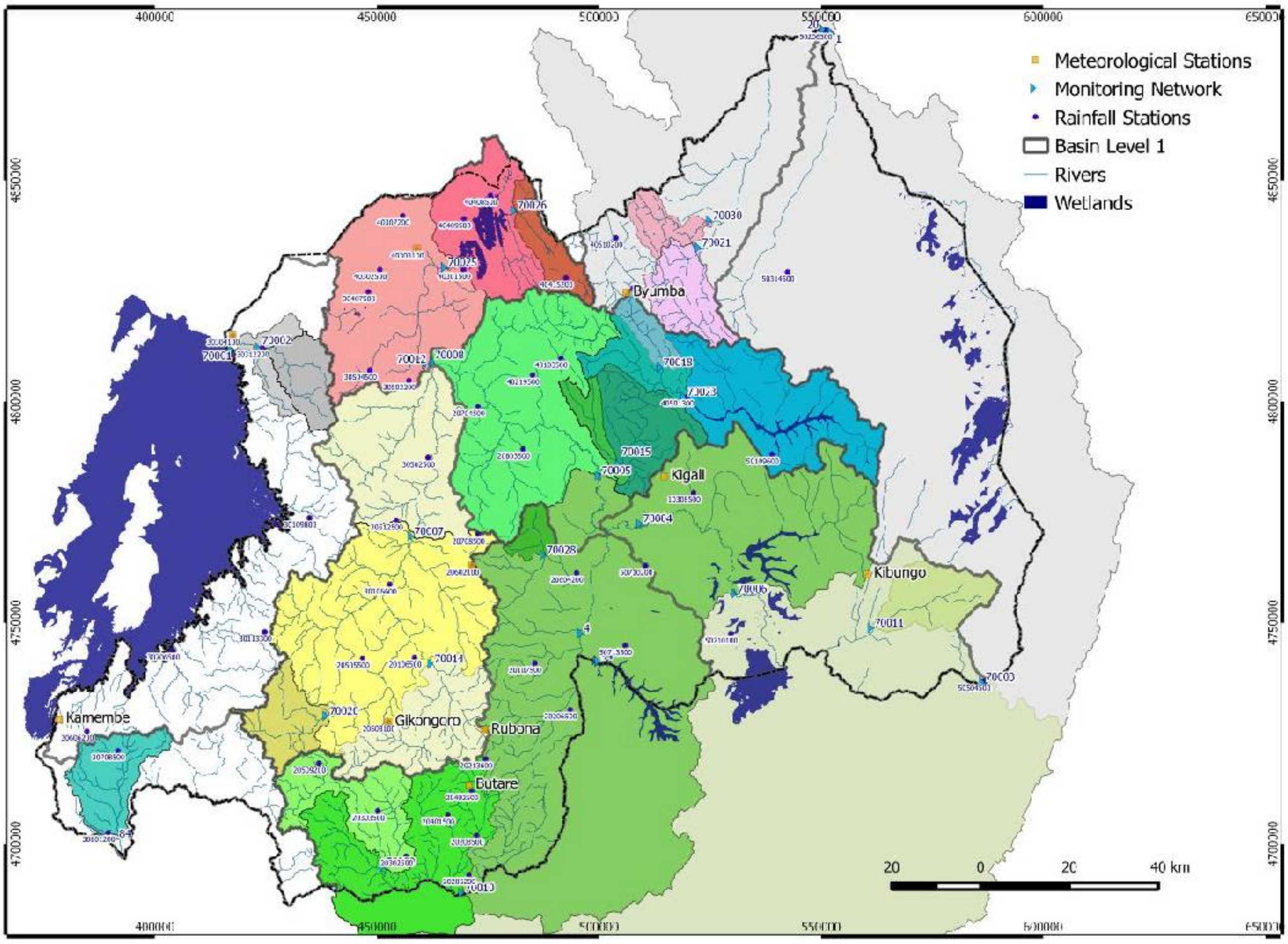


FUGURE 2- 23 ANNUAL AVERAGE PRECIPITATION AT NATIONAL SCALE (SOURCE: REMA, 2015)



FUGURE 2- 24 LOCATION OF GRID POINTS IN THE CATCHMENT

The rainfall monitoring network of Meteo Rwanda comprises sites 112 sites with records. Rwanda Natural Resources Authority (RNRA) needs climate data for IWRM and has requested meteorological data consisting of rainfall, temperature and relative humidity. A dataset of 56 selected active stations (marked in light blue), as documented in the National Water Resources Master Plan (RNRA, 2014) is depicted in **Figure 2-10**. These stations are distributed in such a way that about 3 stations exist per basin within Level 2 catchment scale, evenly distributed to estimate the distribution of rainfall. All altitude ranges are covered and care was taken to have stations in high mountain areas to capture rainfall events there. The territory of Rwanda is evenly covered.



FUGURE 2- 25 RAINFALL STATION NETWORK (SOURCE: NATIONAL WATER RESOURCES MASTER PLAN, 2014)

1.2.1.4 SURFACE WATER RESOURCES

Hydrologic Model

The rainfall-runoff transformation was developed through use of Soil Moisture Model. The model parameters are explained in detail in **Annexure C**.

The main outcome is the surface run-off values along the Akagera Upper catchment.

In order to ensure representativeness of the outcomes, the stream network as defined below was used as the basis of calibration.

Stream Network

In order to represent the spatial variation of surface water resources it is important to understand the hydrologic/hydraulic characterization and associated gauge stages reflecting the water availability within the river basin system. The schematic and basic features of the stream network is defined in below Figure 2-11 and Table 2-3, respectively.

The inlet to the Akagera Upper catchment is defined by:

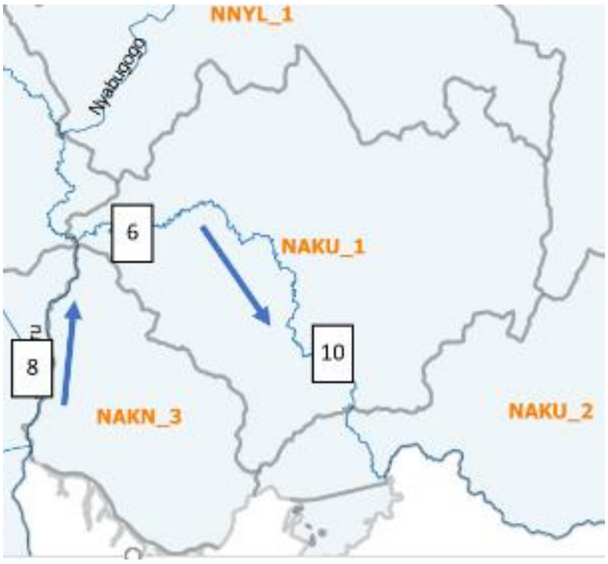
- The inlet to the Akagera Upper catchment is represented by the gauge at Location No. 6 (Gauge No. 259501).
- This gauge data was also evaluated in the context of incoming flows from two upstream catchments, namely Akanyaru and Lower Nyabarongo.
- The contribution of Akanyaru was evaluated by using the National Water Master Plan report. This reference document was used due to the fact that gauge at Location No. 8 (Gauge No. 265701) is significantly upstream of its junction with the Akagera Upper catchment. Therefore, gauge-driven findings cannot represent the surface water potential accurately.

The main lateral mechanisms are wetland systems, which result in "losses" from the river system in the context of storage within the wetland segments of the river system.

The outlet from the Akagera Upper catchment is defined by the gauge at Location No. 10 (Gauge No. 255501 - Mfune). The outcome of the simulation driven by the Hydrologic model and the gauge reading driven by the Rating curve resulted in the outcome shown in Figure 2-12. The maximum difference between simulation and gauged data sets 0.5% (in August).

It is important to note that the outlet at this location account for the storage within the wetland system, and as such gauged flow at the inlet (as measured by Gauge No. 259501) is higher than the gauged flow at the outlet (as measured by 255501), as shown in Figure 2-13.

It is important to note that RWFA is recording stage (water-surface elevation) at respective gauge locations and monitoring associated flow volume using set stage-discharge rating curves. Therefore, by using the stage data as recorded in the Rwanda Water Portal (https://waterportal.rwfa.rw/data/water_level), Table 2-3 and associated rating curves Table 2-4, flow volumes are compared to the outcomes of the flow volume calculated using the rainfall-runoff process.



FUGURE 2- 26 LOCATION OF THE STREAM NETWORK ALONG THE AKAGERA UPPER CATCHMENT

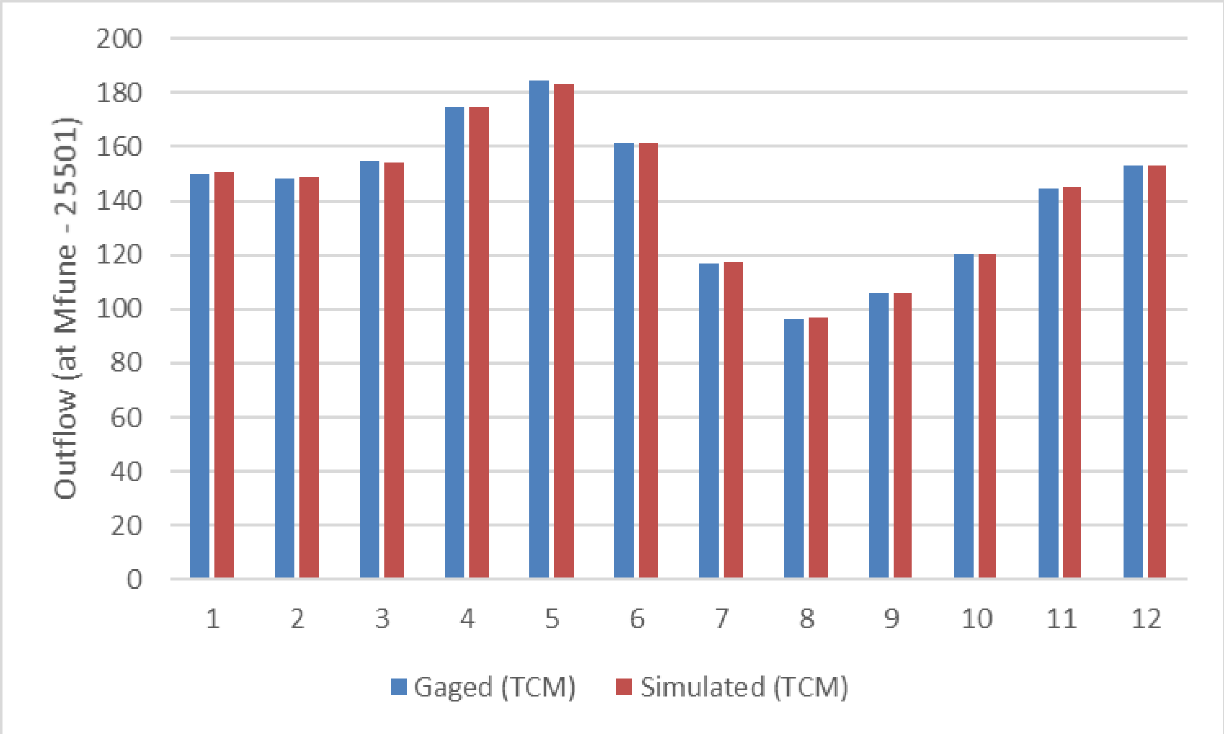
TABLE 2- 2 BASIC FEATURES OF THE STREAM NETWORK ALONG THE AKAGERA UPPER CATCHMENT

Location No	Stage No	Location Name	Period	Remarks
6	259501	Kanzenze	1955-08-18 / 1995-03-28	Inlet of NAKU_1
6_2			1971-03-07 - 2015-02-04	
8	265701	Gihinga	1974-01-01 / 2013-12-31	Within NAKN
10	255501	Mfune	1971-01-01 / 2013-12-17	Outlet of NAKU_1
		Rusumo		Outlet of NAKU_2

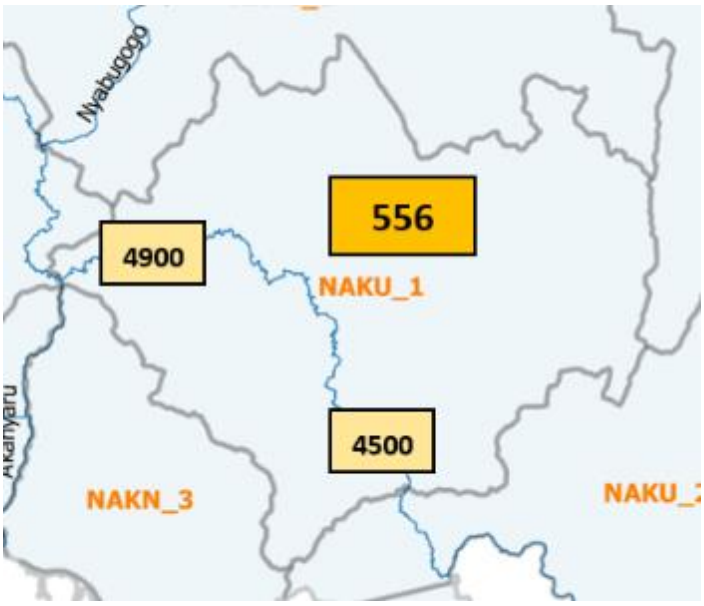
The rating curves are presented in the form **Q = a (b + H)^c.** The specific coefficients at respective locations are listed in Table 2-4.

TABLE 2- 3 RATING CURVE COEFFICIENTS FOR STREAM GAUGES

No	Stage No	Location Name	a	b	c
6	259501	Kanzenze	0.793324	2.70411	3.06893
8	265701	Gihinga			
9	70010	Route Butare-Ngozi	8.185	0.526	2.8
10	255501	Mfune	0.325845	3.63344	3.19893



FUGURE 2- 27 WATER AVAILABILITY AT MFUNE: GAUGED VS SIMULATED



FUGURE 2- 28 EXISTING WATER BALANCE IN AKAGERA UPPER CATCHMENT (TCM)

The corresponding surface water potential is documented in Table 2-5, which represents an approximate volume of 357,375 TCM within the Akagera Upper catchment. This data represents existing conditions by using the reference period of the respective gage record.

TABLE 2- 4 SURFACE WATER POTENTIAL OF SUB-CATCHMENTS

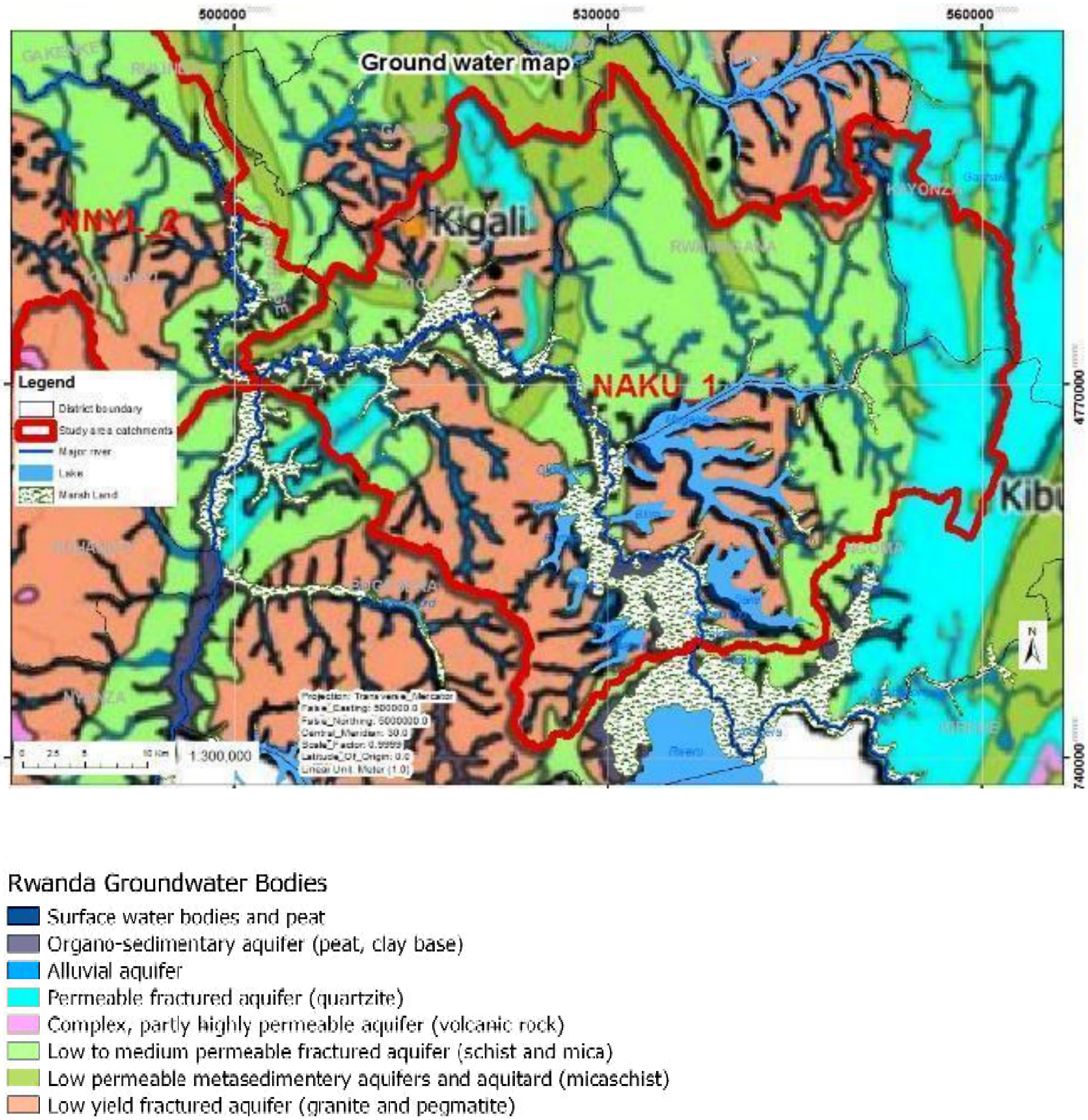
Months	Flow (TCM) for existing conditions in Sub-catchments						
	Sub-catchment 1	Sub-catchment 2	Sub-catchment 3	Sub-catchment 4	Sub-catchment 5	Sub-catchment 6	Sub-catchment 7	Total NAKU
January	9,719	3,819	14,397	6,917	1,587	3,566	1,268	41,273
February	8,118	2,902	11,120	5,125	1,555	3,494	1,243	33,558
Match	8,533	2,343	9,188	4,624	2,539	5,706	2,029	34,962
April	14,213	4,874	19,127	9,374	3,827	8,601	3,059	63,074
May	13,711	5,642	21,078	9,259	2,451	5,509	1,960	59,610
June	2,524	1,070	4,077	1,813	259	583	207	10,533
July	1,650	693	2,654	1,176	85	191	68	6,517
August	1,520	526	1,875	778	280	629	224	5,832
September	1,422	168	731	667	545	,224	435	5,192
October	3,455	493	1,906	1,335	1,277	2,871	1,021	12,358
November	9,410	3,026	12,243	7,076	2,087	4,691	1,668	40,200
December	10,923	3,997	15,372	6,960	1,733	3,895	1,385	44,265
Total	85,198	29,553	113,769	55,103	18,224	40,960	14,569	357,375

1.2.1.5 GROUNDWATER SUBCATCHMENT

Surface basins are defined by topography (DEMs) and associated hydrology. On the other hand; groundwater basins, are defined through use of lithology, geology, aquifer properties and hydro-meteorological characteristics.

The Akagera Upper Catchment is sub-divided into the quartzite aquifers (headwaters, light blue), **Figure 2-14**, the schist-aquifers (green) and alluvial aquifers with an organic matrix. The quartzite aquifer has intermediate storage and provides access to groundwater. The central part of the basin is dominated by schist with low storage. The alluvial aquifers mainly have an organic matrix – their use for groundwater abstraction is difficult due to water quality issues (low oxygen content, mobility of metals). The alluvial aquifer acts as an important storage of water for the catchments downstream.

Groundwater bodies as delineated by the surface-water catchment, through use of these aquifer properties (i.e. distribution of hydraulic conductivity) is depicted in **Figure 2-14**.



FUGURE 2- 29 AQUIFERS IN THE AKAGERA UPPER CATCHMENT (SOURCE: RNRA, 2014)

The different aquifer types have very distinct properties.

- Alluvial aquifers are shallow (10 to 50 meters), very permeable, highly conductive and therefore very vulnerable. They store small amounts of water are usually well connected to streams and rivers. They are good exploration targets, over abstraction may have negative impact on stream ecology, aquifer structure (peat decomposition). In general, these aquifers are very vulnerable and need to be managed well in terms of quality and quantity as their storage is limited.
- Permeable fracture aquifers are found mainly in the eastern part of the country. These are quartzite bearing rock. They can be highly permeable, have low storage and have a good to sufficient recharge. The combination of high permeability and low storage can be a problem in terms of wells running dry during the summer season. In general, these aquifers can be targeted

for sustainable groundwater management, but recharge needs to be assessed and water levels monitored during abstraction. It is very interesting to note, that quartzite bands cross level 1 surface basins and induce an inter-basin transfer from Upper Akagera (NAKU) to Lower Akagera (NAKL).

It is important to note that there are two main sources characterizing groundwater resources:

- "Baseline Study on Water Users and Water Uses in Level 2 Catchments in Rwanda", by Niras (2017), and
- "State of Environment and Outlook" Report, by the Rwanda Environment Management Authority (2015).

Niras report (2017) provides data sets at specific wells surveyed within level 2 catchments. The wells within Akagera Upper catchment is unrepresentative of the catchment-scale conditions (specifically middle and lower parts). In this context, REMA report (2015), with a larger-scale information is also used to evaluate catchment scale conditions at a macro level: The location of these wells is displayed in Figure 2-15, and Table 2-6 indicates the basic characteristics of groundwater at borehole locations (Source: REMA, 2015).

In the context of these two reference documents the main outcomes include

- Data sets presented in the Niras report characterize the groundwater conditions within the Akagera Upper Catchment adequately.
- To get the groundwater potential of level 2.5 we need to disintegrate the data. Figure 2-16 shows that groundwater yield within the Akagera Upper Catchment is between 2,6 to 5,0 l/s/km^2. The steps of estimating the groundwater potential for level is shown in the Tables below.
    - Step 1: Validation of groundwater potential at Level-2 catchment scale by referencing the main aquifer characteristics (yield in l/s/km^2) and groundwater potential (hm^3) presented in the REMA report at Level-1 catchment scale, as shown below:

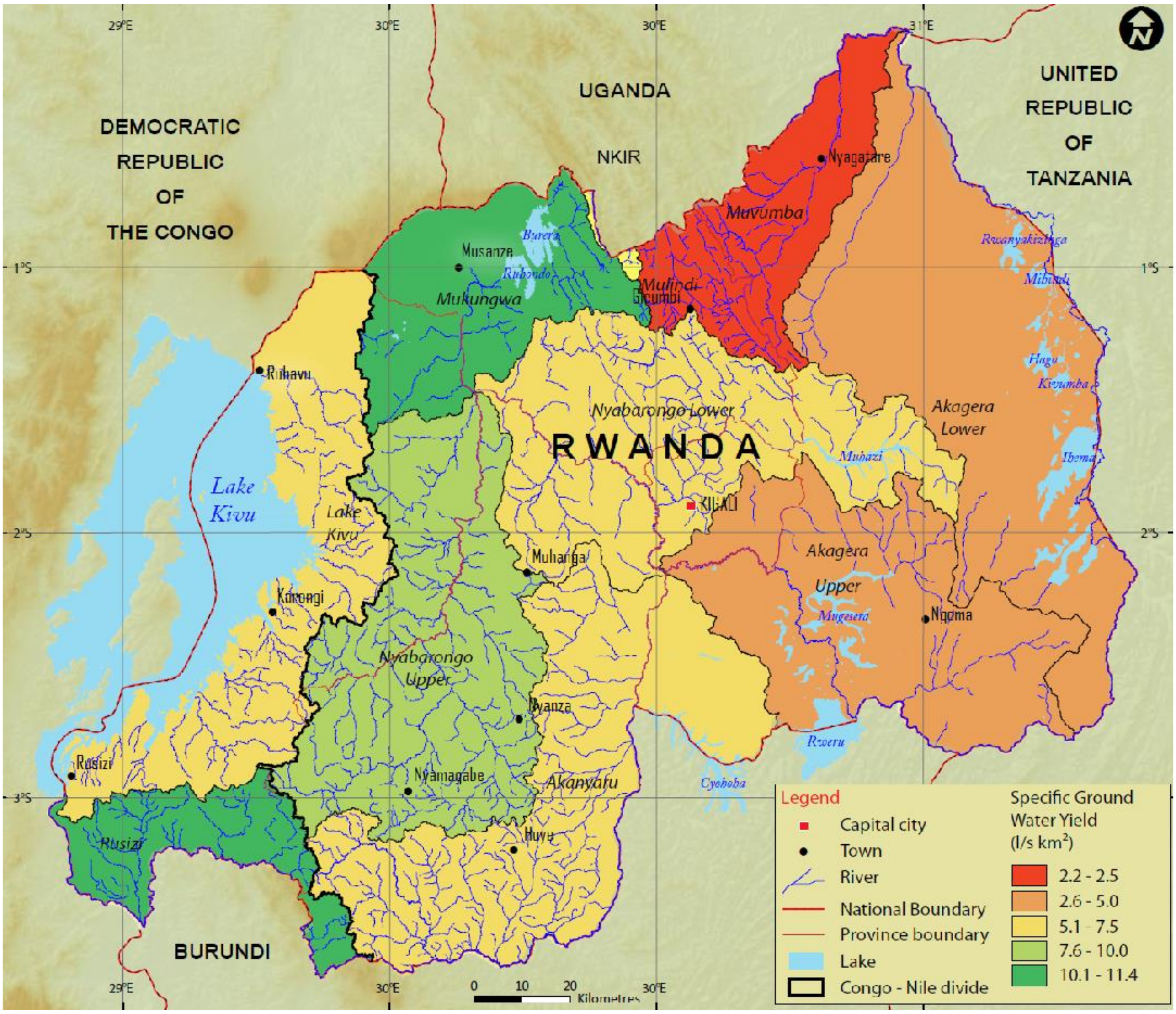
TABLE 2- 5 GROUNDWATER POTENTIAL FOR NAKU CATCHMENT

Level-1 Catchment	GW Potential (hm3)	Area (km2)	Yield (l/s/km2)		Level-2 Catchment	Area (km2)	Yield (l/s/km2)	GW Potential (hm3)
NAKU	351.1	3056	3.7					
					NAKU-1	1888	3.7	217.3
					NAKU-2	1168	3.7	134.4
					TOTAL			**351.7**

- Step 2: Evaluation of groundwater potential (hm3), within respective sub-catchments at Level-2 catchment scale, as shown below:

TABLE 2- 6 GROUNDWATER POTENTIAL FOR 2.5 LEVEL CATCHMENT

Sub-catchment	Area km sq	Groundwater potential (hm3)
1	489.838	56.5
2	216.663	25.0
3	795.560	91.8
4	385.828	44.5
5	288.571	33.3
6	648.604	74.8
7	230.695	26.6
		352.5



FUGURE 2- 30 GROUNDWATER YIELD IN RWANDA GROUNDWATER YIELD IN RWANDA (SOURCE: REMA, 2015)

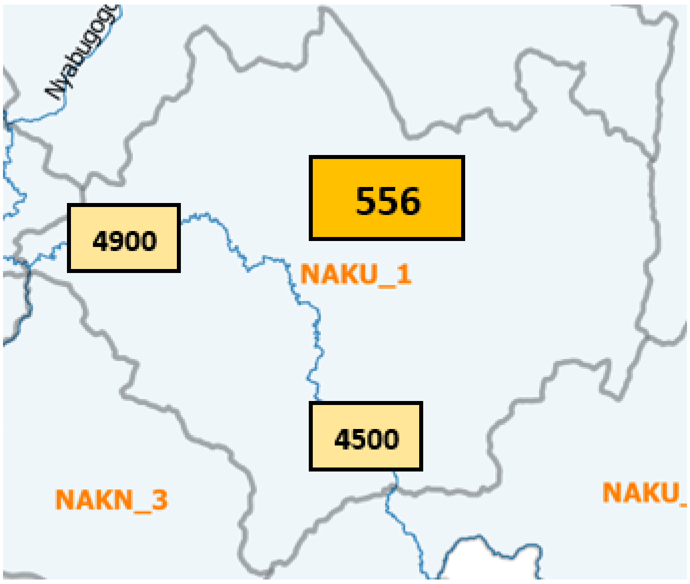
TABLE 2- 7 BASIC CHARACTERISTICS OF GROUNDWATER AT BOREHOLE LOCATIONS (SOURCE: REMA, 2015)

Location	ID	X	Y	Z	Project (Completion date)	Total Depth (m)	Screen (m)	Static Level (m)	Casing Dia. (m)	Disch. (l/min)
27	Nyarugenge /Mageragere / Nyabire	506,829	4,772,814	1,346	4/18/2008	35m	45-33m	2	127	35
56	Rwamagana/Gahengeri/Kiruruma/R	532,835	4,782,354	1,411	1/17/2011	19 m	17.5-19m	3	125	180
70	Bugesera /Mwogo/Rurenge	513,057	4,768,092	1,346	7/17/2008	35m	23-35m	4	127	20
71	Kicukiro /Gahanga/ Gashubi Village	514,732	4,774,980	1,348	8/18/2008	15m		4	127	120
84	Gasabo/Ndera/Kira/Kibenga	520,169	4,786,794	1,162	3/16/2011	36 m	30-36m	4	125	80
107	Gasabo / Ndera / Rudashe/Nyakage	520,363	4,782,494	1,364	12/13/2011	20 m	11-17m	5	125	117
120	Kicukiro / Gahanga/Rukore Village	511,788	4,773,707	1,349		20m	14-20m	6	127	30
148	Nyarugenge /Mageragere/ Mataba	508,678	4,772,861	1,351	3/22/2008	35m	53-23m	7	127	30
149	Nyarugenge /Mageragere/Nunga/N	509,726	4,773,175	1,337	4/16/2008	40m	28-40m	7	127	20
155	Rwamagana/Muyumbu/Akinyambo	527,077	4,783,697	1,342	1/14/2011	40 m	34-40m	7	125	85
212	Rwamagana/Gahengeri/Kamurindi/	529,955	4,784,599	1,128	1/17/2011	50 m	44-50m	10	125	120
228	Bugesera /Mwogo/Rukore	511,788	4,773,707	1,349		24 m	18-24 m	12	100	60
233	Rwamagana/Gahengeri/Karambo/R	531,464	4,787,081	1,130	3/15/2011	40 m	34-40m	12	125	165
243	Gasabo/imena village	515,344	4,785,189	1,405	1/24/2008	21m	9-21m	13	125	23
246	Gasabo/Amariza village	515,333	4,784,767	1,403	1/22/2008	24m	12-24m	14	100	37
247	Kicukiro/ Gahanga /Rugando I	515,197	4,775,859	1,351	8/18/2008	100m		14	127	35
249	Kicukiro /Kagarama/Nyacyonga	512,172	4,779,068	1,430	12/14/2009	71m	65-71m	14	150	45
254	Kicukiro / Gahanga/Nyabigugu Villag	511,524	4,773,744	1,355		20m	14-20m	15	127	25
261	Gasabo/Ndera/Akamusare/Mukuyu	521,183	4,787,792	1,433	3/16/2011	33 m	21-33m	15	125	50
272	Gasabo/Hope Heaven	523,076	4,782,883	1,428		41		15	100	33
276	Nyarugenge /Mageragere/Runzenze	502,651	4,771,883	1,365	3/31/2008	30m	18-30m	16	127	35
283	Kicukiro / Kanombe/Nyarugugu Vill	515,014	4,777,800	1,340	8/21/2008	45m		17	127	25
287	Nyarugenge /Mgeragere/Mataba /	507,616	4,772,891	1,358	2/21/2008	40m	40-28m	18	127	100
288	Nyarugenge /Mageragere/Mataba	508,515	4,772,898	1,365	2/13/2008	43m	43-23m	18	127	22
302	Nyarugenge/Mageragere/Mataba/	508,482	4,775,449	1,414	2/17/2008	40m	40-28m	20	127	18
305	Gasabo/Ndera / Cyaruzige/Gisura	520,766	4,786,755	1,476	3/16/2011	60 m	49-59m	20	125	17
306	Gasabo / Ndera / Kibenga/Cyira I	520,538	4,785,404	1,385	12/14/2011	50 m	36-48m	20	125	67
317	Gasabo / Ndera / Cyaruzinge/Karub	520,400	4,783,751	1,382	12/13/2011	70 m	55-67m	21	125	33
322	Kicukiro / Kanombe/Rubirizi/Zirakar	515,057	4,779,886	1,375	5/26/2008	45m	33-45m	23	127	25
325	Kicukiro /Nyarugunga/Kavumu	517,245	4,783,118	1,410	1/18/2008	45m	33-45m	24	127	20
326	Kicukiro/Kanombe/Hope village	516,682	4,777,613	1,366	8/21/2008	120m		24	127	12
327	Kicukiro/Kanambe/Kariyeri site	516,682	4,777,613	1,366	8/21/2008	120m		24	127	12
332	Nyarugenge /Mataba cell /Runzenz	503,597	4,772,112	1,375	3/31/2008	75m	57-75m	25	127	20
334	Gasabo / Ndera / Runyonza/Rugazi	519,444	4,786,136	1,421	12/13/2011	55 m	41-55m	25	125	50
338	Kicukiro /NyaruguguI Village	515,829	4,776,852	1,362	8/21/2008	150m		26	127	12
343	BUGESERA/NTARAMA S.S	507,508	4,766,626	1,405	7/25/2011	100 m	85m - 97m	28	125	50
345	Kicukiro/ Kanombe /Hope village	515,448	4,777,306	1,380	5/19/2008	110m	92-100m	29	127	120
350	Kicukiro/Masaka/star s/Murambi	523,001	4,779,958	1,380		69 m	63-69m	30	125	83.33
351	Rwamagana/Gahengeri/Nyamugari	530,722	4,784,455	1,393	1/17/2011	70 m	52-70m	30	125	67
353	Nyarugenge /Mageragere/Mataba	505,705	4,773,346	1,383		80m	64-80m	31	127	45
354	Nyarugenge /Mageragere/Nyarurer	506,201	4,773,250	1,379		60m	48-60m	31	127	30
356	Kicukiro/ Masaka/HopeVillage/Ayal	524,583	4,779,173	1,529	8/20/2010	98 m		32	125	50
358	Bugesera /Mwogo/Rwankoronko	517,709	4,771,077	1,343	7/17/2008	95 m	83-95m	34	127	45
374	Rwamagana/Gahengeri/Kabigondo,	531,061	4,783,606	1,425	1/28/2011	110 m	104-110m	45	125	85
378	Gasabo/Rusororo/Nyarutundura, N	524,230	4,781,031	1,418		125 m	110-125m	48	125	20
379	Nyarugenge /Mageragere/Mataba	507,740	4,773,409	1,385	2/22/2008	110m	110-92m	50	127	15
390	Gasabo / Ndera / Kibenga/CyiraII	519,944	4,786,090	1,425	12/14/2011	80 m	65-77m	60	125	67
401	Rwamagana/Gahengeri/Nyamugari	531,625	4,784,332	1,475	5/23/2011	110 m	95-107m	80	100	60

1.2.1.6 WATER AVAILABILITY

The water availability was evaluated for both existing and future conditions.

- The hydrologic and hydraulic setting used in development of existing conditions water availability was explained in detail in Section 2.3.1.1 The outcomes by considering the inflows and outflow are shown in Figure 2-17. The existing conditions surface water potential is approximately 556 hm^3
- The existing conditions for groundwater potential is approximately 216,5 hm^3
- Therefore, total existing water resources potential is approximately 772,5 hm^3.



FUGURE 2- 31 EXISTING WATER BALANCE IN AKAGERA UPPER CATCHMENT (TCM)

The future conditions water availability is evaluated by considering two different climate scenarios, i.e. two different Representative Concentration Pathways (RCP) as agreed by the IPCC agreement, namely RCP 4.5 and RCP 8.5. The corresponding surface water resources are summarized in Table 2-7.

TABLE 2- 8 FUTURE CONDITIONS WATER AVAILABILITY IN AKAGERA UPPER CATCHMENT

Year	Scenario	Sub-catchment-1	Sub-catchment-2	Sub-catchment-3	Sub-catchment-4	Sub-catchment-5	Sub-catchment-6	Sub-catchment-7	Total
2020		92,780,623	33,072,489	127,792,316	63,614,225	19,599,177	44,051,912	15,668,352	396,579,094
2025	RCP 4.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
	RCP 8.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
2030	RCP 4.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
	RCP 8.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
2035	RCP 4.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
	RCP 8.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
2040	RCP 4.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
	RCP 8.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514

2045	RCP 4.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
	RCP 8.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
2050	RCP 4.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514
	RCP 8.5	84,944,869	29,435,177	113,300,403	54,818,668	18,176,659	40,854,603	14,531,136	356,061,514

It is important to note that groundwater flow is a much slower process and the impact of climate change will have a much slower impact on the potential of groundwater resources. Therefore, it is estimated that groundwater potential will remain the same within the Akagera Upper catchment.

1.2.2 WETLANDS

Across current environmental policies, laws and other strategic documents in Rwanda, wetlands are referred to as “marshlands”, “swamps” and “wetlands” interchangeably. For this document, the over-arching term “wetland” is preferred. Importantly, wetland areas that are under cultivation i.e. the natural wetland plants have been cleared away and replaced by crops, are still considered to meet the definition of wetland if the wetland hydrological regime is in place.

1.2.2.1 MANAGEMENT OF WETLANDS

There are five primary national institutions involved in wetland protection and management. These include the Ministry of Environment (MINE) and Rwanda Environment Management Authority (REMA) for the protection and sustainable use of wetlands; and the Ministry of Agriculture and Animal Resources (MINAGRI) and Rwanda Agriculture Board (RAB) which are concerned with wetland development for agricultural use and Rwanda Development Board (RDB) for wetlands declared as protected status.

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1.2.2.2 WETLANDS OF THE CATCHMENT

According to the IMCE National Wetland Inventory (2009) there are 74 wetlands covering an area of 39 569 ha in the Akagera Upper Catchment. Of these there are currently no wetlands which are formally protected i.e. protected within a National Park, but 24 are proposed for Ramsar status. Most of these are part of or connected to the Gashora-Mugesera-Rweru wetland complex.

All the wetlands have been assigned a status, and a list, Table 2-8, of the country’s wetlands and their status was formally gazetted in 2017 (No. 07 of 13/02/2017). **Figure 2-18** indicates the location of all the wetlands and their use within the Akagera Upper Catchment. According to the inventory, only 2,554 ha (6.5%) is still natural. Five of the wetlands have conditions of total protection, i.e. there should be no cultivation. The majority of wetlands within the catchment can be used with conditions, a basic Environmental Impact Assessment (EIA) is required before use can be permitted.

TABLE 2- 9 OVERVIEW OF WETLANDS IN THE AKAGERA UPPER CATCHMENT

Name	Wetland use	Importance	Ramsar Protection	Utilisation status	Natural (ha)	Area (ha)
Cyaruhogo	Cultivated	National		Use with conditions	22	192,10
Cyibumba	Cultivated	National		Use with conditions	5	445,39
Cyimpima	Cultivated	National		Use with conditions	0	113,23
Gashanga	Natural	National	Proposed Ramsar	Use with conditions	100	66,00
Gashonyi-Nkungu-Mwambu	Natural	National		Use with conditions	100	39,23

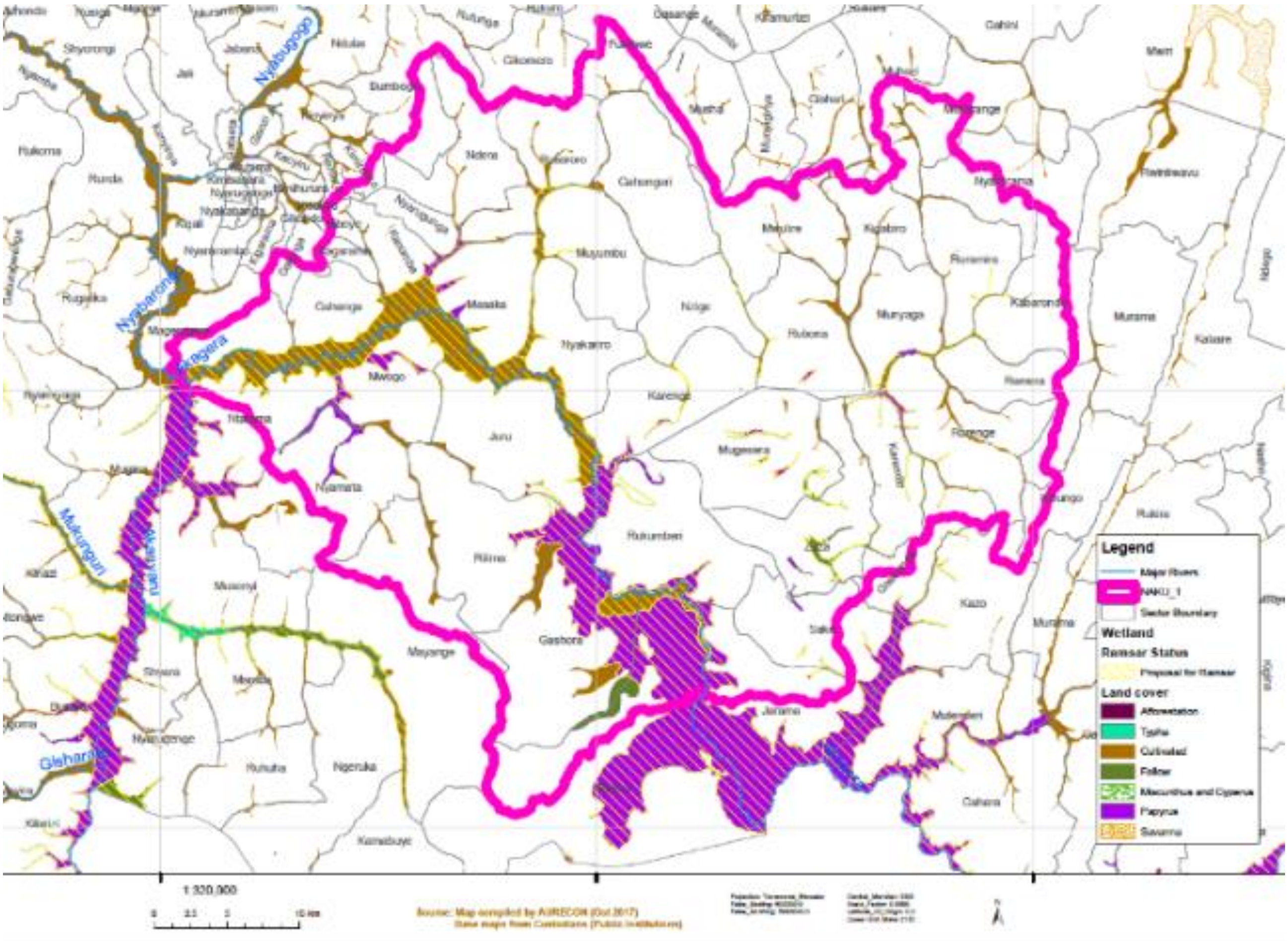
Gashonyi-Nkungu	Cultivated	National	Proposed Ramsar	Use with conditions	31	300,64
Gatare 2	Natural	National	Proposed Ramsar	Use with conditions	72	28,71
Gikono	Cultivated	National		Use with conditions	0	151,38
Gisaya-Rusebeya	Natural	National	Proposed Ramsar	Use with conditions	50	370,38
Gitinda	Cultivated	National		Use with conditions	0	36,80
Kabarali	Natural	National	Proposed Ramsar	Use with conditions	67	235,01
Kadigadiga	Cultivated	National		Use with conditions	0	51,06
Kagomora	Natural	Local		Use with conditions	75	31,99
Kamiranzovu Cyaruhogo	Cultivated	National		Use with conditions	0	85,29
Kanyamwili	Natural	National	Proposed Ramsar	Use with conditions	83	42,50
Kanyetabi	Natural	Local		Use with conditions	100	45,42
Kazanyi	Cultivated	National		Use without conditions	0	14,36
Kidogo-Gaseke	Natural	National	Proposed Ramsar	Use with conditions	100	137,64
Kinugwe	Natural	National		Use with conditions	72	28,55
Kiradiha	Cultivated	Local		Use without conditions	0	42,40
Kitaguzirwa	Natural	National	Proposed Ramsar	Use with conditions	74	290,28
Kiyogoma	Cultivated	Local		Use without conditions	0	36,42
Lake Mugesera	Natural	National		Use with conditions	100	99,07
Mbuganzera	Mix of natural and cultivated	National		Use with conditions	0	399,26
Mubwiba Gashonyi Nkungu	Cultivated	National		Use with conditions	0	33,67
Mugakingo-Mugakindo	Mix of natural and cultivated	National	Proposed Ramsar	Use with conditions	40	49,86

Mugarengwa Mugatengwa	Cultivated	National		Use without conditions	0	62,61
Muhuguka - Nyakagazi	Cultivated	National		Use with conditions	0	187,27
Mulindi-Kanombe	Cultivated	National		Use with conditions	0	121,52
Murugando	Cultivated	National		Use without conditions	0	53,72
Mutembo	Natural	National	Proposed Ramsar	Use with conditions	100	63,74
Muzi	Natural	National		Use with conditions	73	131,73
Muzi 2	Natural	National		Use with conditions	61	212,12
Mwesa-Mweza	Cultivated	National		Use with conditions	14	166,90
Ndabukiye	Cultivated	National		Use with conditions	0	186,45
Ndarago-Ndarage	Cultivated	National		Use without conditions	18	1,43
Nyabarongo-Akagera	Natural	National	Proposed Ramsar	Use with conditions	100	209,29
Bilira downstream	Natural	National		Total protection	100	28,29
Nyabuhoro - Kiruhura	Cultivated	National		Use with conditions	0	27,32
Nyagasenyi	Cultivated	Local		Use without conditions	0	1,32
Nyagashanga	Cultivated	National		Use with conditions	0	45,00
Nyagatare-Cyaruhogo-CODERVAM	Cultivated	National		Use with conditions	0	50,04
Nyagatovu	Cultivated	National	Proposed Ramsar	Use with conditions	11	121,89
Nyamugali-Kavogo	Mix of natural and cultivated	National	Proposed Ramsar	Use with conditions	45	238,69
Nyirabidili	Cultivated	National	Proposed Ramsar	Use with conditions	27	163,33
Nyirabihorwe	Mix of natural and cultivated	Local		Use without conditions	0	19,50

Nyiramagonde	Cultivated	National		Use with conditions	22	75,73
Rubilizi	Cultivated	National		Use with conditions	14	92,05
Bugugu-Gashara	Cultivated	National		Use with conditions	0	125,01
Rugende - Isumo	Cultivated	National	Proposed Ramsar	Use with conditions	22	583,67
Rugurube	Cultivated	National		Use with conditions	0	51,26
Rumira	Cultivated	National		Use with conditions	0	463,90
Ruramira	Cultivated	National		Use with conditions	0	131,63
Rwabashamana	Cultivated	National		Use with conditions	0	209,64
Rwakanuma-Gashonyi-Nkungu	Cultivated	Local		Use without conditions	0	38,55
Rwamugeni	Cultivated	National		Use with conditions	0	134,06
Rwamutara-Gashonyi-Nkungu	Cultivated	National		Use with conditions	0	22,47
Rwibumba-Mirenge	Mix of natural and cultivated	National	Proposed Ramsar	Use with conditions	41	51,82
Rwimbogo	Cultivated	National		Use with conditions	0	54,57
Lac Sake downstream	Natural	National	Proposed Ramsar	Total protection	100	158,72
Umushimba-Rusagara	Cultivated	National		Use with conditions	0	44,13
Rweru-Mugesera-Nyabarongo	Natural	Inter-National	Proposed Ramsar	Use with conditions	89	13601,28
Nyabarongo Downstream	Cultivated	National	Proposed Ramsar	Use with conditions	34	6198,85
Mwanana-Mulindi Kanombe	Cultivated	National		Use with conditions	0	243,92
Nyacyonge-Rubilizi-Nyacyonga	Cultivated	Local		Use with conditions	0	16,85

Ntovi (Village)_ Rukumberi	Cultivated	Local		Total protection	100	6,39
Nyagasozi (Village)	Natural	Local		Total protection	100	6,52
Nyabarongo downstream	Cultivated	National	Proposed Ramsar	Use with conditions	34	857,86
Ruhosha-Ayabaraya	Natural	Local		Use with conditions	100	48,87
Nyabarongo Upstream	Cultivated	National	Proposed Ramsar	Use with conditions	9	4849,38
Mugesera downstream	Natural	National	Proposed Ramsar	Total protection	100	796,83
Akanyaru North	Cultivated	Inter-National	Proposed Ramsar	Use with conditions	86	5146,40
Rwintare	Cultivated	National		Use with conditions	48	79,14
Nyakagezi	Cultivated	National	Proposed Ramsar	Use with conditions	15	20,57
				Total area (ha)	**2554**	**39568,86**

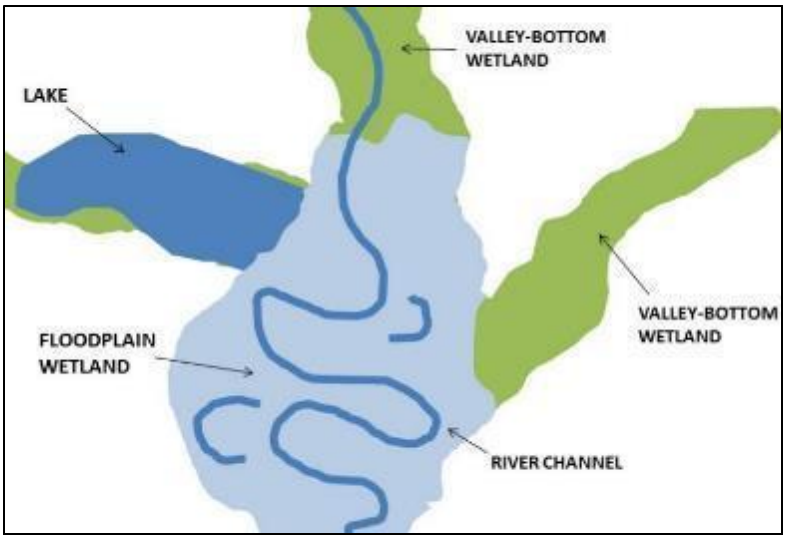
In some areas of the catchment wetland complex, intensive water use from flood rice production have affected the supply of freshwater from the lakes (UNEP, 2007). The Akagera floodplain has lost a high proportion of naturally dense vegetation through intensification of agricultural activities and drying up of streams (UNEP, 2007). The reduced vegetation density radically limits the floodplain’s natural ability to slow down and temporarily store floodwaters. Local people have expressed concern that the declining water levels in lakes and rivers will escalate if the proposed irrigation activities are implemented (UNEP, 2007). Alien invasive plant species, such as water hyacinth, waste discharge from Kigali, and sedimentation are all listed as problems in the catchment. The Akagera River carries a heavy sediment load (UNEP, 2007). Fischer (2016) further lists pressures on the wetlands from cultivation, cattle grazing, production of loam bricks, burning of papyrus, and cutting of plants for animal feeding and construction. Burning to clear weeds and develop ash for fertilizer is also frequently observed.



FUGURE 2- 32 WETLANDS AND THEIR USE WITHIN THE AKAGERA UPPER CATCHMENT (SOURCE: IMCE INVENTORY, 2009)

1.2.2.3 WETLAND TYPE

The broad aquatic ecosystem types present in the Akagera Upper Catchment, include features such as: rivers, lakes and wetlands, as illustrated in Figure 2-19. The wetlands of this catchment can be further grouped into two main functional wetland types, namely, floodplain wetlands, mostly associated with the Akagera River, and valley-bottom wetlands, which fill most of the smaller tributary valleys of the catchment. The Akagera River flows through this catchment within a broad valley floor reaching to 35 km wide in places, before it flows out of the catchment towards Akagera National Park. More information on these types of wetlands and their functions is discussed in the National Wetland Management Plan, 2017.

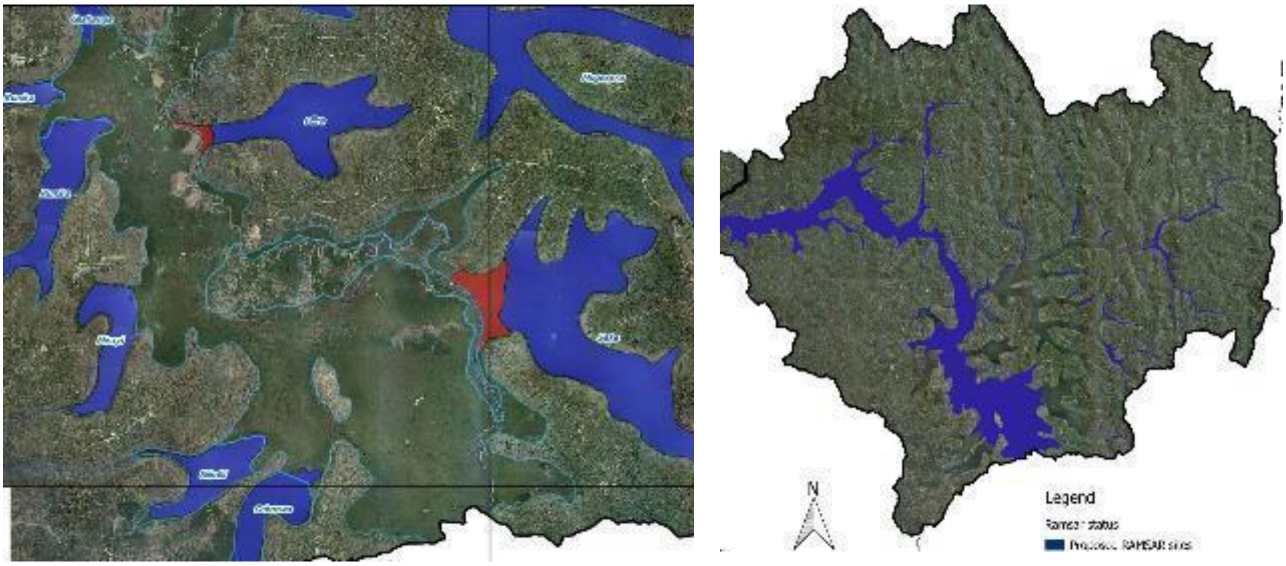


FUGURE 2- 33 MAJOR AQUATIC ECOSYSTEM TYPES IN THE AKAGERA UPPER CATCHMENT (SOURCE: JOBS, 2017)

The catchment is also rich in lakes, forming an interconnected mosaic of habitat in association with the Akagera River and floodplain wetlands, as well as the streams and wetlands which flow to the lakes from the broader catchment. This complex has been identified as the Gashora-Mugesera-Rweru wetland complex. The Gashora-Mugesera-Rweru complex includes several lakes along the eastern flank of the Akagera River floodplain, namely, Lake Mugesera, an un-named lake, Lake Bilira and Lake Sake. The lakes along the west bank include Lakes Gashaga, Murago, Rumira (Figure 2-20), Mirayi, Kilimbi, Gaharwa. Lake Mugesera is the largest (4 000 ha). None of the lakes are more than 5 m deep, with Mirayi noted to be 4 m and Rumira 3 m deep. Lake water levels are reported to rise quite significantly twice a year, fluctuating between 1 to 2 m, driven by the twice-yearly rain season peak flows, when tributary rivers flow towards the complex of wetland and lakes from the surrounding hills (Hughes, et al., 1992; Beuel, 2016). This increase flow is then stored in the lakes and slowly drains back to the mainstem river during dry months.

FUGURE 2- 34 VIEW OF LAKE RUMIRA

The Gashora-Mugesera-Rweru complex is driven by a strongly interdependent relationship of sediment and hydrology. The remaining lakes are arranged around the periphery of the wetland floodplain complex. They are hydrologically connected to the river via wetlands. The combination of dense vegetation and sediment deposition in the region of the outlet of the lakes constitutes a critically important area, understood to directly contribute to the origin and sustained functioning of the lake itself. The IMCE project (2009) reports that peat soils are frequently observed in these areas. This important barrier role was recognised by the IMCE researchers where it was proposed that these areas be afforded total protection, as illustrated in **Figure 2-21**.



FUGURE 2- 35 WETLANDS WITH TOTAL PROTECTION STATUS IN RED (LEFT), AND PROPOSED RAMSAR STATUS (RIGHT). (SOURCE: JOBS, 2017)

The overall extent of peat within these wetlands is unknown, it is potentially less extensive and layered with sandy substrate within the river alluvium, but more extensive at the outlets to lakes, while some areas of floating papyrus would support only a thin layer of peat. Very few indigenous trees remain along the edges of wetlands in this catchment, but in the past, seasonally wet areas may have included species such as *Bridelia micrantha*, *Ficus verruculosa*, *Myrica kandtiana* and *Phoenix reclinata*, with *Acacia polyacantha*, *Acacia seiberana*, and *Albiza gummifera* fringing the wetlands into the adjacent savanna (Hughes, et al., 1992).

2.3.1.2 THREAT TO WETLANDS

The Gashora-Mugesera-Rweru wetland complex is of specific concern, as the remaining natural wetland habitat it is under pressure for conversion to irrigated agriculture (Bugesera and Ngoma District Development Plans), while it is also listed as one of the country's most important wetland areas (REMA, 2010). This is due to its importance for ecosystem service support to people, ecological function (acting like a sponge holding water in the catchment to be released during dry periods and improving water quality) and biodiversity support, providing habitat to more than 16 vulnerable IUCN and CITES-listed species, listed in Table 2-9, including the endangered grey crowned crane, Figure 2-22. For these reasons, the wetland complex has been submitted to the Ramsar secretariat for Ramsar status consideration.

FUGURE 2- 36 IUCN ENDANGERED GREY CROWNED CRANE (SOURCE: IUCN)

TABLE 2- 10 LIST OF VULNERABLE SPECIES NOTED IN MUGESERA-RWERU WETLAND COMPLEX (SOURCE: IMCE, 2009)

Birds	*Balearica regulorum*	Grey crowned crane	Umusambi	IUCN: Endangered, CITES II
	Anhinga rufa	African darter	Umusovu	IUCN: Least Concern
	Circus macrourus	Pallid harrier		IUCN: Near Threatened
	Francolinus afer	Red-necked francolin	Inkware	IUCN: Least Concern
	Laniarius mufumbiri	Papyrus gonolek		IUCN: Near Threatened
	Water species	70 species		
	Migratory birds	19 species		
Mammals	*Hippopotamus amphibius*	Hippopotamus	Imvubu	CITES II IUCN: Vulnerable
	Tragelaphus spekii	Marshbuck	Inzobe	IUCN: Least Concern
	Aonyx capensis	African clawless otter	Igihura	CITES I & II IUCN: Near Threatened
	Leptailurus serval	Serval	Imondo	CITES II, IUCN: Least Concern
	Hydrictis maculicollis	Spotted-necked otter	Inzibyi	CITES II, IUCN: Near Threatened
	Cercopithecus aethiops	Grivet Monkey	Inkende	CITES II, IUCN: Least Concern

	Cercopithecus mitis	Blue monkey	Inkima	CITES II, IUCN: Least Concern
Reptiles	*Crocodylus niloticus*	Nile crocodile	Ingona	CITES I & II, IUCN: Least Concern
	Varanus niloticus	Nile monitor	Imburu	CITES II
	Python sebae	African rock python	Uruziramire	CITES II

The Mugesera-Rweru complex of lakes, river and wetland is known to support a high diversity of bird species as well as other wildlife. More than 173 birds have been identified, and 30 species of fish belonging to 9 families (Nsabagasani, 2009; IMCE, 2009), both based on transects conducted along the Akagera River as well as adjacent to Lake Sake. 28 plant species were noted, with *Vossia cuspidata*, and *Cyperus papyrus* dominant, while Fischer et al. (2016) later recorded 53 plants species. Populations of a rare plant species (*Pycnostachys dewildemaniana*) was noted to be present. In Rwanda, this species is said to be found only in the Mugesera-Rweru complex.138 bird species were noted in the greater lake-wetland complex, of which 6 are considered vulnerable by CITES and IUCN (Table 2-9). The wetland complex is one of very few remaining breeding areas in the country for grey crowned crane and has been identified by multiple conservation organisations as an area warranting conservation focus. The Papyrus Gonolek and the Papyrus Yellow Warbler are noted to be present and are IUCN listed. In addition, the *Laniarius mufumbiri* is restricted to dense papyrus and can be classified as a Victoria Lake Endemic (Fischer et al., 2016). This species is listed as near threatened due to destruction of its habitat. Mammals include the blue monkey *(Cercopithecus mitis)*, hippopotamus (*Hippopotamus amphibius*), sitatunga (*Tragelaphus spekii)* included as least concern by IUCN, other antelope species, two species of otter (*Aonyx capensis, Hydrictis maculicollis)* also recognized by IUCN, mongoose, genet, civet, and serval (Nsabagasani, 2009). The populations of large mammals, e.g. hippopotamus, are said to be considerably declining due to habitat destruction. Nsabagasani (2009) also listed 13 species of amphibians and 6 species of reptiles as well as numerous snakes. Of the four important wetland areas of the country surveyed by Fischer et al (2016), they consider this wetland complex to be the most endangered site, and they proposed that it be protected within a formal nature reserve.

Potential ecosystem services provided by the wetland complex are said to range from provisioning ecosystem services like water for domestic consumption and irrigation, to regulating ecosystem services such as buffering of stream flows, flood amelioration, sediment trapping, water purification, groundwater recharge, micro-climate stabilisation, and wildlife habitat (Nile Basin Transboundary Environmental Analysis, 2001). The future potential of pharmaceutical products and intrinsic benefits offered by cultural services (Nile Basin Transboundary Environmental Analysis, 2001). UNEP (2007) reports that many households obtain water from lakes. However, there is also a high prevalence of water and environmental related diseases. Due to low access to clean domestic water and sanitation, the prevalence of water borne (or water related) diseases such as diarrhoea, bilharzias, intestinal worms, malaria and skin diseases is high (UNEP, 2007). The wetlands are reportedly critical grazing areas during dry seasons, and, support food production during the dry season (UNEP, 2007). During drought and the driest months of June to October, wetland cultivation may become the main source of food. Lakes, rivers and streams are the main watering points for livestock watering, but there are increasing restrictions on use of natural water sources because livestock trample on and degrade river banks and lake shores.

1.2.2.4 WETLAND MANAGEMENT PROJECTS

The district development plans for the seven districts of this catchment were reviewed to see which wetland-related projects are underway and planned for the next few years. The Districts plan to develop wetlands for rice cultivation, and to expand fishing by increasing fishing ponds and organising management cooperatives fishing in Mugesera, Sake, Bilira Lakes (PAIGELAC project). Other ideas include investigation the feasibility of a palm oil factory and other by products, planting palm oil on all the edges of Bilira, Mugesera and Sake lakes and developing a papyrus paper factory. Bugesera district has plans of subdivision around lakes Sake and Bilira to promote tourism.

FUGURE 2- 37 LOCATION OF LVEMP II INTERVENTIONS WITHIN THE CATCHMENT

There are several ongoing wetland related projects being implemented by the member Districts of the Catchments. These are illustrated in Figure 2-23 and summarised in Table 2-10. The LVEMP II projects are discussed later in this report.

TABLE 2- 11 PROPOSED IMPLEMENTATION PROJECTS FOR BUGUSERA, NGOMA, RWAMAGANA AND KICUKIRO DISTRICTS, RWANDA

Outcomes, outputs, indicators, baseline and targets								
Agriculture - Bugesera								
Number of ha developed	Akagera (Gashora) marshland developed	1 422	2 1 72	250	250	250		
	new marshland to be irrigated	1000 ha of (Gashora Phase II)		500 ha (Muzi marshlands)	500 ha (Rurambi marshlands)			
Number of fish ponds	Fish ponds	5	16	4 (Gashora Phase I)	4 (Gashora Phase II)	1 (Rilima)	1 (Juru)	1 (Mareba)
Agriculture - Ngoma								
Ha of marshland developed	Developed marshland increased	1 228	1 888	1 388	1 588	1 788	1 788	1 888
Agriculture - Rwamagana								
Agriculture - Kicukiro								
None found								
Environment and natural resources - Ngoma								
Protect riverbanks and lake shores	River banks and lake shores protected	Plant bamboo and French Cameroon along river banks and Birira and Mugesera lakeshores				Protect Lake Rweru and Akagera swamp in Jarama Sector		
% of lake shore and river banks protected	River banks and lake shores protected	40	100	55	70	80	90	100
Environment and natural resources - Bugesera								
Number of staff trained about land laws and policies	Land laws and policies implemented	2	166	Training of District Land Office, Sector	Training of cell staff in all 15 sectors	-	-	-

				staff in all 15 sectors				
Number of meetings planned	Sensitise population about land laws and policies	0	30	Meetings in 3 sectors	Meetings in 3 sectors	Meetings in 3 sectors	Meetings in 3 sectors	Meetings in 3 sectors
Number of staff trained	Capacity building in GIS and land use planning	1	166	GIS equipment and bureau sector and cell level staff trained in 3 sectors	Staff trained in 3 sectors	Staff trained in 3 sectors	Staff trained in 3 sectors	Staff trained in 3 sectors
Number of people trained in environmental law	Environmental laws enforced	500	2000	300	300	300	300	300
Number of environmental committees and clubs supported	Environmental committees and clubs supported	0	105	3 sectors	6 sectors	9 sectors	12 sectors	15 sectors
	Bamboo planting on Akagera (Nyabarongo River)		125 ha					
	Removal of water hyacinth in lakes and river		500 ha					
Tree nursery, planting	Marshlands and rivers delineation and protection							
Environment and natural resources - Kicukiro								
None found								

1.3 HYDROLOGY OF NAKU CATCHMENT:

Once the temporal and spatial scales are defined, it will be important to evaluate specific components of the hydrologic cycle. The main components of the hydrological cycle, identifying the processes that are either inputs, such as precipitation, evaporation and air temperature, and those that are modelled, such as infiltration, transpiration, percolation, and surface runoff and groundwater water.

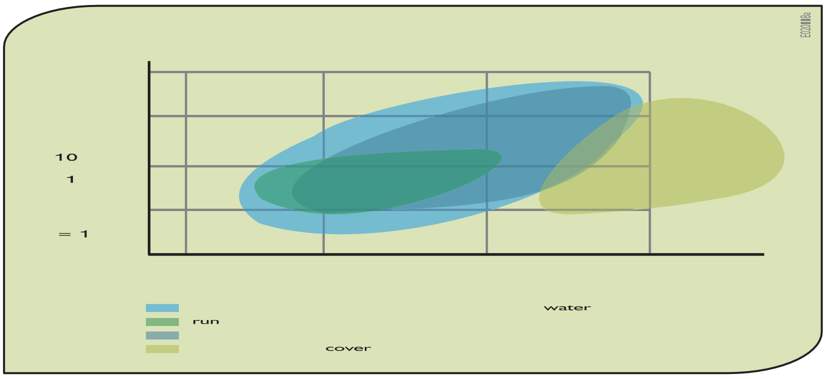
In the context of Level-1 & 2 catchment:

- Meteorological data sets (i.e., precipitation and temperature) are being collected by Meteo Rwanda, and

- Hydrometric data sets (i.e., flow rate and stage) are being collected by RWB.

In order to build a catchment management model by integrating multiple river basin processes, it is important to structure spatial and temporal scales that characterize these processes. Precipitation, which is the source of virtually all freshwater in the hydrological cycle, is typically highly variable and uneven in its distribution over time and space. Similarly, the rates of evaporation and transpiration vary considerably according to climatic and land-cover conditions. The relative magnitudes of the fluxes associated with individual components of the hydrological cycle, such as evapotranspiration, may differ significantly even at small spatial scales such as a micro-catchment, an agricultural field and a woodland.

Figure 2-7 shows the ranges of spatial and temporal scales usually considered when modelling the processes taking place in the three major river basin components – watersheds, surface water bodies and groundwater aquifers. It is important to note that “monthly” temporal scale will suffice the requirements of the surface water and groundwater processes within the LEVEL 1 Nile Akagera Upper catchment.



FUGURE 2- 38 SPATIAL AND TEMPORAL SCALES OF VARIOUS RIVER BASIN PROCESSES (SOURCE: UNESCO, 2005)

It is important to express these processes quantitatively by using representative data sets. Some of the critical data sets and associated administrative authorities are summarized in **Table 2-2**.

2.1.2 PRECIPITATION

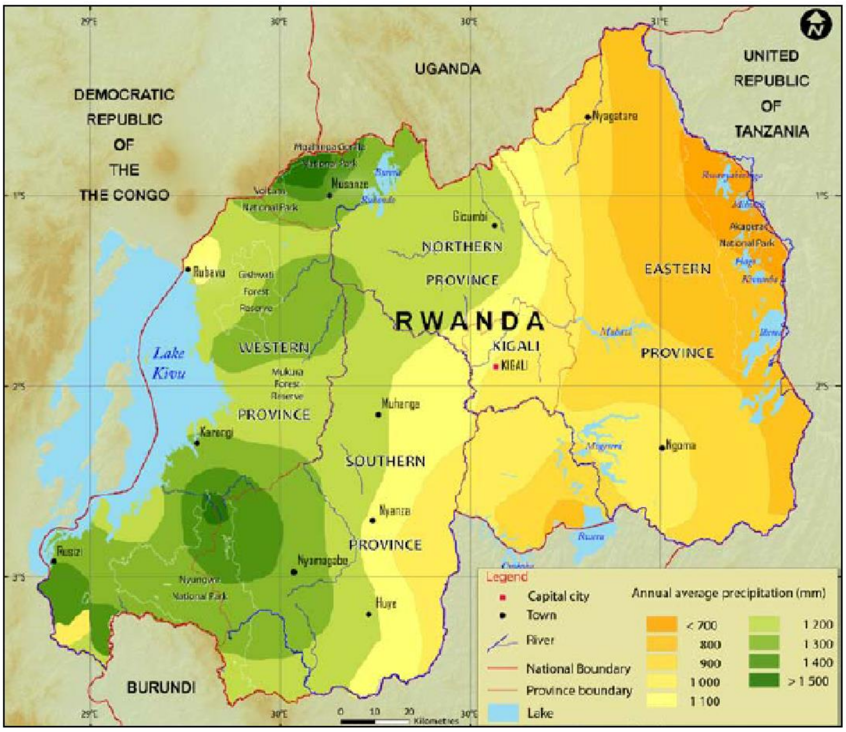
Rwanda is entirely situated within the equatorial zone, but it enjoys a moderate tropical climate due to its high altitude, which ranges from 900 m to 4,500 m above mean sea level (AMSL). There are two rainy seasons, a short one in October and November and a longer one from February to May.

The precipitation data sets have been evaluated by using two-products generated by Meteo Rwanda:

- ❖ Station based measurements (at monthly scale) represent long-term trends in precipitation
- ❖ Grid based data sets (at monthly scale) represent spatial changes in precipitation within Level-2 catchment. The grid data sets are specifically important to evaluate the impacts of geographical conditions on the amount of rainfall. The distribution of grid data sets is displayed below. Each circle within level-2 catchment represent a grid point with precipitation values as collected by Meteo Rwanda, see **Figure 2-7**.

Both of these data sets have been evaluated to understand the changes in precipitation at respective points (using station based data sets) and within the level-2 catchment (using grid based data sets). The location of the grid data sets and associated spatial distribution within the level 2 catchment scale is presented **Figure 2-7**

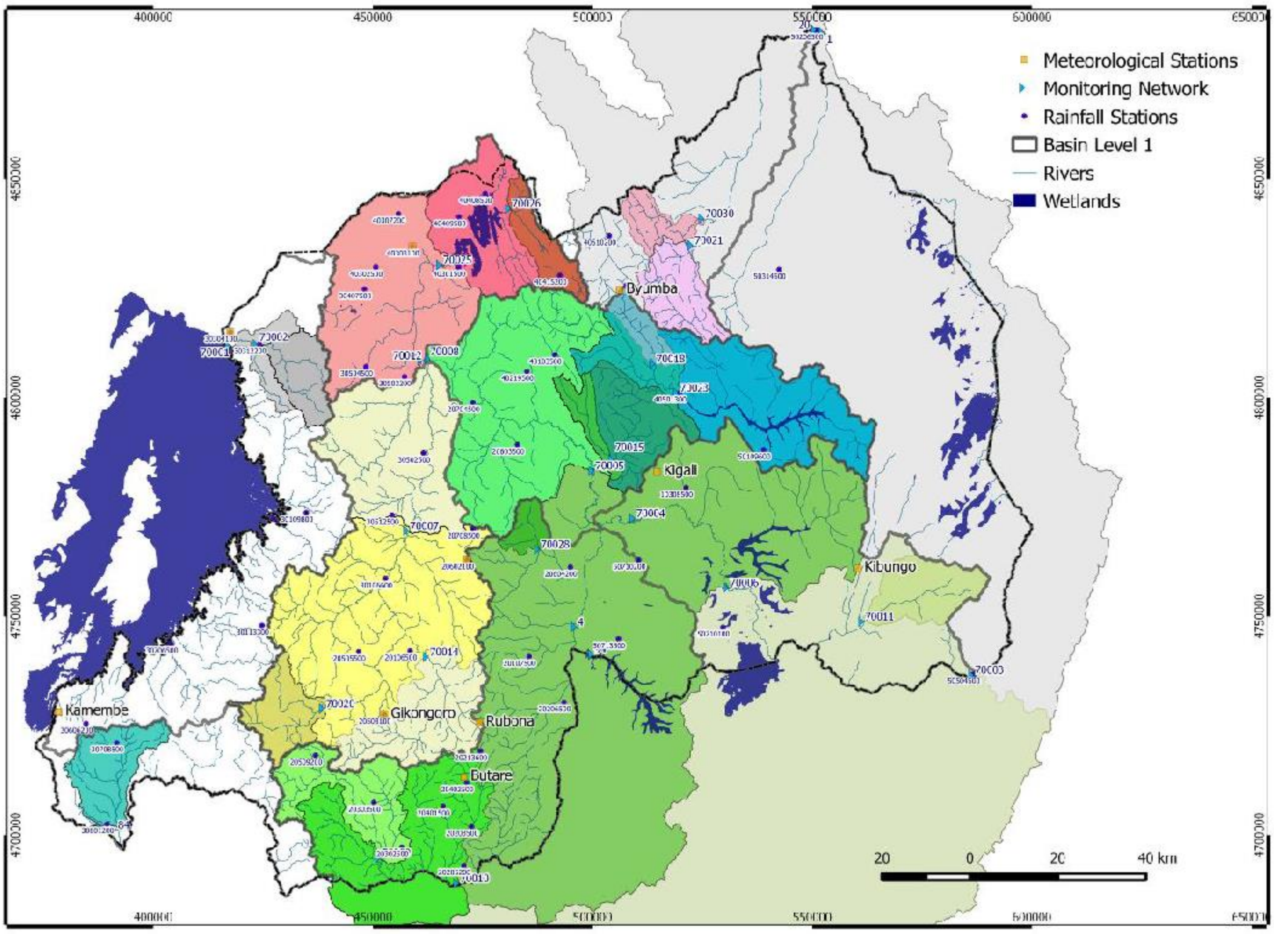
The impacts of climate change on the precipitation trends are documented in **Annexure A**.



FUGURE 2- 39 ANNUAL AVERAGE PRECIPITATION AT NATIONAL SCALE (SOURCE: REMA, 2015 – STATE OF ENVIR)

Figure 2-7 Location of Grid points in NAKU-1 catchment

The rainfall monitoring network of Meteo Rwanda comprises sites 112 sites with records. Rwanda Water Resources Board (RWB) needs climate data for IWRM and has requested meteorological data consisting of rainfall, temperature and relative humidity. A dataset of 56 selected active stations (marked in light blue), as documented in the National Water Resources Master Plan (RNRA, 2014) is depicted in **Figure 2-8**. These stations are distributed in such a way that about 3 stations exist per basin within Level 2 catchment scale, evenly distributed to estimate the distribution of rainfall. All altitude ranges are covered and care was taken to have stations in high mountain areas to capture rainfall events there. The territory of Rwanda is evenly covered.



FUGURE 2- 40 RAINFALL STATION NETWORK (SOURCE: NATIONAL WATER RESOURCES MASTER PLAN, 2014)

2.1.3 SURFACE WATER RESOURCES

Hydrologic Model

The rainfall-runoff transformation was developed through use of Soil Moisture Model. The model parameters are explained in detail in **Annexure C**.

The main outcome is the surface run-off values along the Nile Akagera Upper catchment.

Upper Akagera catchment commences at the confluence of the Lower Nyabarongo and the Akanyaru Rivers and belongs to the Nile basin. The first half of the catchment is located within Rwanda but after Lake Rweru, the Akagera River forms the boundary between Rwanda and Burundi.

The Akagera continues the characteristic meandering path of a river in a wide and extremely flat floodplain that is flooded annually over its entire width. The Akagera connects with a large number of lakes and the flow direction between the river and the lakes may change several times each year depending on the flooding in the river (which is determined by the rainfall on the Nile Congo water divide) and the rainfall in the catchment area itself. The principle tributaries are lakes are Mugesera Lake, Rweru Lake which drains mostly from Burundi, the Nyabugongwe River, and finally the Ruvubu River which takes its water exclusively from Burundi and Tanzania and enters the Akagera just upstream of Rusumo falls. The downstream limit of the catchment is at the Rusumo Falls where its waters fall into the lower Akagera River. The main characteristics of Akagera Upper catchment are listed in section (2.1.2). Other characteristic of NAKU catchment are listed in TABLE 2-3.

TABLE 2- 12 HYDROLOGIC CHARACTERISTICS OF NAKU CATCHMENT, RWANDA

Item	**Unit**	**NAKU**
		transbou
Base Flow	m^3/s	11.13
MQ	m^3/s	16.0
Recharge	mm/y	115
Area	km^2	3053
Yield	hm^3/y	3,500,000
Rainfall	mm/y	925
Flow	mm/y	165
Water balance	mm/y	760
Base flow	mm/y	115
Base flow index		0.70
Rainfall	hm^3	28,000,000
Base flow	hm^3	3,500,000
Water availability per Ha	$m^3/ha/y$	1650
Average Renewable Resource	Mm^3	**504**

Adopted from RNRA, 2015

1.3.1.1 STREAM NETWORK

The stream network of NAKU catchment is shown in Figure 2.15. The network is a dendrick one with interconnected series of Lake and Wetland. Akagera River is the main and longest water cause in the catchment. For hydrological analysi the catchment was devided in 7 seven level 2.5 catchments including 4 in NAKU_1 and 3 in NAKU_2 Figure 2-16. In order to represent the spatial variation of surface water resources it is important to understand the hydrologic/hydraulic characterization and associated gauge stages reflecting the water availability within the river basin system. The inlet to the Akagera Upper catchment are defined by:

- The inlet to the Akagera Upper catchment is represented by the gauge at Location at Kanzenze.

- This gauge data was also evaluated in the context of incoming flows from two upstream catchments, namely Akanyaru and Lower Nyabarongo.
- The contribution of Akanyaru was evaluated by using the National Water Master Plan report. This reference document was used due to the fact that gauge at Location is significantly upstream of its junction with the Akagera Upper catchment. Therefore, gauge-driven findings cannot represent the surface water potential accurately.

The main lateral mechanisms are wetland systems, which result in “losses” from the river system in the context of storage within the wetland segments of the river system.

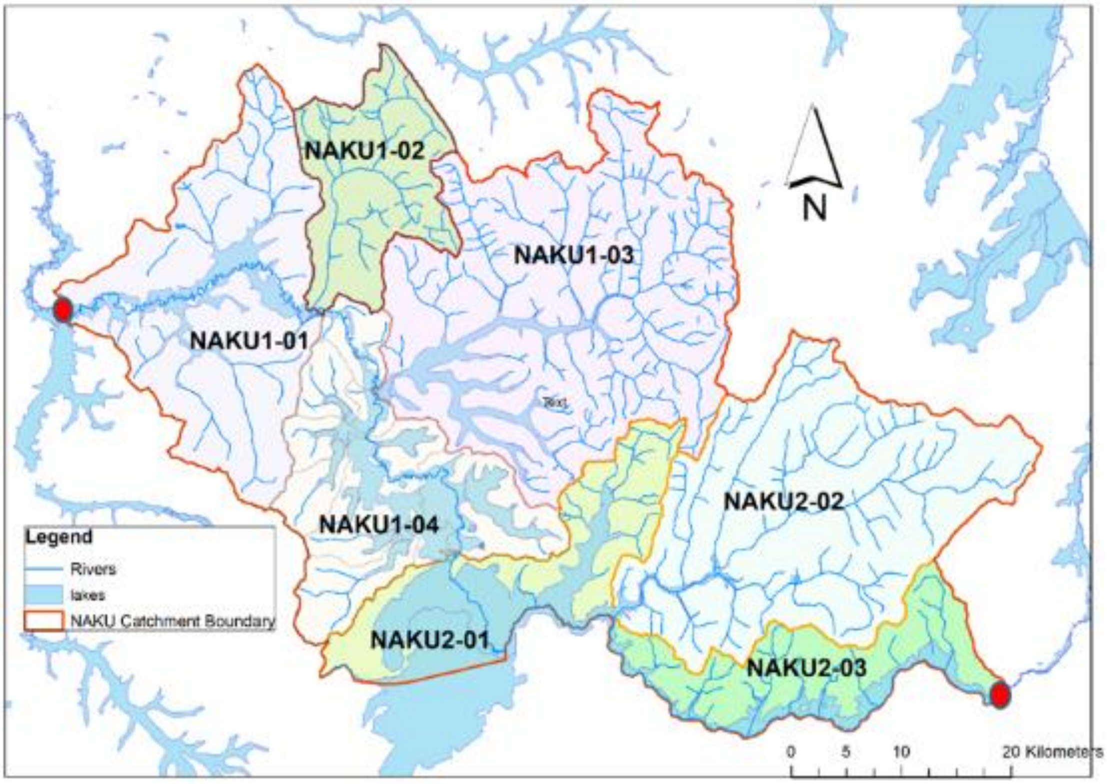
The outlet from the Akagera Upper catchment is defined by the gauge at Location Rusumo. The outcome of the simulation driven by the Hydrologic model and the gauge reading driven by the Rating curve resulted in the outcome shown in Figure 2-9. The maximum difference between simulation and gauged data sets 0.5% (in August). The current construction of Rusumo hydropower is expected to significantly modify the flow at the outlet of the catchment.

TABLE 2- 13 CATCHMENT AT DIFFIRENT LEVELS IN NAKU, RWANDA

S/N	Catchment Level	Number of sub-catchments
1	2	2
2	2.5	7
3	3	94
4	4	1094

TABLE 2- 14 ADMINISTRATIVE AREAS IN NAKU

S/N	Administrative level	Number of Administrative level with their territory in NAKU
1	Province	3
2	District	9
3	Sectors	70
4	Cells	828
5	Villages	2024



FUGURE 2- 41 DELINEATION SEVEN (7) LEVEL 2.5 CATCHMENT AND HYDROLOGIC NETWORK IN NAKU

TABLE 2- 15 STATISTICS OF DELINEATED LEVEL 2.5 CATCHMENT WITHIN NAKU CATCHMENTS

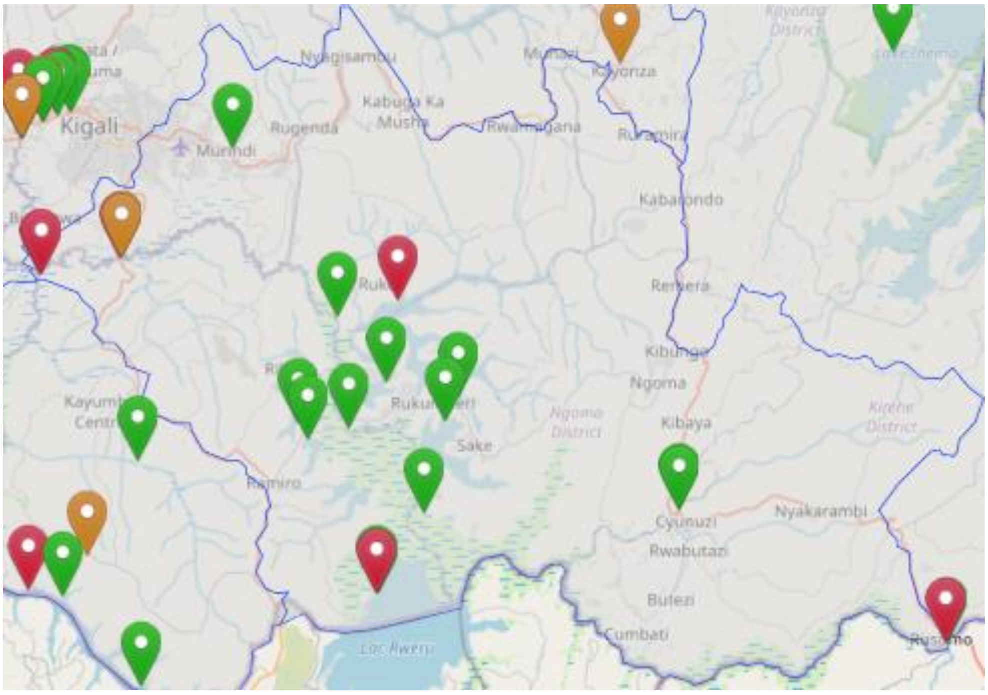
S/N	Sub-catchments	Proposed Name	Perimeter km	Shape Area sq km	Shape Area % of NAKU	Total Population	Population Density	Agriculture	Forest	Wetland	Miscellaneous
1	NAKU1-01	Nyabarango-Gikana	124014.596	489.838	16.03	376,990	770	332.159	95.910	41.342	20.426
2	NAKU1-02	Rusasa	85630.982	216.663	7.09	111,774	516	155.564	57.199	2.297	1.625
3	NAKU1-03	Mugesera	165303.198	795.560	26.03	357,068	449	599.773	137.791	56.883	1.034
4	NAKU1-04	Sake	118916.305	385.828	12.63	104,068	270	215.138	59.803	110.077	0.810
5	NAKU2-01	Rweru	112753.141	288.571	9.44	73,195	254	130.954	31.858	125.730	0.058
6	NAKU2-02	Nyabugongwe	133494.416	648.604	21.23	241,303	372	527.056	112.144	9.016	0.454
7	NAKU2-03	Akagera-Kinoni	113274.426	230.695	7.55	73,433	318	161.094	23.462	46.047	0.115
			Total Area	**3055.759**	**100.00**	**1,337,831**		**2121.737**	**518.167**	**391.391**	**24.523**
							% LULC for NAKU	69.43%	16.96%	12.81%	0.80%

Note: Key to Landuse & Landcover reclassification
Agriculture = **Open Areas or grass/Agriculture(Seasonal)/Agriculture(perennial)**
Forest = **Forest/Sparse Forest**
Wetland = **Water/Wetlands**
Miscellaneous = **Settlements and Buildings/Mines**

TABLE 2- 16 NAKU MONITORING SITES FOR SURFACE WATER, GROUNDWATER ANDA QUALITY

S/N	Location name	Identifier	Catchment L1	Catchment L2
1	Cyunuzi (/location_info/252001)	252001	Akagera Upper	Rweru

2	Gakindo (/location_info/46)	46	Akagera Upper	Rweru
3	Mbuye (/location_info/255101)	255101	Akagera Upper	Rweru
4	Nduruma (/location_info/70011)	70011	Akagera Upper	Rweru
5	Nyiragiseke (Gakindo) (/location_info /254001)	254001	Akagera Upper	Rweru
6	Rusumo(Akagera) (/location_info/239001)	239001	Akagera Upper	Rweru
7	Gashora(Mirayi) (/location_info/255502)	255502	Akagera Upper	Mugesera/Sake
8	Gashora(Rumira) /location_info/255601)	255601	Akagera Upper	Mugesera/Sake
9	Gasogi (/location_info/58)	58	Akagera Upper	Mugesera/Sake
10	Kanzenze (/location_info/259501)	259501	Akagera Upper	Mugesera/Sake
11	Mfune (/location_info/255501)	255501	Akagera Upper	Mugesera/Sake
12	Rubago (/location_info/256001)	256001	Akagera Upper	Mugesera/Sake
13	Rukoma (/location_info/255201)	255201	Akagera Upper	Mugesera/Sake



FUGURE 2- 42 LOCATION OF MONITORING SITES FOR SURFACE WATER, GROUNDWATER ANDA QUALITY

The rating curves are presented in the form **Q = a (b + H)^c.** The specific coefficients at respective locations are listed in Table 2-4.

TABLE 2- 17 RATING CURVE COEFFICIENTS FOR STREAM GAUGES

No	Stage No	Location Name	a	b	c
6	259501	Kanzenze	0.793324	2.70411	3.06893
8	265701	Gihinga			
9	70010	Route Butare-Ngozi	8.185	0.526	2.8
10	255501	Mfune	0.325845	3.63344	3.19893

2.2 ADMINISTRATION AREAS

Catchments are delineated based on hydrological characteristics, i.e. where water flows within a geographic space, and therefore do not align with regular Administrative boundaries. A catchment is comprised, wholly or partially, of the Administrative Districts and Sectors as illustrated in Figure 2-3, i.e. the whole area of a specific District or Sector may not fall entirely within one or the same catchment, but could fall within 2 or even 3 different catchment areas. NAKU catchment has the majority of it territory 2,756.42 sq km (90.20%) located in the Eastern Province, 298.92 sq km (9.78%) in the city of Kigali and 0.39 sq km (0.013%) in the southern province.

It is important to include the Districts and Sectors that fall within the catchment area in the catchment planning process, as the outputs of the CMP will have direct bearing on these administrative areas. The District Development Strategies (DDS) of the member Districts of the Catchment area have been and will be considered in compiling the Nile Akagera Upper CMP. Applicable activities from the CMP will need to be incorporated into the updated DDS of the member Districts. The Districts and Sectors that fall within (wholly or partially) the Nile Akagera UpperCatchment are listed in Table 2-1.

TABLE 2- 18 AREA OF DISTRICTS AND SECTORS IN NAKU CATCHMENT

S/N	Province	District	Sector	Area in sqkm	% of Area in NAKU	Pop 2012 (ALL)	Pop 2019 (ALL)	Pop 2019 NAKU
1	City of Kigali	Gasabo	Bumbogo	17.77	29.58	22,001	26,331	7,789
2	City of Kigali	Gasabo	Gikomero	0.28	0.79	23,673	28,332	225
3	City of Kigali	Gasabo	Ndera	49.75	99.17	29,835	35,707	35,409
4	City of Kigali	Gasabo	Rusororo	51.86	98.83	17,598	21,062	20,816
5	City of Kigali	Gasabo	Kimironko	3.79	33.15	17,978	21,517	7,133
6	City of Kigali	Gasabo	Remera	1.27	18.03	34,922	41,796	7,538
7	City of Kigali	Kicukiro	Nyarugunga	13.82	100	26,803	32,079	32,079
8	City of Kigali	Kicukiro	Kigarama	0	0.03	28,782	34,447	9
9	City of Kigali	Kicukiro	Kanombe	24.56	100	35,381	42,345	42,345
10	City of Kigali	Kicukiro	Niboye	4.99	99.1	16,625	19,897	19,717
11	City of Kigali	Kicukiro	Kicukiro	0.03	1.47	57,430	68,734	1,010
12	City of Kigali	Kicukiro	Gatenga	6.3	55.74	41,764	49,984	27,860
13	City of Kigali	Kicukiro	Kagarama	7.51	77.68	43,279	51,797	40,238
14	City of Kigali	Kicukiro	Masaka	52.31	100	35,453	42,431	42,431
15	City of Kigali	Kicukiro	Gahanga	36.62	100	38,709	46,328	46,328
16	City of Kigali	Nyarugenge	Mageragere	28.06	51.11	34,460	41,243	21,079
17	East	Bugesera	Gashora	98.48	99.68	30,588	36,609	36,491
18	East	Bugesera	Mwogo	52.59	100	25,444	30,452	30,452
19	East	Bugesera	Juru	79.95	100	36,754	43,988	43,989

20	**East**	Bugesera	Ntarama	54.11	54.75	19,522	23,364	12,792
21	**East**	Bugesera	Nyamata	59.62	70.91	14,902	17,835	12,647
22	**East**	Bugesera	Rilima	80.86	100	28,338	33,916	33,916
23	**East**	Bugesera	Mayange	20.27	16.07	28,560	34,181	5,492
24	**East**	Bugesera	Rweru	181.8	84.63	32,730	39,172	33,152
25	**East**	Kayonza	Mukarange	15.26	28.01	30,528	36,537	10,236
26	**East**	Kayonza	Nyamirama	23.61	39.53	44,426	53,170	21,019
27	**East**	Kayonza	Kabare	12.58	11.08	16,450	19,688	2,182
28	**East**	Kayonza	Ruramira	41.9	100	40,057	47,941	47,942
29	**East**	Kayonza	Kabarondo	41.62	75.62	39,484	47,256	35,736
30	**East**	Kayonza	Murama	0.83	1.18	26,923	32,222	380
31	**East**	Kirehe	Nasho	9.96	9.95	27,318	32,695	3,254
32	**East**	Kirehe	Mushikiri	93.29	98.26	20,907	25,022	24,587
33	**East**	Kirehe	Nyarubuye	64.28	74.22	23,703	28,368	21,055
34	**East**	Kirehe	Kirehe	50.04	100	23,478	28,099	28,099
35	**East**	Kirehe	Nyamugali	2.21	2.32	23,407	28,014	651
36	**East**	Kirehe	Gatore	60.31	100	23,033	27,567	27,565
37	**East**	Kirehe	Gahara	109.12	99.99	22,755	27,234	27,230
38	**East**	Kirehe	Kigarama	113.37	99.99	29,505	35,312	35,308
39	**East**	Kirehe	Musaza	90.51	99.99	16,207	19,397	19,396
40	**East**	Kirehe	Kigina	60.81	88.22	16,980	20,322	17,928
41	**East**	Kirehe	Mpanga	11.66	4.7	24,305	29,089	1,369
42	**East**	Ngoma	Remera	35.9	71.97	26,954	32,259	23,217
43	**East**	Ngoma	Rurenge	65.15	100	16,309	19,519	19,519
44	**East**	Ngoma	Kibungo	24.54	57.66	23,861	28,557	16,467
45	**East**	Ngoma	Rukumberi	85.02	100	25,716	30,778	30,778
46	**East**	Ngoma	Rukira	68.64	99.97	19,945	23,871	23,865
47	**East**	Ngoma	Kazo	69.63	100	43,279	51,797	51,798
48	**East**	Ngoma	Murama	50.4	100	25,250	30,220	30,220
49	**East**	Ngoma	Sake	56.93	100	28,555	34,175	34,176
50	**East**	Ngoma	Mutenderi	76.26	100	21,682	25,950	25,949
51	**East**	Ngoma	Jarama	92.75	99.99	23,517	28,146	28,144
52	**East**	Ngoma	Mugesera	73.65	100	24,242	29,013	29,014
53	**East**	Ngoma	Zaza	61.5	100	21,829	26,126	26,126
54	**East**	Ngoma	Karembo	36.95	100	20,196	24,171	24,171
55	**East**	Ngoma	Gashanda	38.4	100	15,504	18,556	18,556
56	**East**	Rwamagan a	Fumbwe	15.63	35.67	16,081	19,246	6,865
57	**East**	Rwamagan a	Muhazi	7.98	16.6	19,945	23,871	3,963
58	**East**	Rwamagan a	Musha	6.83	15.11	16,937	20,271	3,063
59	**East**	Rwamagan a	Gishari	0.69	1.53	27,808	33,281	508

60	**East**	Rwamagana	Munyiginya	0.06	0.17	48,640	58,214	100
61	**East**	Rwamagana	Gahengeri	62.98	100	16,439	19,675	19,675
62	**East**	Rwamagana	Kigabiro	42	88.45	43,907	52,549	46,482
63	**East**	Rwamagana	Mwulire	53.52	97.1	39,548	47,332	45,959
64	**East**	Rwamagana	Muyumbu	50.38	100	26,197	31,353	31,354
65	**East**	Rwamagana	Munyaga	41.29	100	43,907	52,549	52,549
66	**East**	Rwamagana	Nzige	39.99	100	26,909	32,205	32,206
67	**East**	Rwamagana	Rubona	55.53	100	23,784	28,465	28,466
68	**East**	Rwamagana	Nyakariro	51.59	100	31,771	38,024	38,025
69	**East**	Rwamagana	Karenge	63.19	100	28,031	33,548	33,548
70	**South**	Kamonyi	Mugina	0.39	0.44	24,136	28,887	128
		Total Area		**3055.74**		1,941,876	2,324,090	1,609,760

TABLE 2- 19 MSTATISTICS OF ACCESS TO IMPROVED WATER AND SANITATION FOR URBAN AND RURAL POPULLATION IN NAKU CATCHMENT

S/N	Province	District	Sector	Pop 2019 NAKU	% Urban	% Rural	% 6 years Basic educa	12 Years Basic educ	Improved Water Supply	Unimproved Water Supply	Not Stated	Improved Sanitation	Unimproved Sanitation	NotStated
1	**City of Kigali**	**GASABO**	**Bumbogo**	**7,789**	**16.7**	**83.3**	**62.1**	**20.8**	**52.1**	**47.2**	**0.7**	**95.3**	**3.6**	**1.1**
2	City of Kigali	GASABO	Gikomero	225	0	100	73.4	16.1	24.9	73.8	1.3	97.3	1.9	0.8
3	City of Kigali	GASABO	Ndera	35,409	0	100	58.3	28	92.6	6.5	0.9	97.8	1.1	1.1
4	City of Kigali	GASABO	Rusororo	20,816	0	100	71.7	12.4	0.6	98.4	1	97.7	1.8	0.6
5	City of Kigali	GASABO	Kimironko	7,133	0	100	61.3	23.2	26.4	72.9	0.6	95.4	3.2	1.4
6	City of Kigali	GASABO	Remera	7,538	48.9	51.1	51.4	32.4	77.5	21.3	1.2	96.3	2.3	1.5
7	City of Kigali	KICUKIRO	Nyarugunga	32,079	0	100	64.4	23.7	84	15.4	0.6	97.3	1.4	1.2
8	City of Kigali	KICUKIRO	Kigarama	9	0	100	64.2	16.6	14.8	84.6	0.6	95.6	3.6	0.8
9	City of Kigali	KICUKIRO	Kanombe	42,345	12	88	64.7	20.4	68.2	31.1	0.7	96.6	1.5	1.9
10	City of Kigali	KICUKIRO	Niboye	19,717	0	100	71.9	14.2	76.5	22.9	0.6	98	1.3	0.8
11	City of Kigali	KICUKIRO	Kicukiro	1,010	100	0	40.1	33.9	95.6	2.6	1.8	94.2	0.3	5.6
12	City of Kigali	KICUKIRO	Gatenga	27,860	80.1	19.9	56.8	27	81.9	17.4	0.7	97.1	1.1	1.7
13	City of Kigali	KICUKIRO	Kagarama	40,238	100	0	43.4	35.3	95.3	3.1	1.6	95.1	0.3	4.6

14	City of Kigali	KICUKIRO	Masaka	42,431	58.8	41.2	52	30.9	78.6	20	1.5	96.5	1.5	2
15	City of Kigali	KICUKIRO	Gahanga	46,328	38.1	61.9	69	17.9	76.4	22.6	0.9	97	2.4	0.6
16	City of Kigali	NYARUGE NGE	Mageragere	21,079	0	100	67	16.2	66.6	32.1	1.3	96.5	2.7	0.9
17	East	BUGESERA	Gashora	36,491	24.4	75.6	59.7	22.9	71.1	27.4	1.5	97.1	1.5	1.4
18	East	BUGESERA	Mwogo	30,452	0	100	64.2	15.6	49.4	49.2	1.4	95	3	2
19	East	BUGESERA	Juru	43,989	0	100	62.3	17.9	73.6	25.5	1	96	2	2
20	East	BUGESERA	Ntarama	12,792	0	100	61.7	21.7	37.9	61	1	96	3	1
21	East	BUGESERA	Nyamata	12,647	0	100	62.7	8.2	85.9	13.7	0.6	94.6	4.5	0.9
22	East	BUGESERA	Rilima	33,916	40.7	59.3	53	16.7	70.4	27.9	0.9	94.3	3.7	2
23	East	BUGESERA	Mayange	5,492	0	100	55.3	6.1	2.5	96.1	1	94.6	4.6	0.8
24	East	BUGESERA	Rweru	33,152	55	45	51.9	32	93.9	5	1.1	97.4	0.9	1.6
25	East	KAYONZA	Mukarange	10,236	2	98	64.3	18.9	56.4	42.5	1.1	95.5	2.5	2
26	East	KAYONZA	Nyamirama	21,019	100	0	42	36	93.2	5.8	1	93.6	0.5	5.9
27	East	KAYONZA	Kabare	2,182	100	0	34	41	95.6	3.6	0.8	93.6	0.2	6.2
28	East	KAYONZA	Ruramira	47,942	100	0	35	42	98.2	0.5	1.2	93.8	0.1	6
29	East	KAYONZA	Kabarondo	35,736	0	100	66.3	12.2	54.3	44.5	1.2	97	2	1
30	East	KAYONZA	Murama	380	0	100	61.6	21	36.5	62.1	1.4	97	2	1
31	East	KIREHE	Nasho	3,254	0	100	61	8.8	80.6	18.8	1.6	94.4	2.4	3.1
32	East	KIREHE	Mushikiri	24,587	0	100	61	7.4	35.7	63.1	0.8	94.7	4.1	1.2
33	East	KIREHE	Nyarubuye	21,055	0	100	55.2	6.8	54.6	44.4	1.2	93.7	5.7	0.6
34	East	KIREHE	Kirehe	28,099	0	100	63.3	7.5	50.4	48.8	0.8	93.5	4.3	2.2
35	East	KIREHE	Nyamugali	651	0	100	69.5	15.9	83	16.4	0.6	97.5	1.7	0.9
36	East	KIREHE	Gatore	27,565	7.7	92.3	63.4	22	68.3	31.1	0.6	96.3	3	0.8
37	East	KIREHE	Gahara	27,230	22.2	77.8	68.4	23.8	72.7	26.3	1.1	96.5	1.5	2
38	East	KIREHE	Kigarama	35,308	7.2	92.8	55.7	28.4	75.3	23.6	1	96.6	1.9	1.5

39	East	KIREHE	Musaza	19,396	0	100	61.6	18.3	83.8	15.7	0.4	96.3	2.3	1.4
40	East	KIREHE	Kigina	17,928	0	100	69.6	17	55.5	43.6	0.9	96.1	3.1	0.9
41	East	KIREHE	Mpanga	1,369	0	100	65.9	12.3	93.1	6.3	0.6	95.3	3.7	1
42	East	NGOMA	Remera	23,217	0	100	67.9	15.8	82	17	0.9	98	1	1
43	East	NGOMA	Rurenge	19,519	0	100	62.5	6.5	85.9	13.6	0.4	97.1	2.5	0.3
44	East	NGOMA	Kibungo	16,467	0	100	53.6	4.9	33.6	66.1	0.3	94.2	4.6	1.2
45	East	NGOMA	Rukumberi	30,778	0	100	63.5	5.3	29.3	69.5	0.9	96.2	3.4	0.5
46	East	NGOMA	Rukira	23,865	0	100	68	15.9	57.2	42	1.6	95.1	0.3	4.6
47	East	NGOMA	Kazo	51,798	100	0	43.4	35.3	95.3	3.1	0.8	96.2	3	0.9
48	East	NGOMA	Murama	30,220	9.2	90.8	59	10.1	70.2	29	0.9	95.7	3.3	1
49	East	NGOMA	Sake	34,176	0	100	59.5	6.5	62.8	36.2	0.4	92.7	4	3.3
50	East	NGOMA	Mutenderi	25,949	0	100	64.2	19.6	58.2	41.3	0.5	96.4	2.8	0.7
51	East	NGOMA	Jarama	28,144	0	100	68	18.3	39.7	59.4	0.8	96.4	2.8	0.7
52	East	NGOMA	Mugesera	29,014	0	100	65.5	22.5	66.8	32.1	1.1	97.2	1.2	1.6
53	East	NGOMA	Zaza	26,126	0	100	64.9	20.5	82.5	16.2	1.3	96.9	2	1.2
54	East	NGOMA	Karembo	24,171	0	100	72.1	18.3	76.8	22.4	0.8	97.8	1.1	1.2
55	East	NGOMA	Gashanda	18,556	0	100	70.7	19.4	88.4	11.1	0.5	97.8	0.9	1.3
56	East	RWAMAGANA	Fumbwe	6,865	0	100	64.5	25	73.7	25	1.3	98.1	1.4	0.6
57	East	RWAMAGANA	Muhazi	3,963	0	100	68	15.9	57.2	42	0.9	94.3	3.7	2
58	East	RWAMAGANA	Musha	3,063	0	100	67	13.9	47.4	51.2	1.4	95.6	3.6	0.8
59	East	RWAMAGANA	Gishari	508	42.1	57.9	64	22	81	18.1	0.9	97.5	1.2	1.3
60	East	RWAMAGANA	Munyiginya	100	95.2	4.8	47	37	89.2	8.8	2	96.5	0.4	3
61	East	RWAMAGANA	Gahengeri	19,675	0	100	62.9	23	83.6	15	1.5	96.2	2.4	1.5

62	East	RWAMAGANA	Kigabiro	46,482	100	0	40	41	97.4	1.5	1.1	96.3	0.4	3.3
63	East	RWAMAGANA	Mwulire	45,959	49	51	58	30	90.5	8.2	1.2	97.5	0.7	1.9
64	East	RWAMAGANA	Muyumbu	31,354	100	0	33	38	96.9	1.7	1.4	93.7	0.1	6.3
65	East	RWAMAGANA	Munyaga	52,549	100	0	40	41	97.4	1.5	1.1	96.3	0.4	3.3
66	East	RWAMAGANA	Nzige	32,206	26	74	59.1	22.9	53.6	45.1	1.2	95	4	1
67	East	RWAMAGANA	Rubona	28,466	13	87	59.9	24.3	60.8	38	1.2	97	2	1
68	East	RWAMAGANA	Nyakariro	38,025	0	100	64.8	17.2	53.4	45.8	0.7	97	2	1
69	East	RWAMAGANA	Karenge	33,548	0	100	67.7	15.5	34.9	64	1.1	95	3	2
70	South	KAMONYI	Mugina	128	0	100	68.9	18.9	47.6	51.8	0.6	96.7	2.6	0.7
		Total Area		1,609,760										

PRESENT AGRICULTURAL LAND USE

The main agricultural activities in the catchment therefore include relatively extensive rain-fed production of the above crops on the hill slopes and crests, intensive subsistence cultivation in wetlands and large-scale rice production in wetlands under flood irrigation and fishing and fish production in the water bodies.

The wetlands are critical grazing areas during wet seasons, and, importantly, support food production during the dry season (UNEP, 2007). During drought, wetland cultivation may become the main source of food. June to October coincides with the driest months when water stress is highest and hardly anything grows.

AGRICULTURAL DEVELOPMENT POLICIES

Since the scope of physical expansion of cultivable land area are limited, proper utilization of land is paramount to food security for the rapidly growing population. To help manage the farm lands with an objective of supporting economic development and social welfare, Rwanda's **Organic Land law (2005)** endorses the consolidation of the use of small plots of farm lands in order to improve land management and agriculture productivity. The Ministry of Agriculture and Animal Resources (MINAGRI) has embarked on a simplified land use consolidation model whereby farmers in a given area grow the priority food crops (maize, rice, wheat, Irish potato, cassava, soybean and beans) in a synchronized consolidated fashion while keeping their land rights intact. Although consolidation is voluntary, it is a pre-requisite for availing the benefits such as subsidized inputs under the governments Crop Intensification Program (CIP).

Rwanda's **Vision 2020 (2013)** is to transform the country into a middle-income country based on six pillars which, from an agricultural perspective, includes a productive and market-orientated agricultural sector led by the private sector. This includes regulated settlements and land-use consolidation, the introduction of intensive agricultural technologies such as fertilizer use, new and appropriate crop varieties and livestock species, mechanization and a focus on value-chains and transformation from subsistence agriculture to intensified commercial agriculture.

Furthermore, **Rwanda Agricultural and Land policies (2004)**, which embraces the Vision 2020, are focused on intensification and transformation of subsistence agriculture into market-oriented agriculture, which requires modern inputs, notably improved seeds and fertilizers. The policy emphasises marshland development for increased food production because the soils on hillsides are degraded. The policy promotes small-scale irrigation infrastructure development in selected marshlands while preventing environmental degradation. Rice cultivation is prioritised for import substitution. These specific objectives are in contradiction to the conservation and promotion of the Mugesera Wetland complex for Ramsar status and protection of wetland functions. To achieve sustainable agricultural development, the policy emphasises the need to adopt integrated pest management practices.

The **Land policy (2004)** promotes irrigating areas for crop production that are more or less flat and semi-arid while discouraging overgrazing and pasture burning. The policy also stipulates that marshlands meant for agriculture should be cultivated after adequate planning and environmental impact assessment.

In terms of the Rwandan **Irrigation Master Plan (2020)**, Irrigation potential of Rwanda was mapped based on level one catchment NAKU catchment ranked third after NAKL and NAKN catchment with a potential of about 95,783 ha. Table 2.16 summarizes the irrigation potential of Rwanda indicating the total areas of land which apply to the different domains.

TABLE 2- 20 IRRIGATION POTENTIAL OF RWANDA (SOURCE RIMP, 2020)

Domains	CRUS	CKIV	NMUK	NNYU	NNYL	NAKN	NAKU	NAKL	NMUV	All
Runoff for small reservoirs domain	2,148	5,179	4,165	7,155	7,056	7,270	6,521	9,162	3,344	52,000
Dam Potential	167	1,447	172	7,058	15,610	12,859	894	1,430	12,464	52,100
River Potential	-	-	-	12,424	4,710	36,171	25,868	48,241	8,466	135,880
Lake Potential	-	23,909	-	-	28,372	9,125	26,816	14,142	-	102,364
Marshland Potential	3,700	4,702	6,398	9,060	8,998	26,656	33,184	22,731	7,735	123,164
Groundwater	3,000	5,000	5,000	7,000	4,000	5,500	2,500	3,000	1,000	36,000
SUM	**9,015**	**40,237**	**15,735**	**42,697**	**68,746**	**97,581**	**95,783**	**98,706**	**33,009**	**501,509**

Assessment for prioritisation according to RIMP, 2020 highlighted NAKU catchment among the highest priority in all the three criteria used.

TABLE 2- 21 IRRIGATION PRIORITY SCORING

Catchment	Location	Command area	Social
CKIV	1	1	1
CRUS	1	2	2
NNYU	1	2	1
NMUK	1	1	1
NNYL	2	2	3
NAKN	2	2	2
NAKU	3	3	3
NAKL	3	3	2
NMUV	3	3	2

Some priority identified sites for irrigation development within the NAKU catchment are listed in Table 2.14

TABLE 2- 22 IRRIGATION PRIORITY SCORING

Catchment	District	Name	Status	Domain	Ha
Upper Akagera (NAKU)	Kayonza, Gatsibo	Nyamashuri	Identified in IMP	R	8,000
Upper Akagera (NAKU)	Kayonza	Karambi	Identified in IMP	L	6,000
Upper Akagera (NAKU)	Kirehe	Rwampanga	Identified in IMP	L	2,000
Upper Akagera (NAKU)	Kirehe	Nasho	Identified in IMP	R	3,500
Upper Akagera (NAKU)	Kirehe	Kagasa	Identified in IMP	R	4,000

The **Strategic Plan for Agricultural Transformation in Rwanda (2009)** has the overall objective to increase Agricultural output and incomes rapidly under sustainable production systems for all groups of farmers, and food security ensured for all the population. The Specific Objective for the Strategy is to Increase output of all types of agricultural products with emphasis on export products with high potential and create extensive rural employment; and under sustainable modes of production.

With the future of the agricultural sector dependent on the integration of farming systems, farmer training, development of entrepreneurial capacities, and the strengthening of the supporting institutional framework, the Strategic Plan has adopted four interrelated programmes:

1. Intensification and development of sustainable production systems
2. Support to the professionalization of the producers
3. Promotion of commodity chains and agribusiness development
4. Institutional development

Each principal programme has a suite of sub-programmes. In the case of programme 1 (Intensification and development of sustainable production systems) the following sub-programmes are being implemented, Figure 2-30:

1.1 Sustainable management of natural resources, water and soil conservation

1.2 Integrated development and intensification of crops and livestock:

1.3 Marshland development

1.4 Irrigation development

1.5 Supply and use of agricultural inputs

1.6 Food security, vulnerability management.

Al these overarching policies and programmes impact directly on land use in the NAKU 1. The areas under terracing and proposed further terracing are indicated in **FIGURE 2-23**. The irrigation projects that fall within the NAKU catchment are shown in **FIGURE 2-24** and are listed in **TABLE 2-19**. The irrigation projects under development (240ha) and those being planned are also shown in the figure.

The project facilitators and sponsors include:

LWH - Land Husbandry, Water Harvesting and Hillside Irrigation Project

MINAGRI - Ministry of Agriculture and Animal Resources

RSSP -Rural Sector Support Project (various phases)

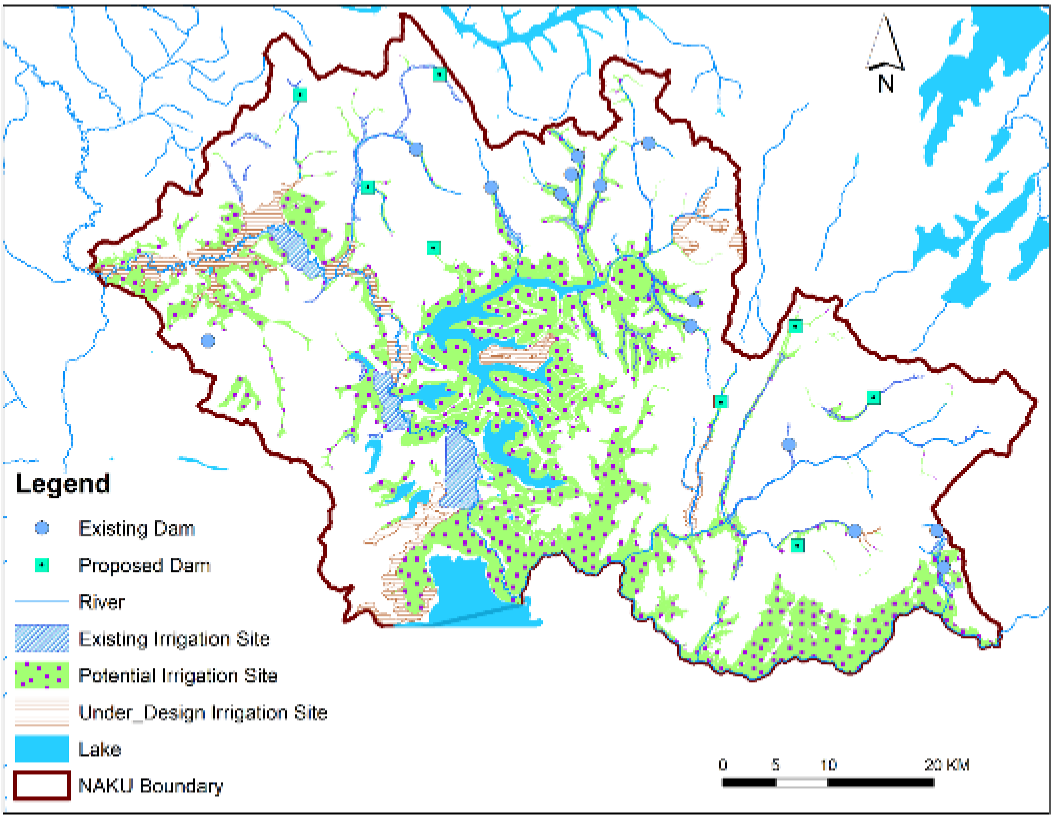
PAPSTA - Support Project to the Strategic Plan for the Agriculture Transformation

PADAB - Bugesera Agricultural Development Support Project

PAIRB - Bugesera Natural Region Rural Infrastructure Support Project

GFI- Immediate Action Irrigation Project

Lux-Dev. - The Luxembourg Agency for Development Cooperation. A private limited company (société anonyme)



FUGURE 2- 43 EXISTING AND POTENTIAL IRRIGATION SITE IN NAKU

TABLE 2- 23 SUMMARY IRRIGATION PROJECTS IN THE CATCHMENT

Projects	**District**	**Irrigated Areas (ha)**
Nyaburiba	Bugesera	32
Ntovi	Ngoma	
GFI IMP- Gatare site	Ngoma	200
Lux Dev Gashora 1	Bugesera	1,000
Lux Dev Gashora 2	Bugesera	19
Lux Dev Gashora 3	Bugesera	46
Lux Dev Gashora 4	Bugesera	62

LWH Rwamagana 34 and 35	Rwamagana	267
MINAGRI Bugugu	Rwamagana	40
MINAGRI Cyaruhogo	Rwamagana	100
MINAGRI Cyimpima	Rwamagana	75
MINAGRI Gashara	Rwamagana	35
MINAGRI Gitinga	Rwamagana	225
MINAGRI Kayonza	Rwamagana	150
MINAGRI Mwambu	Rwamagana	210
MINAGRI- JICA Ngoma22	Ngoma	275
PADAB Rurambi	Bugesera	850
PAIRB Gashora site A	Bugesera	750
PAIRB Gashora site B	Bugesera	750
PAIRB Hillside sites around Rweru, Gaharwa and Kirimbi lakes	Bugesera	1,000
PAPSTA Kibaza	Bugesera	50
QW-MDP Nyaburiba	Bugesera	53
QW-MDP amukungu	Ngoma	58
QW-MDP Rwakaganza	Ngoma	153
RSSP Gahondo	Ngoma	200
RSSP1 Gatare- Rwabikwano	Bugesera	135
RSSP1 Kiruhura	Bugesera	70
RSSP1 Ruvubu	Bugesera	90
RSSP1 Kibaya lower	Ngoma	130
RSSP2 Gisaya	Ngoma	88
RSSP2 Kibaya upper	Ngoma	103
Total (ha)		**7,255**

AGRICULTURAL TRENDS IN THE CATCHMENT

The above programmes and initiatives have mainly manifested themselves in the catchment through the development of large-scale, intensive rice and sugar cane production under irrigation in the wetland flood plains. Of the 39 566ha of wetlands last mapped only 2554ha were not cultivated. With increasing encroachment of agricultural land use, this area is reducing. In particular, the Irrigation Master Plan and projects by JICA specifically target the development of the wetland areas without the necessary feasibility studies being conducted. Continued cultivation of the wetlands poses a significant risk to the water supply in dry months to the surrounding villages and Districts, not just for irrigation water and livestock watering, but for domestic supply as well. As the wetlands are drained for cultivation the natural storage of the wetland is lost, the tilling of the soil results in the loss of soil moisture. International research (e.g. Richards, *et al.*, 2010), has identified a direct link between increased occurrence of malaria (and other vector illnesses) and paddy rice. While the objective of the paddy-rice-project may be food security, the resultant impact on health detracts from developing community wealth building as households are spending more of their income on health care and medicine as a result. The increased occurrence of Malaria was confirmed by the District officials during the Catchment Management Planning workshops in September 2017.

In addition to the extensive irrigation, there are further pressures on the wetlands from rain-fed subsistence agriculture and cattle grazing.

The lakes and floodplain wetlands are fished, mainly from canoes. However, it is noted in a review of District Development Plans that, with declining water levels in the lakes, people who depended entirely on fishing have now shifted to cultivation of crops because the lakes have been seasonally drying up and some fish species have disappeared, leading to lower catches. This was confirmed during the Catchment Management Planning workshop on 14 September 2017 especially in Rwamagana, Bugesera and Ngoma Districts.

During the Socio-economic Household survey, households within the catchment area were questioned about their agricultural practices. The following tables summarise the results from the surveys.

Most of the households indicate that they use inputs from land-use consolidation:

Use of agricultural inputs from land-use consolidation	Responses	% response
Yes, seed only	27	6.8
Yes, fertilizer only	39	9.8
Yes, pesticide only	2	.5
Yes, more than one seed, fertilizer, pesticide	64	16.0
No	5	1.3
Total	137	34.3
Missing	262	65.7
Total	399	100.0

The majority responded that the farm predominantly in wetland areas.

Where they grow their crops?	Response	% response
terrace (progressive or radical)	74	18.5
slope	121	30.3
wetland/dambo	202	50.6
Total	397	99.5

The main crops grown are vegetables and rice.

Types of crops grown	Responses	% response
Rice (paddy)	10	2.5
Maize/ sorghum/millet	4	1.0
Beans	8	2.0
Bananas	1	.3
Potato (Irish)	3	.8
Potato (African/sweet)	7	1.8
Vegetables (tomato, onion, spinach)	22	5.5

Other (please name)	14	3.5

Among other crops that are found in Akagera Upstream include '*amateke/igname*', sugar cane, 'iminyorogoto', '*intoryi/obergine*', 'macadamia', "*inzuzi/courge', soja, ground nuts, cassava, onion, 'poivre' and water melon.*

The primary purpose of farming activities is for household consumption

Purpose of farming?		Responses	% response
Only for the household		310	49.7
Selling at local market		155	24.8
Selling at external markets		19	3.0
Home consumption and sell the rest		59	9.5
Other (please specify) markets		8	1.3
Total		551	88.3
System		3	0.5
	624	100.0	100.0

The primary reason for decline in agricultural productivity from the previous season is loss of soil fertility:

Reasons why agricultural production decreased?	Responses	% of response
Erosion	35	5.6
Flooding	25	4.0
Poor soil fertility	33	5.4
Not using enough fertilizer/pesticide	21	3.4
Lack of labour	9	1.4
Low product prices	4	0.6
Lack of extension support	4	0.6
Lack of Government sponsored inputs	1	0.2
family labour was sick	5	0.8
Other, please specify	96	15.4

2.2.1 ENERGY

ENERGY CONSUMPTION

Rwanda has considerable opportunities for energy development – from hydro sources, methane gas, solar and peat deposits. Most of these energy sources have not been fully exploited. As such, wood is still the major source of energy for Rwanda the population. The EICV 5 report presents and discusses detailed results and compares them with EICV4 in the sector of energy. The survey provides also information on the main source of energy for cooking and lighting. In urban areas, the majority (67%) of households use charcoal as cooking fuel.

In rural areas, firewood remains the most used type of cooking fuels, (94%). Use of electricity for lighting has approximately doubled at national level since 2010-11 from 11% to 20% in 2013-14. The highest proportion of households using electricity for home lighting is found in Kigali city (73%). In other provinces, the proportion of households using electricity for home lighting ranges between 9% and 15% (NISR 2015).

CURRENT ELECTRICITY GENERATION STATUS

Electricity generation in Rwanda is composed by domestic generation and the imported generation from neighbour countries and regional shared Company. Although only solar power generation exists within the catchment, the source of energy used in the catchment is from the following sources: hydropower plants (located outside the catchment), thermal power plants (Diesel, Heavy fuel generators and methane gas) and solar energy.

There are no hydropower plants observed in Nile Akagera Upper Catchment but only Gigawatt Global (GWG) solar plant was observed in the catchment area. The GWG power station is located near the campus of Agahozo Shalom Youth Village, in Rwamagana District, Eastern Province of Rwanda, Figure 2-25. The GWG solar plant produces 8.5 Megawatt and connects to the National grid. It is the first utility-scale solar PV power plant in East Africa with a production capacity of 8.5 MW.

It is important to monitor releases from reservoir systems, upstream of the level-2 catchment, to avoid any conflicts with the existing water requirements of respective sectors (i.e., irrigation, consumptive use, livestock, industry, etc.).

SOURCES OF ENERGY IN THE CATCHMENT

As resulted by the EICV 5, the Nile Akagera Upper Catchment is electrified with rate of 48.4%. This rate is higher than National average because around half of the catchment is urban area where the electrification situation is high. Table 2-12 shows that among 51.6% of District households which are not connected to electricity, 3.6% of them use oil lamp for lighting, 1.09% use firewood, 6.01% use candle, 8.35% use lanterns, 32.99% use batteries (including torches) and 5.08% use other sources of energy for lighting.

TABLE 2- 24 DISTRICT BREAKDOWN OF ENERGY TYPES USED FOR LIGHTING (SOURCE: EICV5)

Catchment	District	Electricity distribution	Oil lamp	Firewood	Candle	Lantern	Batteries	Solar panel	Other
Nile Akagera Upper Catchment	74.7	1	0.7	11.8	1.9	8.8	1	0.1	74.7
	84.4	0.5	0	9.9	1.1	3.9	0.3	0	84.4
	81.3	0.5	0	7.7	1.1	7.6	1.3	0.5	81.3
	66.3	1	3.7	2.6	2.7	53.4	4.4	0	66.3
	28.1	3.3	0.4	7.8	4.1	46.1	9.1	1.1	28.1
	18.9	4.3	1.1	4.7	11.6	47.9	10.6	0.9	18.9
	18.1	2.7	2.1	2.2	27	38.9	7.5	1.5	18.1
	15.6	1.4	0.7	1.4	17.3	57.3	6.4	0	15.6
	387.4	**14.7**	**8.7**	**48.1**	**66.8**	**263.9**	**40.6**	**4.1**	**387.4**
	48.43	1.84	1.09	6.01	8.35	32.99	5.08	0.51	48.43

The majority of the District populations member to the Nile Akagera UpperCatchment use firewood as their main sources of energy especially for cooking at a rate of 66% followed by charcoal at 31.7%, as summarised in Table 2-13. Basing on results given by the fourth Integrated Households Living Conditions Survey (EICV 4) conducted by National Institute of Statistics in Rwanda in 2014, it is clear that the rate of using green energy in cooking is very low (0.3% of households using gas for cooking). Generally, energy use in the member Districts of the Nile Akagera UpperCatchment for both cooking and lighting is mainly firewood which drives the deforestation within the catchment area.

TABLE 2- 25 DISTRICT SUMMARY OF ENERGY SOURCES FOR COOKING (SOURCE: NISR-EICV4)

Catchment	District	Firewood	Charcoal	Crop waste	Gas or Biogas	Others
Nile Akagera Upper Catchment	Gasabo	43.5	53.7	0	1.1	1.7
	Kicukiro	20.7	77.2	0	0.5	1.6
	Nyarugenge	23.2	70.7	0.2	0.4	5.4
	Bugesera	96.3	1.9	0	0	1.8
	Rwamagana	88.4	10.3	0.5	0	0.8
	Kayonza	92.8	6.7	0	0.3	0.2
	Ngoma	97.3	1.7	0.7	0.1	0.2

	Total	**462.2**	**222.2**	**1.4**	**2.4**	**11.7**
	Average	**66.0**	**31.7**	**0.2**	**0.3**	**1.7**

This is verified through the household surveys conducted in the catchment area. Households were asked the source of energy use for lighting. Residents in Nile Akagera Upperappeared to use mostly electricity as the main energy source for lighting (38.1%). The other sources of light use include candle, torch and solar energy.

Energy used for lighting		Responses	% of responses
Electricity		292	46.8
Candle		96	15.4
Kerosene Lamps		35	5.6
Battery		17	2.7
Solar energy		82	13.1
Torch		98	15.7
Other (specify)		2	0.3
Total		622	99.7
System		2	0.3
	Total	624	Total

In terms of energy for cooking, fuelwood remains the dominant energy source:

	Electricity	Gas	Wood	Charcoal	Biogas	Biomass	Other
Frequency	4	11	514	76	4	7	5
Percent	0,6	1,8	82,4	12,2	0,6	1,1	0,8

The households were also asked where they collect the wood and biomass from; the predominant source being unprotected forests then agricultural farmland.

Where biomass is collected?		Responses	% of responses
Protected forest		27	4,3
Unprotected forest		213	34,1
Agriculture farmland		205	32,9
Own woodlot		23	3,7
Community/village woodlot		10	1,6
Buffer areas		12	1,9
Other (specify)		35	5,6
Total		525	84,1
System		100	16,0
	Total	624	100.0

2.2.2 INDUSTRY

In Rwanda, the industry sector is usually categorized into three groupings (REMA, 2015):

Primary industries that collect and use resources directly produced through physical processes, such as forestry (incl. plantation), mining and agriculture (including cash crops, fish farming);

Secondary industries that convert raw materials into goods, such as manufacturing; and

Tertiary industries that provide services for individuals and groups, such as tourism.

It is worth noting that Rwanda's industrial and services sectors grew at a faster rate over the period of 1999-2010. Industrial products include, agricultural products, small-scale beverages, soap, furniture, shoes, plastic goods, textiles and cigarettes. Additionally, the manufacturing sector is dominated by construction materials, manufacturing and agro-processing subsectors, mainly due to the local availability of raw materials and the booming construction sector.

Within the Nile Akagera UpperCatchment, Table 2-15 provides an overview of the industries located in the Catchment according to Integrated Household Living Conditions Survey (EICV3) districts profile (NISR, 2011).

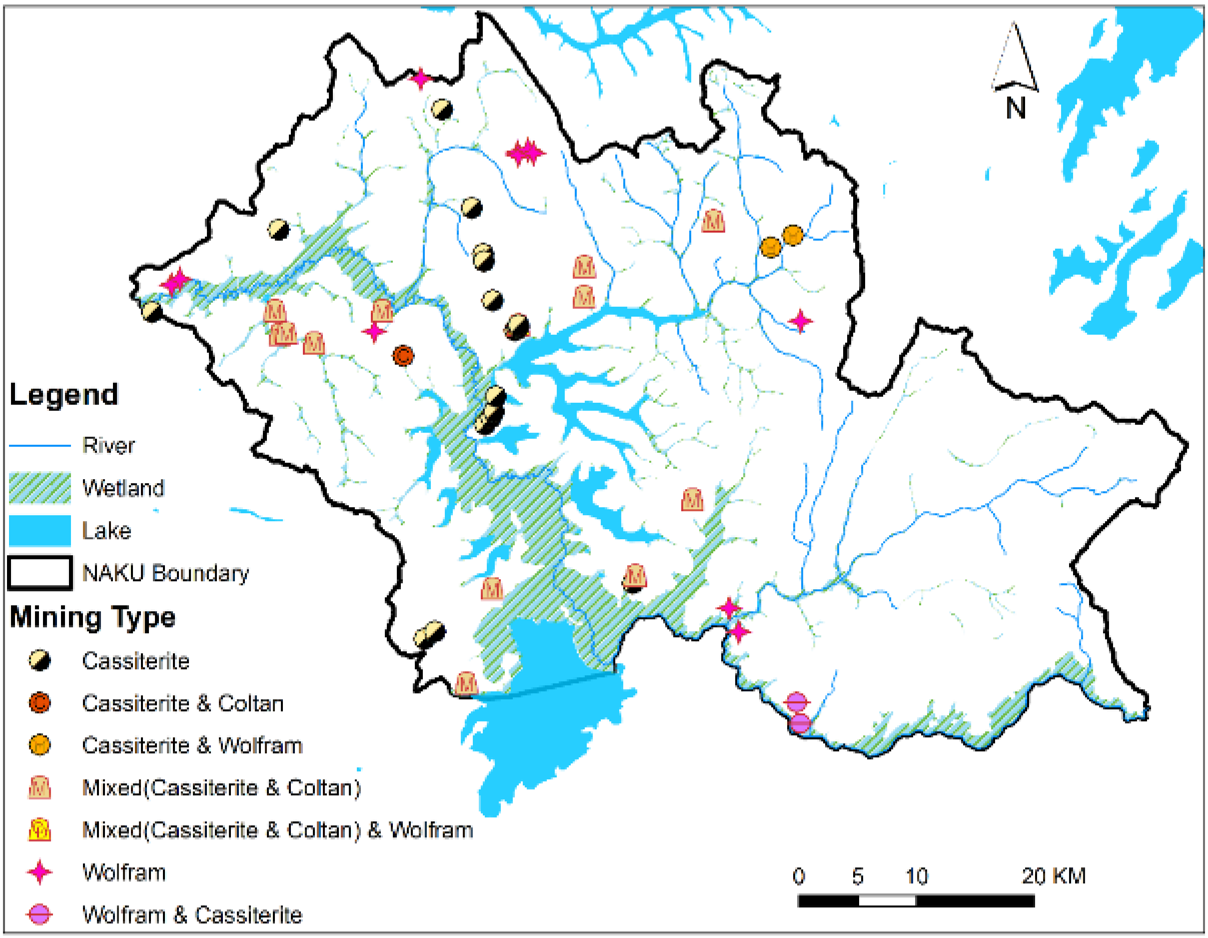
Furthermore, Figure 2-33 indicates the location of main infrastructure in the member Districts of the Nile Akagera UpperCatchment. Those of interest in the industry sector are Tea factories, trade centres, coffee washing station and fish farming. There is also a proposed industrial zone at Gashanda Sector in Ngoma District.

Table 2-14 illustrates that agriculture remains the catchment's largest economic contributor (57.3%), followed by trade (12.2%) and construction (4.2%). Transport/communications and manufacturing contribute almost at the same rate to the economy (3.3% and 3.1% respectively). The tertiary industry (recreation and tourism) are not well developed in the catchment with only 0.9% similarly to the mining industry discussed in more details. The catchment has the potential to develop more eco-tourism through wetland conservation such as Ramsar status and the occurrence of IUCN red list avian species. Eco-tourism includes formal employment through lodges, drivers, guides, conservation management, catering and curious, while visitors will bring investment into the area by bringing external expenditure into the catchment, i.e. spending by tourists contribute to the pool of money available within the catchment. Furthermore, the re-location of the International Airport to Bugesera District will also facilitate increased tourism to the catchment.

TABLE 2- 26 KEY INDUSTRIES WITHIN THE CATCHMENT AREA (SOURCE: NISR, 2011)

Districts	Percentage (%) of industry of usual main Job					
	Agriculture, Fishing & Forestry	Mining & Quarrying	Manufacturing	Construction	Trade	Transport & ICT	Recreation & Tourism
Nyarugenge	17.1	1.0	7.1	4.7	26.2	6.6	2.5
Gasabo	31.4	1.1	4.0	7.0	17.1	6.0	1.5
Kicukiro	18.6	0.4	4.7	6.8	18.9	5.7	1.8
Rwamagana	76.0	0.5	2.1	3.5	8.2	1.3	0.0
Kayonza	79.0	1.5	1.6	1.6	9.8	1.5	0.5

Ngoma	81.5	0.5	2.6	1.3	5.6	1.3	0.0
Bugesera	77.8	1.3	1.4	4.7	4.8	1.9	0.6
Average	57.3	0.9	3.1	4.2	12.2	3.3	0.9



FUGURE 2- 44 MAP INDICATING THE MINING AREAS AND KEY INDUSTRY WITHIN THE CATCHMENT

2.2.3 TOURISM

Nature based tourism, eco-tourism, is among the fastest growing tourism sectors in Africa. Rwanda boasts an environment with a rich biodiversity. In particular the Nile Akagera UpperCatchment is well known for bird-watching, Figure 2-27, and has the potential to contribute significantly to the development of the tourism sector both in the catchment and in Rwanda, especially with the construction of the Bugesera Airport.

FUGURE 2- 45 SIGN BOARD FOR BIRDING VISITORS TO LAKE RUMIRA IN THE CATCHMENT

Rwanda has ecosystems that are the home to many plant and animal species due to the suitable tropical climate. Most conservation initiatives are primarily focused on creating protected areas, and thus there is a further need of processes that assess the economic value of these ecosystems. A study under MINAGRI was commissioned to determine the economic evaluation of Nyungwe National Park and the Rugezi wetlands, as a process of understanding their natural ecosystem processes and the range of associated economic, social, cultural and spiritual benefits known as ecosystem services. The project provides quantitative and qualitative estimates of the natural capital stored in Nyungwe National Park and Rugezi Wetlands to enable a visualization of their value to the Rwandan economy and society. Although neither of these study areas falls within the Nile Akagera Upper Catchment, the lessons learnt from the project can be extrapolated and applied to the eco-tourism potential of the Nile Akagera Upper Catchment.

In summary from the study, the economic value of the ecosystem functions provided by Rugezi Wetlands is reflected in United States Dollars in Table 2-15, adapted from WCS Rwanda. It is important to note that this is for a protected area, where conservation of the ecosystem functions is promoted, unlike in unprotected areas where prevailing land use reduces the potential of ecosystem functions. Although some of the ecosystem good and services would not be applicable say in Mugesera Wetland complex e.g. hydropower generation, the value of other services such as water provisioning and storage, carbon sequestration, tourism would be higher. This demonstrates that there is economic value derived from protecting ecologically sensitive areas.

TABLE 2- 27 SUMMARY OF ECONOMIC VALUE OF ECOSYSTEM FUNCTIONS IN RUGEZI WETLANDS

Type of function	Ecosystem goods and services	Value (US$)
Provisioning services	Employment generation, agriculture, fuel wood, grazing/fodder, timber, non-wood produce, small timber,	59,818,769

	gene pool protection, tea plantation, rice farming, honey, hydroelectricity, water provisioning	
Regulating services	Carbon sequestration, sediment regulation/retention, biological control, moderation of extreme events, pollination, soil fertility, microclimate, waste assimilation	195,392,364
Cultural services	Recreation, research, education and nature interpretation	Not evaluated
Supporting services	Habitat/refugia, nutrient recycling, soil formation	Not evaluated
Value 2014 US$1 = RWF 700		**US$ 255,211,133 per year**

The results from the NIRAS study to compare the economic benefit of eco-tourism to agriculture are not yet available.

According to the WCS Rwanda Report (2017), tourism in Rwanda was estimated to generate 293.6 million US$ in 2013 in comparison to 281.8 million US $ in 2012 marking a 4% increase (RNR, 2014). Direct employment from the tourism sector for the year 2010/2011 was estimated at 23,000 jobs with more represented by indirect sources of employment such as restaurants, transportation, services and retail trade (RNR, 2014). This led to the development of the Rwanda Protected Areas Concessions Management (RPACM) policy under the Ministry of Trade and Industry to attract private sector investment in tourism based businesses (RNR, 2014). Rwanda's Vision 2020 considers biodiversity as a key goal that is focused towards sound policy hinged upon sustainable development while implementing land and water management techniques (RNR, 2014) and EDPRS-2 specifically identifies increasing tourism in the Districts within the Catchment area as an economic growth strategy. However, the areas (e.g. Gashora-Mugesera wetland system a proposed Ramsar site) for potential tourism growth are currently being cultivated agriculture, therefore there is a conflict in policy implementation.

The number of international tourists arriving in Rwanda has increased significantly over the past few years, almost doubling from 2008 to 2014 (Rwanda Development Board 2016). Tourism related expenditures in 2014 accounted for 24.5% of Rwanda's export, a figure more than four-times the world export contribution average (World Bank Development Indicators: Travel and Tourism, 2016). The contribution of travel and tourism investment out of the total capital investment in Rwanda is 7.9%, almost twice the world average (World Travel and Tourism Commission, 2016). As there are no formal tourist records within the catchment area, this information is only presented at the National level

Therefore, the tourism potential coupled with the economic value of conservation of the ecosystem functions of Mugesera Wetland Complex within the Catchment should be considered as an economic scenario in developing the Catchment Management Plan.

2.2.4 MINING

As it is described in the Rwanda Environmental Outlook report 2015 (REMA, 2015), the mining industry in Rwanda mainly refers to the "3T minerals". These are tin, tungsten and tantalum ores (cassiterite, coltan and wolframite). In Rwanda, private companies began mining for cassiterite and wolframite in the 1930s. The mining sector was nationalized in 1973 but mismanagement resulted in its collapse in the 1980s-1990s. Later, in 1997, mines were privatized and the mining sector began to recover, aided by increased foreign investment in exploration and mining between 2006 and 2009. Currently, the mining sector is characterized by private sector and small scale/ artisanal mining operations, usually organized as cooperatives. This sector has seen considerable growth over the years, increasing its contributions to the GDP. Within the Nile Akagera Upper Catchment there are 42 formal concessions, mostly for underground mines. The main minerals mined are Cassiterite and Wolframite, both members of the Tungsten family of minerals, and used in the production of electric filaments and armour piercing ammunition. Noteworthy, there are several mines within or adjacent to the proposed Ramsar site of the Akagera- Mugesera wetland complex. The impacts of sediment and acid mine drainage must be specifically monitored to mitigate impacts to the proposed Ramsar site.

Annexure B provides information on the few mining concessions, minerals produced and the production details in the Nile Akagera Upper Catchment. Figure 2-26 indicates where these concessions are localised. Note that all these mine concessions references here are certified by Ministry of Environment. There may be other uncertified mines in the Catchment.

The majority of these mining concessions are underground mining. This type of mining has a minimal amount of overburden removed to gain access to the mineral deposit. Access to this minerals deposit is gained by tunnels or shafts. Underground mining has a less environmentally-destructive means of gaining access to an ore deposit, but it is often costlier and entails greater safety risks than strip mining, including open-pit mining. Only two of these concessions are large open-pit mining. Open-pit mining often involves the removal of natively vegetated areas, and is therefore among the most environmentally destructive types of mining. The major impacts associated with mining activities include deposit of tailings from the mine digs – if not managed properly these contribute to increased turbidity and sediment loads in the water resources; dewatering of mines as they dig through aquifers and fissures can also result in reduced water quality e.g. pH, and the suspension of heavy metals into the water resources thereby reducing the quality for other users as well has associated health impacts from contaminated water.

Furthermore, all these concessions are active mines. This normally means that the mining company has constructed access roads and prepared staging areas that would house project personnel and equipment one mining has commenced. The activities have their own associated impacts.

2.3 SOCIO-ECONOMIC STATUS

The estimate population of the Catchment is approximately 1,609,760 people. The population within the sectors in the Catchment and population density are presented in Table 2-1 above. The socio-economic status of Nile Akagera Upper Catchment was collected through the Socio-economic household surveys (Aurecon, 2017 and UR, 2020). The full report is available separately. Key findings are included in this report in the following tables. The methodology used for the household surveys is included in Annexure E. During the survey, socio-economic features were explored in line with the study in Nile Akagera Upper catchment.

Of the households surveyed across the Nile Akagera Uppercatchment, 76.2% own the house with legal title where 34.3% of owners are men, only 12.5% are women and 45.6% are both the owner.

Respondents' professional activity (employment) is predominantly in agriculture, (90.5% of respondents):

Respondents' professional activity (employment)	Responses	% response
Agriculture	533	85.4
Government salaried	13	2.1
Private sector salaried	35	5.6
Transport	7	1.1
Labour / casual pay	10	1.6
Skilled handcraft (Carpentry, Masonry, Weaver, Electrician, Repair work etc.),	9	1.4
Self-employed professional	6	1.0
Unemployed	11	1.8
Other	3	0.5
Total	622	99.7

The majority of the households fall into the income brackets of 5,000 to 50,000 per month; 29.1 % fall into the income brackets of 5000 to 20000 per month, 42.6% into the income brackets of 21000 to 50000 while 15% fall into the income brackets of 51000 to 100000.

Monthly income	Responses	% response
Under 5,000	39	6.3
5,000 to 20,000	213	34.1
21,000 to 50,000	222	35.6
51,000 to 100,000	75	12.0
101,000 to 300,000	43	6.9
301,000 to 500,000	8	1.3
501,000 to 1,000,000	1	0.2
1,001,000 and above	3	0.5

A large proportion of the respondents (43.6%) still consider themselves as poor, however the there is a large proportion (37.6%) who consider themselves in the lower middle-income level. This is significant given the Vision 2020 objective of moving towards a middle-income country.

Respondents' personal considerations in terms of income

How do you consider yourself? (economically)	Responses	% response
Very poor	79	12.7
Poor	287	46.0
Lower middle-income level	230	36.9
Middle income level	24	3.8
Higher middle-income level	3	0.5

When asked what the causes of poverty were, the households (46.1%) indicated the lack of land as being the primary reason: 30.3% reported climate change as being the factor of poverty.

	Lack of land	Soil infertility	Climate change	High population pressure	Others
Frequency	308	55	159	35	65
Percent	49.4	8.8	25.5	5.6	10.4

Apart from weather related factors, other explanatory factors of poverty in Nile Akagera Upperinclude laziness, limited job opportunities, absence of water and electricity, lack of job, illiteracy, family instability and conflicts, farm and grow diseases, lack of land and seeds, poor road infrastructure and limited development projects.

When asked what would make the respondents happier? The respondents explained that more financial income as the lead factor that would bring them happiness, but other activities that would make them happier include buying a personal car, getting a better work place, having a job, having a better health, assured peace, having a land to cultivate, assistance to get a loan and any other sort of development support, having a personal house, water, electricity and the market in the neighbourhood. In addition, respondents quoted getting a construction permit, tuition fees for the children, having enough food, land, rain, fertilizer, training and agricultural tools. Some respondents also underlined the obtainment of sheep, goat, pig or cow.

Vulnerable groups in the households include: people with disability (6.5 %), orphans (5.3%), genocide survivors and widows (5%) and widows (2.5%).

Categories of vulnerable groups	Responses	% response
Refugees	12	1.9
Orphans	101	16.2
Child-headed households	10	1.6
Widows	48	7.7
Woman-headed households	14	2.2
Genocide survivors and widows	17	2.7
People with disability	82	13.1
Albinos	2	0.3
People with illness e.g. HIV/AIDS, TB	8	1.3

Within the past six months members of the household experience illness is very high because 74.7% of the households living in Nile Akagera Upperhave had a sick person in the last six months.

Household member illnesses in the past six months?	Responses	% response
Yes	477	76.4
No	174	27.9

Types of illnesses: The data indicates that malaria is the leading illness in the Nile Akagera Upper(24.8% of respondents) followed by Diarrhoea (1%). the rarest illness in the Nile Akagera Upperare chest infection, mood swings and migraines (0. 8% each).

Types of illnesses	Responses	% response
Malaria	185	29.6
Diarrhoea	24	3.8
Chest infection/cough/breathing difficulty	97	15.5
Mood swings, depression/ anxiety	3	0.5
Migraines or headaches	3	0.5
Visual disturbances (blind spot, halos, etc.	1	0.2
Burning extremities	6	1.0
Other	16	2.6

International research (e.g. Richards, *et al.*, 2010) has shown a direct link between occurrence of Malaria and paddy-rice. During the Catchment Management Planning workshop in September 2017, Districts confirmed there was an increase in Malaria since the implementation of the wet field rice cultivation projects.

Access to medical care/treatment: The data indicates that the majority of residents, i.e. 46.1% in Nile Akagera Upperhave medical care/treatment easily available to the household. 17.3 % reported that they have accessibility to medical treatment but far away from the households while 6.3 % are still using traditional medicine.

	Yes, close	Yes, but far away	No	Use traditional medicine
Frequency	184	69	20	25
Percent	46.1	17.3	5.0	6.3

In relation to energy used for lighting (cooking is already indicated in the Energy section of this report), the households (72%) indicated that a torch was the most common form of lighting.

Energy type used for lighting	Responses	% response
Electricity	292	46.8
Candle	96	15.4
Kerosene Lamps	35	5.6
Battery	17	2.7
Solar energy	82	13.1
Torch	98	15.7
other (specify)	2	0.3
Total	622	99.7

Residents in Nile Akagera Upperappeared to use mostly electricity as the main energy source for lighting (38.1%). The other sources of light use include candle (19.3%), kerosene (5.5%) and solar energy (13.8% of respondents.

In relation to identifying types of disasters experienced in the catchment area over the previous 2 years, it was indicated that flooding (6.3%) and drought (16%) are the sounding disasters that affected residents. However, 18.3 reported no disaster in Akagera Mugesera. the households indicated the types of disasters they've experienced as:

Kind of disaster faced in 2 past years	Responses	% response
Erosion	88	14.1
Flooding	89	14.3
Land sliding	17	2.7
Drought	102	16.3
Earthquake	5	0.8
Snow	4	0.6
None	97	15.5
Other (specify)	28	4.5

The other types of disasters communicated by respondents include widespread farm insects like '*nkongwa*', crocodile and hippopotami attacks, hunger, long sun shine period, dryness, malaria, heavy wind, '*urubura*' and lack of water.

The causes of the disasters were identified as:

Causes of the disasters	Responses	% response
Unsuitable agriculture activities	6	1.0
Deforestation	35	5.6
Mining activities	11	1.8
Climate change	429	68.8
Irrigation infrastructures	7	1.1
Topography of the area	24	3.8
Spell/curse/magic	3	0.5
Other (specify)	81	13.0
Total	596	95.5

Climate change is the pinpointed lead factor to the experienced disasters (66.2%) followed by deforestation (6.3%). Among other suggested factors behind these disasters as communicated by informants include God' punishments to human beings' sins, non-collection of rain water and the absence of tap water in the community.

In terms of access to water the households indicated that the residents of Nile Akagera Upperdid much use public tap/standpipe (24.8 %) as the main source of water. While 13.8% use unprotected spring and 9% of households use piped into dwelling.

Main sources of water	Responses	% response
Piped into dwelling	45	7.2
Piped to yard/plot	27	4.3
Public tap/standpipe	260	41.7
tube well /borehole	16	2.6
covered well	1	0.2
protected well	10	1.6
unprotected well	29	4.6
protected spring	10	1.6
unprotected spring	55	8.8

rainwater	12	1.9
rain water harvesting	9	1.4
surface water (river /lake /pond /stream / irrigation channel)	147	23.6
other (specify)	1	0.2
Total	622	99.7

However, challenges experienced with the water supply include the following; notably water that is very expensive (42%, water cuts (35%), not clean water (21%) and runs dry (19%). Other challenges include difficult to access (9%) and long way from the house (6%).

Existing problems with water supply	**Responses**	**% response**
Expensive	53	8.5
Water cuts	187	30.0
Runs dry	19	3.0
Difficult to access	28	4.5
It is a long way from the house	6	1.0
Not clean (water is muddy or unusual colour or not transparent)	49	7.9
Water smells bad/unnatural (for example, swampy smell, chemical smell, rotten egg smell)	3	0.5
Water tastes bad/unnatural (for example, too salty, soapy taste, unnatural taste)	3	0.5
other (specify)	29	4.6

Majority of households (67.9%) reported that they spent less than an hour collecting and treating the water while 22.6% of households spent 1 hour collecting and treating water a day, 6% spent 2 hours and 3% more than 2 hours per day.

Time daily spent on water collection and treatment	**Responses**	**% response**
Less than an hour	271	67.9
1hour	90	22.6
2hour	24	6.0
more than 2 hours per day	12	3.0
Total	397	99.5

In terms of access to sanitation, the majority of households surveyed in the catchment indicated toilet facilities were pit latrines (majority of 46.6% with a constructed floor slab and 48.1 % without a constructed floor slab). Within increasing population growth more formal sanitation and treatment of waste water is necessary to avoid contamination of groundwater sources.

Types of toilets used	**Responses**	**% response**
Flush toilet	13	2.1
Pit latrine with constructed floor slab	259	41.5
Pit latrine without constructed floor slab	320	51.3
No toilet, open defecation	24	3.8

composting toilet/econoloo	4	0.6
Other	1	0.2
Total	621	99.5

The lack of formal disposal of solid waste was raised by Districts during the Catchment Management Planning Workshops in September 2017 as a serious issue. The poor management of solid waste is re-iterated in the household responses: It was reported that the solid waste are mostly disposed in open pit (54.4%), nearby household, while 14.8 % reported to compost it and 13.8 % reported that they are collected regularly and disposed in a pre-defined landfill. 7.8 % indicated that they are disposed to a wild disposal area and 3.8 said that they disposed irregularly

Disposal of solid wastes	**Responses**	**% response**
They are collected regularly and disposed in a predefined landfill	120	19.2
Disposed to a wild disposal area	45	7.2
Disposed in my own open pit (nearby household)	359	57.5
Disposed irregularly	18	2.9
Burning,	7	1.1
Disposed to the river/lake	1	0.2
compost it	59	9.5
other(specify)	13	2.1
Total	622	99.7

In terms of agricultural practices, the main types of crops grown by the households surveyed in the catchment include vegetables (5.5%), rice (2.5%), beans (2%)and potatoes (1.8%).

Types of crops grown	**Responses**	**% response**
Rice (paddy)	10	2.5
Maize/ sorghum/millet	4	1.0
Beans	8	2.0
Bananas	1	.3
Potato (Irish)	3	.8
Potato (African/sweet)	7	1.8
Vegetables (tomato, onion, spinach)	22	5.5
Other (please name)	14	3.5

Among other crops that are found in Akagera Upstream include ‘*amateke/igname*’, sugar cane, ‘iminyorogoto’, ‘*intoryi/obergine*’, ‘macadamia’, “*inzuzi/courge’, soja, ground nuts, cassava, onion, ‘poivre’ and water melon.*

The primary purpose of farming activities if for the household consumption. When respondents were also asked for what purpose do they farm, they reported that the primary purpose of farming activities was for the household consumption (46.9% of respondents) and 31.8 % reported to farm for selling to local market and 14.8 % reported to farm for home consumption and selling the rest. Only very few indicated that the purpose of farming was to sell to external markets (3.8%).

Purpose of farming	**Responses**	**% response**
Only for the household	310	49.7

Selling at local market	155	24.8
Selling at external markets	19	3.0
Home consumption and sell the rest	59	9.5
Other (please specify) markets	8	1.3
Total	624	100.0

2.4 WATER BALANCE

In order to evaluate water balance at the level NAKU catchment scale, water consumption was evaluated for existing and future conditions in the following sectors:

- Domestic water
- Irrigation water
- Industry
- Mining
- Coffee Washing Station
- Fish ponds
- Livestock

2.4.1 EXISTING DEMAND

Domestic water Consumption

Domestic Water Consumption (DWC) was calculated by using three main factors as considered by WASAC for their water supply projections and associated investment plans. These main factors include; urban water supply, rural water supply and small-scale industrial facilities. This group of consumptive use is referenced as “domestic water consumption” in order to make the terminology consistent with the main water consumption categories presented in the National Master Plan of Rwanda (2014).

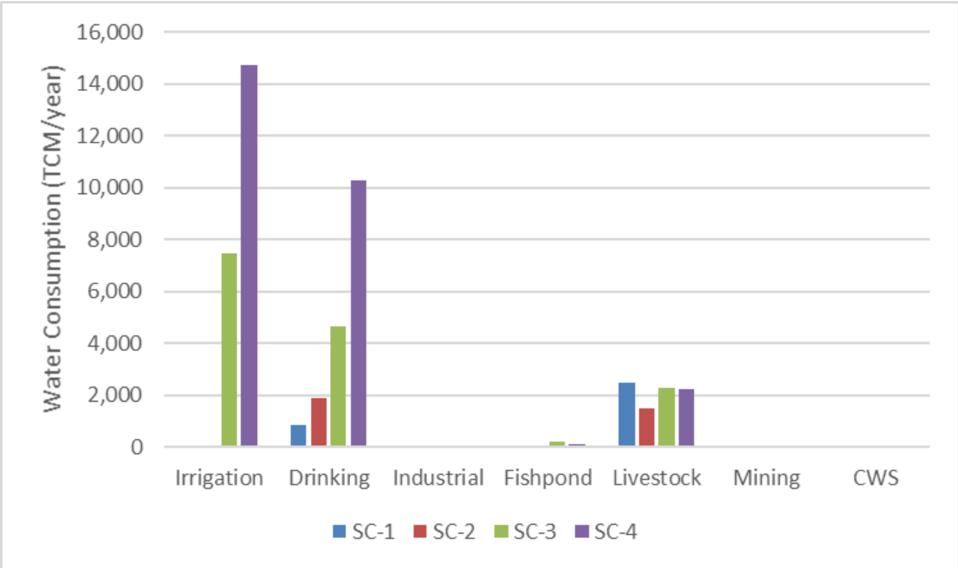
The outcomes are summarized in Table 2-17 at the end of this section and further details are documented in **Annexure D**.

2.4.1.1 MAIN OUTCOMES

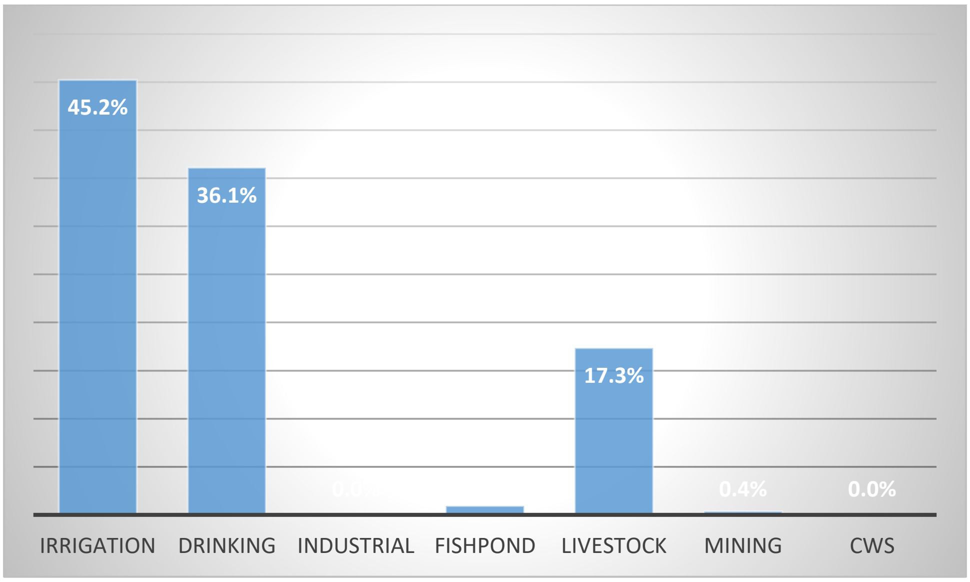
Based on the existing sectoral water consumption values, the main outcomes are summarized below:

- The highest water consuming sectors include Irrigation, Drinking and Livestock, **Figure 2-36**. These three sectors account for approximately 99% of total water consumption.
- Irrigation water consumption, which account for approximately 45% of total water demand, is driven by the consumption needs large-scale agricultural command areas.
- In all sectors, water consumption is the highest in Sub-catchment 4.
- It is important to note that all other sectors (including industry, fishpond, coffee washing station and mining) consume significantly lower amount of water.

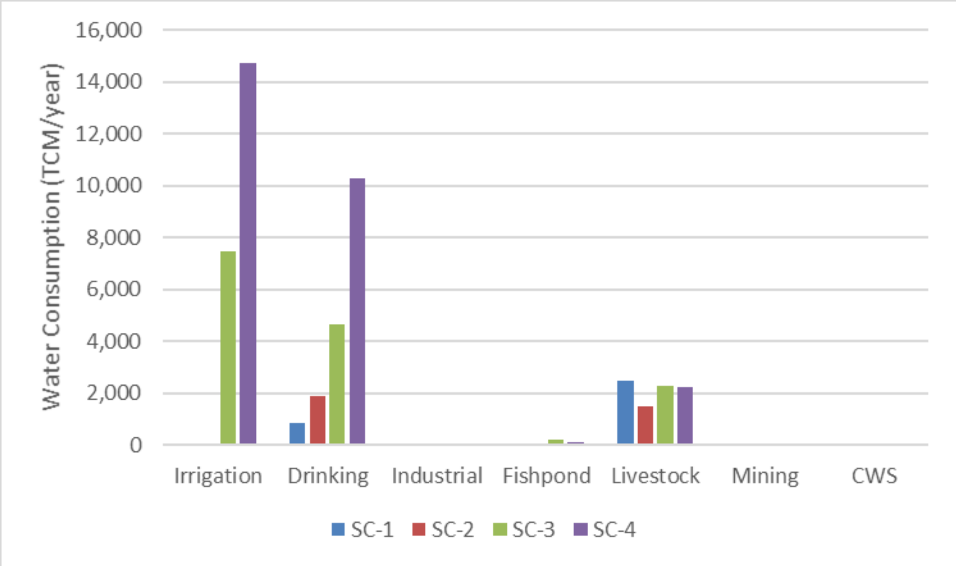
- In this context, these low water consuming sectors should be monitored in the context of point and distributed sources of pollution introduced to surface water and/or groundwater environment during operations of such facilities.



a. Water Consumption of Respective Sectors - Existing Conditions (TCM/year): Sub-catchment scale



b. Water Consumption of Respective Sectors - Existing Conditions (%): Level-2 Catchment scale



FUGURE 2- 46 SUMMARY WATER CONSUMPTION

FUTURE CONDITIONS

The changes in water consumption were evaluated by considering the impacts of climate change and population growth. The impacts of climate change were reflected through use of two main scenarios of RCP 4.5 and RCP 8.5. The impacts of population growth were reflected through use of low, medium and high growth scenarios as documented by NISR. The resulting total water consumption values are summarized below:

Future conditions water demand and consumption at level-2 catchment scale were identified by using the processes defined in previous sections.

- ❖ In 2020, the consumptive water is documented in Table 2-18, to explore the feasibility of the Vision 2030 targets in the light of the available resources;
- ❖ In 2030, the consumptive water demand is documented in Table 2-19, to explore the feasibility of the corresponding scenario for each sector.
- ❖ In 2050, the consumptive water demand for all use sectors combined over the year per level 2 catchment is documented in Table 2-20, to evaluate level of fluctuation in highest demand scenario during the year.

Future conditions water demand and consumption at level-2 catchment scale were identified by using the processes defined in Section 2.3.1.2.

- ❖ Total sectoral consumptive demand is expected to increase from approximately 46.0 hm^3/year in NAKU-1 in 2012 to approximately 51.0 hm^3/year in 2020, to approximately 70.0 hm^3/year in 2030 and to approximately 200.0 hm^3/year in 2050.
- ❖ This corresponds to an expected increase of approximately four-fold in NAKU-1 within a 30-year time frame.
- ❖ The existing and future conditions water resources has the potential to compensate such increase in demands.

TABLE 2- 28 WATER AVAILABILITY

Water Availabilty in NAKU and its 2.5 level subcatchments at RCP4.5 [CM/Year]

Subcatchment	Year						
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Subcatchment1	472,928,792	472,928,792	472,928,792	472,928,792	472,928,792	472,928,792	472,928,792
Subcatchment2	209,183,793	209,183,793	209,183,793	209,183,793	209,183,793	209,183,793	209,183,793
Subcatchment3	768,097,269	768,097,269	768,097,269	768,097,269	768,097,269	768,097,269	768,097,269
Subcatchment4	372,509,217	372,509,217	372,509,217	372,509,217	372,509,217	372,509,217	372,509,217
Subcatchment5	269,975,485	269,975,485	269,975,485	269,975,485	269,975,485	269,975,485	269,975,485
Subcatchment6	606,807,958	606,807,958	606,807,958	606,807,958	606,807,958	606,807,958	606,807,958
Subcatchment7	215,829,014	215,829,014	215,829,014	215,829,014	215,829,014	215,829,014	215,829,014
NAKU	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**

Water Availabilty in NAKU and its 2.5 level subcatchments at RCP8.5 [CM/Year]

Subcatchment	Year						
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Subcatchment1	472,928,792	472,928,792	472,928,792	472,928,792	472,928,792	472,928,792	472,928,792
Subcatchment2	209,183,793	209,183,793	209,183,793	209,183,793	209,183,793	209,183,793	209,183,793
Subcatchment3	768,097,269	768,097,269	768,097,269	768,097,269	768,097,269	768,097,269	768,097,269
Subcatchment4	372,509,217	372,509,217	372,509,217	372,509,217	372,509,217	372,509,217	372,509,217
Subcatchment5	269,975,485	269,975,485	269,975,485	269,975,485	269,975,485	269,975,485	269,975,485
Subcatchment6	606,807,958	606,807,958	606,807,958	606,807,958	606,807,958	606,807,958	606,807,958
Subcatchment7	215,829,014	215,829,014	215,829,014	215,829,014	215,829,014	215,829,014	215,829,014
NAKU	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**	**2,915,331,529**

No change in water availability is expected in NAKU Catchment base on the considered climate scenarios

Water Out Flows from NAKU and its 2.5 level subcatchments at RCP4.5 [CM/Year]

Subcatchment	Year						
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Subcatchment1	399,966,258	378,245,457	378,245,457	378,245,457	378,245,457	378,245,457	378,245,457
Subcatchment2	186,389,291	175,560,700	175,560,700	175,560,700	175,560,700	175,560,700	175,560,700
Subcatchment3	683,252,733	639,612,761	639,612,761	639,612,761	639,612,761	639,612,761	639,612,761
Subcatchment4	344,280,322	311,583,792	311,583,792	311,583,792	311,583,792	311,583,792	311,583,792
Subcatchment5	255,106,938	247,448,902	247,448,902	247,448,902	247,448,902	247,448,902	247,448,902
Subcatchment6	573,388,803	556,176,288	556,176,288	556,176,288	556,176,288	556,176,288	556,176,288
Subcatchment7	203,942,513	197,820,379	197,820,378	197,820,378	197,820,378	197,820,378	197,820,378
NAKU	2,646,326,858	2,506,448,278	2,506,448,278	2,506,448,278	2,506,448,278	2,506,448,278	2,506,448,278

Water Out Flows from NAKU and its 2.5 level subcatchments at RCP8.5 [CM/Year]

Subcatchment	Year						
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Subcatchment1	399,966,258	378,245,457	378,245,457	378,245,457	378,245,457	378,245,457	378,245,457
Subcatchment2	186,389,291	175,560,700	175,560,700	175,560,700	175,560,700	175,560,700	175,560,700
Subcatchment3	683,252,733	639,612,761	639,612,761	639,612,761	639,612,761	639,612,761	639,612,761
Subcatchment4	344,280,322	311,583,792	311,583,792	311,583,792	311,583,792	311,583,792	311,583,792
Subcatchment5	255,106,938	247,448,902	247,448,902	247,448,902	247,448,902	247,448,902	247,448,902
Subcatchment6	573,388,803	556,176,288	556,176,288	556,176,288	556,176,288	556,176,288	556,176,288
Subcatchment7	203,942,513	197,820,379	197,820,378	197,820,378	197,820,378	197,820,378	197,820,378
NAKU	2,646,326,858	2,506,448,278	2,506,448,278	2,506,448,278	2,506,448,278	2,506,448,278	2,506,448,278

Note:

1. Water outflows of the NAKU catchment is also expect not to change as a result of the two considered climate scenarios
2. The inflows are high than the out flows this is because of water storage within the catchment (Groundwater, Lake and Reserviours)

TABLE 2- 29 FUTURE WATER CONSUMPTION CONDITIONS - 2020 (TCM/YEAR)

Sub-catchment		Irrigation	DW-L	DW-M	DW-H	Industrial	Fishpond	Livestock	Mining	CWS	Total-L	Total-M	Total-H
1	RCP 4.5	2,472.6	993.2	1,009.4	1,015.1	0.0	26.9	2,887.1	81.9	0.0	6,461.7	6,477.9	6,483.5
2		4,696.4	2,258.6	2,295.5	2,308.2	0.0	71.7	1,747.5	25.3	7.8	8,807.3	8,844.1	8,856.8
3		20,478.0	5,551.4	5,642.0	5,673.4	0.0	215.0	2,685.0	0.0	12.4	28,941.8	29,032.4	29,063.8
4		35,445.9	12,219.6	12,418.8	12,483.4	84.0	134.4	2,616.3	89.3	4.0	50,593.5	50,792.7	50,857.2
TOTAL		63,092.9	21,022.9	21,365.8	21,480.0	84.0	448.0	9,935.8	196.5	24.2	94,804.3	95,147.1	95,261.3
1	RCP 8.5	2,470.7	993.2	1,009.4	1,015.1	0.0	26.9	2,887.1	81.9	0.0	6,459.7	6,475.9	6,481.6
2		4,686.2	2,258.6	2,295.5	2,308.2	0.0	71.7	1,747.5	25.3	7.8	8,797.1	8,833.9	8,846.6
3		20,433.7	5,551.4	5,642.0	5,673.4	0.0	215.0	2,685.0	0.0	12.4	28,897.6	28,988.2	29,019.5
4		35,417.9	12,219.6	12,418.8	12,483.4	84.0	134.4	2,616.3	89.3	4.0	50,565.4	50,764.6	50,829.2
TOTAL		63,008.5	21,022.9	21,365.8	21,480.0	84.0	448.0	9,935.8	196.5	24.2	94,719.8	95,062.7	95,176.9

TABLE 2- 30 FUTURE WATER CONSUMPTION CONDITIONS - 2030 (TCM/YEAR)

Sub-catchment		Irrigation	DW-L	DW-M	DW-H	Industrial	Fishpond	Livestock	Mining	CWS	Total-L	Total-M	Total-H
1	RCP 4.5	2,474.6	1,188.5	1254.72	1639.68	0.0	26.9	3,500.9	90.0	0.0	7,280.9	7,347.1	7,732.1
2		4,695.7	2,703.1	2853.12	3691.44	0.0	71.7	2,119.1	27.8	6.5	9,624.0	9,774.0	10,612.3
3		20,475.1	6,643.0	7012.68	9325.56	192.0	215.0	3,256.0	0.0	10.0	30,791.1	31,160.8	33,473.7
4		35,474.3	14,743.9	15436.08	19411.56	276.0	134.4	3,172.8	98.2	3.4	53,903.1	54,595.3	58,570.8
TOTAL		63,119.7	25,278.5	26,556.6	34,068.2	468.0	448.0	12,048.8	216.1	20.0	101,599.1	102,877.2	110,388.8
1	RCP 8.5	2,467.8	1,188.5	1254.72	1639.68	0.0	26.9	3,500.9	90.0	0.0	7,274.1	7,340.3	7,725.3
2		4,660.0	2,703.1	2853.12	3691.44	0.0	71.7	2,119.1	27.8	6.5	9,588.3	9,738.3	10,576.6
3		20,390.6	6,643.0	7012.68	9325.56	192.0	215.0	3,256.0	0.0	10.0	30,706.6	31,076.3	33,389.2
4		35,376.2	14,743.9	15436.08	19411.56	276.0	134.4	3,172.8	98.2	3.4	53,805.0	54,497.2	58,472.6
TOTAL		62,894.6	25,278.5	26,556.6	34,068.2	468.0	448.0	12,048.8	216.1	20.0	101,374.0	102,652.1	110,163.7

TABLE 2- 31 FUTURE WATER CONSUMPTION CONDITIONS - 2050 (TCM/YEAR)

Sub-catchment		Irrigation	DW-L	DW-M	DW-H	Industrial	Fishpond	Livestock	Mining	CWS	Total-L	Total-M	Total-H
1	RCP 4.5	2,478.5	1,579.1	1,725.1	2,537.5	0.0	26.9	4,728.6	99.0	0.0	8,912.1	9,058.2	9,870.6
2		4,703.3	3,590.8	3,923.9	5,835.7	0.0	71.7	2,862.2	30.6	7.0	11,265.5	11,598.6	13,510.4
3		20,507.8	8,825.9	9,642.1	13,900.4	276.0	215.0	4,397.7	0.0	11.4	34,233.8	35,050.1	39,308.4
4		117,546.1	19,532.4	21,428.4	34,467.2	408.0	134.4	4,285.4	108.0	4.0	142,018.4	143,914.4	156,953.2
TOTAL		145,235.6	33,528.1	36,719.5	56,740.9	684.0	448.0	16,273.9	237.7	22.4	196,429.8	199,621.2	219,642.6
1	RCP 8.5	2,462.0	1,579.1	1,725.1	2,537.5	0.0	26.9	4,728.6	99.0	0.0	8,895.6	9,041.7	9,854.1
2		4,629.7	3,590.8	3,923.9	5,835.7	0.0	71.7	2,862.2	30.6	7.0	11,191.9	11,525.0	13,436.8
3		20,342.7	8,825.9	9,642.1	13,900.4	276.0	215.0	4,397.7	0.0	11.4	34,068.8	34,885.0	39,143.3
4		116,757.8	19,532.4	21,428.4	34,467.2	408.0	134.4	4,285.4	108.0	4.0	141,230.1	143,126.1	156,164.9
TOTAL		144,192.2	33,528.1	36,719.5	56,740.9	684.0	448.0	16,273.9	237.7	22.4	195,386.3	198,577.7	218,599.1

2.4.2 WATER POTENTIAL

Total water potential has two main components: surface water and groundwater. The specific details on the formulation of surface water potential and groundwater potential were described in Section 2.3.1.4 and Section 2.3.1.5, respectively. The resulting Surface and Groundwater resources potential for both Surface and Groundwater resources for both

- ❖ Existing conditions (monthly time scale); and
- ❖ Future conditions (for the years 2020, 2030 and 2050 at a monthly time scale) are presented in **TABLE 2-21** and **Table 2-22** respectively.

In both the existing and future conditions, surface water resources potential in sub-catchment 4 is higher than the surface water potential in other sub-catchments summarized below.

It is important to note that changes in groundwater potential is a much slower process (in terms of spatial and temporal processes), in comparison to the surface water potential and does not necessarily reflect the wet and dry cycles experienced in surface water systems. It was also determined that the quantitative pressure on groundwater resources was quite low. In this context, it was assumed that groundwater potential for both existing and future conditions will remain the same.

2.5 CHALLENGES AND IMPACTS IN THE CATCHMENT

There are several cross-cutting themes in the catchment. The issues of these cross-cutting themes are summarised in Table 2-25 and are experienced throughout the issues raised and identified in the catchment. Specific challenges and issues identified in the catchment are detailed in this section.

TABLE 2- 32 SUMMARY OF CROSS-CUTTING ISSUES IN THE CATCHMENT

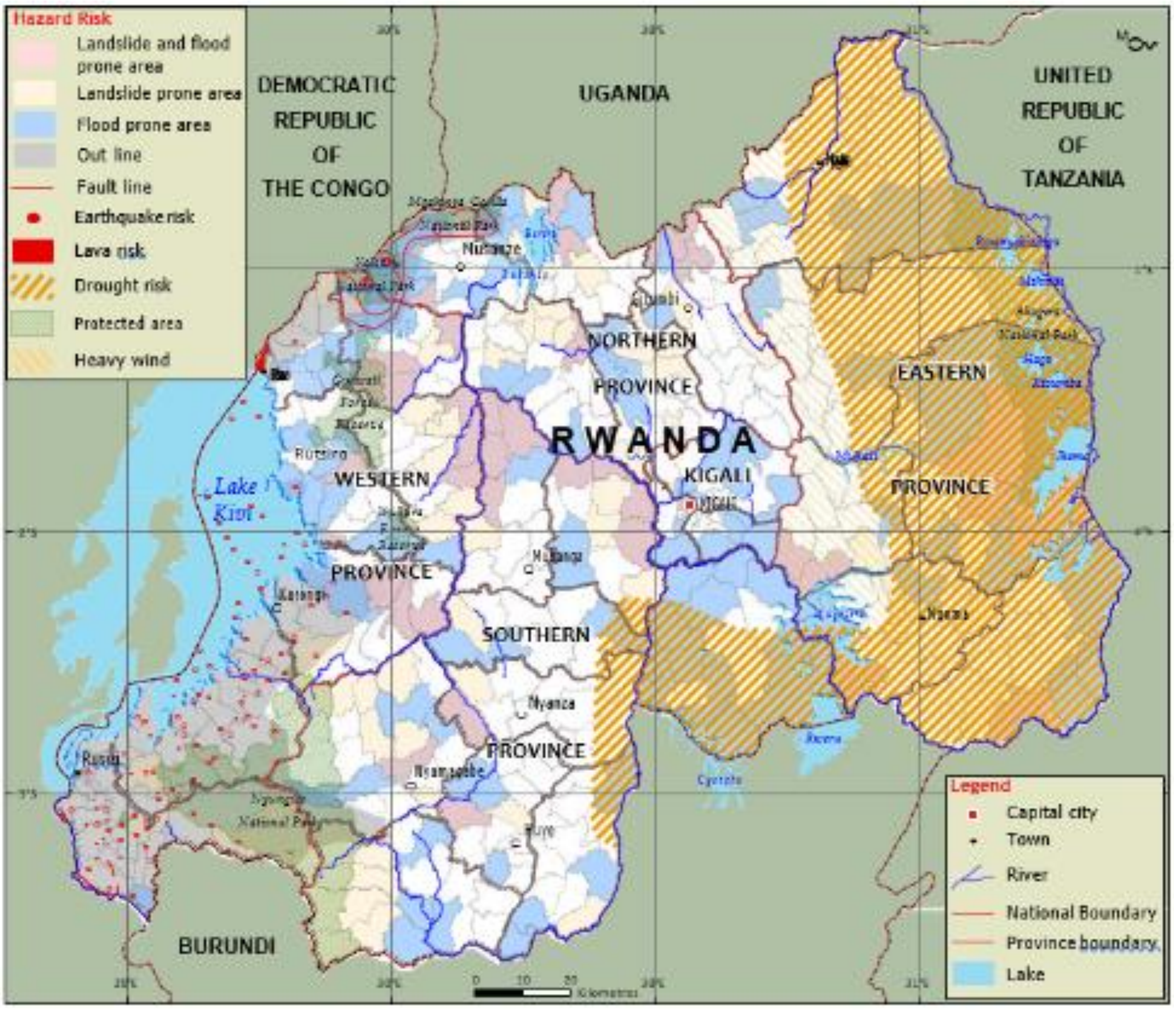
Cross Cutting Issue	Summary / Description
Climate Change	Effects include: Changes to the frequency and intensity of rainfall; increased temperatures - which impact evaporation and air temperature.
	Effects will have direct impact on the availability of water resources which will affect the development scenarios feasible within the catchment.
	E.g. Promotion of wet-paddy rice (linked to the spread of Malaria) over upland (dry) rice must also consider the impacts on the communities' health doing the farming and the resultant impact on their household expenditure to pay increased medical costs.
Health	Many health issues are directly related to water resources.
	When considering the management and development of water resources and associated economic sectors using the water resources, the impact on the communities' health also relying on the water resource or downstream of it must be considered.
Gender Issues	Issues or concerns determined by gender-based and/or sex-based differences between women and men.
	Issues include: All aspects and concerns related to women's and men's lives and situation in society (how they interrelate, their differences in access to and use of resources, their activities, and how they react to changes, interventions and policies) (European Institute for Gender Equality – EIGE, 2014).
	Women and men experience the process of development and the impact of the project differently. Their needs and priorities may also differ.
	Typical gender roles may also be affecting the development of natural resources, which will need to be considered in the catchment planning process.
Land Use Change	Changes in land use: Especially unregulated or unplanned result in degradation of natural resources, water resources of the catchment impacting climate change, health and other cross-cutting issues.

	E.g. Deforestation of natural forest areas to farming or to housing results in loss of biodiversity, increased soil erosion and sedimentation of water resources. Similarly: illegal mining, industry and development contribute to reduced water quality amongst other issues.
Poverty Reduction	Priority development objective of the Government of Rwanda.
	The development of a catchment management plan and development options must contribute to the reduction of poverty within the catchment in order to contribute towards achieving the national objective of poverty reduction.
Environmental Protection	Ecosystem functions provide the products to sustain all life (such as freshwater, clean air, food to eat, minerals to mine, fibres for cloth, materials to build, etc.).
	Life and economic development are reliant on healthy ecosystem functions to provide the resources required.
	Scenarios for the growth and development of the catchment must consider the environment from a conservation aspect and also protection from impacts to the ecosystem goods and services produced.
Economic Development	Rwanda is striving to become a middle-income country: Development scenarios within the catchment must promote economic development activities.

2.5.1 DISASTER RISK

In 2015, Rwanda published The National Risk Atlas of Rwanda, a comprehensive assessment of existing risks at the national and local level, led by the Ministry of Disaster Management and Refugee Affairs (MIDIMAR). It reports that over the last decade, the frequency and severity of natural disasters, particularly floods and droughts, have significantly increased, raising the toll of human casualties as well as economic and environmental losses (MIDIMAR, 2015). These hazards have caused mortalities, displaced populations, damaged infrastructure (roads, bridges, houses, schools and other properties), destroyed crops and caused serious environmental degradation. Hydro-meteorological hazards such as floods and droughts have affected the most people in Rwanda over the past two decades (UNDP, 2013). Over the 33-year period from 1974 to 2007, drought affected about 4 million Rwandans and 2 million were affected by floods (Zimmerman & Byizigiro, 2012).

Natural hazards across Rwanda as a whole can be categorized as: geological; hydro-meteorological; and biological and technological (UNDP, 2013). Rwanda is subject to hydro-meteorological hazards such as droughts, floods and various types of storms (i.e., windstorms, rainstorms and thunderstorms). Geological hazards in Rwanda include earthquakes and landslides, while biological and technological hazards include traffic accidents, diseases and epidemics. Figure 2- 46 shows the areas in Rwanda most prone to the major types of natural hazards. It is important to note that the wetland areas of Nile Akagera Upperare particularly prone to drought.



FUGURE 2- 47 HAZARD PRONE AREAS ACROSS RWANDA (SOURCE: MIDIMAR, 2014)

DROUGHT

In terms of droughts the focus is solely on agricultural droughts. Bugesera, Ngoma and Kirehe Districts are characterized by a high frequency of rainfall shortage, late onset of rainfall, early rainfall interruptions, and a significant number of dry spells and are prone to drought (MIDIMAR, 2015). Droughts have a significant impact in these regions as family farms are in general small and farmers are rainfall dependent. In terms of the Nile Akagera UpperCatchment, most of the catchment area falls within a high drought susceptibility zone during Season B according to the Drought Risk Atlas, illustrated in Figure 2-25, with Rwamagana District having a low drought susceptibility during Season A (MIDIMAR, 2015). Crop loss due to drought is very high in Rwamagana (16%), Ngoma (15%), and Bugesera (8%) Districts. Major crops such as banana and cassava are the crops with high vulnerability particularly in the districts of Rwamagana and Ngoma. The district of Rwamagana has the most volume of crops vulnerable to severe drought at very high susceptibility.

Issues of drought and water shortage were specifically raised by Nyarugenge, Bugesera, Rwamagana, Ngoma Kirehe and Kayonza Districts.

LANDSLIDE

In terms of landslides the landslide frequency and extent is estimated by using lithology, soil type and depth, rainfall, slope, land cover and distance to roads (MIDIMAR, 2015). Despite this assessment landslides remain difficult to predict, often requiring quantitative research in highly susceptible areas. The Eastern Province is not considered an area with a high likelihood of landslides. Table 2-24 summarises the slope susceptibility to landslide per District in the Catchment[2]. About 26% of people located in Nyarugenge, Gasabo and Kicukiro Districts in the capital Kigali City are vulnerable to landslides. The high population density and concentration of informal settlements in the urban centres like Kigali City is cited as a key factor in the high population vulnerability in these areas. Nyarugenge District has the highest number of vulnerable houses with 4,280 followed by Kicukiro with 2,444 houses and Gasabo with 2,101 houses. The most vulnerable houses are found in districts in the urban centre i.e. Kigali City.

TABLE 2- 33 SUMMARY OF SLOPE SUCEPTABILITY WITHIN THE PARTICIPATING DISTRCTS OF THE CATCHMENT (SOURCE: MIDIMAR 2015)

District	% slope susceptibility class				
	Very high	High	Moderate	Low	Very low
Bugesera	0	3	11	66	19
Ngoma	0	0	4	71	25
Rwamagana	0	1	26	61	13
Kicukiro	0	1	5	83	11
Nyarugenge	3	9	27	53	8
Gasabo	1	9	22	59	8
Kayonza	0	0	5	59	36

2.5.2 FLOODS

Due to its dense river network and large wetlands, the country is threatened mainly by riverine floods which leads to infrastructure damage, loss of life, landslides, damage to agricultural crops, soil erosion and environmental degradation (MIDIMAR, 2015). In terms of flood hazard mapping, floodplain areas have been mapped across the country. Bugesera, Kicukiro, Nyarugenge, Rwamagana and Ngoma Districts were part of this assessment as they are connected to Akagera River. Akagera River affected the most districts, with numerous flooding events happening in these districts. Bugesera District is the

[2] This information is not available at Sector level. The data sets required to make these calculations are not readily available.

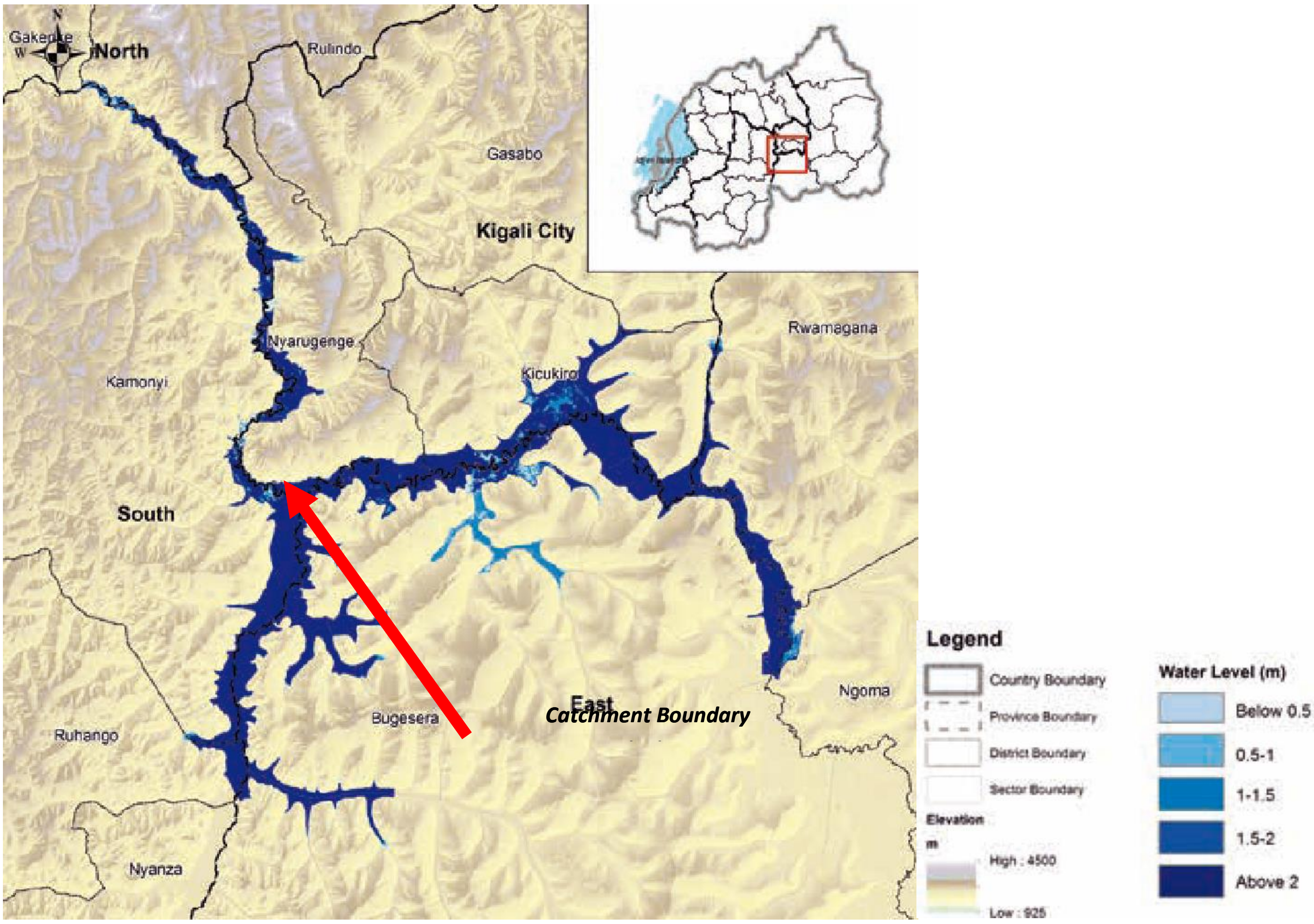
most affected in total area with water depths above 2m for the 25-year return period, **Table 2-25**, although it is not the most affected in terms of population (MIDIMAR, 2015).

TABLE 2- 34 FLOOD WATER LEVEL PER PARTICIPATING DISTRICT IN THE CATCHMENT (SOURCE: MIDIMAR 2015)

	Flood Water level area (ha)					
District	**Above 2m**	**1.5-2m**	**1-1.5m**	**0.5-Below 0.5m**	**below 0.5m**	**Total flooded area**
Bugesera	6285	0	875	0	405	7565
Ngoma	139	0	92	0	10	241
Rwamagana	926	0	38	0	27	990
Kicukiro	2282	0	264	0	107	2652
Nyarugenge	1711	0	150	0	100	1961
Gasabo	28	0	6	0	5	39
Kayonza	0	0	0	0	0	0
Kirehe						

Issues of flooding were specifically raised by Kicukiro (Masaka Sector), Gasabo, Rwamagana (Nyakariro Sector), and Ngoma Districts.

In particular the flooding along the Nyabarongo – Akagera River, especially in Bugesera District within the catchment is of concern as illustrated in Figure 2-27. These flood risks must be considered in all development planning, land use planning and mitigatory measures should be promoted through land management initiatives.



FUGURE 2- 48 MAP INDICATING FLOOD PRONE AREAS IN BUGESERA DISTRICT ALONG THE AKAYANRU AND NYABARONGO/AKAGERA RIVERS. (SOURCE: MIDIMAR, 2014)

The hazards or disasters that occurred from January to December 2015 (MIDIMAR, 2016), i.e. heavy rain, flooding and landslides, impacted on the level of erosion during that year. A general overview of disasters during this time indicated that heavy rain combined with wind has the most devastating impact nationally. The greatest impact in the catchment was seen in Bugesera District where there were large numbers of damaged houses and crops, Table 2-26. Bugesera District also suffered a landslide during this time, Table 2-27**.** No flooding cases were recorded in the catchment during this time.

TABLE 2- 35 THE DAMAGES AND LOSSES ASSOCIATED WITH WIND AND HEAVY RAIN IN THE ADMINISTRATIVE DISTRICTS OF THE NILE AKAGERA UPPERCATCHMENT. (SOURCE: MIDIMAR 2015)

District	Number of cases	Damaged houses	Deaths	Injuries	Damaged crops (ha)	Livestock
Bugesera	7	195	0	2	142	0
Ngoma	1	8	0	0	0	0
Rwamagana	15	109	0	0	2.5	0

Gasabo	2	43	0	0	0	0
Kayonza	2	2	0	0	0	0

TABLE 2- 36 THE DAMAGES AND LOSSES ASSOCIATED WITH LANDSLIDES IN BUGESERA DISTRICT. (SOURCE: MIDIMAR 2015)

District	Number of cases	Damaged houses	Deaths	Injuries	Damaged crops (ha)	Livestock
Bugesera	2	0	1	3	0	0

Riverine floods are more frequent in the marshlands of the country - low lying areas along major streams and lakes - and occur when run-off from sustained and heavy rainfall exceeds the capacity of a river's channel. Although households having access to marshland have the opportunity to cultivate during the dry season, their increased exposure to floods means important areas of crops cultivated in those marshlands are destroyed. The household proportions affected by floods are much higher in marshland districts i.e. Bugesera (50%). Households exposed to flooding are largely those whose livelihoods rely heavily on agriculture and livestock, and the poorest households were considered the least resilient to floods.

2.5.3 CONFLICTING LAND USE

The major conflicting land use occurring within the Nile Akagera UpperCatchment is between cultivated/irrigated agriculture and the Mugesera/Rweru Wetland Complex. The Mugesera Wetland Complex has been recommended for Ramsar status for the protection of wetland ecosystem function and habitat provision of a number of threatened bird, plant and wildlife species. Importantly the wetland complex plays a critical role in maintaining and regulating the storage of water to the adjacent lakes, which, in turn, provide water supply for socio-economic activities, and provide water supply back to the river in dry months. As highlighted in climate change and disaster risk sections and water resources section, the Catchment is likely to start facing water stress from 2020. The growing demand for water supply to Kigali City and the growing demand for Bugesera District (with the airport development) will place additional stress on this already stressed wetland system.

However, the Irrigation Master Plan, without considering the feasibility of its proposals, recommends that the Mugesera Wetland be developed for cultivated and irrigated agriculture as a means of meeting food security requirements. The plan does not address issues of loss of function (flood protection, biodiversity support, and other livelihood support services), mitigation measures such as offsets, identifying areas for permanent protection, or rehabilitation of degraded lands,and issues of loss of soil fertility as a priority before opening new land for agriculture. The irreversibility of certain choices which might preclude future potential uses were not adequately considered against scenarios where multiple uses, including expanded tourism, local micro enterprises, and the long term resilience of the ecosystem, are supported.

Furthermore, the conservation value of the Mugesera Wetland Complex has not been well communicated. The proposed high voltage powerline from the proposed Rusumo Falls hydropower generation plant (Rusumo-Shango 220Kv transmission line) is proposed to run straight through an area of critical no-go protection within the Wetland Complex, as indicated by the red circle in Figure 2-40. High voltage powerlines are a major obstruction to birds, for which the wetland was proposed as a Ramsar site. Furthermore, the management of lands underneath powerlines requires clearing of vegetation to prevent fire risks to the powerline network, this will result in the clearing of the critical no-go area of the Mugesera Wetland.

FUGURE 2- 49 CONFLICTING LANDUSE IN MUGESERA WETLAND COMPLEX

Understanable is the requirement to transfer the power to Kigali and the region, therefore we propose that the route of the transmission lines be moved further north, i.e. that the line changes to a northerly route before reaching the wetland system, then routes in a more direct line along the northern side of the wetland as indicated by the yellow line in Figure 2-28.

Completemntary to the high voltage powerline is a proposed railway line, also from Rusumo Falls to Kigali. Again the proposed route of the railway will pass directly through the critically sensitve area of the Mugesera Wetland. Again and alternative route is proposed strongly recommended, either more southerly so that it still passes through Bugesera District, or similar to the power transmission lines along a more northerly route around the wetland.

A potential factor contributing to the miscommunication of the sensitivity of the wetland is the name by which the wetland is referred, i.e. MINRENA refers to it as the Rweru-Akagera Complex but REMA refers the same wetland complex as the Mugusera / Rweru complex. As the Nile Akagera Uppercatchment area excludes Rweru, the same wetland is refered to inthis report as Gashora-Mugesera wetland system. A uniform name should be applied to prevent further confusion. Furthermore, while several years have been well invested in updating and gazetting the spatial extent of wetlands in the country, the next phase of work, namely updating and communicating the associated management information and desired status for the wetlands has now become urgent. This will require an extensive amount of work, including financing for the most recent available remote sensing imagery and for field surveys to support any motivations for change in wetland status, as this will have legal, economic and livelihoods consequences. At the least, it is recommended that the very small current extent of wetland designated for "total protection" status be expanded quite extensively to support the current RAMSAR application and ensure that the long term resilience of the wetland, river and lake ecosystems is supported.

Also linked to conflict in land use is the encroachment of agricultural and mining activities into the buffer areas of the wetlands and rivers in the Catchment. This has specifically been raised by the Districts during the Catchment Management Planning workshop in September 2017. Due to pressure on land availability, access to irrigation water and loss of soil fertility, the buffer areas designed to protect ecosystem function are being encroached and cultivated. This results in the loss of ecosystem function including habitat, and contributes to soil erosion.

2.5.4 UNPLANNED SETTLEMENTS

Population growth is a major driver of water demand either directly through urban and rural water supply and sanitation services, as well as indirectly through services (e.g. energy, housing, transport, etc. that may likely require water) and a variety of economic activities (food production, mining activities, services, etc.) at household level or larger industrial units. A further important tendency is the likelihood that the main part of the population increase will be absorbed by urban centres almost exclusively which is resulting in unplanned settlements and the unplanned expansion of urban areas. These unplanned settlements do not include appropriate infrastructure for rain water harvesting or water supply, waste management, runoff management or land management resulting in pollution into water resources from increase runoff, leaching of waste, flooding, and low access to adequate water. Furthermore, as the population increase the demand for food increases and the area per farming family needs to increase which results in encroachment in forest and buffer protection areas. A cause of this unplanned settlement expansion, identified by the Districts during the Catchment Management Planning workshop in September 2017, is the lack of settlement master plans and land use plans. Although there is a National Land Use Master Plan (MINIRENA, 2011) this is not being implemented efficiently or effectively.

There is overall a very significant increase in urban population from less than 20% as of 2012 to about 50% by 2040. This seems to be particularly significant at the Nile Akagera UpperCatchment that host the predominantly urban districts of Gasabo, Kicukiro and Nyarugenge. By 2040, about two third of the population of this catchment will be city/urban dwellers. It is critical that the Kigali Master Plan be implemented.

Issues of unplanned settlements were specifically raised by Rwamagana, Ngoma and Kayonza Districts.

2.5.5 LAND USE CHANGE

According to NUR (2011), the main landscape of the Eastern Province was initially dominated by savannas. Very recently (since 1994), a very large part of that landscape has been converted to agriculture and husbandry farms, especially for the resettlement of persons displaced from the genocide. The most destructive land use type remains conversion to agriculture while husbandry farms can allow persistence of some forms of biodiversity.

Change in land use is not limited to farming activities only, but also applies to urban expansion of villages, towns and cities. Where land use change has taken place from an area of natural environment to that of disturbed results in the displacement of biodiversity from the natural environment. If no alternative habitat is provided, then biodiversity will die off. This is anecdotally illustrated with the grey Crowned cranes. The Crowned crane is a fairly large bird species that roosts in trees with large canopy structures (i.e. wide branches). However due to change in land use, cultivation in the natural breeding areas, and the deforestation of indigenous trees that are replaced with quick growing alien tree species with narrow canopy structures e.g. Eucalyptus and Grevillea has resulted in a loss of habitat for the Cranes to roost. This loss of habitat has placed additional stress on the already threatened birds.

Land use change does not only negatively impact on species biodiversity but also on soil chemistry and rainfall runoff. Changing from natural vegetation cover to intensive agriculture and mono-cropping results in the nutrient mining of nutrients from the soil that are required by the planted crop. Overdrawing of nutrients from the soil without associated soil fertility practices and nutrient replenishment will result in altering the soil chemistry and result in soil degradation. Degraded soils are particularly prone to soil erosion. Similarly, water logging of soils can drain particular nutrients resulting in leaching of soils and loss of soil fertility.

The resulting surface water runoff from the watershed land surfaces is affected by many factors. Among them are the amount and intensity of precipitation, land cover, soil type and slope, and the infiltration, evaporation and transpiration processes that take place. Infiltration, evaporation and transpiration rates are dependent on the land cover, soil type, soil moisture content and air temperature. Changes in land use alter the rates of infiltration, evaporation and transpiration. Both the erosion that takes place and the sediment in the runoff depend on the intensity of precipitation, the land cover, the soil type and the slope. The concentration of chemical constituents in the runoff will depend on the accumulation of chemicals on the land at the time of a storm, the extent they dissolve in the surface water and the extent they are attached to the soil particles that are contained in the runoff. Depending on the land use, will then contribute to increased runoff of sediment and particulates, e.g. impermeable surfaces result in higher runoff, whereas permeable and well-vegetated land uses result in slower and reduced runoff.

- Issues of wetland encroachment, cultivation on rivers banks and loss of buffer areas were specifically raised by Nyarugenge, Kicukiro (Masaka and Gahanga Sectors), and Rwamagana Districts.
- Issues of deforestation were specifically raised by Gasabo, Bugesera, Rwamagana, Ngoma and Kayonza Districts.

2.5.6 OVER RELIANCE ON IRRIGATION

Irrigated agriculture has an impact on water resources. It is fully recognized that it is of paramount importance to develop food production. Still, the development must also take into account impact on water resources, the cost-benefit analysis of the water not being available to other uses, the socio-economic benefit of the irrigation scheme and its impact on other irrigation schemes.

The impact of different irrigation schemes on water resources must be assessed by special investigation programs, even small impacts on the hydrological cycle may have significant consequences on water services and other users. This is especially important for the eastern part of Rwanda, especially Nile Akagera UpperCatchment, with a balanced or even seasonally negative water balance. Different types of irrigation need to be investigated in terms of their impact on water resources, water quality and sediment transport and efficiency of use. Irrigation practice needs to be improved and adapted in a way to sustain water resources and maintain natural storage.

The Nile Akagera UpperCatchment is likely to come under stress from 2020 onwards (Water Resources Master Plan 2014). Already by 2030 the situation becomes very difficult whereas for the 2040 planning situation (full development), the water balance is completely unmanageable unless external resources are mobilized. The unmanageable water balance is largely due to the unbridled development of the irrigation sector which requires important resources during the least favourable time (dry season). The (unadjusted) overall water demand is scheduled to reach about 130% of the average renewable resource (657 over 504 MCM/year). It is absolutely imperative that the different water demand categories are examined with intent to obtain a workable water balance for this catchment. Agricultural development must also consider the promotion of drought resistant crop types, and crops with lower water demands for this area in order to achieve sustainable food security in the future while maintaining water storage capacity in the wetlands. Water supply problems will arise prior to 2040 if and when envisaged development activities are implemented without further consideration.

For example, the Gashora-Mugesera wetland system is being converted to rice-paddy cultivation. The wetland which provides necessary natural water storage is being drained for agricultural cultivation. The natural storage of the wetland provides water supply to adjacent lakes, especially during the dry months, and the natural storage is critical for future impacts of climate change in the catchment. However, in order to cultivate the land a berm has been constructed through the wetland system and the land under current cultivation has been drained, Figure 2-29. The area of the rice paddies is approximately 2 m lower than the adjacent wetland on the other side of the berm. This natural storage capacity has been lost, and will require extensive rehabilitation to restore it.

FUGURE 2- 50 GASHORA-MUGESERA WETLAND WITH BERM AND RICE PADDIES

2.5.7 SOIL EROSION

Soil degradation (the long-term decline on soil productivity) is exacerbated through the physical decline in soil structure or through accelerated erosion via water and wind (Lal, 2001). Soil erosion and sedimentation may be considered to be one the biggest problems facing mankind globally due to the serious environmental, economic and social consequences, including loss of productive land, siltation of reservoirs, reduction of water quality for human use and impacts on aquatic ecosystems. Soil erosion involves the detachment, transport and eventual deposition of soil particles (Lal, 2001). Energy for these processes is provided for by physical (wind/water), gravity (landslides), chemical (weathering) or tillage sources.

Issues of soil erosion were specifically raised by Kicukiro (Masaka, Gatenga and Gahanga Sectors), Gasabo, Bugesera, Rwamagana, Ngoma and Kayonza Districts.

2.5.8 CURRENT LAND MANAGEMENT PROJECTS

One of the biggest contributors to erosion is poor runoff management. Land management activities such as contour ditches, vegetation barriers and hillside terraces act to reduce the erodibility of hillslopes. These need to be used in conjunction with improved farming systems, reforestation and agroforestry to improve vegetation cover.

Within the Nile Akagera UpperCatchment there are specific projects which focus on the reduction of erosion through land management. These are as follows, **TABLE 2-28**:

- **Rweru-Akagera Complex Rehabilitation project**

  The Organic Law of Environment of 2005 limits agricultural and pastoral activities around bodies of water, activities need to be undertaken at a distance of 10 meters from the banks of streams and rivers and 50 meters from the banks of lakes and resevoirs. This buffer zone if vegetated appropriately can be designed and managed so that sediment and pollutant transport from hillslopes is reduced. Buffer zones may reduce impacts on aquatic ecosystems from adjacent land uses, contribute to channel bank stabilisation and provide habitat for a range of semi-aquatic and terrestrial species that make use of aquatic ecosystems for water, food or shelter.

The aim of a vegetation buffer around the wetland and lakes of the Rweru-Akagera System is mainly to reduce impacts of surrounding land uses onto the water resouces. The strategy implemented is planting an agroforestry tree buffer strip around the wetland/lakes in order to demarcate the buffer zone. The recommended vegetation design around the lakes and wetlands includes:

- 15 m of a thick **grass belt** which will act as a silt trap between the lake and the upland area. The grass can be harvested for fodder for livestock (harvesting must retain the root network and at least a 10cm stalk.
- 15 m of **shrub belt** following the grass belt. This zone will act as gravel trap between the grass belt and upland area. The shrubs shuld be planted along contour lines in a spacing of 0.5 meter along the same contour line, and interspaced along consecutive contour lines.
- 20 m of **tree belt** after the shrub belt which will act as a boulders trap during heavy rains. The tree spacing of 1 m (depending on species type) along the same contour line and interspaced along consecutive contour lines is recommended. It is important that the tree species chose are beneficial and non-invasice species, preferably indigenous species to promote support of biodiversity habitat e.g. roosting for the threatned Crowned Crances found in the Catchment area.

Despite the buffer area being implemented to protect the weltand and ecosystem functions, during the dry season communities farm within the buffer zone due to the improved productivity potential and access to water. During the site visit it was noted, **FIGURE 2-51**, that papyrus is removed and the soil dug up to plant vegetables, which erases the function of the grass belt as a sediment trap. The papyrus is then used as mulch.

FUGURE 2- 51 EXAMPLE OF TREE BUFFER LINE AND CULTIVATION WITHIN THE BUFFER ZONE (PICTURES: JULY 2017)

TABLE 2- 37 PROJECTS IMPLEMENTED BY MINRENA WITHIN THE NILE AKAGERA UPPERCATCHMENT (SOURCE: RWB)

Institution	Project name	Project Type	Details	Location
MINISTRY OF ENVIRONMENT	LVEMP II: Rweru-Akagera Complex Rehabilitation project	Lake vegetation buffer	74 Ha of Lake Rweru Vegetation Buffer	Bugesera District; Rweru Sector; Kintambwe to Nkanga Cells; Nyirarubomboza to Mishoroti Village
			151 Ha of Lake Karaba Vegetation Buffer	Ngoma District; Jarama Sector; Jarama Cell; Akabeza Village
			70 Ha of Lake Nyakabingo Vegetation Buffer	Ngoma District; Jarama Sector; Kigoma Cell; Vunga Village
			50 Ha of Lake Rweru Vegetation Buffer	Ngoma District; Jarama Sector; Kibimba Cell; Murama Village

- **Construction of remaining works of 292 Ha irrigation system for Rwamagana – 34 site**

The Land Husbandry, Water harvesting and Hillside irrigation (LWH) project aim is to help improve the agricultural systems in Rwanda, considered to be weakened due to soil loss from erosion, impoverished soil fertility, high acidic soil and limited water holding capacity. The project focuses on commercialization of agriculture, including the introduction of sustainable land husbandry measures for hillside agriculture and investing in water harvesting infrastructure (dams and irrigation infrastructure) at selected sites. Within the Nile Akagera UpperCatchment an example of the LWH project is the hillside terraces that have been developed in Rwamagana District (**FIGURE 2-52**).

FUGURE 2- 52 HILLSOPE TERRACING FOR IRRIGATION SYSTEM IN RWAMAGANA DISTRICT (PICTURES: APRIL 2017).

Although the site has had much success with the implementation of terracing on hillslopes, issues may arise if the roads and footpaths are not effectively incorporated into the erosion mitigation strategy. Roads and footpaths are areas with limited vegetation cover and may become preferential paths for water runoff (and sediment). By looking at the catchment scale it is clear that roads increase the connectivity between sediment sources (hillslopes) and the downstream catchment, especially where runoff mitigation measures are not implemented.

- **Reforestation**

  - Agroforestry, and the linkages with cultivation

    Agroforestry is the intentional integration of trees within a cropping system for multiple benefits. It is increasingly recognised as one way of dealing with the lack of space and infertile soils. It is recommended that hedge rows be planted which have multiple uses, with big trees. Agroforestry is usually practiced with the development of terraces.

  - Natural forests

    Forests are important to return moisture to the air through evapotranspiration, which then generates rain, as well as to stabilise soils with their root systems; they can also be rich in terms of biodiversity as well as stores of carbon. Reforestation is usually proposed with slopes of 40% or more, which is limited in the catchment. Species used should be of interest for farmers and the general economy and should be combined with crops to ensure farmers interest. PAREF Be2 and PAREF NL2 are projects which support the reforestation in the Northern and Eastern Provinces of Rwanda

Table 2-38 lists the Sectors with the highest soil erosion rates in the catchment.

Ngoma District has noticed an increase in soil erosion, while Bugesera, Kayonza, Kicukiro and Rwamagana have only decreased slightly and the average rate of erosion has remained the same over the five-year period. In order to reduce the rate of soil erosion additional activities of increase vegetation cover on bare soil including on the terraces, implementation of the riverine buffers throughout the catchment and improved runoff management from paths and dirt roads will also be required. Priority areas are Ngoma and Gasabo Districts.

TABLE 2- 38 SECTORS WITH THE HIGHEST RATE OF EROSION IN THE CATCHMENT

District	Sector	Area (ha)	Erosion Rate (highest class)
Bugesera	Ntarama	180.0	130-200
	Nyamata	0.1	130-200
	Juru	8.3	130-200
Gasabo	Ndera	2082.7	130-200
	Rusororo	1894.4	130-200
	Bumbogo	1076.7	130-200
Kicukiro	Gatenga	418.4	130-200
	Gahanga	217.4	130-200
Ngoma	Zaza	1001.5	130-200

	Mugesera	177.5	130-200
	Karembo	0.5	130-200
Nyarugenge	Magneragere	135.2	130-200
Rwamagana	Nyakariro	1659.6	130-200
	Mwulire	23.6	130-200
	Muyumbu	2741.3	130-200
	Karenge	2545.0	130-200
	Nzige	1759.8	130-200
	Gahengeri	2507.2	130-200
	Fumbwe	133.2	130-200
	Musha	46.8	130-200

There has been a significant increase in the rate of erosion in the Rwamagana District, as well as in areas of Gasabo and Ngoma Districts. In particular, the sectors of Gahengeni, Muyumbu, Nzige, Nyakariro, Karenge in Rwamagana Districts, the sectors of Kabarondo, Remera, Rurenge, Karembo and Zaza in Ngoma District, and the sectors of Ndera and Rusororo in Gasabo. There has been a reduced rate of soil erosion in the sectors of Ntarama, Nyamata, Mwogo and Juru sectors in Bugesera District, Masaka and Nyarugunga sectors in Kicukiro District and Ruramira in Kayonza District.

The Sectors reflecting an increased rate of soil erosion should be prioritised for mitigation measures e.g. reforestation, buffer implementation, terracing, runoff water management and vegetation cover implementation.

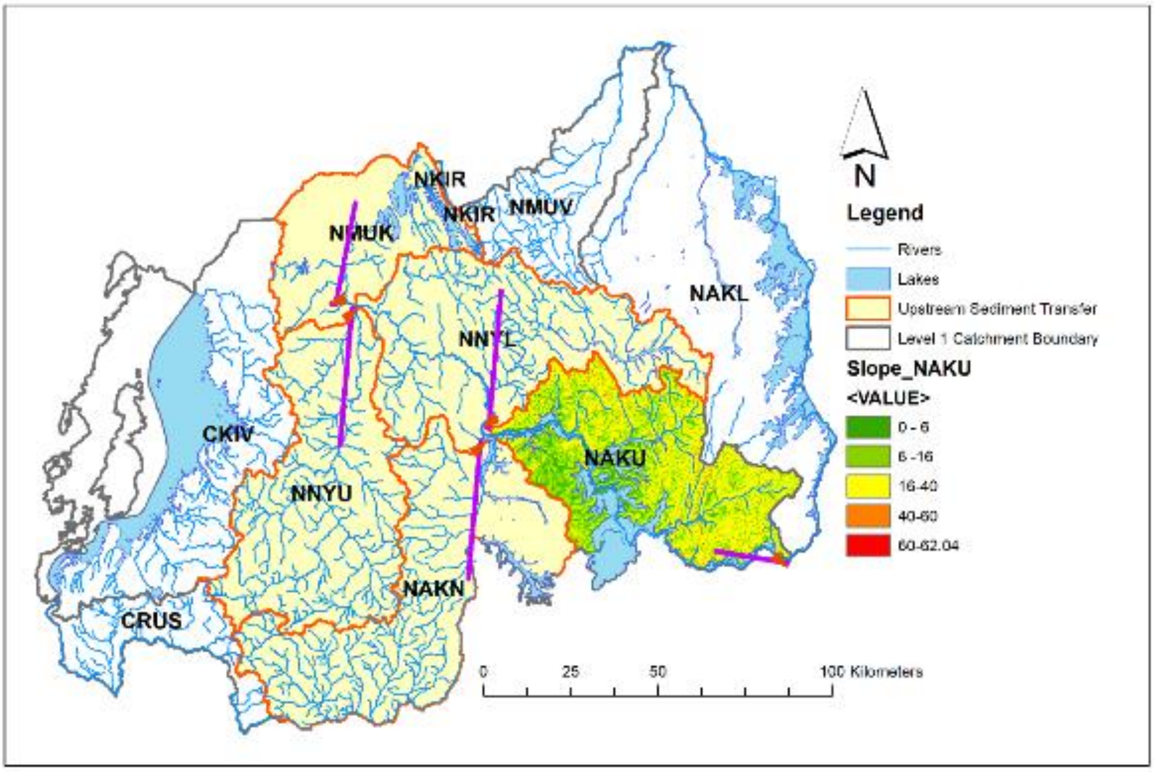
2.5.9 SEDIMENTATION /SILT BUILD UP

Sediment particles once entrained by water are more likely to spend a short amount of time being transported, and in fact more time in storage (Mead, 1982). This means that an understanding of the source (i.e. source of sediment via erosion) and sink (i.e. depositional areas) zones are needed in order to understand the impact of sedimentation. Erosion acts as the source of sediment, which travels downstream and has indirect impacts, Figure 2-55. These impacts can be seen when sediment travels in suspension, i.e. turbidity impacts to biodiversity, and when sediment stops moving and is deposited, i.e. sedimentation impacts to biodiversity and infrastructure. On the one hand deposited sediment renews soil fertility and lines channels of canal beds against seepage, but on the other hand it reduces capacity of reservoirs, inlet channel and irrigation canals (Ali, 2014). High sediment loads transported by the river during flood seasons has major influences on operation of reservoirs and in general reduces storage capacity. When in suspension sediment becomes a pollutant in its own right, as it limits light penetration and limits healthy plant growth. When sediment settles on the river bed it may smother aquatic habitats and impact fish spawning grounds. Nutrient rich sediments (especially sediments linked to agricultural lands) create turbid conditions which may result in eutrophication where fish species may be unable to survive.

The Nyabarongo and Akagera Rivers are part of a larger fluvial system, one that is a key element driving landscape change due to it acting as a conveyance for both sediment and water from land to oceans. On a global scale the majority of continental erosion is currently related to high elevation watersheds (Roy and Lamarre, 2011) such as Rwanda. In assessing the conveyance of sediment through a landscape it is necessary to take an integrated catchment approach. An understanding of catchment connectivity can provide this holistic framework (van der Waal and Rowntree, 2015). Sediment may reach the Nyabarongo River via upstream sources, or via tributaries conveying sediment eroded from hillslopes/riverbanks. Sediment sources may also come from disturbing temporary sediment sinks (wetlands) or through riverbank erosion.

SUSPENDED SEDIMENT FROM UPSTREAM SOURCES

The Nile Akagera Uppercatchment receives suspended sediment from the Nyabarongo and Akanyaru River catchment in the upper part of the catchment, **FIGURE 2-56**. This suspended sediment is either deposited within the Nyabarongo Valley or transported into Nile Akagera Uppercatchment (**FIGURE 2-57**). Karamage et al. (2016) indicate that the Nyabarongo River Catchment is naturally vulnerable to soil erosion by water with a rate of 1397 t.ha^{-1}.year^{-1}. The turbidity at the catchment outlet was not recorded.



FUGURE 2- 53 THE NILE AKAGERA UPPERRECEIVES SUSPENDED SEDIMENT FROM UPSTREAM CATCHMENTS

1.1.1.1.4 HILLSLOPES

The characteristically gentle relief of Nile Akagera Uppercatchment promotes sediment deposition, particularly in the wetland areas. There is limited hillslope erosion, which would be considered as sediment sources within the catchment. Activity in the catchment may provide additional sediment inputs, such as the "temporary" high impacting activities such as pathways, roads and mining activities. These activities are not necessarily considered as a long-term sediment source and yet they may act as conduits of sediment, effectively increasing the connectivity of sediment source zones to the Akagera River.

- **Hillslopes (cultivation)**

  As described in the Erosion section above, the main project currently being implemented in the Nile Akagera UpperCatchment to reduce sedimentation impacts from hillslopes is the riverbank protection and catchment rehabilitation LVEMP II projects**.** Although the aim of the project is linked to the development of Lake buffers.

- **Hillslopes (agroforestry)**

  Agroforestry is usually practiced in combination with terraces/riverbank protection projects. Within the catchment agroforestry trees are used for Lake buffer vegetation. Trees provide an additional erosion mitigation and provide a vegetative buffer for the transfer of sediments and nutrients from the surrounding area.

- **Hillslopes (landslides)**

  As described in the Erosion section above, the National Risk Atlas of Rwanda (MIDIMAR, 2015) provides hazard assessment and mapping. The main issues of concern in terms of sedimentation are floods and landslides. These events are directly linked to rainfall events which increase the connectivity of sediment source zones with the main drainage channel. During this time areas such as pathways and roads act as sediment conduits, or channels, linking source zones with river channels. The Eastern Province may not have a high likelihood of landslides, but when they do occur the populations which are more susceptible are those where there is a high density of people near roads, i.e Kigali City. Flooding by the Akagera River affected the most districts, in particular Bugesera District being the most affected in total area.

1.3.1.2 SEDIMENT SINKS

1.1.1.1.5 WETLANDS

The wetlands and lakes within the Akagera Mugusera catchment act as sediment sinks for the sediment received from upstream sources (i.e. Nyabarongo River) and the surrounding hillslopes (**FIGURE 2-34**). Any activity within these wetlands may reactivate these storage zones and wetlands could become sediment source zones instead.

- **Peat removal**

  Peatland, organic wetland soils (**FIGURE 2-54**), functions include: biodiversity maintenance, carbon and water storage, solute detention and water regulation. In addition to their intrinsic values, peatlands are also valued for the wide variety of benefits they provide, including for agriculture, forestry and culture (IPC, 2010). Peatland areas in the lower parts of catchments act as transition areas for water, providing temporary storage for both rainfall and runoff. Peatlands located on floodplains may also provide flood attenuation. Management of peatlands in areas such as Bugesera and Ngoma Districts requires an understanding of the seasonality of use and an understanding of which areas are considered to be most vulnerable to the impacts of agricultural use. A specific threat to the peat is both mining of peat as well as burning of vegetation to clear for farming.

FUGURE 2- 54 ORGANIC WETLAND SOILS SURROUNDING THE LAKE AREAS OF THE CATCHMENT (PICTURES: JULY 2017)

1.1.1.1.6 IRRIGATION CANALS

Reservoirs are expensive to build, with construction usually entailing high social and environmental costs. The reduction of the lifespan of reservoirs therefore has both an economic and social cost. Extending reservoir lifespan through managing of sediment is important. The build-up of sediment in front of intakes may result in significant costs for irrigation operations (in terms of the mechanized irrigation of large rice plantations). Dredging may be required to remove excess sediment and allow a full flow of water through the system. If the sediment accumulation is high, the outlet may also become clogged. Abrasion of hydraulic machinery may also occur, decreasing efficiency and increasing maintenance costs.

This is demonstrated in the Bugesera Agricultural Development Support Project located in Gashora within the Catchment area. The project comprises both irrigation and catchment basin development with the purpose to reduce the impact of drought in Bugesera District by irrigating the 650 ha Mwesa Valley for rice and market-garden crops and erosion control on nearly 5 000 ha on the surrounding hillslopes. Rice is grown in marshlands in puddled soil in two seasons a year. During the wet season the soil is constantly moist due to rains and the occasional flooding.

The irrigation of the Mwesa Valley required the pumping of water from the Akagera River and its channeling through canals and supply ducts up to the head of the Valley. The amount of water to be pumped from the river varies from 235 l/s in November to 716 l/s in September, depending on the needs of crops cultivated (PADB, 2006). The components of the irrigation infrastructure involves an intake channel of nearly 750m, a pumping station equipped with five electric pumps, **FIGURE 2-55**, a 700m reverse conduit, a main canal running over nearly 3.2 km, grounded ducts for a total 22.4 km, ring canals and secondary canals covering 75km, valley planning works and thirty rice threshing and drying floors. Additional measures, such as the construction of a dyke on the bank perpendicular to the direction of flow from adjacent hills, were meant to protect the irrigation canals against sedimentation and silting and prevent such waters from flowing directly into the canals (PADB, 2006).

It is clear that in the actual functioning of the canal system the main canal is being dredged far more regularly than expected, and that most of the sediment is coming from Akagera River itself via the pumping station.


FUGURE 2- 55 PUMPING STATION AND SILTED CANALS IN THE BUGESERA AGRICULTURAL DEVELOPMENT SUPPORT PROJECT (PICTURES: APRIL 2017)

This project did not consider the environmental impact or socio-economic feasibility when it was designed. The rice-paddies are located at a lower level than the Akagera River, resulting in the need for constant pumping to maintain hydrostatic pressure to keep the high river water from flooding the cultivated area (i.e. like the dykes in Holldand). This has resulted in pumping out the "stored" water of the wetland to dry it out for cultivation. This will negatively impact on future availability of water. The high silt load of the incoming water from Akagera river has resulted in sedimentation (due to reduced velocity of water flow in the distribution canal), resulting in the need for physically clearing the sediment upto 3 times per week – this reduces the time the community spend in their field maintaing their crops; there is also nowhere to "dump" the cleared silt so it ultimately ends up back in the rice paddies irrigation scheme or back in the river. Furthermore, wet-field rice has been globally proven to directly increase occurrence of Malaria and other mosquito-spread diseases, as the rice paddies are suitable habitat for mosquito breeding. The anticpated wealth creation from the cultivated rice will be unrealsitic as the household cost of medical treatment will increase to address increased occurences of malaria and other waterborne vector and bacterial illnesses. In the long term, the drying out of the wetland will also negatively impact water storage in dry months, including for downstream users.

The Rural Sector Support Program (RSSP) was introduced to develop a modified watershed approach learnt from LWH experience introduced for sustainable land husbandry measures on hillsides adjacent to the marshlands on selected sites. These measures were proposed to reduce soil erosion on cultivated hillslopes which were experiencing low productivity. Technologies introduced include soil bunds, terraces, cut-off drains, water ways, afforestation and reforestation as well as strengthening terraces with risers to develop appropriate land husbandry practices. These technologies were intended with the dual purpose of providing modern agricultural techniques for higher production, as well trapping silt from the hillsides so that it did not result in sedimentation of downstream irrigation dams or wetlands.

Although the project alludes to "rehabilitation of marshlands", the project is actually concerned with rehabilitating the hillslopes surrounding the wetland in order to allow farmers increased productivity during the wetland crop growing period. The project is now carrying on its activities in 22 existing rice wetlands for the intensive capacity building program in production, postharvest, marketing and value addition. Main project activities are being implemented in hillsides surrounding marshlands to be developed, where those hillsides' areas have been or are being treated with comprehensive land husbandry technologies in order to control the severe soil erosion encountered in the region and increase productivity in treated areas.

1.3.1.3 SEDIMENT TRANSPORT

1.1.1.1.7 SUSPENDED SEDIMENT LEAVING THE CATCHMENT

The catchment outlet occurs in a deposition zone, within a wetland (**FIGURE 2-56**). This indicates that this is naturally an area of sedimentation. The tubidity in this area has been increasing rapidly from 2011 to 2017 **TABLE 2-39**. This may mean that the wetland is less effective at trapping sediments, or that there is increasing activity within the catchment.

TABLE 2- 39 THE TURBIDITY AT THE AKAGERA/RUSUMO BORDER (SOURCE: RWB)

Location	**Turbidity (NTU)**					
	Oct-Nov 2011	**Apr-May 2012**	**Oct-Nov 2012**	**Apr-May 2016**	**Sep-Nov 2016**	**Apr-May 2017**
Akagera/Rusumo border	64.9	91.8	91.8	-	535.767	758

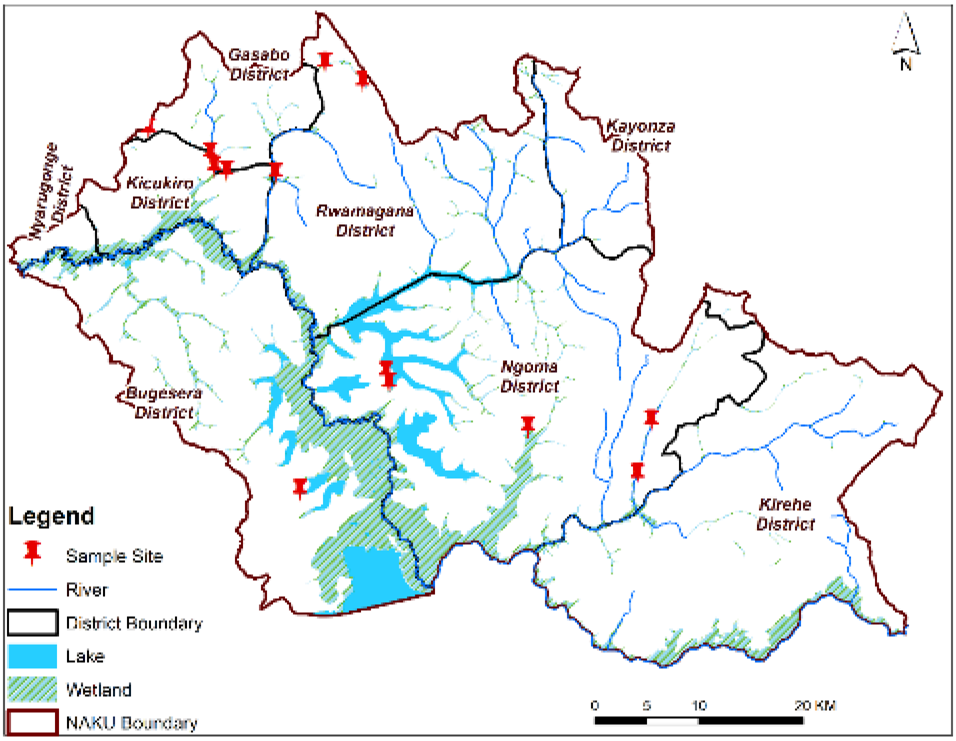
1.3.1.4 SUMMARY

In terms of the catchment specific contribution towards erosion it is clear that a focus on the individual erosion factors may produce reductions in erosion on certain sediment “source” areas, but that an understanding of how these areas are related at a catchment scale is lacking. The current strategy in Rwanda is related to focused erosion mitigation projects under the LVEMP II projects (under MINRENA) and the Land Husbandry, Water harvesting and Hillside irrigation (LWH) projects (under MINAGRI), with an emphasis on controlling the source of sediment. The MIDIMAR focus has been on the extreme climatic events, i.e. droughts, flooding and landslides. The MIDIMAR has focused on the development of hazard maps which indicate areas of risk for these extreme events. Although sedimentation is considered to be a significant issue in Rwanda, these projects have a main focus on soil erosion reduction. It is likely that the source of erosion is a significant concern as the impacts of removed soil and decreased soil fertility have a more direct impact on farmers’ livelihoods, as opposed to the indirect, downstream impacts of increased turbidity and sedimentation.

POLLUTION

A number of pollution issues have been identified in the Nile Akagera Upper Catchment, both through the District Development Plans as well as in consultation with the Districts and Sectors of the catchment. These include concerns about microbial pollution and water-borne diseases, nutrient enrichment and eutrophication, invasive alien plants, organic pollution and dissolved oxygen, hydrocarbon pollution, solid waste and litter, and agrochemicals. Each concern is introduced below as well as the manifestation of the concern in the Nile Akagera UpperCatchment. Figure 2-62 indicates where the sample points are collected from within the Catchment. Sample points upstream indicate the quality of water entering the catchment, while sample point downstream indicate the quality of the water leaving the catchment. The results of the RWB monitoring points for different parameters at the sampling points is presented in Table 2-33.

Issues of pollution and poor waste management were specifically raised by Kicukiro (Niboye Sector), Gasabo, Rwamagana (Kigabiro, Muhazi, Fumbwe, Mwurire, and Karenge Sectors), and Ngoma Districts.



FUGURE 2- 56 LOCATION OF SAMPLING POINTS IN THE CATCHMENT (SOURCE: RWB, 2020)

TYPES AND SOURCES OF POLLUTION

Microbial pollution refers to the presence of microorganisms and parasites which cause diseases in humans, animals and plants. Most waterborne pathogens occur in human or animal faeces and enter waterways via various pathways. Microorganism include protozoa (e.g. Giardia & Cryptosporidium), bacteria (e.g. Faecal coliforms, Escherichia coli), bacterial infections (e.g. Shigella), viruses (e.g. hepatitis) and helminths. Microbial pollution originates from untreated or partially-treated sewage effluents entering surface and groundwater, and seepage and run-off from inadequate sanitation and waste disposal. The disposal of grey water into urban storm water drains also pose a risk to receiving streams and rivers. In the Nile Akagera UpperCatchment the wastewater from most towns and villages are not treated, such that there is extensive faecal pollution in the rivers resulting in outbreaks of water borne diseases. Many of the urban streams in the Kicukiro district drains towards the Akagera River and exhibits symptoms of urban runoff pollution. Some of the streams carry high microbial pollution loads especially in areas where informal settlements are located that have no or rudimentary sanitation facilities. The Nile Akagera UpperCatchment has inflow from Akanyaru and Nyabarongo rivers with a substantial pollution risk from the Nyabarongo. E coli monitoring in 2017 indicated that E coli counts were 92 counts/100ml upstream of the Akanyaru confluence, and increased to 153 counts/100ml downstream of the Akanyaru confluence. At the confluence, the Akanyaru contributed 750 counts/100ml. Further downstream at the Gashora bridge near Lake Bilira, the E coli counts had dropped to 35 counts/100ml indicating an improvement in microbial quality (Sekomo & Kagisha, 2017).

Nutrient enrichment and eutrophication refers to the accumulation of plant nutrients in rivers and dams in excess of natural requirements resulting in nutrient enrichment and eutrophication. The direct impacts include excessive growth of algae and macrophyte (rooted and free-floating water plants), the presence of toxic metabolites in cyanobacteria (blue-green algae), the presence of taste- and odour-causing compounds in treated domestic water, and difficulty in treating the water for potable and/or industrial use. Concerns have been expressed about nutrient pollution and eutrophication in rivers and in Lake Mugesera, and feeding into the Nile Akagera UpperCatchment. The high turbidity in the Akagera River would mitigate against excessive growth of algae in the river. However, eutrophication is a concern in lakes. Recent water quality monitoring did not indicate wide fluctuations in dissolved inorganic phosphorus and nitrogen in the Akagera River. DIP concentrations varied between 1.2 – 2.0 mg/l and DIN concentrations varied between 4.6 – 5.5 mg/l (Sekomo & Kagisha, 2017). In Bugesera Lake and Sake Lake the DIP was 0 and 0.4 mg/l respectively, and the DIN was 3.7 and 3.6 mg/l respectively. The DIN was regarded as elevated for lake ecosystems.

Invasive alien aquatic plants are not indigenous to the region, have no natural adversaries, and have a prolific growth rate. The main invasive aquatic plant in Rwanda is the water hyacinth (*Eichhornia crassipes*). Water hyacinth is a very fast-growing plant, with populations known to double in as little as 12 days. Infestations of this weed block waterways, limit boat traffic, clog water abstraction points, and interfere with fishing activities. Water hyacinth also prevents sunlight and oxygen from reaching the water column and submerged plants. It's shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems. In the Nile Akagera Upper Catchment WASAC has raised concerns about the presence of water hyacinth mats in Lake Mugesera and it is interfering with water abstractions for potable water treatment. The floating mats block the intake structures and the water beneath the mats are often coloured black due to the high organic content from decomposing dead plants. The water is also low in oxygen which can further interfere with the water treatment process. Water hyacinth originating from the Kagera River Basin is a major concern for Lake Victoria.

Organic pollution refers to the discharge of organic or bio-degradable material to surface water that consumes oxygen when they decay, leading to low dissolved oxygen concentrations in the water. Elevated concentrations of organic matter from decomposing plant matter can occur naturally in water but can be aggravated by poor waste disposal practices. Low dissolved oxygen concentrations are detrimental to aquatic organisms and it affects the solubility of metals. Metals adhered onto bottom sediment particles in streams, lakes and reservoirs can dissociate under low or anoxic conditions, dissolving back into the water where it can affect aquatic biota or human users. Coffee washing stations in the catchment pose a major source of industrial wastewater pollution. A USAID-commissioned study (2008) found that coffee washing or depulping stations often operate without adhering to recognised standards and best practices for effluent discharge. Containing high levels of carbohydrates and organic matter, the wastewater is released untreated directly into streams. The wastewater reduces available oxygen in receiving waters due to the high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) loads, affecting downstream water quality including those used for domestic water purposes. The effluent discharge can have a significant impact on freshwater ecosystems and aquatic life and may stimulate growth in harmful micro-organisms or pathogens due to its anaerobic characteristics. There are several coffee washing stations within the Nile Akagera UpperCatchment. Industries that process agricultural products (dairy products, fruit juices, etc), soft drink, and brewing industries in the Kicukiro district discharge effluents that are often high in COD. Although the impacts of high organic loads would be localised to the receiving streams, the high COD and low dissolved oxygen could carry through into the Akagera River. The same is also true for partially treated abattoir wastes discharged to streams eventually flowing into the Akagera River.

The dissolved oxygen concentration in the water is reduced in the presence of high organic loads. Monitoring of dissolved oxygen in the Akagera River indicated that upstream of the Akanyaru confluence, DO saturation was high (71.4%), but very low in the Akanyaru (5.1%) which impacted on the DO saturation in the Akagera downstream of the confluence (43.9%). Further downstream at the Gashora bridge the DO saturation was still low (53.2%) (Sekomo & Kagisha, 2017).

Hydrocarbon pollution refers to pollution with petroleum and petroleum-derived products such as petrol, napthas and solvents, aviation gasoline, jet fuels, paraffin, diesel fuel, fuel oils and lubricating oils. Hydrocarbon pollution originate form wash off from road surfaces and parking lots, especially during the early season rains, and dumping of used oil into storm water drains. In the Nile Akagera UpperCatchment there are numerous filling stations and vehicle workshops that can contribute to hydrocarbon pollution, as well as the main thoroughfare road between Rusumo Falls and Kigali frequented by trucks. There does not appear to be a formal used oil collection programme in Rwanda, probably due to the relatively small market size hampering investment by waste oil recyclers. District environmental officers have expressed concerns that used motor oil is informally disposed of into storm water drains, nearby wetlands, on the soil at the workshop, or into unlined solid waste dumps.

Agrochemicals refer to pesticides and herbicides residues in surface waters that are harmful to aquatic ecosystems and/or users of the water. It includes pesticides or their residues such as chlorpyrifos, endosulfan, artrazine, deltamethrin, DDT & penconazole. These compounds can have chronic or acute impacts on aquatic biota and/or it can cause respiratory diseases in humans and animals. Sources include spray-drift of pesticides/herbicides into surface water courses, the wash off of pesticides into surface and groundwater during rainfall events or irrigation of crops, or accidental spillages at storage facilities or during loading operations. In the Nile Akagera UpperCatchment pesticide are probably used and pesticide and herbicide residues would probably be found in receiving waters in the catchment. Due to the high cost of pesticides and herbicides in Rwanda, its use is probably limited and it is used judiciously.

Solid waste refers to litter (other terms used include trash / rubbish / garbage / refuse / floating matter) that enter storm water drainage system and that are deposited into streams, rivers and lakes. It also refers to semi-formal and informal solid waste dumps where seepage from the dump drains into surface water streams. The impacts of decomposing solid waste and litter on surface waters include reduced dissolved oxygen, bacteriological contamination, impeding flow and river bank destabilisation, hydrocarbon pollution, trace metal pollution, and nutrient enrichment. The main landfill for Kigali is situated north of the city in the Nyabugogo catchment. However, in the Nile Akagera UpperCatchment there are a number of informal or village level solid waste disposal sites. Water leaching from these sites would be high in organic material, heavy metals, hydrocarbons, etc.

2.6 NATIONAL OBJECTIVES

In the development of the Catchment Management Plan, the national objectives and strategies need to be taken into consideration.

VISION 2050

Rwanda commenced with Vision 2020 between 1997 and 2000, and the Vision was later revised in 2012. The Vision 2020 represents an ambitious plan with the purpose to uplift the people of Rwanda out of poverty as well as transform the country into a middle-income economy. To attain the goal, the Vision identifies six interwoven pillars, inclusive of good governance and an efficient state, skilled human capital, vibrant private sector, world class physical infrastructure and modern agriculture and livestock, all designed towards prospering in national to global markets.

Rwanda has made good progress on implementing Vision 2020, however in order to incorporate recent international agreements and development goals such as: Addis Ababa Action Agenda (Financing for Development)-2030; Sustainable Development Goals (SDGs)-2030; Paris Declaration on climate change (2030); East African Community Vision 2050; and the African Union Agenda 2063; it was required to develop a new Vision for Rwanda, the Vision 2050. This Vision 2050 takes into account the lessons learned from Vision 2020 and is centred on ensuring high standards of living for all Rwandans, food security, protection of the Rwandan family, and improved access to affordable services in health, education, finance, housing, energy, infrastructure, amongst others. One of the main goals of the Vision 2050 is to work towards reaching an upper middle income by 2035 and high income by 2050.

The blueprint development of Vision 2050 focuses on 5 main pillars: (1) Quality of life; (2) Modern infrastructure and livelihoods; (3) Transformation for prosperity; (4) Values for Vision 2050; and (5) International cooperation and positioning.

The Integrated Catchment Management Plan (CMP) for the Nile Akagera UpperCatchment would integrate the principles of Vision 2050 as best practice to meet the expected standards of living, contributing to enable sustained food security and nutrition for all households and age groups, and universal, sustainable and reliable access to water (in houses) and sanitation.

GREEN GROWTH AND CLIMATE RESILIENCE STRATEGY 2011

According to Green Growth and Climate Resilience (2011), Climate change is identified as ‘’a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods’’.

The Green Growth and Climate Change Strategy is set to guide the process of mainstreaming climate resilience and low carbon development based on key sectors of the economy. This strategy includes a strategic framework with a vision for 2050, guiding principles, strategic objectives, programmes of action, enabling pillars and a road map for implementation.

Rwanda is greatly depended on rainfed agriculture. The uncertainty of rainfall patterns and limited irrigation infrastructure, transport and post-harvest storage, mostly results in food insecurity. The Nile Akagera UpperCatchment Management Plan is vital as water resources are limited. The water resources need to be managed sustainably to ensure green economic growth which will ultimately result in higher quality of life and poverty reduction. An ambitious strategy naturally is accompanied by various challenges which Rwanda will also require significant support from development partners, civil society and the private sector to achieve its future aspirations. This strategy if supported by the enabling pillars, is implemented and actioned, Rwanda will lead to a sustainable secure future.

The Catchment Management Plan is important as the crop intensification programme in Rwanda is making use of inorganic fertilisers in efforts to increase crop yields especially with the population growing at 2.8% per year and it is anticipated that the population will increase over two-fold by 2050 which puts pressure for food security. The demand for inorganic fertilisers can be reduced by applying an integrated approach to soil fertility and nutrient management, however this needs to be implemented, managed and monitored at a local level and the CMP provides a framework for this implementation. This practice would result in reducing vulnerability of local communities to external shocks whilst improving the soil structure and the water retention capacity of soils. This approach would also produce climate resilient agricultural ecosystems and sustainable food security within the Catchment area.

The Nile Akagera UpperCatchment annual rainfall is particularly vulnerable to climate change. The unpredictability in planning for wet seasons presents a challenge for the farmers to arrange when to plant and to harvest good crops. The Akagera Catchment Management Plan would institute sustainable irrigation infrastructure and water conservation methods which would allow the farmers to manage the available water resources more efficiently and thus reduce the susceptibility to changing rainfall patterns. This would also promote efficient land management and water usage whilst providing water storage to supply to dry areas. In adopting an integrated approach in the CMP, not only does it enable increased water supply and efficiency but also provides added benefits of reducing disaster risks through mitigation of floods and landslides.

Figure 2-63, presents the programme of action: Integrated Water Resource Management Planning (IWRMP) which is of particular interest, as the substantial freshwater resources that Rwanda is endowed with has not yet necessitated water storage, water monitoring or irrigation infrastructure. To combat this challenge, Rwanda will:

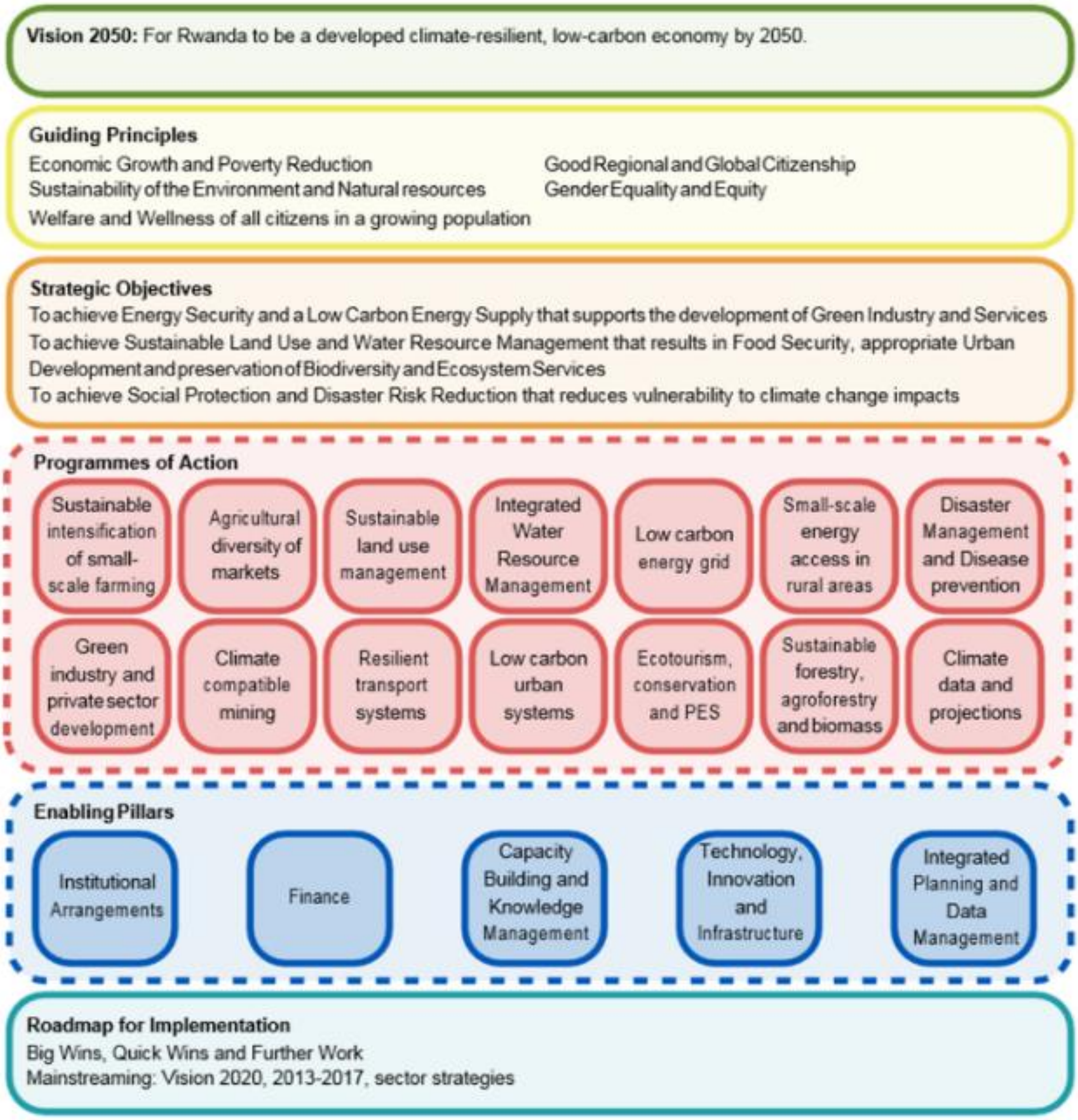
- Establish a national integrated water resource management framework that incorporates district community-based catchment management;
- Develop water resource models, improved meteorological services, water quality testing, and improved hydro-related information management; and
- Develop a National Security Plan to employ water storage and harvesting, water conservation practices, efficient irrigation, and other water efficient technologies.

One of the aims of the Catchment Management Plan is to compile a development plan for the management and sustainable utilisation of the water resources within the Catchment. This will include the points identified above.

The Vision 2050 is guided by principles such as (a) economic growth and poverty reduction and (b) sustainability of the environment and natural resources. These strategies can be explained by one of the three key strategic objectives:

❖ To achieve Sustainable Land Use and Water Resource Management that results in Food Security, appropriate Urban Development and preservation of Biodiversity and Ecosystem Services.

The Programme of Action: Integrated Water Resource Management and Planning, i.e. developing an Integrated Catchment Management Plan, is cross-cutting among all sectors i.e. agriculture, land, built environment, forestry, mining, energy, industry, health, education, local government and disease management, all of which utilise and/or impact on the water resources of the Catchment. It is thus vital that the Nile Akagera UpperCatchment is managed sustainably in order to ensure the requirements for growth and development as per the Vision 2030, GreenGrowth and Climate resilience strategy, and the growth objectives of the various sectors can be met within the Catchment area.



FUGURE 2- 57 STRATEGIC FRAMEWORK FOR RWANDA'S NATIONAL STRATEGY ON CLIMATE AND LOW CARBON DEVELOPMENT (SOURCE: REPUBLIC OF RWANDA, 2011)

ECONOMIC DEVELOPMENT POVERTY REDUCTION STRATEGY - 2

The Second Economic Development and Poverty Reduction Strategy (EDPRS 2) is the last phase to Vision 2020. The aim is for the private sector to lead economic growth and poverty reduction during this period. The overarching goal of EDPRS 2 is: "Accelerating progress to middle income status and better quality of life for all Rwandans through sustained average GDP growth of 11.5% and accelerated reduction of poverty to less than 30% of the population."

The strategy sets out key Thematic Area Priorities. Of specific relevance to Nile Akagera UpperCatchment Management Planning include:

Economic Transformation: This thematic area targets accelerated economic growth (11.5% average) and restructuring of the economy towards more services and industry as Rwanda move towards middle income country status. The main targets relate to: strategic infrastructure investment for exports, increased private sector financing for increased exports coverage of imports, urbanisation and green economy approach for sustainability.

Priority 5: Pursue a 'green economy' approach to economic transformation. The green economy approach favours the development of sustainable cities and villages. Key innovations include: piloting a green city, piloting a model mine and attracting investors in green construction Interventions will focus on green urbanisation and the promotion of green innovation in industrial and private sectors.

Rural Development: This thematic area is focused on ensuring that poverty is reduced from 44.9% to below 30% by 2018. This will be achieved through focus on increased productivity of agriculture which engages the vast majority of the population and ensures sustainable poverty reduction.

Priority 2: Increase the Productivity of Agriculture by building on the sector's comparative advantage. The focus is therefore on irrigation and land husbandry, proximity advisory services for crops and livestock and connecting farmers to agribusiness.

Priority 4: Connect Rural Communities to Economic Opportunity through Improved Infrastructure. Interventions will include a feeder roads programme and information and communications technologies (ICT) expansion for rural areas with the aim of linking communities to markets, the electrification programme, modern biomass and other cooking methods, and full coverage of quality water and sanitation.

Cross cutting issues (CCIs):

b) Environment and Climate Change: major areas of attention will be mainstreaming environmental sustainability into productive and social sectors and reducing vulnerability to climate change

f) Disaster Management includes investment in rapid response disaster management equipment, early warning systems and awareness campaigns.

Specific objectives for the Districts within the Catchment, identified in EDPRS-2 are listed in **Table 2-40**.

TABLE 2- 40 LIST OF DISTRICT OBJECTIVES WITHIN THE CATCHMENT

Nyarugenge	Fast track implementation of Nyarugenge district master plan projects such as: mobilizing private sector to invest in those projects.

	Promote tourism within the District by developing existing potentials like Mt. Kigali (historical site where some kings built palaces in the past centuries).
Kicukiro	Improve road networks through: construction and rehabilitation of existing roads in conjunction with transport sector, developing road junctions & fly-overs, expanding the width of existing main roads and attracting more private companies in the public transport system
	Facilitate and partner with the private sector in the construction of six higher learning institutions and rehabilitation and construction of eight modern markets
	Promote urbanisation and group settlements by: developing identified sites through availing the necessary infrastructure, partnering with private sector to construct affordable housing and promotion of pro-poor building materials such as provision and training of cooperatives on the use of hydro-foam machines.
Gasabo	Improve urbanisation settlement as per Gasabo master plan through developing affordable houses in collaboration with private sector & other partners like Rwanda Social Security Board
	Promote private sector investment through tourism development and establishment of business development centres to tap into investment opportunities like Kigali Convention Centre
	Improve the transport network in the district by: constructing fly-overs in high density areas to reduce traffic jam & ease doing business, create dedicated bus lanes on expanded roads, secure 17km of land and construct rapid bus terminals
	Sensitize, train and mobilise citizens and private sector to tap into investment projects in the Special Economic Zone in order to create forward and backward linkages (Between SMEs and large firms in the Special Economic Zone).
Bugesera	Promote tourism activity on virgin sites around Lakes Rumira, Mirayi, Kirimbi
	Promote private investment in fish farming in the 9 existing lakes and fish ponds
	Infrastructure development (construction and operationalization of industrial park and hotels and guest houses targeting Bugesera Airport opportunities will: attract business, investors, service providers and tourists. This will boost off-farm jobs.
Ngoma	Agakiriro development centre to increase off-farm jobs
	Attract private investors in industrial development with focus on palm oil processing and paper factory
	Urban and rural road network (construction of 15km of tarmac roads, construction of 11.68km of stone paved roads, rehabilitation of 350km of feeder roads and upgrading (asphalt) of 53km road from Ngoma to Ramiro (Bugesera district to improve urban and rural accessibility and easy movement of persons, goods and services

Rwamagana	Modern settlement and centre
	Increase production and promotion of export crops (floriculture currently at 300ha)
	Develop tourism through the construction of tourism infrastructures (4 new hotels and beaches around Lake Muhazi)
Kayonza	Increase access to electricity and rural water coverage to support in the agro-processing plus feeder roads to boost agricultural growth and SMEs.
	Support to youth cooperatives in all sectors of Districts, TVET construction and youth centres in Mukarange sector and this will support youth employment

SUSTAINABLE DEVELOPMENT GOAL

The objective of Catchment Planning is to compile a Catchment Management Plan (CMP) for the Nile Akagera UpperCatchment. It is essential that the final CMP is integrated with links to, and builds on, other national plans and strategies –including but not limited to national strategies to meet the Sustainable Development Goals.

The 2030 Agenda for Sustainable Development, is a plan of action for people, the planet and prosperity. The scale and ambition of this Agenda is made up of 17 Sustainable Development Goals (SDGs) and 169 targets which are a built-up from the un-achieved Millennium Development Goals. The new goals and targets came into effect on 1 January 2016 and provide guidance to achieve these goals on the next 15 years. The 17 SDGs and targets are integrated, undividable and balance the three dimensions of sustainable development: the economic, social and environmental. Many of the SDGs are already partly or fully reflected in the national development plans and Rwanda’s goal is to fully consolidate the SDG’s into the Rwanda Economic Development and Poverty Reduction Strategy the latest strategy is the National Transformation Strategy (2017-2024) and Vision 2050.

The development of the Akagera CMP will take into account all the SDGs; however, the following goals are the ones that would have a direct influence:

- **Goal 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture** Although the Akagera CMP is being developed only for the Akagera catchment, it aims to food security in the region and it is aligned with the other National CMPs that are also focused on the same goal – Vision 2050

- **Goal 3: Ensure healthy lives and promote well-being for all at all ages.** Access to clean water and sanitation has to be increased to ensure healthy lives and well-being which are essential to sustainable development.

- **Goal 6: Ensure availability and sustainable management of water and sanitation for all.** The anticipated challenges in meeting the Agenda, require integrated solutions and the goals are linked to each other and are interdependent. Having access to clean water is a Goal and Vision for Rwandans. Rwanda lacks the economics and infrastructure to provide the residents with adequate water supply, sanitation and hygiene. As water is cross-cutting, poor water quality and poor sanitation negatively affect food security, livelihood choices and educational opportunities for poor families in Rwanda. The Akagera CMP aims to enable the catchment population to have access to improved domestic water sources, and to promote sustainable water usage whereby the water usage does not exceed the recharge, as well as to manage and increase water and sanitation infrastructures.

- **Goal 9: Build resilient infrastructure, promotes sustainable industrialization and foster innovation** is in line with the Akagera CMP vision. Investing in infrastructure for water resources conservation is important to achieving sustainable development, is empowering and allows for sustained increases in living standards for Rwandans. Technological progress is vital as is it recognized as the foundation of efforts to achieve environmental objectives such as increased water resources. Water Infrastructure is important as it remains scarce in Rwanda.
- **Goal 12: Ensure sustainable consumption and production patterns**-sustainable consumption promotes resource efficiency and sustainable infrastructure. The Akagera CMP would be promoting water efficiency through sustainable infrastructures by reducing resource usage, degradation and pollution while increasing the quality of life.
- **Goal 13: Take urgent action to combat climate change and its impacts**. Aligned with the Vision 2050 and the Green Growth and Climate Resilience Strategy. This goal is fully incorporated into the Akagera CMP Plan as the climate change impacts have a huge influence on the catchment, not only regarding the water availability and the changes in the rainfall patterns and intensity but also on the consequences of this on the all catchment.
- **Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development.** This goal is directly incorporated into the CMP philosophy as the CMP aims to improve the natural resources management in the catchment.
- **Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation, and halt biodiversity loss.** This goal is directly incorporated into the CMP philosophy as the CMP aims to improve the natural resources management in the catchment.

The further and accelerated development of water resources constitutes both a requirement in terms of attaining SDG’s with respect to water supply and sanitation as well as a major development opportunity for water dependant commercial ventures of any type in the fields of agriculture and industry. The Sustainable Development Goals were set to guarantee a sustainable development and have inter-linkages between goals and sectors, thus for the goals to be achieved, everyone, including governments, the private sector, and Rwandans need to do their part.

NAKU CATCHMENTS ISSUES AND OPPORTUNITIES

Integrated Situation Analysis of Upper Nyaborongo (NNYU) catchment revealed an inventory of the general catchment related to it land, water and inhabiting population. Issues and opportunities were identified in a participatory manner. Typical catchment list of issues and opportunities was made by through various consultations with relevant stakeholders at different levels. These issues were properly located and mapped and appropriate intervention suggested. The identified key issues and opportunities are listed below:

Issues:

1. Erosion and sedimentation
2. Mining
3. Deforestation
4. Poor agricultural practices
5. Deteriorated water quality
6. Intensive population pressure
7. Lack of access sufficient potable water

1.3.2 DPSIR ANALYSIS

The Driver-Pressure-State-Impact-Response (DPSIR) scheme is a flexible framework that can be used to assist decision-makers in many steps of the decision process. According to this framework there is a chain of causal links starting with 'driving forces' (economic sectors, human activities) through 'pressures' (emissions, waste) to 'states' (physical, chemical and biological) and 'impacts' on ecosystems, human health and functions, eventually leading to political 'responses' (prioritisation, target setting, indicators), (Kritensen, 2004). The DPSIR analysis of NAKU catchment is provided in TABLE 2-41

TABLE 2- 41 DRIVER-PRESSURE-STATE-IMPACT-RESPONSE (DPSIR)

DRIVERS	PRESSURE	STATE	IMPACT	RESPONSE
• Population & urbanization • Climate change • National socio-economic development • Land use in catchments (agriculture, mining, housing, roads, etc.) • Topography (slopes) • Poverty • Education and level of awareness • Lack and/or limited access	• Siltation • Extreme climate events (floods or draught) • Mining of clay soil for brick making • Agriculture conversion • Artisanal Quarry/Illegal mining Invasive species • Water abstraction • Peat extraction • Wetland compaction • Wetland defragmentation (roads embankment	• Land degradation • Erosion • Floods • Drought • Sedimentation • Eutrophication • Pollution • Polluted fishes • Wastewater and solid waste from urban areas	• Water borne diseases • Loss of agricultural land • Reduced wetland productivity • Damage of infrastructure and properties in or near wetland • Loss of biodiversity	• Catchment restoration • Enforcement of relevant laws • Advocating wise use of natural resources • Buffer zones • Pollution prevention from upstream (e.g. Point sources like wastewater, solid waste, etc.). • Recycling

to improve water supply ● Lack and/or limited access to waste management infrastructures	during road construction) ● Wastewater and solid waste from urban areas			

Drivers

According to the National Strategy for Transformation, Rwanda has targeted to have 35 % of its population in urbans areas by 2024 from 18.4% in 2016/2017 However, urban areas are linked with wastewater and solid waste increase. This has a negative aspect on adjacent wetlands particularly the City of Kigali which has a direct interaction with wetlands (Gikondo, Nyabugogo, Nyabarongo and Akagera). It is urgent to align the targeted urbanization to sanitations strategies to avoid any potential water and wetland contamination. In the study conducted on Fate of heavy metals in Nyabugogo wetland revealed a heavy metals accumulation particularly in sediments of Nyabugogo Wetlands. This contamination was mainly from industries and reached fishes (clariaas sp, Oreochromis sp and Oligochaetes) with high concentration in cadmium (Cd), Chromium (Cr) and lead (Pb); therefore a human concern for the people using water and Nyabugogo wetland products[3].

Plastic pollution is another threat to wetland functions. Thanks to the Government of Rwanda to prohibit the importation, production, sale and use of plastic bags (law No 57/2008 of 10/09/2008) and recently another law on plastic carry bags and single use plastic items (Law No 17/2019 of 10/08/2019).

Negative impacts of urbanization, agriculture, mining and other land use activities are worsened by the hilly topography of Rwanda and climate and weather related hazards especially heavy rains that trigger

[3] Sekomo, B, C., Nkuranga, E. Rousseau, D, P.L., Lens, P.L.N. (2010). Fate of Heavy Metals in an Urban Natural Wetland : The Nyabugogo Swamp (Rwanda).

soil erosion, landslides, and floods that are followed by wetland sedimentation and pollution of different kind.

FUGURE 2- 58 PLASTIC WASTE IN AKAGERA WETLANDS (GASHORA BRIDGE ON JANUARY 2018).

Plastic bottles accumulation in Akagera river (Gashora Bridge) when there was a pontoon bridge before construction of the bridge) January 12, 2018). Fortunately enough the new law No 17/2019 of 10/08/2019 banned the importation, manufacturing, sale, and use of single use plastic bottle. Without this pontoon bridge that acted as a barrage to the bottles and other floating waste, it would proceed until Lake Victoria! These plastic bottles were probably mostly from the city of Kigali. Without proper sanitation regulation and enforcement, water bodies and wetlands may get polluted by different waste types from urban settlement in catchments.

Land use in catchments may also affect wetlands ecological character particularly agriculture, mining, urbanization, etc. This may led to sedimentation, point or diffuse sources of pollutions, etc.

Pressure

- *Mining*: Mining is also one of the sources of soil erosion and sedimentation and water pollution (siltation, accumulation of heavy metals in floodplains, etc.) especially with open mining on steep slopes, changes in surface and ground water flows, etc. Particularly in upper Nyabarongo catchment, Bijyojyo,Mbobo and Gatumba are examples of open cast mining that are associated with soil erosion and sedimentation. Apart from the impacts from mining done hillside, mining inside rivers and wetlands was also highlighted by the Auditor General of states finance as a challenge[4].
- *Agriculture*: Rice production,

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[4] NISR, Rwanda Natural Capital Account-Minerals Resource Flow, December 2019

- *Housing*:
- Wetland area reduced by 13% up to 2015 [5]

1.3.3 *CONCLUSION AND RECOMMENDATIONS*

This survey in NAKU catchment has provided the community perception on ecosystem services delivered by wetlands, the importance of ecosystem services, economic and livelihood dependence on wetlands, trends of ecosystem services in past five years, drivers of declining ecosystem services, natural hazards occurring in wetlands and neighbouring area, wetlands restoration opinions and wetlands degradation indicators. The purpose is for a better strategic plan for Ecosystem Based Adaptation and wetland management framework in Rwanda.

The level of wetlands management in NAKU catchment was analysed particularly in Eastern Province and the District's interventions to address the existing problems in wetlands and other concerned sectors were also suggested by the District officials. The main categories of wetlands found in this catchment are fully protected wetlands; partially protected wetlands and non- protected wetlands. The detailed analysis of key issues concerning wetlands management in this catchment found that flooding is a major issue of concern. The survey also highlights other significant major issues of concern in this catchment like erosion, wastes management, water contamination, violation of buffer zones and substandard quarry & mining activities. Understanding the connection between these issues to allow a suitable strategy to be developed and the selection of most suited interventions, the report recommends the followings:

i. Wetlands in this catchment are affected by flooding and erosion from neighbouring environment. Developed measures to minimize the level of flooding and erosion should be implemented for a better management of wetlands in this catchment. This should be supported by establishment of well-designed drainage systems within the wetlands.

ii. The current deforestation rate in Kicukiro District part of this catchment is the root cause for erosion. Reforestation of Rebero Mountain should be reinforced on yearly basis by focusing on indigenous species plantation.

iii. Substandard mining activities are still applied in Ngoma District and lead to pollution of wetlands and both surface and ground water.

iv. Wastes management is still a major issue in this catchment. Sustainable wastes management including the construction of modern landfill and composting are recommended for the benefit of public health improvement and the protection of environment including wetlands.

[5] NISR, Rwanda Natural Capital Account-Land, March 2018

CHAPTER 2 CATCHMENT MANAGEMENT STRATEGY

3.1 VISION, GOALS AND OBJECTIVES

The vision for the catchment is:

A sustainable catchment that supports economic growth and welfare

Where:

Sustainable relates to the state of the catchment and ecosystem functions to sustain the current and future generations.

Ensuring sustainable water resources management is not limited to the construction of water related infrastructure, but also ensuring that the use of- and impacts to- the water resources are managed sustainably. Therefore, activities identified in the Catchment Management Plan include soft-issues as well. Therefore, the achievement of the Vision will be through three strategic goals:

Goal 1: Improved access to clean water by 2030

Goal 2: Full protection of the Nile Akagera Upper Catchment by 2030

Goal 3: Improved Food Security by 2030

The strategic goals are further supported by specific objectives and targets.

Goal 1:	**Improved access to clean water by 2030**		
access clean water	**Objective 1.1.**	**Reduce Pollution by 30% by 2030**	
		Target 1.1.1	Runoff management
		Target 1.1.2	Pollution management plan and guidelines implementation
		Target 1.1.3	Buffer enforcement
		Target 1.1.4	Hyacinth Removal
	Objective 1.2	**Improve access to water**	
		Target 1.2.1	Rain water harvesting
		Target 1.2.2	Investigate groundwater potential
	Objective 1.3	**Watershed protection**	
		Target 1.3.1	Slope stabilization
		Target 1.3.2	Increased vegetation cover

Goal 2:	**Full protection of the Nile Akagera Upper Catchment by 2030**	
Protected	**Objective 2.1.**	**Promote biodiversity protection**
	Target 2.1.1	Declare Gashora-Mugesera-Rweru Wetland as a Ramsar Wetland
	Target 2.1.2	Sustainable wetland utilisation and rehabilitation
	Target 2.1.3	Develop Ecotourism

Objective 2.2		**Afforestation**
	Target 2.2.1	Reforestation (natural forest, plantation, agroforestry)
Objective 2.3		**Improved mine management**
	Target 2.3.1	Improved quality of discharge
	Target 2.3.2	Establish a Rehabilitation Fund
Objective 2.4		**Reduce Soil erosion**
	Target 2.4.1	Improved Monitoring and Enforcement
	Target 2.4.2	Improved Awareness / Education in Natural Resources Management

Goal 3:	**Improved Welfare by 2030**		
Welfare	**Objective 3.1**		**Improve Food Security**
		Target 3.1.1	Increase levels of soil fertility
		Target 3.1.2	Terracing on slopes
		Target 3.1.3	Appropriate crop selection
		Target 3.1.4	Expand and enhance Crop Intensification Programme
		Target 3.1.5	Markets
		Target 3.1.6	Improve Irrigation Efficiency
	Objective 3.2		**Planned settlements**
		Target 3.2.1	Implement land use plans
		Target 3.2.2	Implement model villages
		Target 3.2.3	Implement waste water treatment plants
		Target 3.2.4	Implement solid waste management
		Target 3.2.5	Establish reuse and recycle programmes throughout the catchment
	Objective 3.3		**Improve health**
		Target 3.3.1	Reduce Malaria
		Target 3.3.2	Improved domestic water quality

3.2 ECONOMIC STRATEGY

Economic growth is a national objective in order to elevate the country to a middle-income country. This can be achieved in different regions of the country through the adoption of the most appropriate strategy for each region. The Gashora-Mugesera wetland, located in Bugesera and Ngoma District, is a proposed Ramsar Wetland of International Importance. It provides habitat for an array of threatened bird species amongst others. The Bugesera District is already internationally known for its abundance of bird life. Birdwatching tourism (avitourism) has become a large industry and is the largest niche revenue-source within the eco-tourism industry. The annual spend of wildlife watchers (primarily bird watchers) in the US alone is about the same as the entire GDP of Costa Rica, according to a United States Fish and Wildlife survey. In poor countries such as Guyana, the bird tour industry has been actively developed by organizations including USAID, as an important alternative to less environmentally-friendly economic ventures such as deforestation and subsistence farming. Tourism is supported by several service industries including the provision of accommodation (hotels, lodges, camps), guiding, food, drivers, curios, etc., which provide off-farm employment opportunities. The proposed relocation of the Kigali International Airport to the Bugesera District would support the opportunity to develop tourism within the Akagera-Mugesera Catchment.

The economic growth strategy proposed for this catchment area, is the *rehabilitation and protection of Gashora-Mugesera wetland for the growth and expansion of the tourism sector*. This is compatible with the District Development Plans of the districts within the catchment area in terms of the expansion of tourism activities within these districts and specifically their objective to increase the number of hotels.

The rehabilitation of the Gashora-Mugesera wetland will also secure the natural storage of water within the catchment area, which in turn contributes to water security during dry months, a serious requirement in terms of climate change resilience. The Nile Akagera Upper Catchment is at risk of drought, and the topography of the catchment does not lend itself to the construction of a large dam for water storage to meet demands during the dry months.

The water management scenario for this catchment area has been based on meeting future demands in support of the proposed economic strategy for this catchment area.

3.3 STRATEGIC MEASURES

3.3.1 GASHORA-MUGESERA-RWERU WETLAND REHABILITATION

The first step in rehabilitation the Gashora-Mugesera-Rweru Wetland complex is to identify what needs rehabilitation. Detailed functional, ecological and environmental flow requirement assessments must be conducted for the wetland complex. This should make detailed recommendations as to what aspects of the wetland need to be rehabilitated to meet the Ramsar conditions and to develop the avitourism potential of the complex.

The recommendations of the detailed rehabilitation plan should be implemented. This will require agreement at national level between Ministries, and supported by decision-makers. The detailed plan must be implemented. The final request for proclamation of the Ramsar site must be made.

Community awareness, capacity building and training must be provided to both communities and officials regarding the rehabilitation and development of avitourism in the wetland complex. The protection of Gashora-Mugesera-Rweru wetland complex is not just about restoring wetland function but the development of tourism and economic growth through the wetland complex, as supported by Ramsar resolution XI.7:

Resolution XI.7 of the Ramsar Convention (*11th Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971*) provides guidance on the management and sustainable utilisation of wetland of International Importance and the tourism and recreational use. In particular articles1 -4, 17 *inter alia* have relevance:

Section 1. RECOGNIZING that wetlands are amongst the most productive of the world's ecosystems; that many wetlands worldwide, both coastal and inland, natural and artificial, offer significant ecosystem services including opportunities for sustainable tourism and recreation necessary for human well-being, and that these services can offer both material and non-material value to governments, the tourism industry, indigenous peoples and local communities;

Section 2. AWARE of the additional sustainable tourism opportunities and attractions provided through the internationally acknowledged importance of Ramsar Sites (Wetlands of International Importance), and RECOGNIZING the value of sustainable tourism and recreation in and around wetlands for development, poverty alleviation, local empowerment, human health, wetland conservation and wise use, and for providing a meaningful experience for visitors;

Section 3. AWARE that sustainable tourism and recreation can contribute to the achievement of public policy objectives and can bring economic opportunities for securing wetland conservation and wise use and the maintenance of key socio-economic wetland values and functions, both in Ramsar Sites and in other wetlands;

Section 4. NOTING that sustainable tourism and recreation can both benefit wetlands and contribute to the conservation of global biodiversity and sustainable development goals and targets, including the Millennium Development Goals (MDGs), climate change adaptation and mitigation, the Aichi targets established in the Strategic Plan for Biodiversity 2011-2020 adopted by the Convention on Biological Diversity, and the Ramsar Strategic Plan 2009-2015;

Section 17: ENCOURAGES Contracting Parties, and especially their Ramsar CEPA National Focal Points, to help raise awareness of wetland wise use and sustainable tourism in their Ramsar Sites, guided by the CEPA Programme and paying special attention to this Programme as a key tool for easy understanding of wetland values and functions.

Capacity building and training in the various services lines to support tourism should be conducted concurrently to the implementation of the rehabilitation. Service lines include, hotel industry, chef and catering, drivers and guiding, management and maintenance of ecotourism infrastructure, brand development and marketing for the ecotourism route, corporate gifting and conference venue facilitation and management, etc.

The rehabilitation of the wetland complex and development into a tourism destination may require a phased approach, prioritising areas of critical ecosystem restoration, and phasing out of formal cultivation from the wetland areas as the tourism sector increases.

3.3.2 SIZING OF RAINWATER HARVESTING STORAGES FOR HOUSEHOLDS

For the sizing of the required storage for a particular rainwater harvesting (RWH) system, the Code of Practice for rainwater harvesting systems, issued by the Rwanda Bureau of Standards as Rwanda Standard RS187:2013, specifies three different approaches: a simplified approach, an intermediate approach and a detailed approach. These approaches can be outlined as follows:

(i) The simplified approach is viewed as suitable for residential properties with consistent daily water demand. No calculations are carried out, because the required storage size for a particular runoff surface area is read off from graphs provided in RS187:2013.

(ii) The intermediate approach comprises the calculation of storage capacity as the lesser of 5 % of the average annual rainwater yield or 5 % of the annual non-potable water demand.

(iii) The detailed approach should be used to calculate the storage size more accurately for any situation by developing a flexible and continuous model of rainwater yield, demand and storage changes, which is based on a continuous daily rainfall time series for a minimum of 3 years and, preferably, 5 years.

This Study needs a flexible calculation method in view of the variation in housing types, household demand and site-specific characteristics and annual rainfall across the Study catchment; hence, we have followed the above “detailed approach” but with some simplifications to accommodate the fact that the Level 2 catchment are relatively large and therefore only a generalised sizing of RWH storages can be provided.

- A GENERALISED RWH CALCULATION TOOL

The generalised RWH calculation tool developed for this Study uses long-term mean monthly rainfall to perform a continuous mean monthly water balance of rainwater runoff, water usage and resulting storage fluctuations. For a particular storage-volume the tool outputs mean monthly overflows (if any) and mean monthly supplement volumes required from other water sources. The mean monthly rainfall values were reduced by 14% to account for losses due to absorption by roofing materials, evaporation, leaking or blocked gutters and pipework, etc. The tool is developed in spreadsheet format and the calculations are controlled by the following user-specified parameters:

- Runoff Surface Area (m^2) – This should be the horizontal footprint of the runoff surface.
- Runoff coefficient (%) – This is dependent on the roofing/runoff material and the following typical values apply: galvanised iron sheets – 90%; clay tiles – 75%; thatch/plant material – 30%; concrete – 80%; bricks – 60%; soil – 20%; natural stone – 50%.
- Number of persons using the water.
- Water consumption (l/p/d).
- Storage volume selected (m^3).

Table 3-1 and Table 3-2 present tabular versions of the spreadsheet-based tool and all its inputs and outputs for two different runoff surface areas and materials, but with identical rainfall, number of water users and storage volume. By changing the “Calculation Parameters” in the spreadsheet sequentially, any number of alternatives may be examined for a particular location and runoff surface, leading to a first-order estimate of an acceptable storage volume.

For the refined optimisation and design of a particular RWH system, the above analysis should be conducted using a continuous daily rainfall time series for the area being investigate. The above tool can be comfortably modified to operate on a daily time-step, using the same calculations as described above.

TABLE 3- 1 RWH STORAGE CALCULATION FOR A 60M2 RUNOFF SURFACE AREA AND GALVANISED IRON ROOF SHEETS

Calculation Parameters	
Area of runoff surface (m^2)	60
Runoff coefficient (%)	90
No. persons using the water	6
Consumption (l/p/d)	25
Storage volume selected (m^3)	5

Calculation Inputs and Outputs	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
No. days in month	31	30	31	31	30	31	30	31	31	28	31	30
Mean monthly rainfall (mm)	105	24	13	42	92	107	144	99	78	94	127	179
Reduced mean monthly rainfall (mm)	90	21	11	36	79	92	124	85	67	81	109	154
Monthly storage inflow (m^3)	4.9	1.1	0.6	2.0	4.3	5.0	6.7	4.6	3.6	4.4	5.9	8.3
Monthly water usage (m^3)	4.7	4.5	4.7	4.7	4.5	4.7	4.5	4.7	4.7	4.2	4.7	4.5
Monthly balance (m^3)	0.2	-3.4	-4.0	-2.7	-0.2	0.3	2.2	-0.1	-1.0	0.2	1.2	3.8
Actual storage (m^3)	5.0	1.6	0.0	0.0	0.0	0.3	2.5	2.5	1.4	1.6	2.8	5.0

Monthly overflow (m^3)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Monthly supplement required (m^3)	0.0	0.0	2.4	2.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3- 2 RWH STORAGE CALCULATION FOR A 40M2 RUNOFF SURFACE AREA AND A THATCH ROOF

Calculation Parameters	
Area of runoff surface (m^2)	40
Runoff coefficient (%)	30
No. persons using the water	6
Consumption (l/p/d)	25
Storage volume selected (m^3)	5

Calculation Inputs and Outputs	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
No. days in month	31	30	31	31	30	31	30	31	31	28	31	30
Mean monthly rainfall (mm)	105	24	13	42	92	107	144	99	78	94	127	179
Reduced mean monthly rainfall (mm)	90	21	11	36	79	92	124	85	67	81	109	154
Monthly storage inflow (m^3)	1.1	0.2	0.1	0.4	0.9	1.1	1.5	1.0	0.8	1.0	1.3	1.8
Monthly water usage (m^3)	4.7	4.5	4.7	4.7	4.5	4.7	4.5	4.7	4.7	4.2	4.7	4.5
Monthly balance (m^3)	-3.6	-4.3	-4.5	-4.2	-3.6	-3.5	-3.0	-3.6	-3.8	-3.2	-3.3	-2.7

Actual storage (m^3)	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monthly overflow (m^3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monthly supplement required (m^3)	0.0	2.8	4.5	4.2	3.6	3.5	3.0	3.6	3.8	3.2	3.3	2.7

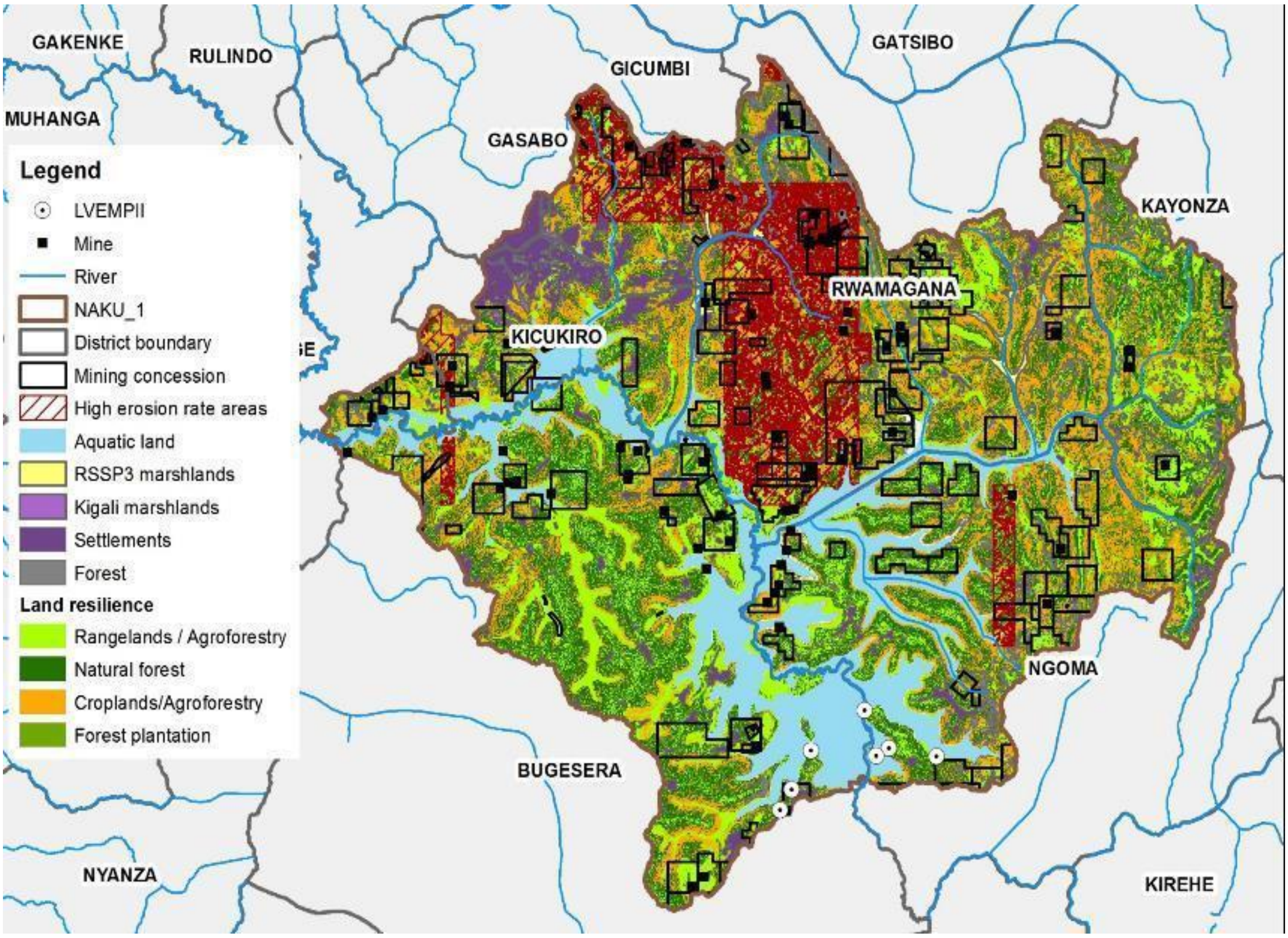


FIGURE 3- 1 RESILIENCE UNIT WITH EXISTING LAND USE

3.3.3 LAND MANAGEMENT AND REHABILITATION

A land use map, **Figure 3-1**, indicating land resilience units and existing mining, settlement and interventions e.g. RSSP 3 and LWH was created. Erosion hotspots (especially Ngoma, Rwamagana and Bugesera Districts) are indicated on the map in red.

Land management options may be proposed for areas in the catchment according to the land husbandry technique by determining land unit classification of the catchment and determining the appropriate land unit for each land unit.

In terms of land development there are land husbandry measures that can be implemented according to the land unit classification matrix, with certain measures being applicable to certain slopes and soil depths (**TABLE 3-3**). The different unit classifications are suitable for different land husbandry techniques, these are described in **TABLE 3-4**. In Akagera-Mugesera catchment it is clear that most of the area falls under Classes I to III (i.e. Agroforestry and contour ploughing/grass strips; Progressive terraces/contour bunds; Bench terraces) with Class V and Class VI (Narrow cut terraces and Forestry) occurring in the steeper areas (Figure 3-3). Note, no slopes fell into Class IV.

TABLE 3- 3 THE SITE DEVELOPMENT CLASSIFICATION MATRIX (SOURCE: RWB, 2017)

	Slope categories				
Soil depth	**0-6%**	**6-16%**	**16-40%**	**40-60%**	**>60%**
0-50 cm	Class I	Class II	Class III	Class V	Class VI
50-100 cm	Class I	Class II	Class III	Class V	Class VI
>100 cm	Class I	Class II	Class IV	Class VI	Class VI

TABLE 3- 4 LAND HUSBANDARY TECHNIQUES MATRIX

Class	Site development	Description
I	Agroforestry and contour ploughing/grass strips	Land without biophysical limitations or hazards in association with other appropriate crop management practices. Appropriate soil farming techniques should be conducted in this class.
II	Progressive terraces/contour bunds	Land has a level of biophysical limitations or hazards, the slope gradient is increasing and is suitable for simple practices such as contour bunds or progressive terraces (with application of compost, lime and proper drainage).
III	Bench terraces	Land is more at risk, but is suitable for cropping with soil and water conservation measures. Bench terracing and soil fertility management is required.
IV	Progressive terraces/contour bunds	This type of land is subject to biophysical limitations, but is suitable for cropping with intensive soil and water conservation techniques.

V	Narrow cut terraces	This class of land has severe soil/slope limitations (erosion hotspot). Narrow cut terraces are recommended for this type of land.
VI	Forestation (biological measures)	This land has a steep slope, with shallow soil depth and is considered to have excessive limitations. This class of land is subject to landslides and is not suitable for most activities, except afforestation. Forest regeneration includes afforestation (plantation) and agroforestry activities together with natural forest regeneration. Activities of forest regeneration contribute to improving soil stability, reducing soil erosion, replacing loss of tree vegetation from deforestation, replacing fuel wood, providing habitat for biodiversity and improving soil fertility, each of which addresses impacts being experienced in the catchment area. Furthermore, forest regeneration contributes towards Rwanda's commitment to the Bonn Challenge.

Indicative cost table for the land husbandry techniques activities (as provided by RWB and REMA):

Activity Type	**Unit per (RWF)**
Agroforestry	20,900
Progressive terraces	633,600
Bench terraces	2,358,420
Radical terraces	2,427,420
Forest	75,000

The area (ha) of the different land husbandry classes per sector is summarised in Table 3-3 and summarised in Figure 3-2.

TABLE 3- 5 THE AREA COVERAGE FOR EACH CLASS OF LAND HUSBANDRY PER SECTOR OF THE CATCHMENT

District	**Sector**	**Site Development (area cover in Ha)**					
		I	**II**	**III**	**IV**	**V**	**VI**
Gasabo	Remera	275	1290	1987		184	
	Kimironko	57	254	62			
	Bumbogo	44	759	904		56	2
	Ndera	422	2287	2086		179	10
	Rusororo	574	2326	1927		297	68
TOTAL District Area		**1372**	**6916**	**6966**	**0**	**717**	**80**
Kicukiro	Gatenga	3	176	433			6
	Kagarama	55	426	252		17	
	Niboye	82	340	85			
	Nyarugunga	351	802	242			
	Kanombe	753	1201	510			
	Masaka	1578	2816	867		1	

	Gahanga	1161	1442	1036		11	
TOTAL District Area		**3983**	**7203**	**3423**	**0**	**29**	**6**
Nyarugenge	Maneregere	721	776	1223		120	7
TOTAL District Area		**721**	**776**	**1223**	**0**	**120**	**7**
Bugesera	Ntarama	1086	1687	821		10	
	Mwogo	2807	2229	239			
	Juru	2370	3900	1670		56	
	Nyamata	1282	3986	409			
	Mayange	2045	2082	17			
	Rilima	4225	3775	102			
	Gashora	5664	4068	144			
	Rweru	4322	2331	136			
TOTAL District Area		**23801**	**24058**	**3538**	**0**	**67**	**0**
Ngoma	Rukumberi	5230	3023	245			
	Mugesera	3511	3159	672		1	
	Jarama	1930	1298	145			
	Sake	1378	1894	573		5	
	Zaza	1804	3251	1094		22	
	Gashanda	95	816	1061		44	
	Karembo	314	1489	1808		85	1
	Rurenge	453	2646	3249		172	2
	Remera	275	1290	1987		184	
	Kibungo	10	96	445		74	
	Kazo	15	180	255		11	
TOTAL District Area		**15015**	**19141**	**11537**	**0**	**598**	**2**
Kayonza	Kabarondo	447	1499	2091		155	5
	Nyamirarama	372	720	1120		152	6
	Mukarange	389	736	390		24	
TOTAL District Area		**1208**	**2955**	**3602**	**0**	**330**	**11**
Rwamagana	Muhazi	336	747	455		2	
	Kgabiro	468	1781	1225		5	
	Munyaga	369	2116	1571		85	3
	Rubona	889	3245	1425		26	2
	Mwulire	298	2357	2511		188	6
	Musha	30	169	344		101	13
	Fumbwe	85	384	874		206	38
	Gahengeri	238	2178	3505		392	5
	Muyumbu	413	2636	1925		58	
	Nyakaliro	934	2384	1778		52	
	Karenge	1154	3383	1722			
	Nzige	334	1993	1514		141	1
TOTAL District Area		**5547**	**23373**	**18847**	**0**	**1257**	**67**

3.4 WATER USE MANAGEMENT

3.4.1 STRUCTURE OF SCENARIOS

The water management scenarios will help better understand the pressures driven by either supply driven (mainly climate change) and demand driven (mainly sectoral water consumption) **factors**. In order to evaluate these scenarios by using the water balance model, key **indicators** need to be expressed in terms of water parameters. The scenarios will then be based on varying r**ange of values** of these indicators. The basis for factors, indicators and associated range of values are defined in **Table 3-**6 to **Table 3-**7.

TABLE 3- 6 FACTORS, INDICATORS AND RANGES

Factors	Indicators	Range of Values
Economy (EC)	Irrigation Water Consumption (linkages with agro-economy and eco-tourism)	Existing Conditions and Reference Years (2020, 2030, 2050)
Social (SC)	Population (pressures of urban)	Existing Conditions and Reference Years (2020, 2030, 2050)
Water Pollution (WP)	Water Pollution as measured through Biological Oxygen Demand and Dissolved Oxygen Turbidity Nutrient enrichment Salinity	Existing Conditions and Reference years (2020, 2030, 2050) water quality values and associated restrictions in water use and reductions in sectoral (mainly agriculture and domestic) consumption of surface+ groundwater resources and associated return flows
Environment Flow (EF)	Environmental flow needs as measured through use of Tennant driven ranges (EPA, 1975)	Existing Conditions and Reference Years (2020, 2030, 2050)
Climate Impact (CI)	Changes in Precipitation and Temperature and associated total water resources potential through use of surface and groundwater resources Evaporation	Existing Conditions and Reference Years (2020, 2030, 2050) through use of RCP 4.5 and RCP 8.5

TABLE 3- 7 FACTORS AND RANGES

Factors	Low (2020)	Medium (2030)	High (2050)
Economy (EC)	EC-Low	EC-Medium	EC-High
Social (SC)	SC-Low	SC- Medium	SC- High

Water Pollution (WP)	WQ-Low	WQ- Medium	WQ- High
Environment Flow (EF)	EN-Low	EN- Medium	EN- High
Climate Impact (CI)	CI-Low	CI- Medium	CI- High

TABLE 3- 8 SCENARIOS

SCENARIOS	EC	SC	WP	EF	CI	Driver
1	Existing Conditions					All
2						All
3						All
4						All
5						Economy
6						Social
7						Water Quality
8						Environment
9						CI

3.4.2 SENARIO OUTCOMES

In the Level II catchment, spatial and temporal variation in allocation of water resources to respective sectors include:

- ❖ Irrigation; marshland and hillside – if site-specific data is not available, irrigation water consumption to be derived through use of satellite and remote sensing data sets
- ❖ Potable; urban and rural
- ❖ Industrial
- ❖ Coffee Washing Stations
- ❖ Livestock
- ❖ Fish ponds

By accounting water demand as a water need that needs to be maintained at a specific location (i.e., wetland) within a specified time frame (i.e., specific months within the year):

- ❖ Hydroelectric power plants

- ❖ Wetlands
- ❖ Ecological (lakes and rivers)

As shown below, in all scenarios (both population growth and climate change) water availability is higher than water demand at each sub-catchment for all 12 months.

Therefore, existing conditions and future conditions water allocation is in-line with water availability.

A detailed environmental flow assessment for the Akagera river as a system should be conducted, and the recommendations from this incorporated into the models developed for the different catchments.

It is important to note that **main drivers of change in the flows** include natural and human-driven pressures on the water balance. In the context of Nile Akagera Upper catchment:

- Natural pressures are induced by the impacts of climate change and associated changes in spatial and temporal distribution of precipitation
- Human-driven pressures are mainly induced by irrigation and consumptive uses.
- In order to structure a strategic road-map for catchment management strategies, it is important to understand the spatial and temporal changes driven by both the natural and human-driven changes at the sub-catchment-scale within the level 2 catchment
- In this context, both the existing conditions and "expected" conditions in the future years are summarized in below tables.

TABLE 3- 9 EXISTING WATER BALANCE CONDITIONS (TCM)

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,928	6,205	22,225	21,086	54,444	215	253	553	988	2,010
2	4,281	4,863	19,191	19,381	47,715	215	253	553	988	2,010
3	4,693	4,546	20,758	23,586	53,584	213	249	541	989	1,992
4	8,246	9,132	39,076	38,861	95,316	213	249	541	986	1,989
5	7,350	9,787	37,477	32,498	87,112	213	249	541	986	1,989
6	1,737	2,014	9,755	7,616	21,122	491	411	1,559	4,196	6,656
7	1,175	1,017	4,987	4,541	11,720	491	410	2,307	6,956	10,163
8	965	1,420	4,395	4,672	11,453	491	410	2,266	6,742	9,909
9	767	1,065	5,348	7,240	14,420	214	251	717	1,642	2,824
10	1,627	2,072	10,550	14,097	28,346	214	251	546	987	1,998
11	5,415	6,240	26,878	28,456	66,989	214	251	546	987	1,998
12	5,854	6,034	26,294	25,482	63,664	215	253	564	987	2,020
Total	47,039	54,395	226,934	227,517	**555,885**	3,399	3,492	12,697	25,930	**45,558**

TABLE 3- 10 FUTURE WATER BALANCE CONDITIONS: 2020 (TCM) RCP 4.5 – LOW POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,942	6,222	22,289	21,146	54,599	252	298	649	1,172	2,371
2	4,305	4,891	19,306	19,492	47,994	252	298	649	1,172	2,371
3	4,698	4,553	20,784	23,609	53,644	250	295	638	1,173	2,357
4	8,250	9,136	39,096	38,880	95,363	250	295	638	1,171	2,354
5	7,356	9,795	37,509	32,527	87,188	250	295	638	1,171	2,354
6	1,729	2,004	9,716	7,584	21,032	576	483	1,690	4,425	7,173
7	1,171	1,012	4,969	4,525	11,676	576	481	2,436	7,185	10,677
8	961	1,414	4,377	4,656	11,408	576	481	2,395	6,971	10,423
9	760	1,056	5,308	7,193	14,318	251	296	814	1,830	3,191
10	1,621	2,066	10,532	14,089	28,308	251	296	642	1,171	2,360
11	5,452	6,285	27,067	28,641	67,444	251	296	642	1,171	2,360
12	5,874	6,056	26,387	25,567	63,885	252	298	658	1,171	2,379
Annual tota	47,119	54,491	227,340	227,910	**556,860**	3,989	4,111	12,697	25,930	**50,371**

TABLE 3- 11 FUTURE WATER BALANCE CONDITIONS: 2020 (TCM) RCP 4.5 MEDIUM POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,942	6,222	22,289	21,146	54,599	254	301	657	1,189	2,400
2	4,305	4,891	19,306	19,492	47,994	254	301	657	1,189	2,400
3	4,698	4,553	20,784	23,609	53,644	252	298	645	1,190	2,385
4	8,250	9,136	39,096	38,880	95,363	252	298	645	1,187	2,383
5	7,356	9,795	37,509	32,527	87,188	252	298	645	1,187	2,383
6	1,729	2,004	9,716	7,584	21,032	577	486	1,697	4,442	7,202
7	1,171	1,012	4,969	4,525	11,676	577	484	2,443	7,201	10,706
8	961	1,414	4,377	4,656	11,408	577	484	2,403	6,988	10,452
9	760	1,056	5,308	7,193	14,318	253	299	822	1,847	3,220
10	1,621	2,066	10,532	14,089	28,308	253	299	649	1,187	2,388
11	5,452	6,285	27,067	28,641	67,444	253	299	649	1,187	2,388
12	5,874	6,056	26,387	25,567	63,885	254	301	666	1,187	2,408
Total	47,119	54,491	227,340	227,910	**556,860**	4,005	4,148	12,697	25,930	**50,714**

TABLE 3- 12 FUTURE WATER BALANCE CONDITIONS: 2020 (TCM) RCP 4.5 HIGH POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,942	6,222	22,289	21,146	54,599	254	302	659	1,194	2,410
2	4,305	4,891	19,306	19,492	47,994	254	302	659	1,194	2,410
3	4,698	4,553	20,784	23,609	53,644	252	299	648	1,195	2,395
4	8,250	9,136	39,096	38,880	95,363	252	299	648	1,193	2,392
5	7,356	9,795	37,509	32,527	87,188	252	299	648	1,193	2,392
6	1,729	2,004	9,716	7,584	21,032	577	487	1,700	4,447	7,211
7	1,171	1,012	4,969	4,525	11,676	577	485	2,446	7,207	10,715
8	961	1,414	4,377	4,656	11,408	577	485	2,405	6,993	10,461
9	760	1,056	5,308	7,193	14,318	253	300	824	1,852	3,229
10	1,621	2,066	10,532	14,089	28,308	253	300	652	1,193	2,398
11	5,452	6,285	27,067	28,641	67,444	253	300	652	1,193	2,398
12	5,874	6,056	26,387	25,567	63,885	254	302	669	1,193	2,418
Total	47,119	54,491	227,340	227,910	**556,860**	4,011	4,160	12,697	25,930	**50,828**

TABLE 3- 13 FUTURE WATER BALANCE CONDITIONS: 2020 (TCM) RCP 8.5 LOW POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,947	6,229	22,322	21,183	54,681	252	298	649	1,172	2,371
2	4,279	4,861	19,190	19,385	47,714	252	298	649	1,172	2,371
3	4,695	4,552	20,794	23,638	53,679	250	295	638	1,173	2,357
4	8,244	9,130	38,985	38,874	95,233	250	295	638	1,171	2,354
5	7,333	9,765	37,400	32,434	86,932	250	295	638	1,171	2,354
6	1,729	2,003	9,712	7,583	21,027	576	483	1,690	4,425	7,173
7	1,169	1,011	4,963	4,520	11,664	576	481	2,436	7,185	10,677
8	953	1,403	4,343	4,625	11,323	576	481	2,395	6,972	10,424
9	760	1,056	5,315	7,216	14,346	251	296	811	1,818	3,176
10	1,609	2,052	10,472	14,027	28,160	251	296	642	1,171	2,360
11	5,438	6,267	27,007	28,601	67,312	251	296	642	1,171	2,360
12	5,910	6,105	26,573	25,752	64,339	252	298	653	1,171	2,374
Total	47,065	54,435	227,075	227,837	**556,411**	3,989	4,111	12,697	25,930	**50,351**

TABLE 3- 14 FUTURE WATER BALANCE CONDITIONS: 2020(TCM) RCP 8.5 MEDIUM POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,947	6,229	22,322	21,183	54,681	254	301	657	1,189	2,400
2	4,279	4,861	19,190	19,385	47,714	254	301	657	1,189	2,400
3	4,695	4,552	20,794	23,638	53,679	252	298	645	1,190	2,385
4	8,244	9,130	38,985	38,874	95,233	252	298	645	1,187	2,383
5	7,333	9,765	37,400	32,434	86,932	252	298	645	1,187	2,383
6	1,729	2,003	9,712	7,583	21,027	577	486	1,697	4,442	7,202
7	1,169	1,011	4,963	4,520	11,664	577	484	2,443	7,201	10,706
8	953	1,403	4,343	4,625	11,323	577	484	2,403	6,988	10,452
9	760	1,056	5,315	7,216	14,346	253	299	819	1,835	3,204
10	1,609	2,052	10,472	14,027	28,160	253	299	649	1,187	2,388
11	5,438	6,267	27,007	28,601	67,312	253	299	649	1,187	2,388
12	5,910	6,105	26,573	25,752	64,339	254	301	660	1,187	2,402
Total	47,065	54,435	227,075	227,837	**556,411**	4,005	4,148	12,697	25,930	**50,693**

TABLE 3- 15 FUTURE WATER BALANCE CONDITIONS: 2020 (TCM) RCP 8.5 HIGH POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,947	6,229	22,322	21,183	54,681	254	302	659	1,194	2,410
2	4,279	4,861	19,190	19,385	47,714	254	302	659	1,194	2,410
3	4,695	4,552	20,794	23,638	53,679	252	299	648	1,195	2,395
4	8,244	9,130	38,985	38,874	95,233	252	299	648	1,193	2,392
5	7,333	9,765	37,400	32,434	86,932	252	299	648	1,193	2,392
6	1,729	2,003	9,712	7,583	21,027	577	487	1,700	4,447	7,211
7	1,169	1,011	4,963	4,520	11,664	577	485	2,446	7,207	10,715
8	953	1,403	4,343	4,625	11,323	577	485	2,405	6,994	10,462
9	760	1,056	5,315	7,216	14,346	253	300	821	1,840	3,214
10	1,609	2,052	10,472	14,027	28,160	253	300	652	1,193	2,398
11	5,438	6,267	27,007	28,601	67,312	253	300	652	1,193	2,398
12	5,910	6,105	26,573	25,752	64,339	254	302	663	1,193	2,412
Total	47,065	54,435	227,075	227,837	**556,411**	4,011	4,160	12,697	25,930	**50,808**

TABLE 3- 16 FUTURE WATER BALANCE CONDITIONS: 2030 (TCM) RCP 4.5 LOW POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,977	6,267	22,460	21,304	55,009	303	357	791	1,428	2,879
2	4,365	4,965	19,601	19,777	48,708	303	357	791	1,428	2,879
3	4,713	4,569	20,852	23,671	53,806	301	353	779	1,429	2,863
4	8,259	9,149	39,058	38,931	95,398	301	353	779	1,426	2,861
5	7,373	9,816	37,593	32,602	87,384	301	353	779	1,426	2,861
6	1,708	1,979	9,619	7,502	20,807	695	580	1,881	4,751	7,907
7	1,160	1,001	4,922	4,485	11,568	695	578	2,628	7,511	11,412
8	950	1,400	4,333	4,615	11,299	695	578	2,587	7,298	11,158
9	743	1,034	5,210	7,079	14,066	302	354	959	2,098	3,713
10	1,608	2,051	10,486	14,070	28,215	302	354	784	1,427	2,867
11	5,545	6,396	27,532	29,140	68,613	302	354	784	1,427	2,867
12	5,923	6,119	26,621	25,782	64,445	303	357	797	1,427	2,883
Total	47,326	54,746	228,287	228,958	**559,317**	4,806	4,928	12,697	25,930	**57,150**

TABLE 3- 17 FUTURE WATER BALANCE CONDITIONS: 2030 (TCM) RCP 4.5 MEDIUM POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,977	6,267	22,460	21,304	55,009	309	369	822	1,486	2,986
2	4,365	4,965	19,601	19,777	48,708	309	369	822	1,486	2,986
3	4,713	4,569	20,852	23,671	53,806	307	366	810	1,487	2,970
4	8,259	9,149	39,058	38,931	95,398	307	366	810	1,484	2,967
5	7,373	9,816	37,593	32,602	87,384	307	366	810	1,484	2,967
6	1,708	1,979	9,619	7,502	20,807	701	592	1,912	4,809	8,013
7	1,160	1,001	4,922	4,485	11,568	701	591	2,659	7,568	11,518
8	950	1,400	4,333	4,615	11,299	701	591	2,618	7,355	11,265
9	743	1,034	5,210	7,079	14,066	308	367	990	2,155	3,820
10	1,608	2,051	10,486	14,070	28,215	308	367	815	1,484	2,974
11	5,545	6,396	27,532	29,140	68,613	308	367	815	1,484	2,974
12	5,923	6,119	26,621	25,782	64,445	309	369	827	1,484	2,990
Total	47,326	54,746	228,287	228,958	**559,317**	4,873	5,078	12,697	25,930	**58,428**

TABLE 3- 18 FUTURE WATER BALANCE CONDITIONS: 2030 (TCM) RCP 4.5 HIGH POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	4,977	6,267	22,460	21,304	55,009	341	439	1,015	1,817	3,611
2	4,365	4,965	19,601	19,777	48,708	341	439	1,015	1,817	3,611
3	4,713	4,569	20,852	23,671	53,806	339	436	1,003	1,818	3,596
4	8,259	9,149	39,058	38,931	95,398	339	436	1,003	1,815	3,593
5	7,373	9,816	37,593	32,602	87,384	339	436	1,003	1,815	3,593
6	1,708	1,979	9,619	7,502	20,807	733	662	2,105	5,140	8,639
7	1,160	1,001	4,922	4,485	11,568	733	660	2,851	7,900	12,144
8	950	1,400	4,333	4,615	11,299	733	660	2,811	7,687	11,890
9	743	1,034	5,210	7,079	14,066	340	437	1,183	2,486	4,446
10	1,608	2,051	10,486	14,070	28,215	340	437	1,008	1,816	3,600
11	5,545	6,396	27,532	29,140	68,613	340	437	1,008	1,816	3,600
12	5,923	6,119	26,621	25,782	64,445	341	439	1,020	1,816	3,616
Total	47,326	54,746	228,287	228,958	**559,317**	5,258	5,917	12,697	25,930	**65,940**

TABLE 3- 19 FUTURE WATER BALANCE CONDITIONS: 2030 (TCM) RCP 8.5 LOW POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,062	6,373	22,852	21,661	55,948	303	357	791	1,428	2,879
2	4,337	4,931	19,456	19,626	48,351	303	357	791	1,428	2,879
3	4,784	4,649	21,201	24,037	54,671	301	353	779	1,429	2,863
4	8,341	9,247	39,446	39,277	96,311	301	353	779	1,426	2,861
5	7,350	9,792	37,491	32,502	87,135	301	353	779	1,426	2,861
6	1,724	1,999	9,694	7,566	20,983	695	580	1,881	4,751	7,907
7	1,171	1,014	4,973	4,528	11,686	695	578	2,628	7,511	11,412
8	944	1,392	4,307	4,590	11,233	695	578	2,588	7,299	11,160
9	762	1,059	5,342	7,266	14,430	302	354	948	2,055	3,660
10	1,606	2,049	10,465	14,029	28,148	302	354	784	1,427	2,867
11	5,572	6,429	27,672	29,292	68,965	302	354	784	1,427	2,867
12	6,116	6,345	27,556	26,664	66,680	303	357	791	1,427	2,878
Total	47,768	55,278	230,455	231,038	**564,539**	4,806	4,928	12,697	25,930	**57,093**

TABLE 3- 20 FUTURE WATER BALANCE CONDITIONS: 2030 (TCM) RCP 8.5 MEDIUM POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,062	6,373	22,852	21,661	55,948	309	369	822	1,486	2,986
2	4,337	4,931	19,456	19,626	48,351	309	369	822	1,486	2,986
3	4,784	4,649	21,201	24,037	54,671	307	366	810	1,487	2,970
4	8,341	9,247	39,446	39,277	96,311	307	366	810	1,484	2,967
5	7,350	9,792	37,491	32,502	87,135	307	366	810	1,484	2,967
6	1,724	1,999	9,694	7,566	20,983	701	592	1,912	4,809	8,013
7	1,171	1,014	4,973	4,528	11,686	701	591	2,659	7,568	11,518
8	944	1,392	4,307	4,590	11,233	701	591	2,618	7,357	11,266
9	762	1,059	5,342	7,266	14,430	308	367	979	2,113	3,766
10	1,606	2,049	10,465	14,029	28,148	308	367	815	1,484	2,974
11	5,572	6,429	27,672	29,292	68,965	308	367	815	1,484	2,974
12	6,116	6,345	27,556	26,664	66,680	309	369	822	1,484	2,984
Total	47,768	55,278	230,455	231,038	**564,539**	4,873	5,078	12,697	25,930	**58,371**

TABLE 3- 20 FUTURE WATER BALANCE CONDITIONS: 2030 (TCM) RCP 8.5 HIGH POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,062	6,373	22,852	21,661	55,948	341	439	1,015	1,817	3,611
2	4,337	4,931	19,456	19,626	48,351	341	439	1,015	1,817	3,611
3	4,784	4,649	21,201	24,037	54,671	339	436	1,003	1,818	3,596
4	8,341	9,247	39,446	39,277	96,311	339	436	1,003	1,815	3,593
5	7,350	9,792	37,491	32,502	87,135	339	436	1,003	1,815	3,593
6	1,724	1,999	9,694	7,566	20,983	733	662	2,105	5,140	8,639
7	1,171	1,014	4,973	4,528	11,686	733	660	2,851	7,900	12,144
8	944	1,392	4,307	4,590	11,233	733	660	2,811	7,688	11,892
9	762	1,059	5,342	7,266	14,430	340	437	1,172	2,444	4,392
10	1,606	2,049	10,465	14,029	28,148	340	437	1,008	1,816	3,600
11	5,572	6,429	27,672	29,292	68,965	340	437	1,008	1,816	3,600
12	6,116	6,345	27,556	26,664	66,680	341	439	1,015	1,816	3,610
Total	47,768	55,278	230,455	231,038	**564,539**	5,258	5,917	12,697	25,930	**65,883**

TABLE 3- 21 FUTURE WATER BALANCE CONDITIONS: 2050 (TCM) RCP 4.5 LOW POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,049	6,357	22,802	21,621	55,829	405	473	1,050	1,897	3,825
2	4,486	5,112	20,193	20,349	50,141	405	473	1,050	1,897	3,825
3	4,742	4,603	20,988	23,793	54,126	403	470	1,039	1,898	3,810
4	8,277	9,175	39,166	39,031	95,649	403	470	1,039	1,895	3,807
5	7,406	9,857	37,757	32,750	87,770	403	470	1,039	1,895	3,807
6	1,667	1,930	9,424	7,338	20,360	933	774	2,240	5,360	9,308
7	1,139	978	4,830	4,405	11,352	933	772	2,987	8,119	12,812
8	929	1,370	4,246	4,535	11,081	933	772	2,946	7,907	12,559
9	710	990	5,018	6,854	13,573	404	471	1,225	2,589	4,689
10	1,581	2,022	10,397	14,031	28,032	404	471	1,043	1,895	3,813
11	5,733	6,620	28,483	30,143	70,978	404	471	1,043	1,895	3,813
12	6,022	6,234	27,092	26,214	65,562	405	473	1,056	1,895	3,829
Total	47,742	55,248	230,398	231,065	**564,453**	6,434	6,562	12,697	25,930	**69,895**

TABLE 3- 22 FUTURE WATER BALANCE CONDITIONS: 2050 (TCM) RCP 4.5 MEDIUM POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,049	6,357	22,802	21,621	55,829	417	501	1,118	2,055	4,091
2	4,486	5,112	20,193	20,349	50,141	417	501	1,118	2,055	4,091
3	4,742	4,603	20,988	23,793	54,126	415	498	1,107	2,056	4,075
4	8,277	9,175	39,166	39,031	95,649	415	498	1,107	2,053	4,073
5	7,406	9,857	37,757	32,750	87,770	415	498	1,107	2,053	4,073
6	1,667	1,930	9,424	7,338	20,360	946	801	2,308	5,518	9,574
7	1,139	978	4,830	4,405	11,352	946	800	3,055	8,277	13,078
8	929	1,370	4,246	4,535	11,081	946	800	3,014	8,065	12,825
9	710	990	5,018	6,854	13,573	416	499	1,293	2,747	4,955
10	1,581	2,022	10,397	14,031	28,032	416	499	1,111	2,053	4,079
11	5,733	6,620	28,483	30,143	70,978	416	499	1,111	2,053	4,079
12	6,022	6,234	27,092	26,214	65,562	417	501	1,124	2,053	4,095
Total	47,742	55,248	230,398	231,065	**564,453**	6,580	6,895	12,697	25,930	**73,086**

TABLE 3- 23 FUTURE WATER BALANCE CONDITIONS: 2050 (TCM) RCP 4.5 HIGH POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,049	6,357	22,802	21,621	55,829	484	661	1,473	3,141	5,759
2	4,486	5,112	20,193	20,349	50,141	484	661	1,473	3,141	5,759
3	4,742	4,603	20,988	23,793	54,126	483	658	1,462	3,142	5,744
4	8,277	9,175	39,166	39,031	95,649	483	658	1,462	3,140	5,741
5	7,406	9,857	37,757	32,750	87,770	483	658	1,462	3,140	5,741
6	1,667	1,930	9,424	7,338	20,360	1,013	961	2,663	6,605	11,242
7	1,139	978	4,830	4,405	11,352	1,013	959	3,410	9,364	14,746
8	929	1,370	4,246	4,535	11,081	1,013	959	3,369	9,151	14,493
9	710	990	5,018	6,854	13,573	484	658	1,648	3,834	6,623
10	1,581	2,022	10,397	14,031	28,032	484	658	1,466	3,140	5,748
11	5,733	6,620	28,483	30,143	70,978	484	658	1,466	3,140	5,748
12	6,022	6,234	27,092	26,214	65,562	484	661	1,479	3,140	5,763
Total	47,742	55,248	230,398	231,065	**564,453**	7,392	8,807	12,697	25,930	**93,108**

TABLE 3- 24 FUTURE WATER BALANCE CONDITIONS: 2050 (TCM) RCP 8.5 LOW POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,292	6,663	23,921	22,624	58,499	405	473	1,050	1,897	3,825
2	4,452	5,071	19,987	20,106	49,616	405	473	1,050	1,897	3,825
3	4,962	4,844	22,016	24,856	56,677	403	470	1,039	1,898	3,810
4	8,532	9,457	40,363	40,079	98,431	403	470	1,039	1,895	3,807
5	7,382	9,842	37,666	32,633	87,523	403	470	1,039	1,895	3,807
6	1,715	1,989	9,655	7,530	20,890	933	774	2,240	5,360	9,308
7	1,174	1,020	4,990	4,542	11,726	933	772	2,987	8,119	12,812
8	927	1,369	4,234	4,521	11,052	933	772	2,947	7,910	12,563
9	766	1,067	5,395	7,365	14,593	404	471	1,197	2,487	4,559
10	1,599	2,042	10,450	14,032	28,123	404	471	1,043	1,895	3,813
11	5,844	6,754	29,030	30,685	72,313	404	471	1,043	1,895	3,813
12	6,536	6,833	29,554	28,513	71,435	405	473	1,050	1,895	3,824
Total	49,181	56,950	237,261	237,486	**580,877**	6,434	6,562	12,697	25,930	**69,764**

TABLE 3- 25 FUTURE WATER BALANCE CONDITIONS: 2050 (TCM) RCP 8.5 MEDIUM POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,292	6,663	23,921	22,624	58,499	417	501	1,118	2,055	4,091
2	4,452	5,071	19,987	20,106	49,616	417	501	1,118	2,055	4,091
3	4,962	4,844	22,016	24,856	56,677	415	498	1,107	2,056	4,075
4	8,532	9,457	40,363	40,079	98,431	415	498	1,107	2,053	4,073
5	7,382	9,842	37,666	32,633	87,523	415	498	1,107	2,053	4,073
6	1,715	1,989	9,655	7,530	20,890	946	801	2,308	5,518	9,574
7	1,174	1,020	4,990	4,542	11,726	946	800	3,055	8,277	13,078
8	927	1,369	4,234	4,521	11,052	946	800	3,015	8,068	12,829
9	766	1,067	5,395	7,365	14,593	416	499	1,265	2,645	4,825
10	1,599	2,042	10,450	14,032	28,123	416	499	1,111	2,053	4,079
11	5,844	6,754	29,030	30,685	72,313	416	499	1,111	2,053	4,079
12	6,536	6,833	29,554	28,513	71,435	417	501	1,118	2,053	4,090
Total	49,181	56,950	237,261	237,486	**580,877**	6,580	6,895	12,697	25,930	**72,955**

TABLE 3- 26 FUTURE WATER BALANCE CONDITIONS: 2050 (TCM) RCP 8.5 HIGH POPULATION GROWTH

	Available water (TCM)					water demand (TCM)				
Month	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1	Sub-catchment1	Sub-catchment2	Sub-catchment3	Sub-catchment4	NAKU_1
1	5,292	6,663	23,921	22,624	58,499	484	661	1,473	3,141	5,759
2	4,452	5,071	19,987	20,106	49,616	484	661	1,473	3,141	5,759
3	4,962	4,844	22,016	24,856	56,677	483	658	1,462	3,142	5,744
4	8,532	9,457	40,363	40,079	98,431	483	658	1,462	3,140	5,741
5	7,382	9,842	37,666	32,633	87,523	483	658	1,462	3,140	5,741
6	1,715	1,989	9,655	7,530	20,890	1,013	961	2,663	6,605	11,242
7	1,174	1,020	4,990	4,542	11,726	1,013	959	3,410	9,364	14,746
8	927	1,369	4,234	4,521	11,052	1,013	959	3,370	9,155	14,497
9	766	1,067	5,395	7,365	14,593	484	658	1,620	3,732	6,493
10	1,599	2,042	10,450	14,032	28,123	484	658	1,466	3,140	5,748
11	5,844	6,754	29,030	30,685	72,313	484	658	1,466	3,140	5,748
12	6,536	6,833	29,554	28,513	71,435	484	661	1,473	3,140	5,758
Total	49,181	56,950	237,261	237,486	**580,877**	7,392	8,807	12,697	25,930	**92,976**

CHAPTER 3 INSTITUTIONAL ARRANGEMENTS

The institutional arrangements in a catchment management plan shall specify plans that provide the supporting cooperative arrangements and requirements for implementing water management related strategies, including-

Formal institutional structures and arrangements are required for the implementation and monitoring of the Catchment Management Plan (CMP) and the daily management of the water resources of the catchment. The *Law Nº49/2018 of 10/09/2008 Putting in place the use, conservation, protection and management of water resources regulations* ("the Law") sets out the institutional structures tasked with catchment management. It should be noted that the Law uses different terminology for example the Law refers to Basin rather than Catchment). For the purpose of this report the terminology will remain as Catchment, this is in line with the terminology of the National Policy for Water Resources Management, 2011.

3.1 NATIONAL LEVEL

3.1.1 RWANDA WATER RESOURCES BOARD

Article 17 of the Law establishes the Rwanda Water and Forestry Authority (RWB). The latest powers, responsibilities, organisation and functioning of the National Water Authority are set out in Official Gazette Nº33 of 14/08/2017, Order Nº103/03 of 10//08/2017 *Prime Minister's Order determining the organisational structure, salaries and fringe benefits for employees of Rwanda Water and Forestry Authority*, **Figure 4-1**.

The structure makes provision for a centralised monitoring unit, centralised water resources protection and development unit which includes 5 Catchment officers although there are 9 catchments, a regulatory unit and then the shared corporate services with the Forestry Department i.e. MIS and IT Support unit and the Administration and Finance unit. The structure is very thin. RWB is the lead institution for the implementation of the Catchment Management Plan and water resources management within the catchments, and will require additional capacity dedicated to each catchment for the implementation, permitting, monitoring, regulation, awareness raising and tariff collection activities.

3.1.2 WATER INTERMINISTERIAL COMMITTEE

Article 18 of the Law makes provision for the establishment of the Water Interministerial Committee. The Committee is comprised of Ministerial representatives concerned by water, and is supervised by a Director in the Ministry of water. According to the Article, the Committee shall be consulted on all legislative drafts/Bills regarding planning in the water domain elaborated at the national, regional and international level.

The Committee should be engaged in more than just legislative drafts/Bills but also the coordination between Ministerial Departments and the resolution of conflicts between policies. For example, whereas the Vision 2020 under pillar 2 Human Resource Development and a Knowledge-based economy- sub-section Health and population sets an objective that "malaria and other potential epidemic diseases will have been controlled", pillar 5: Productive high value and market oriented agriculture- promotes the "production of high value crops". This has resulted in the wide area implementation of wet field rice (also called paddy rice) due to its perceived "higher" value. However, wet field rice is directly related to the increased occurrence of malaria in districts implementing the paddy rice schemes, resulting in households spending more time ill and more income on health care. A preferred alternative would be to rather promote upland rice (dry rice) which is yielding similar results (e.g. in southern province yield of 5.25 tons per hectare), and a moratorium be placed on wet field rice to control the increase occurrence of malaria. Both improved health and food security are National Objectives. This discussion should be conducted through the Water Interministerial Committee. Similarly, the loss of natural water storage capacity in drought prone areas due to draining for cultivation activities e.g. Gashora-Mugesera wetland system, also requires discussion at the Water Interministerial Committee.

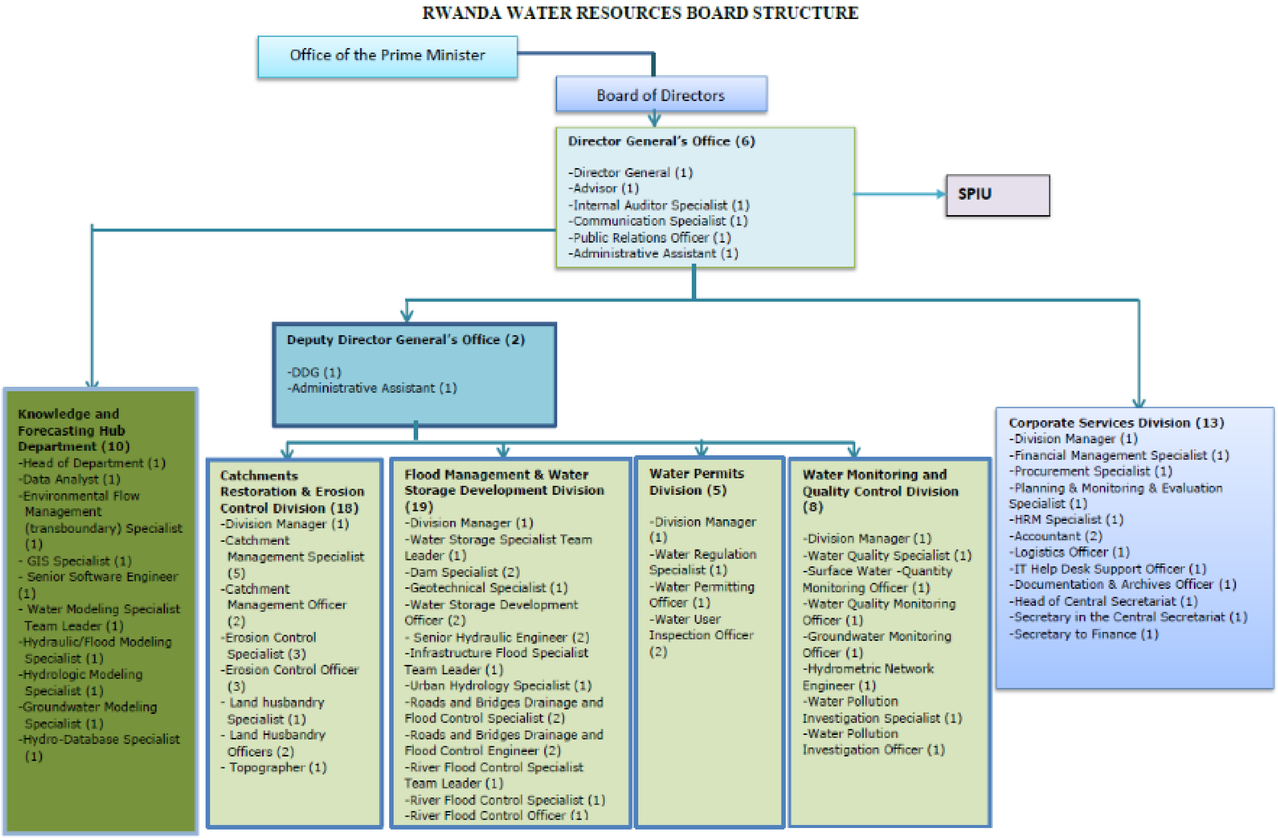


FIGURE 4- 1 ORGANOGRAM OF RWB STRUCTURE

3.2 CATCHMENT LEVEL

3.2.1 CATCHMENT COMMITTEE

Article 20 of the Law establishes District Committees for Hydrographic Basins, referred to as Catchment Committees. The Catchment Committee is composed of:

- Administrations representatives concerned by water, i.e. district officials concerned with water e.g. District Hydrology Officer;
- Elected representatives of the local decentralised communities; and
- Representatives of the different categories of water users *e.g. agricultural uses, domestic uses, etc*.

The organisation and functioning of the Catchment Committees shall be determined by Ministerial Order. To date this has not been proclaimed. However, as an interim measure RWB has establish Task Catchment Committees comprised of a representative of each District and the RWB Catchment Officer. Article 21 of the Law sets out the mission of the Catchment Committee. The Catchment Committees is charged with:

- To propose the initial version of the master plan and management of the basin waters as provided for in this law. *In catchment management it is referred to as a Catchment Management Plan (CMP) rather than a Master Plan. This report is the first Catchment Management Plan for the Nile Akagera Upper Catchment.*
- To propose the delimitation, if necessary, of under-basins and the designation of the aquifer for which an integrated management of the water resource must be done. *Under-basins are referred to as sub-catchments.*
- To formulate orientations and proposals concerning the planning and management of the waters of under-basins or aquifer.
- To formulate propositions or arbitration or solution in case of conflict of water uses.
- To formulate opinions on all technical or financial questions that is submitted to it by the administration.
- To value the relevance and feasibility of basin organisms, to prepare their setting up in the event that it would be judged necessary.

The operations and functions of the Catchment Committees (CC) must be determined. The CC is comprised of representatives from the Districts, local communities in the Districts, and the Water Users. These representatives are formerly employed in other roles but will sit on the CC on a regular basis to execute the functions of the CC. When setting out the operations and functions of the CC, it should ensure there is no conflict of interest in the representatives of the CC, clearly set out how often they sit, procedures for meetings, and the juristic nature of the CC. The members of the CC, including the Task CC will require capacity building before being able to execute their functions to ensure they understand the aims and objectives of integrated water resources management and the catchment management approach, and the role of the Catchment Management Plan and the Catchment Committee, as how this links back to their formal duties.

The Catchment Committee is tasked with the implementation and monitoring of the Catchment Management Plan at the District level. The CC must ensure that there is coordination and cooperation between all role-players and engagement with stakeholders for the effective implementation of the CMP. The Implementation Plan identifies lead institutions for various activities of the CMP. The CC is tasked to ensure these institutions integrated their responsibilities into their development plans, and monitor that the activities are implemented. This will require technical support from RWB.

3.2.2 BASIN COMMITTEE AT THE SECTOR LEVEL

Article 22 of the Law establishes Basin Committees at the Sector Level, referred to as Sub-Catchment Committees (SCC), for the management of a small basin or aquifer at the level of the administrative decentralised authority of the district to which it is connected. The structure and functioning of this Sub-Catchment shall be the same as set out for the Basin Committee/ Catchment Committee at the District level, when this is proclaimed.

CHAPTER 4 CATCHMENT MANAGEMENT IMPLEMNTATION PLAN

This requires that the legislative framework supports the sustainable management activities, there are institutional structures in place to implement the plan, and economic tools to finance the implementation of the plan. The proposed activities of the plan should be incorporated into the District Development Plans to ensure implementation. The DDSs then indicate the site-specific location for the activities.

The Implementation Plan is presented in Table 5-1**.** For each ***Strategic Goal***, similar / related activities were integrated into one or more ***Target/Aims.*** The ***Activities*** outline the key actions to achieve the Targets/Aims. ***Indicators/Outputs*** were identified for each ***Activity***, against which to monitor progress made in implementing the Implementation Plan. ***Indicative phasing*** provides a timeframe for implementing the activities, with ***Responsibilities*** assigned to lead role-player's, and where applicable specific District/Sectors are identified and an indicative costing for activities requiring funding that is not part of daily operations. These headings are summarised below.

TABLE 5- 1 PRESENT THE COST ESTIMATE FOR CATCHMENT RESTORATION. THE AREA HIGHLIGHTED IN THERE ARE IN ACCORDANCE TO THE PROPOSAL FOR CROM DSS AVAILABLE AT THE RWANDA WATER RESOURCES BOARD.

Target / Aim	Activities	Indicators / Outputs	Indicative phasing	Responsible Authority	Applicable District / Sectors	Indicative costing
What action needs to be achieved to meet the objective	*Specific activities to be carried out to meet the Target/Aim*	*For monitoring / Links to limits set by Districts*	*Short = 1-2 years*	*Who should be responsible to ensure this action is implemented*	*If actions are specific/ prioritised to a District or Sector area*	Low < US$500,000
			Medium = 2-5 years			Moderate: US$500,000 - $1 million
			Long = 5-10 years			High >US$1 million
						n/a =part of operational costs

TABLE 5- 2 THE IMPLEMENTATION PLAN FOR CATCHMENT RESTORATION

S/N	Proposed Intervention Measures	Unit	Quantity	Area (%)	Unit cost Rwf	Total cost Rwf
1	Contour Bank Terraces	ha	61664.51	54.09	2,392,000	147,501,512,704
5	Perennial crop	ha	0.74	0.00	120,500	89,170
6	Agroforestry	ha	1837.49	1.61	120,500	221,417,786
7	Water Harvesting Infrastructure	Nr	14657.71	12.86	100,000	1,465,771,300

8	Afforestation	ha	1135.38	1.00	369,000	418,954,482
9	Reforestation	ha	5029.55	4.41	369,000	1,855,902,843
10	Waterways Infrastructure	ha	751.27	0.66	169,000	126,965,306
11	Hedgerows	ha	4171.94	3.66	369,000	1,539,447,336
12	No-Till	ha	5713.68	5.01	200,000	0
13	Bamboo to close gullies	ha	446.57	0.39	216,500	96,682,838
14	Bench terraces	ha	793.96	0.70	2,392,000	1,899,145,144
15	Contour bank	ha	12422.47	10.90	2,392,000	29,714,555,416
16	Grassed waterways	ha	4.51	0.00	257,500	1,161,840
17		km	508.47	0.45	257,500	130,930,253
18	Riverside bamboo	ha	34.46	0.03	120,500	4,152,310
19	Shrub restoration	ha	3865.15	3.39	241,000	465,750,334
				99.16		**185,442,439,061**

TABLE 5- 3 THE IMPLEMENTATION PLAN WITH GOALS, OBJECTIVES, TARGETS, ACTIVITIES AND OUTPUTS

Goal 1:	**Improved access to clean water by 2030**					
Objective 1.1:	**Reduce Pollution by 30% by 2030**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
1.1.1 Improve runoff management on steep slopes	1. Compile a runoff management plan for main roads especially on ridgeline of hills, including energy dissipation e.g. mitre drains, and water harvesting techniques	1. Reduced rate (energy) of runoff from tarred roads. 2. Reduced volume of runoff entering fields (resulting in soil erosion)	Short	MINIFRA RTDA, RWB	**Muhanga :** Kiyumba	Low US$500,000 including detailed design of mitre drains and attenuation ponds
	2. Compile guidelines for runoff management along secondary (dirt roads) and pathways e.g. footpaths in fields. Including use of swales, mitre rains, contour bunds.	1. Reduced rate (energy) of runoff along roads and pathways (causing gully erosion along secondary roads and pathways). 2. Reduced volume of runoff entering fields resulting in soil erosion	Short	MINILaF Ministry of Environment District Infrastructure Officer	**Muhanga :** Kiyumba	Low US$50,000 (Community guidelines for pathway runoff management)
	3.Compile a detailed terrain model to specifically identify area for terracing and	• Detailed terrain model for the country	Short	Ministry of Lands, RLUMA	**Ngoma, Bugesera, Rwamagana**	Low US$500,000

	soil erosion mitigation measures. e.g. using Lidar[6], DEMs, etc.					
	4. Continued implementation of terracing projects e.g. LVEMP II, RSSP-LWH. Using the Detailed terrain model identify additional areas for terracing.	* Reduced slope gradient for cultivation in hilly areas	Short	MINAGRI, MIN of Environment REMA	**Ngoma, Rwamagana, Gakenke:** Gakenke, Mataba	As budgeted Refer section 3.3.2 for indicative cost of types of terracing.
1.1.2 Pollution management plan and guidelines implementation	1. Conduct baseline assessment of priority polluters in the catchment.	* Baseline water quality to monitor polluters	Short	REMA	All, Prioritise: **Kicukiro:** Niboye Sector	Low >US$100,000
	2. Set resource quality objectives (RQOs) for the Akagera river including flow, environmental flow and water quality thresholds	* Set of RQOS are determined for different reaches of the river	Short-medium	REMA, RWB	All	High >US$1 Million

[6] LIDAR, which stands for *Light Detection and Ranging,* is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. This is then used to create a Digital Elevation Model (DEMs) to provide more detail for rehabilitation and land management planning.

	3. Monitor the RQOs	* Regular monitoring and reports of against the baseline and RQOs	Medium	REMA, RWB, Districts	All	n/a
	4. Enforcement of non-compliance		Medium	REMA, RWB, RURA	All	n/a
	5. Set improvement targets for specific polluting sectors to reduce effluents over a set timeframe e.g. Domestic effluent, fertilizer runoff, coffee washing stations, garages, mining activities	* Targets for the improvement interventions to achieve	Medium	REMA, RURA, RSB, Industries	All, Prioritise: **Kicukiro:** Niboye Sector	Low >US$250,000
1.1.3 Improve Buffer enforcement	1. Districts to assess where there is encroachment into buffer areas	* Buffers are intact and operational in all Districts	Short	REMA - LVEMP Field staff	All	n/a
	2. Implement buffer rehabilitation and remove illegal farming activities on river banks		Short	REMA - LVEMP Field staff	All	>1M RWF
	3. Regular monitoring of buffer areas		Ongoing	REMA - LVEMP Field staff	All	n/a
1.2.4 Hyacinth removal	Removal of water Hyacinth, and use for biomass	* No hyacinth	Short	REMA, District	**Rwamagana**	Low >US$10,000 (Depends on extent of infestation, and method

						of removal manual vs motorised)

Goal 1:	Improved access to clean water by 2030					
Objective 1.2:	**Improve access to water**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
1.2.1 Implement Rain Water Harvesting techniques	1. Domestic / Urban: Identify site specific location for RWH. Based on site specific characteristics determine best method for storage - tanks installation or reservoir construction	* Installation / construction of rain water harvesting devices	Short	MININFRA, RHA, WASAC, RWB, Districts	All. Prioritise: **Bugesera; Gasabo; Kicukiro:** Gahanga Sector	High >US$1 Million (Includes detailed design and construction or installation at identified priority sites throughout the catchment)
	2. Agriculture/infield: Measure the volume of runoff at specific identified sites. Calculate storage capacity required. Install plastic lined pond	* Installation / construction of rain water harvesting devices	Short	MINAGRIC, Districts	All. Prioritise: **Bugesera; Gasabo; Kicukiro:** Gahanga Sector	Medium >US$500,000 (includes all priority sites in the catchment)

1.2.2 Investigate groundwater potential	1. Conducted a detailed productivity assessment of aquifers within the catchment.	* Groundwater yield/potential map for the catchment	Medium	WASAC, RWB	**All**	Medium >US$750,000 (includes all yield potential, pump testing and monitoring boreholes sites in the catchment)

Goal 1:	**Improved access to clean water by 2030**					
Objective 1.3:	**Watershed protection**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
1.3.1 Slope stabilization	1. Continued construction of progress and radical terraces	* Reduced soil erosion in the catchment area	Short-medium	MINAGRI, districts	Prioritise areas prone to landslides	n/a Refer costing per terrace type in section 3.3.2
1.3.2 Increased vegetation cover	1. Establish local nurseries to supply vegetation materials	* local nurseries to supply vegetation materials for planting	Short term	RWB, RAB	All	Low US$10 000 (Depends on size and complexity of

						plant types at nursery)
	2. Implement seed collection of local indigenous species for nursery propagation		Short term / ongoing	RWB, RAB	All	Low US$10 000 (Depends on size and complexity of plant types at nursery)
	3. Plant out in degraded areas	* Increase vegetation cover on exposed soils	Medium term / ongoing	MINAGRI, Ministry of Lands and Forestry, and land tenure owners	All. Prioritise areas specifically identified: **Kicukiro:** Masaka, Gahanga Sectors	n/a

Goal 2:	**Full protection of the Nile Akagera Upper Catchment by 2030**					
Objective 2.1:	**Promote biodiversity protection**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
2.1.1 Declare Gashora - Mugesera-	1. Remove all harmful activities from the wetland area proposed for Ramsar	* Rehabilitated wetland area	Short	REMA and RDB	**Bugesera, Rwamagana, Ngoma,**	*Low* *<US$250 000*

Rweru Wetland as a Ramsar Wetland					**Kicukiro, Nyarugenge**	
	2. Conduct an assessment to determine the environmental flow requirements, and other ecological functions, for the maintenance of the Gashora-Mugesera Wetland. Making recommendations for site specific rehabilitation and management.		Short	REMA, RWB	**Bugesera, Rwamagana, Ngoma, Kicukiro, Nyarugenge**	Medium >US$500 000
	2. Implement rehabilitation activities to restore the natural environmental functions including implementing the environment flows of the wetland that support the Ramsar nomination		Short	REMA and RDB, Ministry of Land and Forestry	**Bugesera, Rwamagana, Ngoma, Kicukiro, Nyarugenge**	High >US$1 Million
	3. Submit outstanding documents to declare Ramsar status	* Proclaimed Ramsar status	Medium	RDB, Ministry of Land and Forestry	**Bugesera, Rwamagana, Ngoma, Kicukiro, Nyarugenge**	*Low* *US$100 000*

2.1.2 Sustainable wetland utilisation and rehabilitation	1. Refer to National Wetland Management Plan and Guidelines, identify smaller wetlands for rehabilitation within the catchment	* List of wetlands per district requiring rehabilitation	Short	Districts, REMA	**All,** prioritise Gasabo: Mulindi wetland	*Low* *US$100 000*
	2. Conduct awareness raising with farmers of good farming practices in wetlands, marshes, swamps	* Improved awareness by communities about wetland function and use. * materials for awareness raising	Short	Districts, REMA (LVEMP staff)	**All**	*Low* *US$250 000*
	3. Monitor compliance of wetland use within the catchment area to the National Classification of wetlands in Rwanda (IMCE Inventory)	* Compliance with national classification and inventory	Short	Districts, REMA (LVEMP staff)	**All**	n/a
2.1.3 Develop Ecotourism	1. Develop a Tourism training programme: topics include guiding, birding, maître D, cooking, curios and crafts, driving	* Certified tourism services training programme	Short	RDB, REMA	Bugesera, Rwamagana, Ngoma, Kicukiro, Nyarugenge including Masaka Lake and Nyandungu Ecotourism Park.	High >US$1 Million

	2. Identify and construct hotels	* Increase in hotels and tourism support services	Medium	RDB, Districts	All	n/a
	3. Develop an ecotourism route around the participating districts including cultural and biodiversity activities	* Establish tourism route in the Catchment	Short	RDB, REMA	Bugesera, Rwamagana, Ngoma, Kicukiro, Nyarugenge including Masaka Lake and Nyandungu Ecotourism Park.	Medium US$400 000 (Including, routes, signage, maps, etc.)

Goal 2:	**Full protection of the Nile Akagera Upper Catchment by 2030**					
Objective 2.3:	**Improved mine management**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
2.3.1 Improved quality of discharge	1. Conduct baseline survey of mine water discharges, WQ and discharge rate.	* Baseline to monitor mine compliance	Short	RWB, RMB	All	High >US$1 Million

	2. Conduct feasibility study for cooperative treatment of decanted mine water before discharging, including alternative use of treated waters and package plant treatment and sediment control. E.g. pollution control dams	* Detailed standard operating procedure for mine water and sediment control	Medium	RMB, RWB, RSB	All	High >US$1 Million
	3. Construct engineered wetlands at problem discharge points including use of metallophytes.	* Improved quality of mine water	Medium	REMA, RWB	All	Medium >US$500,000 (Includes assessment, design and construction)
	4. Implement legislation for dirty water separation and onsite treatment prior to discharge (See point 2).	* regulation to enforce mine compliance	Short	RWB, RMB, RSB	All	Low >US$150,000
2.3.2 Establish a Rehabilitation Fund	1. Together with mines determine an appropriate percentage of mine income (specifically not profit but income) to be paid annually to the restoration fund.) Fund to be used for rehabilitation of old/abandoned mine and restoration works in the catchment.	* Mine Rehabilitation Fund is established and operating	Medium	RMB, REMA, RWB	ALL	n/a

Goal 2:	Full protection of the Nile Akagera Upper Catchment by 2030					
Objective 2.4:	**Compliance and Enforcement**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
2.4.1 Improved Monitoring and Enforcement	1. Establish a dedicated unit for compliance and enforcement of environmental crimes (water pollution, biodiversity, CITES, land use crimes, etc.)	* Establishment of an agency for prevent of environmental crimes	Medium	REMA, RWB	n/a	High >US$1 Million (includes staff recruitment, office establishment, operating requirements)
	2. Develop Standard Operating Procedures (SOPs) and training for inspections, investigations, evidence collection, prosecution	* Unit operating	Long	REMA, RWB, RURA, RSB	n/a	Low >US$250,000
	3. Implement regular compliance monitoring of environmental -related legislation	* Improved compliance with standards, procedures, permits	Long	REMA, RWB, RURA, Districts	All	n/a
2.4.2 Improved Awareness / Education about Natural Resources	1. Compile a community-based training and awareness programme in Natural Resources Management	* Extension programme for capacity building in NRM	Short	REMA, RWB, MINAGRI	n/a	Low >US$250,000 (Includes development of training

						materials, translation, and training of trainers)
	2. Implement the programme		Short	District Extension Officers	All	Low >US$250,000 (Includes roll out of training to areas and printing of first bath of materials)

Goal 3:	**Improved Welfare by 2030**					
Objective 3.1:	**Food security by 2030**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
3.1.1 Increase levels of soil fertility through a combination of organic and inorganic fertilizers to offset the	1. Research and demonstrate fertilizer requirements to match crop nutrient removal	* Demonstration manual on fertilizers and crop nutrient requirements	Short	RAB	All	n/a

ongoing nutrient removal by crops	2. Training and demonstration on judicious fertilizer selection and application to maximise benefits to crops and minimise negative environmental impacts	* Demonstration manual on fertilizers and crop nutrient requirements	Short	MINAGRI, RAB, Districts	All	Low >US$200,000
	3. Demonstrate use and application of combination of organic fertilizers and inorganic fertilizers	* Demonstration manual on fertilizer application methods	Short	RAB, MINAGRI	All	Low >US$200,000
	4. Guidelines and training in composting as a form of organic fertilizer	* Guidelines and training materials	Short	MINAGRI, RAB, Districts	All	Low >US$150,000 (based on training trainers, and cost of trainers to training community leaders)
3.1.2 Terracing on slopes	1. Continue implementation of progressive and radical terracing programme	* Improved land husbandry activity with consequent reduction in soil loss and siltation	Short-medium	MINAGRI, RAB, District Agricultural Officers	All, prioritise Kayonza: Kabarondo Sector	n/a See costing in section 3.3.2

3.1.3 Appropriate crop selection	1. Selection of crops according to climate, soil type and marketing opportunity (viability)	* Improved food security and cash income	Short	MINAGRI, RAB, District Agricultural Officers	ALL	n/a
3.1.4 Expand and enhance Crop Intensification Programme (synchronised cropping)	Expand programme and enhance its content with more focus on soil fertility as described in 3.1.1	Modify programme documentation to enhance the soil fertility issue	Short	MINAGRI, RAB, District Agricultural Officers	ALL	n/a
3.1.5 Markets	Identification and construction of modern markets and processing facilities.	Improved food security and cash income	Short	RHA, District	All, prioritise: Kayonza: Mukarange Sector	Low >US$200,000
3.1.6 Improve Irrigation Efficiency	1. Agriculture/infield: Measure the volume of runoff at specific identified sites. Calculate storage capacity required. Install plastic lined pond	* Installation / construction of rain water harvesting devices	Short	MINAGRIC, RAB, Districts Agricultural Officers	All.	Low >US$250,000(Includes monitoring, design, and construction or installation at identified priority sites throughout the catchment)
	2. Develop a commercial irrigation strategy to improve the	* Commercial Irrigation strategy and guideline	Short	MINAGRIC, RAB, RWB, Districts Agricultural Officers	Prioritise: Commercial sugar cane	Low >US$200,000

	irrigation technique, timing, duration of irrigation at commercial farms					

Goal 3:	**Improved Welfare by 2030**					
Objective 3.2:	**Planned settlements**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
3.2.1 Implement land use plans	1. Compile District specific land use plans in accordance with DDP and national Land use	* District Specific land use plans	Short	District infrastructure office, district one stop Centre	**All,** Prioritise **Gasabo District:** Kagondo, Remera Sectors	n/a
	2. Implement the plan	* No unplanned settlements	Medium	District infrastructure development office, district one stop Centre	All, Prioritise Gasabo District: Kagondo, Remera Sectors	n/a
	3. Migrate unplanned settlements to formal settlements		Medium	District infrastructure development office, district one stop Centre, MIDMAR	All, Prioritise Gasabo District: Kagondo, Remera Sectors	n/a

3.2.2 Implement model villages	1. Continued rollout and implementation of model villages	* Operating model villages	Short-Long	MINALOC, District	**Kayonza:** Mukarange, Nyamirama, Rurmira and Kabarondo Sectors	n/a
3.2.3 Implement waste water treatment plants	1. Develop standards for "green drop" assessment/certification for waste water treatments works considering design versus operating capacity, meeting discharge thresholds and improvement conditions.	* WWTW Standards	Short	WASAC, RURA, RSB, REMA		Low <US$250,000
	2. Conduct assessments of WWTWs and regularly report/publish results.	* Regular reports on state of WWTWs	Medium	REMA, RURA, RSB, WASAC	**All**	Low >US$100,000
	3. Where no formal WWTW, investigate feasibility of package plant installations.	* Package plant WWTW installed and monitored	Medium	District, WASAC, RHA	**All**	Low >US$50,000
3.2.4 Implement solid waste management	1. Identify sites for landfill and solid waste management.	* List of potential sites in each District	Short	REMA & Districts	ALL (Where appropriate sites can be shared by Districts)	Low <US$50,000

	2. Conduct feasibility and impact studies on proposed sites, include gas harvesting in site select criteria and design.	* Most feasible site selected	Short	Districts	ALL	Low US$150,000
	3. Detailed design and operation of most feasible site	* detailed design and operation guidance manual	Medium	RURA, REMA, RSB	All	Low >US$250,000 (includes authorisations)
	4. Implement establishment of landfill site	* landfill sites established and operational	Medium	Districts	ALL	Medium >US$500,000 (construction of site)
	5. Engage solid waste collection services	* Weekly collection of solid waste	Short	Districts	ALL	Low >US$250,000 (this is based on establishing a collection service – payment for the service will contribute to ongoing operating costs)
3.2.5 Establish reuse and recycle programmes throughout the catchment	1. Investigate and establish waste collection agreements with production industries e.g. Coca cola, plastic bank, collect-a-can, etc.	* Recycling and reuse strategy developed and implemented	Short term	REMA, RURA	All	n/a

	2. Establish collection stations for recyclable products e.g., glass, tins, paper, plastic, etc.		Short term	REMA, RURA	ALL	Low US$150,000 (total for all districts in catchment)
	3. Incentivise collection of recyclable products, e.g. refund, payment per weight/volume		Short - Medium	RURA, REMA, waste collection companies	ALL	Low US$100,000 (total for all districts in catchment)
	4. Implement marketing campaigns e.g. school competitions, national collection day.	* Active collection programmes operating	Short - Medium	REMA, MINEDUC	ALL	Low US$50,000 (total for all districts in catchment)
	5. Update manufacturing regulations to place onus on manufacturers to operate/contribute to operation of recycling programme and collection stations.	* Updated industrial processing permit conditions	Medium - Long	REMA, NIRDA	All	n/a

Goal 3:	Improved Welfare by 2030					
Objective 3.3:	**Improve Health**					
Target / Aim	**Activities**	**Indicators/ Outputs**	**Indicative phasing**	**Responsible Authority**	**Applicable District / Sectors**	**Indicative costing**
3.3.1 Reduce Malaria	1. MoU between Ministries of Agriculture and Health to ensure agricultural development projects and practices do not cause health impacts.	* Signed agreement on farming practices	Short	MINAGRI & HEALTH	ALL	n/a
	2. Moratorium on wet-field rice. Shift to upland rice. Phase out existing wet field rice	* No wet field rice	Medium	MINAGRI, District	ALL	n/a
3.3.2 Improved domestic water quality	1. Include UV filtration on water kiosk and RWH supply points	*Updated standards to include UV. * UV filtration units fitted to water kiosks and RWH reservoirs	Short	RWB, RSB, RURA	ALL	Medium US$500 000

4.1 INFORMATION AND MONITORING

In order to ensure implementation, an effective monitoring, evaluation and review process must be adhered to. A logframe matrix has been developed, providing a list of key performance indicators (impacts, outcomes, and outputs) to be used in the progress reports. The monitoring and evaluation of the Catchment Management Plan has been included in the National Monitoring and Evaluation Framework which was developed to provide an integrated monitoring platform. This is detailed in the M&E Framework report. Data collected regularly should be analysed to enrich and update the Catchment MIS of the IWRMD.

4.2 CLOSING REMARKS

The Nile Akagera Upper catchment is characterised predominantly with wetlands. The main wetland system being the Gashora-Mugesera wetland which has been proposed by the Rwandan Government for Ramsar status. This presents an excellent opportunity for supporting a green economy within the catchment, which is in line with National policies. The wetland system is threatened by poor land management practices both upstream and within the catchment resulting in high sediment loads, and encroachment into the proposed protected area. Managing the wetland is critical to secure water availability during dry months for communities living around the wetland, especially as the forecast impacts of climate change are likely to be longer drier spells in this area.

Catchment management is not limited to activities regarding water but includes land use activities that utilise and impact on the water resources within the catchment. The planned activities include improvement to the management framework for the natural resources and sustainable utilisation of the resources as well as rehabilitation activities for degraded areas.

Sustainable water resources management is not a function of RWB in isolation. All users of water have a part to play. Water is an integrated system and requires integrated management and coordination by all. The plan is comprehensive and includes numerous activities to be undertaken by various institutions. This Catchment Management Plan is the first plan for the Nile Akagera Upper Catchment. Implementation of the recommendation actions will contribute towards the sustainable management and development of the water resources of the catchment. It is recommended that this plan be reviewed and updated in 10 years. It is the role of the CC to monitor that the activities are being implemented and report on progress of the overall implementation of the Catchment Management Plan.

(8) REFERENCES

(9) ANNEXURE A: CLIMATE CHANGE PROJECTIONS FOR PRECIPITATION

Climate models are based on well-established physical principles and have been demonstrated to reproduce observed features of recent climate and past climate changes. There is considerable confidence that Atmosphere-Ocean General Circulation Models (AOGCMs) provide credible quantitative estimates of future climate change, particularly at continental and larger scales. Confidence in these estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation).

The AOGCMs, which are used widely in the global climate change network are summarized in below table. It is important to note that enhancements have taken place, which can be grouped into three categories:

- First, the dynamical cores (advection, etc.) have been improved, and the horizontal and vertical resolutions of many models have been increased.
- Second, more processes have been incorporated into the models, in particular in the modelling of aerosols, and of land surface and sea ice processes.
- Third, the parametrizations of physical processes have been improved.

These various improvements, developed across the broader modelling community, are well represented in the climate models and are reflected in data sets used in this report. Despite the many improvements, numerous issues remain.

It is also importnat to note that it continues to be the case that multi-model ensemble simulations generally provide more robust information than runs of any single model. The formulations used in this report include:

- CCCma-CanESM2 driven by the Canadian Centre for Climate Modelling and Analysis.
- CNRM-CERFACS driven by the National Centre for Meteorological Research
- CSIRO-QCCCE driven by the Commonwealth Scientific and Industrial Research Organisation; Queensland Climate Change Centre of Excellence (CSIRO-QCCCE team) in the Centre for Environmental Data Analysis
- ICHEC-EC-EARTH driven by the consortium, which consists of 24 academic institutions and meteorological services from 11 countries in Europe
- IPSL-CM5A driven by the Institute Pierre Simon Laplace (IPSL), which is part of 20 climate modelling groups involved around the world through the World Climate Research Programme's (WCRP), the Working Group on Coupled Modelling (WGCM) to engage the fifth phase of the Coupled Model Intercomparison Project (CMIP5).

- MIROC-MIROC5, which is driven by the Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
- MOHC-HadGEM2, which is driven by the Met Office Hadley Centre
- MPI, which is driven by the Max Planck Institute for Meteorology
- NCC-NorESM1-M, which is driven by the Norwegian Climate Centre
- NOAA-GFDL, which is driven by the Geophysical Fluid Dynamics Laboratory within the National Oceanic and Atmospheric Administration (NOAA)

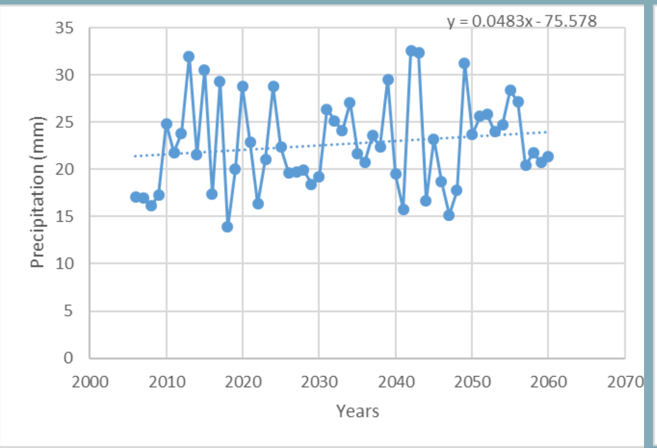
The specific formulations of each of the AOGCMs are documented in detail in the **Table A-0-1** presented below.

TABLE A- 1 FEATURES OF THE AAOGCMS AS LISTED BY THE IPCCFEATURES OF THE AOGCMS AS LISTED BY THE IPCC

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
1: BCC-CM1, 2005	Beijing Climate Center, China	top = 25 hPa T63 (1.9° x 1.9°) L16 Dong et al., 2000; CSMD, 2005; Xu et al., 2005	1.9° x 1.9° L30 depth, free surface Jin et al., 1999	no rheology or leads Xu et al., 2005	heat, momentum Yu and Zhang, 2000; CSMD, 2005	layers, canopy, routing CSMD, 2005
2: BCCR-BCM2.0, 2005	Bjerknes Centre for Climate Research, Norway	top = 10 hPa T63 (1.9° x 1.9°) L31 Déqué et al., 1994	0.5°–1.5° x 1.5° L35 density, free surface Bleck et al., 1992	rheology, leads Hibler, 1979; Harder, 1996	no adjustments Furevik et al., 2003	Layers, canopy, routing Mahfouf et al., 1995; Douville et al., 1995; Oki and Sud, 1998
3: CCSM3, 2005	National Center for Atmospheric Research, USA	top = 2.2 hPa T85 (1.4° x 1.4°) L26 Collins et al., 2004	0.3°–1° x 1° L40 depth, free surface Smith and Gent, 2002	rheology, leads Briegleb et al., 2004	no adjustments Collins et al., 2006	layers, canopy, routing Oleson et al., 2004; Branstetter, 2001
4: CGCM3.1(T47), 2005	Canadian Centre for Climate Modelling and Analysis, Canada	top = 1 hPa T47 (~2.8° x 2.8°) L31 McFarlane et al., 1992; Flato, 2005	1.9° x 1.9° L29 depth, rigid lid Pacanowski et al., 1993	rheology, leads Hibler, 1979; Flato and Hibler, 1992	heat, freshwater Flato, 2005	layers, canopy, routing Verseghy et al., 1993
5: CGCM3.1(T63), 2005		top = 1 hPa T63 (~1.9° x 1.9°) L31 McFarlane et al., 1992; Flato 2005	0.9° x 1.4° L29 depth, rigid lid Flato and Boer, 2001; Kim et al., 2002	rheology, leads Hibler, 1979; Flato and Hibler, 1992	heat, freshwater Flato, 2005	layers, canopy, routing Verseghy et al., 1993
6: CNRM-CM3, 2004	Météo-France/Centre National de Recherches Météorologiques, France	top = 0.05 hPa T63 (~1.9° x 1.9°) L45 Déqué et al., 1994	0.5°–2° x 2° L31 depth, rigid lid Madec et al., 1998	rheology, leads Hunke-Dukowicz, 1997; Salas-Mélia, 2002	no adjustments Terray et al., 1998	layers, canopy,routing Mahfouf et al., 1995; Douville et al., 1995; Oki and Sud, 1998
7: CSIRO-MK3.0, 2001	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	top = 4.5 hPa T63 (~1.9° x 1.9°) L18 Gordon et al., 2002	0.8° x 1.9° L31 depth, rigid lid Gordon et al., 2002	rheology, leads O'Farrell, 1998	no adjustments Gordon et al., 2002	layers, canopy Gordon et al., 2002
8: ECHAM5/MPI-OM, 2005	Max Planck Institute for Meteorology, Germany	top = 10 hPa T63 (~1.9° x 1.9°) L31 Roeckner et al., 2003	1.5° x 1.5° L40 depth, free surface Marsland et al., 2003	rheology, leads Hibler, 1979; Semtner, 1976	no adjustments Jungclaus et al., 2005	bucket, canopy, routing Hagemann, 2002; Hagemann and Dümenil-Gates, 2001
9: ECHO-G, 1999	Meteorological Institute of the University of Bonn, Meteorological Research Institute of the Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea	top = 10 hPa T30 (~3.9° x 3.9°) L19 Roeckner et al., 1996	0.5°–2.8° x 2.8° L20 depth, free surface Wolff et al., 1997	rheology, leads Wolff et al., 1997	heat, freshwater Min et al., 2005	bucket, canopy, routing Roeckner et al., 1996; Dümenil and Todini, 1992

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
10: FGOALS-g1.0, 2004	National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)/Institute of Atmospheric Physics, China	top = 2.2 hPa T42 (~2.8° x 2.8°) L26 Wang et al., 2004	1.0° x 1.0° L16 eta, free surface Jin et al., 1999; Liu et al., 2004	rheology, leads Briegleb et al., 2004	no adjustments Yu et al., 2002, 2004	layers, canopy, routing Bonan et al., 2002
11: GFDL-CM2.0, 2005	U.S. Department of Commerce/ National Oceanic and Atmospheric Administration (NOAA)/Geophysical Fluid Dynamics Laboratory (GFDL), USA	top = 3 hPa 2.0° x 2.5° L24 GFDL GAMDT, 2004	0.3°–1.0° x 1.0° depth, free surface Gnanadesikan et al., 2004	rheology, leads Winton, 2000; Delworth et al., 2006	no adjustments Delworth et al., 2006	bucket, canopy, routing Milly and Shmakin, 2002; GFDL GAMDT, 2004
12: GFDL-CM2.1, 2005		top = 3 hPa 2.0° x 2.5° L24 GFDL GAMDT, 2004 with semi-Lagrangian transports	0.3°–1.0° x 1.0° depth, free surface Gnanadesikan et al., 2004	rheology, leads Winton, 2000; Delworth et al., 2006	no adjustments Delworth et al., 2006	bucket, canopy, routing Milly and Shmakin, 2002; GFDL GAMDT, 2004
13: GISS-AOM, 2004	National Aeronautics and Space Administration (NASA)/ Goddard Institute for Space Studies (GISS), USA	top = 10 hPa 3° x 4° L12 Russell et al., 1995; Russell, 2005	3° x 4° L16 mass/area, free surface Russell et al., 1995; Russell, 2005	rheology, leads Flato and Hibler, 1992; Russell, 2005	no adjustments Russell, 2005	layers, canopy, routing Abramopoulos et al., 1988; Miller et al., 1994
14: GISS-EH, 2004		top = 0.1 hPa 4° x 5° L20 Schmidt et al., 2006	2° x 2° L16 density, free surface Bleck, 2002	rheology, leads Liu et al., 2003; Schmidt et al., 2004	no adjustments Schmidt et al., 2006	layers, canopy, routing Friend and Kiang, 2005
15: GISS-ER, 2004	NASA/GISS, USA	top = 0.1 hPa 4° x 5° L20 Schmidt et al., 2006	4° x 5° L13 mass/area, free surface Russell et al., 1995	rheology, leads Liu et al., 2003; Schmidt et al., 2004	no adjustments Schmidt et al., 2006	layers, canopy, routing Friend and Kiang, 2005
16: INM-CM3.0, 2004	Institute for Numerical Mathematics, Russia	top = 10 hPa 4° x 5° L21 Alekseev et al., 1998; Galin et al., 2003	2° x 2.5° L33 sigma, rigid lid Diansky et al., 2002	no rheology or leads Diansky et al., 2002	regional freshwater Diansky and Volodin, 2002; Volodin and Diansky, 2004	layers, canopy, no routing Alekseev et al., 1998; Volodin and Lykosoff, 1998
17: IPSL-CM4, 2005	Institut Pierre Simon Laplace, France	top = 4 hPa 2.5° x 3.75° L19 Hourdin et al., 2006	2° x 2° L31 depth, free surface Madec et al., 1998	rheology, leads Fichefet and Morales Maqueda, 1997; Goosse and Fichefet, 1999	no adjustments Marti et al., 2005	layers, canopy, routing Krinner et al., 2005
18: MIROC3.2(hires), 2004	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	top = 40 km T106 (~1.1° x 1.1°) L56 K-1 Developers, 2004	0.2° x 0.3° L47 sigma/depth, free surface K-1 Developers, 2004	rheology, leads K-1 Developers, 2004	no adjustments K-1 Developers, 2004	layers, canopy, routing K-1 Developers, 2004; Oki and Sud, 1998
19: MIROC3.2(medres), 2004		top = 30 km T42 (~2.8° x 2.8°) L20 K-1 Developers, 2004	0.5°–1.4° x 1.4° L43 sigma/depth, free surface K-1 Developers, 2004	rheology, leads K-1 Developers, 2004	no adjustments K-1 Developers, 2004	layers, canopy, routing K-1 Developers, 2004; Oki and Sud, 1998

The corresponding changes in climatic parameters were reflected through use of low and high emission scenarios represented using (RCP) using both the 4.5 Watt / m2 and 8.5 Watt 7 m2, which are referred to as RCP 4.5 and RCP 8.5 scenarios, respectively. The precipitation trends within the level 2 catchment boundaries, represented through RCP 4.5 and RCP 8.5 over a fifty-year time frame (2010-2060) are depicted for the months of January – December and presented in **Figure A-0-1** and **Figure A-0-2**,respectively. The data sets represent Regional Climate models as determined by the IPCC, which is extracted from the Coordinated Regional Climate Downscaling Experiment (CORDEX). The significance of CORDEX models is its representation through Regional Climate Downscaling (RCD) techniques, including both dynamical and statistical approaches, which are being increasingly used to provide higher-resolution climate information than is available directly from contemporary global climate models.



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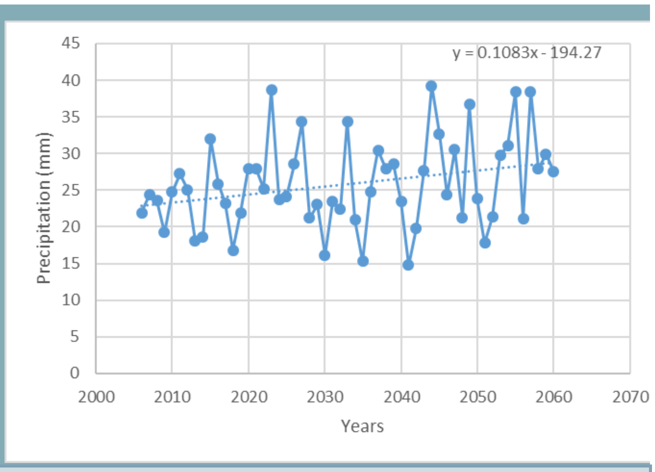

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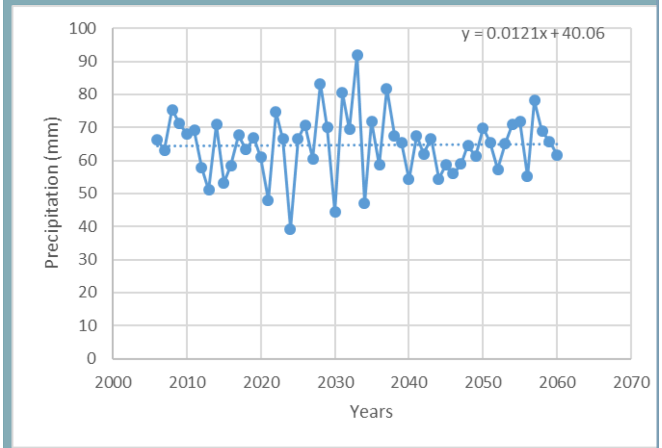

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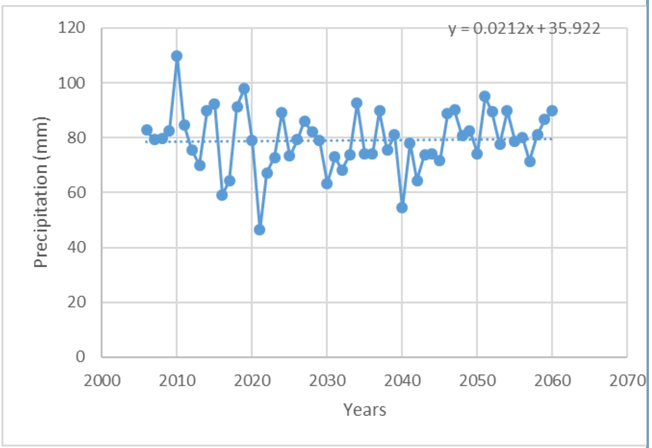

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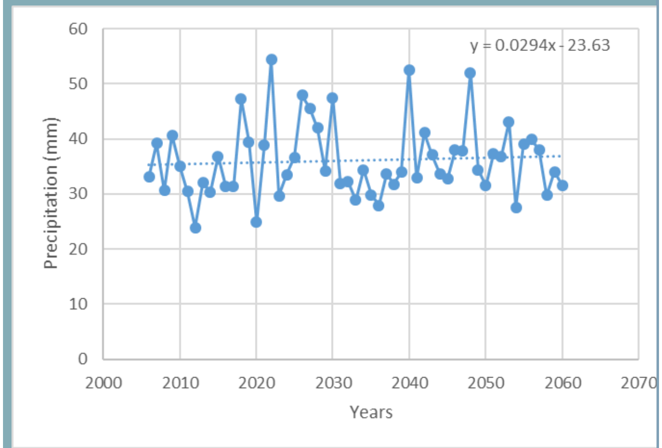

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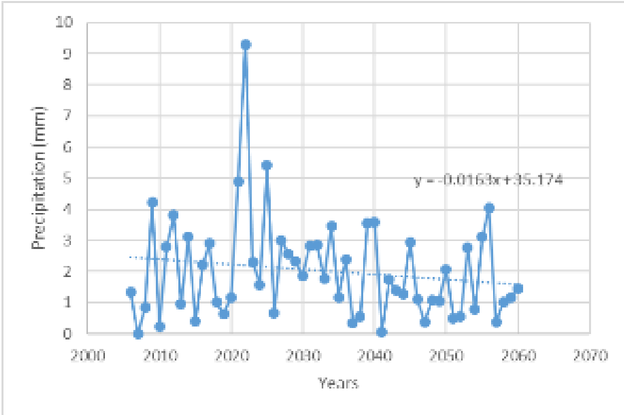

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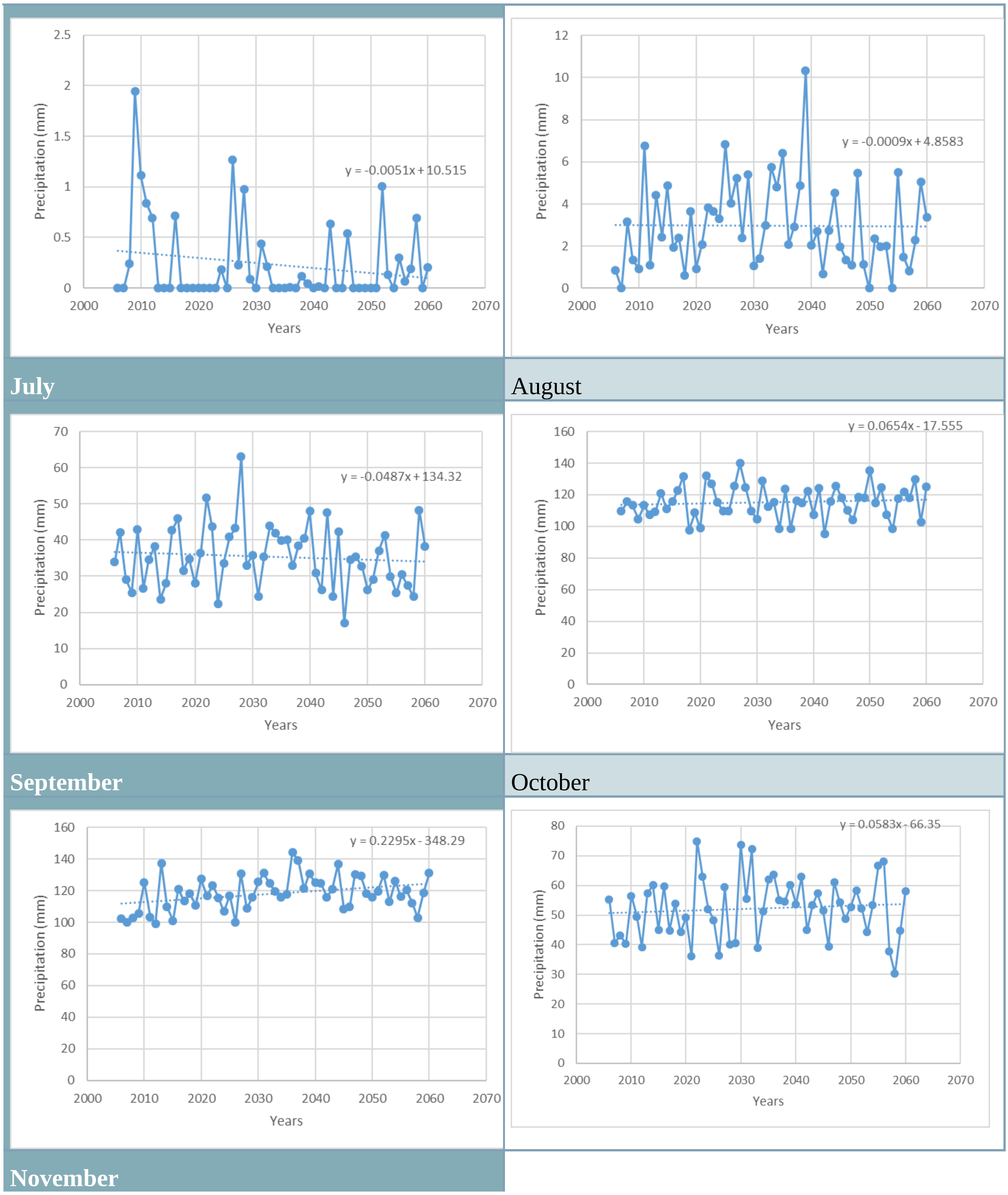
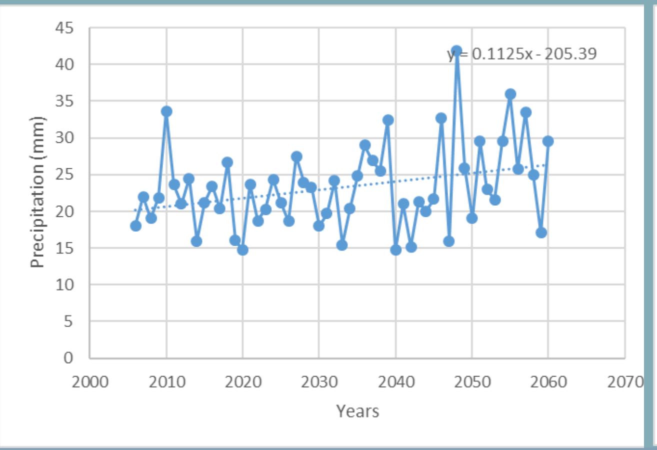


FIGURE A-0 1 PRECIPITATION TRENDS WITHIN LEVEL 2 CATCHMENT THROUGH RCP 4.5



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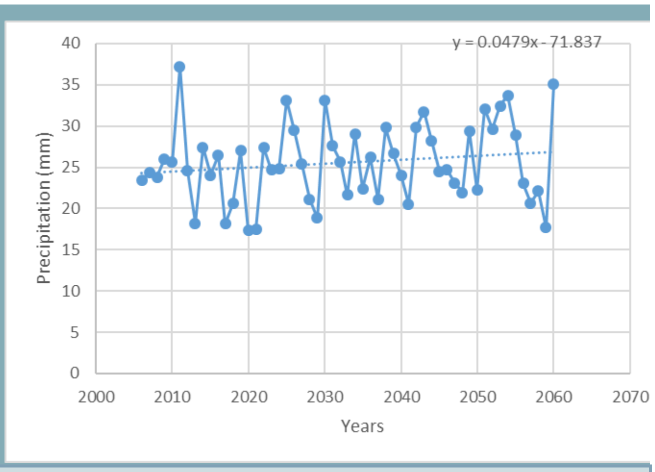

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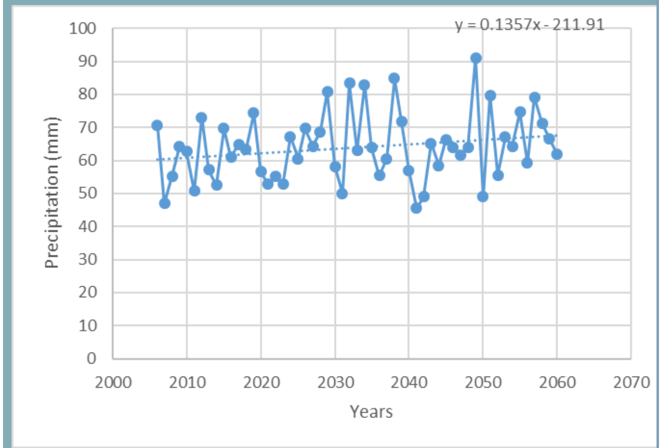

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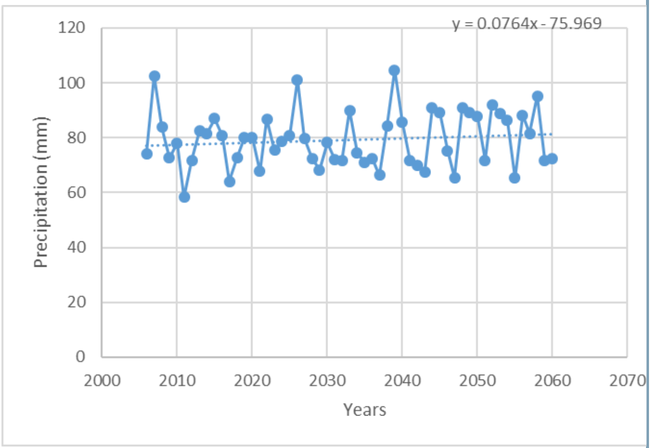

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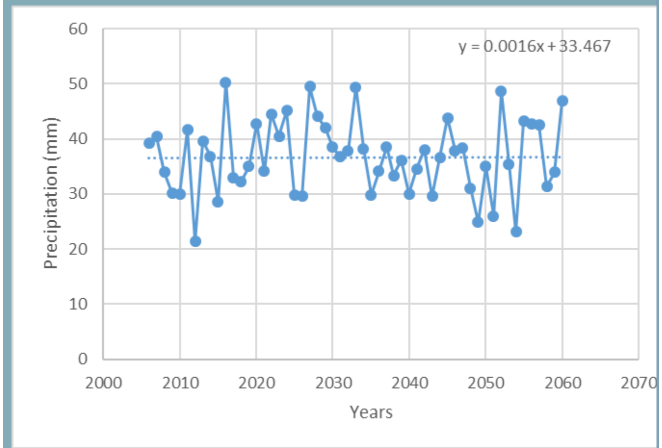

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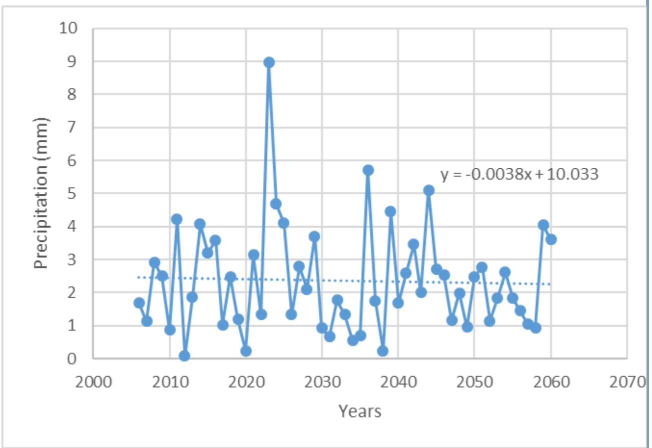

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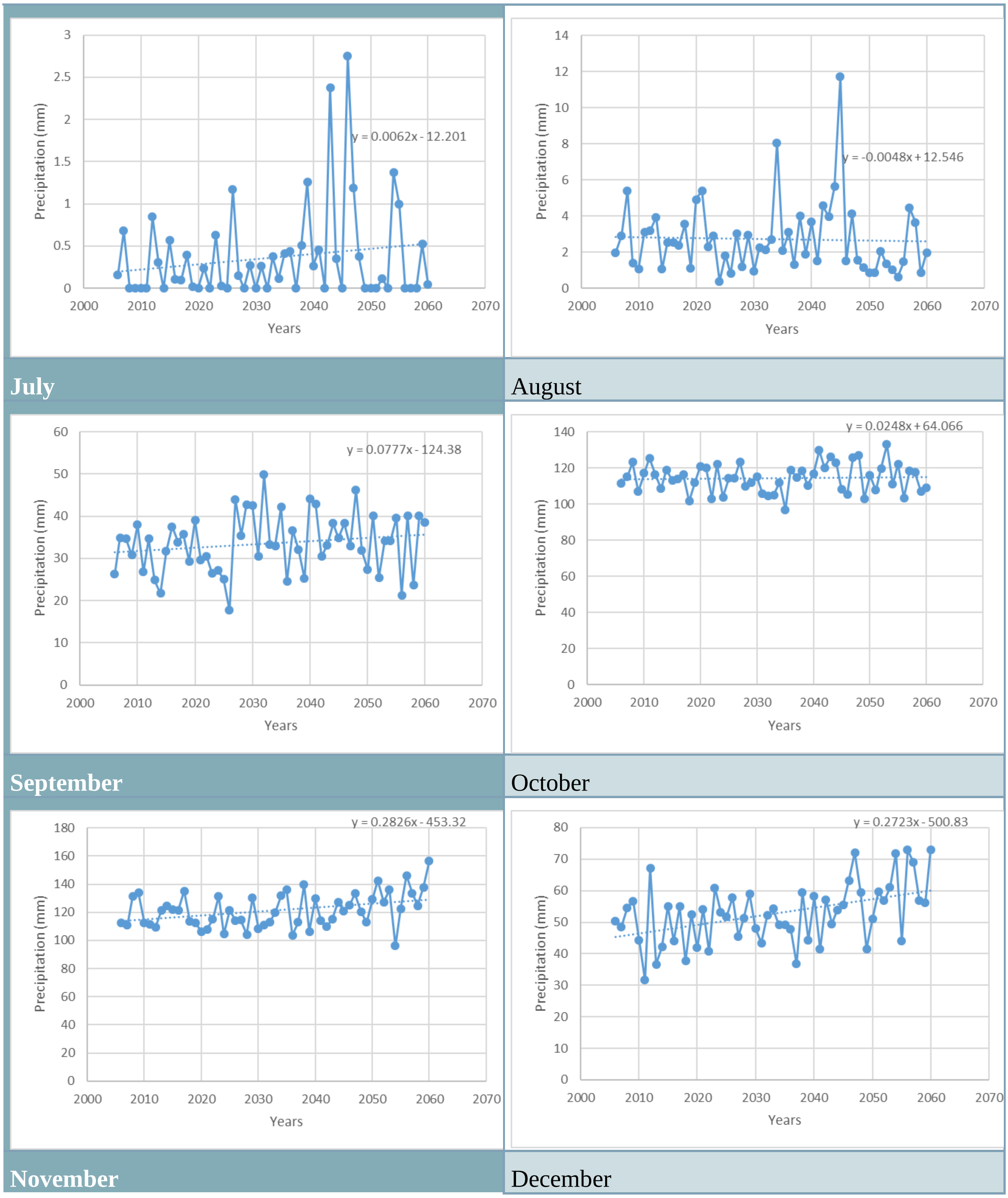


FIGURE A-0 2 PRECIPITATION TRENDS WITHIN LEVEL 2 CATCHMENT THROUGH RCP 8.5

The Nile Akagera Upper Catchment lies on the Eastern Plateau with an average altitude of 1500 metres above sea level, and average temperature 20–21 °C.

The temperature data sets are being evaluated by using two-products generated by Meteo Rwanda:

- Station based measurements (at monthly scale) represent long-term trends in temperature
- Grid based data sets (at monthly scale) represent spatial changes in temperature within level-2 catchment. The grid data sets are specifically important to evaluate the impacts of geographical conditions on temperature. Temperature grid data sets are at the same location as the precipitation grid data sets.

Both of these data sets are being evaluated to understand the changes in temperature at respective points (using station based data sets) and within the level-2 catchment (using grid based data sets).

International Panel on Climate Change (IPCC) reports that there has been increased warming over Africa's land regions in the last 50 to 100 years, as is consistent with human-induced climate change (IPCC, 2014). In Rwanda, the average temperature increased by 1.4°C since 1970, higher than the global average, and by the 2050s, it is likely to rise by up to 2.5°C from the 1970 average (RoR, 2011).

A study by Safari (*Trend Analysis of the Mean Annual Temperature in Rwanda during the Last 52 Years, 2012*), based on 1958 to 2010 data from the Rwanda National Meteorological Service, also detected statistically significant abrupt changes and trends and concluded that climate change has indeed occurred in Rwanda. It noted the major change in the annual mean temperature around 1977, followed by a significant warming trend (Safari, 2012).

The resulting rainfall-runoff processes are complex, and depend on the particular physical and biological characteristics of each watershed. One of the difficulties in developing accurate predictive models of the rainfall-runoff relationships is the considerable amount of data that needs to be collected to accurately represent the physical processes and their spatial and temporal distribution. It is important to understand that some of these processes are taking place at rather small spatial and temporal scales, specifically along the mountainous areas of the Akagera catchment, which is characterized by steep slopes and valley sections. As in the case of the two catchments being evaluated in this project, such data are just not available, yet it is essential to structure a way to predict, at least in some relative sense, the quantities and qualities of surface runoff associated with alternative land use policies or practices and precipitation events.

In an ideal setting, these processes should be represented through use of continuous records of net precipitation and air temperature for each catchment or sub-sub-catchment being modelled using hourly and daily averages. Thus, the project setting might require use of monthly time steps, accepting that this does not capture the intensities of shorter duration storms during the day or month. As an example, a shorter duration (within an hour of the day) cloud burst from a thunderstorm over a portion of a modelled watershed may generate much more surface runoff (and sediment loads) than the same amount of precipitation evenly distributed over the entire watershed being modelled over a 24-hour period. The use of daily or monthly averages over larger areas will not predict runoff accurately, but they might be the most detailed data that can be expected to obtain in practice. More detailed rainfall data can sometimes be obtained from radar images, but the processes of calibrating and analysing such images are not able to reflect rainfall-runoff processes accurately, specifically when the surface measurements lack the required level of temporal and spatial accuracy.

The depth of surface water available for runoff, SA_t, as driven by the integrated processes within the catchment, can be formulated through use of the precipitation R_t, less the infiltration I_t, and evaporation, E_t:

$SA_t = R_t - I_t - E_t$

The depth of surface runoff, SR_t, is some fraction of this amount, depending on the slope, the extent of ponding, the surface area and the land cover of the watershed. Surface runoff can be estimated in a number of ways. A good example, for the Nile Akagera Upper Catchment, Soil Moisture Assessment method (SMA), is expected to represent rainfall-runoff processes along the project catchments.

The Soil Moisture method represent the catchment with two soil layers, as well as the potential for snow accumulation. In the upper soil layer, it simulates evapotranspiration considering rainfall and irrigation on agricultural and non-agricultural land, runoff and shallow interflow, and changes in soil moisture. The method allows for the characterization of land use and/or soil type impacts to these processes. Baseflow routing to the river and soil moisture changes are simulated in the lower soil layer. Correspondingly, the Soil Moisture Method requires extensive soil and climate parameterization to simulate associated processes.

It is also important to estimate the groundwater contribution of the total runoff, it is necessary to evaluate the surface water–groundwater interaction. As shown in , groundwater can move along flow paths of varying lengths from areas of recharge to areas of discharge. The generalized flow paths in start at the water table of the upper unconfined aquifer and continue through the groundwater system, terminating at the surface water body. In the uppermost, unconfined aquifer, flow paths near the stream can be tens to hundreds of metres in length and have corresponding travel times ranging from days to several years. The longest and deepest flow paths in may be thousands of kilometres in length, and travel times may range from decades to millennia.

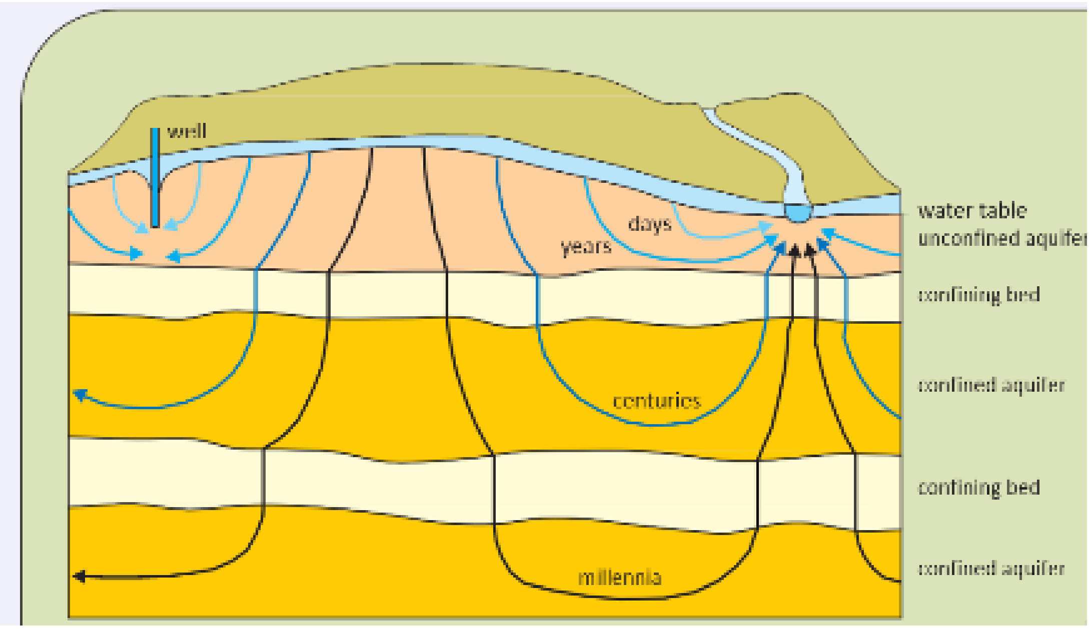


FIGURE A-0 3 SCHEMATIC DIAGRAM OF THE HYDROLOGICAL CYCLE APPLICABLE TO A WATERSHED (SOURCE: UNESCO, 2005)

In general, shallow groundwater is more susceptible to contamination from human sources and activities because of its close proximity to the land surface.

Streams interact with groundwater in three basic ways.

- ❖ Gain water from inflow of groundwater through the streambed (gaining stream,),
- ❖ Lose water to groundwater by outflow through the streambed (losing stream,), or
- ❖ they do both, gaining in some reaches and losing in others.

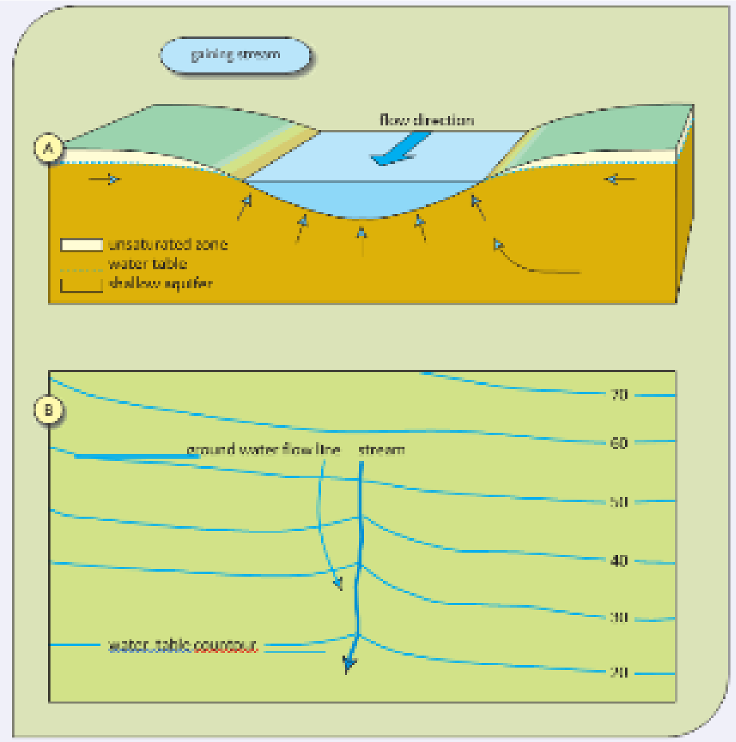


FIGURE A-0 4 GAINING STREAMS RECEIVING WATER FROM THE GROUNDWATER SYSTEM (SOURCE: UNESCO, 2005)

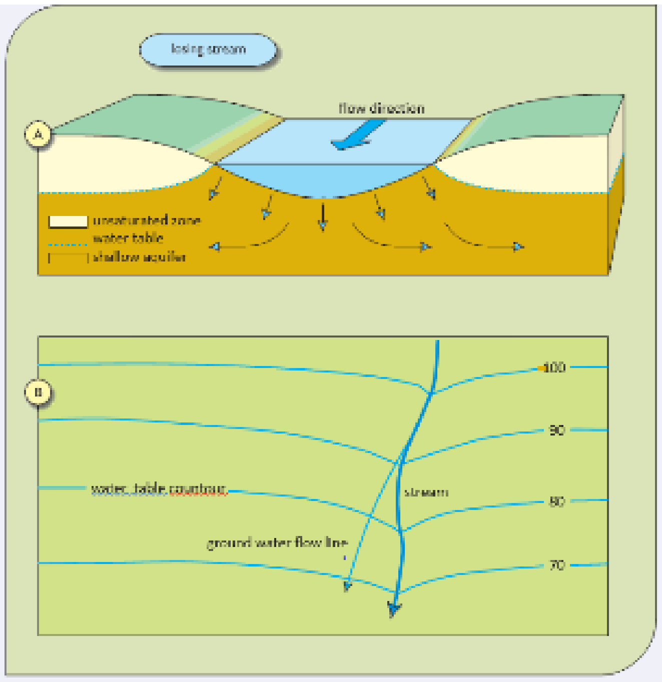


FIGURE A-0 5 LOSING STREAMS LOSING WATER TO THE GROUNDWATER SYSTEM (SOURCE: UNESCO, 2005)

For groundwater to flow into a stream channel, the elevation of the groundwater table in the vicinity of the stream must be higher than that of the stream-water surface. Conversely, for surface water to seep to groundwater, the elevation of the water table in the vicinity of the stream must be lower than that of the stream-water surface. Contours of water-table elevation indicate gaining streams by pointing in an upstream direction (), and indicate losing streams by pointing in a downstream direction () in the immediate vicinity of the stream. Losing streams can be connected to the groundwater system by a continuous saturated zone or can be isolated from the groundwater system by an unsaturated zone.

Given the complexity of the interactions between surface water and groundwater at specific sites under different conditions, it becomes difficult to evaluate these interactions without considerable site-specific data based on many detailed observations and measurements. In this context, it will be assumed that the catchment is neither receiving water from nor losing water to groundwater resources.

In this context data sets to be evaluated will include:

- ❖ - Meteorological records: Existing conditions (monthly time scale)
- ❖ - Meteorological models: Future conditions (for the years 2020, 2030 and 2050 at a monthly time scale)
- ❖ - Flow gage stations: historical (at monthly time scale)

Rainfall is measured by the Meteorological Office of Rwanda. RWB does not operate its own rainfall monitoring network. Therefore, data exchange between Meteo Rwanda and RWB is an important issue for the institutional setup. Within the National Master Plan of Water Resources, alternative means of obtaining information on rainfall have also been evaluated (TRMM); however, the preliminary analysis has shown that neither rainfall data nor evaporation data (MODIS) are very precise and do not replace the analysis on station data yet.

The functional relationship between rainfall and runoff will be defined by using:

- Mathematical equations of the SMA method,
- Lumped process within respective sub-catchments, and
- Deterministic approach by considering the specific years of analysis.

Some of the drivers of the selection process are summarized in the **Table A-0-2**.

TABLE A- 2 SUMMARY OF FUNCTION AND PROCESSES

Function	Processes
Physical versus Mathematical	Physical approach attempts to simulate actual physical processes, often by similitude (i.e. – a 1:10 physical model of a stream channel). Mathematical equations will be used to represent physical characteristics in Level-2 catchment, because existing data sets cannot support development of a physical based model.
Lumped versus Distributed	Distributed models account for variations throughout the system. Often on point to point basis (as represented through grid points). But this requires representation and associated data availability at a smaller scale to represent variations in both water supply and water consumption. Lumped models do not allow for variation in model parameters throughout the catchment. But this issue can be overcome by dividing the catchment into smaller representative units. Lumped model will be used to represent physical characteristics in Level-2 catchment, by subdividing the catchment and developing a semi-distributed model.
Deterministic versus Stochastic	Deterministic models generally use inputs that are known with a reasonable degree of certainty, whereas, Stochastic models may have input that is generated or synthesized – perhaps from a probability distribution – i.e. ESP. Level-2 catchment will be evaluated using the deterministic model approach, because the uncertainties at parameter scale and catchment scale cannot be represented through long-term measurements of the meteorological and hydrometric parameters.

(10) ANNEXURE B: MINING CONCESSIONS

TABLE B- 1 SUMMARY OF MINING CONCESSIONS WITHIN THE NILE AKAGERA UPPER CATCHMENT

No	Mine site (Perimeter)	Sub-site	District	Sector	Cell	Mining License Information			
						ICGLR Classification	Type of mineral license	Issue date + Expired date	Expired date
1	Kityazo	Kityazo	Gasabo	Bumbogo	Nkuzuzu	Artisanal	Exploitation	25/04/2013	25/04/2018
2	Nunga	Rugasa A, Rugasa B	Kicukiro	Gahanga	Nunga	Artisanal	Exploration	11/01/12	11/01/16
3	Kibaza/Dihiro	Kibaza/Dihiro	Rwamagana	Fumbwe	Nyagasambu	Artisanal	Exploration	23/06/14	22/06/18
4	Kibabara	Kinyovi	Rwamagana	Gahengeri	Kibare	Artisanal	Exploration	2/06/13	2/05/17
5	Rwamashyongoshyo &Rweri	Rweri	Rwamagana	Gahengeri	Rweri	Artisanal	Exploration	25/4/2013	24/4/2017
6	Kangamba	Byimana	Rwamagana	Karenge	Byimana	Small scale	Exploitation	9/09/13	9/08/18
7	Rukankama	Rukankama	Rwamagana	karenge	Karenge	Artisanal	Exploitation	7/10/13	10/07/18
8	Kabayezi-Karambo	Kabayezi	Rwamagana	Munyaga	Zinga	Artisanal	Exploitation	4/02/10	4/02/15
9	Munini-Bujyujyu	Bujyujyu	Rwamagana	Muyumbu	Bujyujyu	Artisanal	Exploitation	23/04/12	23/04/17
10	Rubona	Nzige, Manene	Rwamagana	Mwulire	Bicumbi	Artisanal	Exploration	13/08/13	12/08/14
11	Ruramira-Bugambira	Bugambira	Kayonza	Ruramira	Bugambira	Artisanal and Small scale	Exploitation	26/03/2014	25/03/2019
12	Murwa-Jarama	Murwa-Jarama	Ngoma	Jarama	Jarama/Karenge	Artisanal	Exploration	13/2/2014	2/12/18
13	Rwamuhimbura	Rwamuhimbura	Ngoma	Karembo	Akaziba	Artisanal	Exploitation	24/8/2012	23/8/2017
14	Ngara	Ngara	Ngoma	Karembo	Akaziba	Small scale	Exploitation	23/06/2014	22/6/2019

15	Gituza	Mugwate	Ngoma	Rukumberi	Ntovi	Artisanal	Exploration	23/06/14	23/06/19
16	Rugunga	Rugunga	Bugesera	Ntarama	Cyugaro	Artisanal	Exploration	2/01/13	2/01/17
17	Murara	Murara	Bugesera	Nyamata	Kanazi	Artisanal	Exploitation	28/02/11	27/02/16
18	Karambi	Karambi	Bugesera	Nyamata	Kayumba	Artisanal	Exploration	18/01/2014	17/01/2018

TABLE B- 2 TYPES OF MINERALS PRODUCED AND MINE PRODUCTION DETAILS WITHIN THE CATCHMENT AREA

No	Mine site (Perimeter)	Sub-site	District	Sector	Cell	Types of minerals produced				Mine production details		
						Mineral 1	Mineral 2	Mineral 3	Mineral 4	Type of Mine (open pit, underground, both)	Mining Activity Status (Active, Non-active, Abandoned)	Exploitation Begun
1	Kityazo	Kityazo	Gasabo	Bumbogo	Nkuzuzu	Cassiterite	N/A	N/A	N/A	Underground	Active	N/A
2	Nunga	Rugasa A, Rugasa B	Kicukiro	Gahanga	Nunga	Cassiterite	mixed concentrate (cassiterite-coltan)	N/A	N/A	Underground	Active	1946
3	Kibaza/ Dihiro	Kibaza /Dihiro	Rwamagana	Fumbwe	Nyagasambu	Wolframite	N/A	N/A	N/A	Underground	Active	1960
4	Kibabara	Kinyovi	Rwamagana	Gahengeri	Kibare	Wolframite	N/A	N/A	N/A	Underground	Active	2013
5	Rwamashyong	Rweri	Rwamagana	Gahengeri	Rweri	Wolframite	N/A	N/A	N/A	Small open	Active	1960

	oshyo &Rweri									pit, Underground		
6	Kangamba	Byimana	Rwamagana	Karenge	Byimana	Cassiterite	Coltan	N/A	N/A	Underground	Active	2011
7	Rukankama	Rukankama	Rwamagana	karenge	Karenge	Cassiterite	N/A	N/A	N/A	underground	Active	1961
8	Kabayezi-Karambo	Kabayezi	Rwamagana	Munyaga	Zinga	mixed concentrate (cassiterite-coltan)	N/A	N/A	N/A	Underground	Active	1935
9	Munini-Bujyujyu	Bujyujyu	Rwamagana	Muyumbu	Bujyujyu	Cassiterite	N/A	N/A	N/A	Underground	Active	2005
10	Rubona	Nzige, Manene	Rwamagana	Mwulire	Bicumbi	mixed concentrate (cassiterite-coltan)	N/A	N/A	N/A	Underground	Active	1960
11	Ruramira-Bugambira	Bugambira	Kayonza	Ruramira	Bugambira	Wolframite	N/A	N/A	N/A	Underground	Active	1960
12	Murwa-Jarama	Murwa-Jarama	Ngoma	Jarama	Jarama/Karenge	Cassiterite	N/A	N/A	N/A	Underground	Active	1960
13	Rwamuhimbura	Rwamuhimbura	Ngoma	Karembo	Akaziba	mixed concentrate (cassiterite-coltan)	N/A	N/A	N/A	Underground	Active	2012
14	Ngara	Ngara	Ngoma	Karembo	Akaziba	Cassiterite	Coltan	N/A	N/A	Underground	Active	1960
15	Gituza	Mugwate	Ngoma	Rukumberi	Ntovi	Cassiterite	mixed concentrate (cassiterite-	N/A	N/A	Underground	Active	2013

							coltan)					
16	Rugunga	Rugunga	Bugesera	Ntarama	Cyugaro	Cassiterite	N/A	N/A	N/A	Large open pit Underground	Active	1960
17	Murara	Murara	Bugesera	Nyamata	Kanazi	mixed concentrate (cassiterite-coltan)	N/A	N/A	N/A	Large open pit Underground	Active	2012
18	Karambi	Karambi	Bugesera	Nyamata	Kayumba	mixed concentrate (cassiterite-coltan)	N/A	N/A	N/A	Underground	Active	2014

(11) ANNEXURE C: WEAP MODEL

○ C.1 MODEL STRUCTURE

WEAP supports the use of three hydrologic modelling methods:

- Rainfall Runoff Method FAO (Food and Agriculture Organization of the United Nations),
- Irrigation Demands Only of FAO, and
- Soil Moisture Method.

In order to create a hydrologic model that can be calibrated in the future, Soil Moisture Method was chosen. This model also provides the most comprehensive analysis by allowing for the characterization of land use and/or soil type impacts to hydrological processes.

Soil Moisture Method, is a one-dimensional, two soil layer algorithm for calculating evapotranspiration, surface runoff, sub-surface runoff and deep percolation for a defined land area unit. A conceptual diagram of the equations incorporated into the Soil Moisture Method water balance calculations are shown in Figure C-0-1.

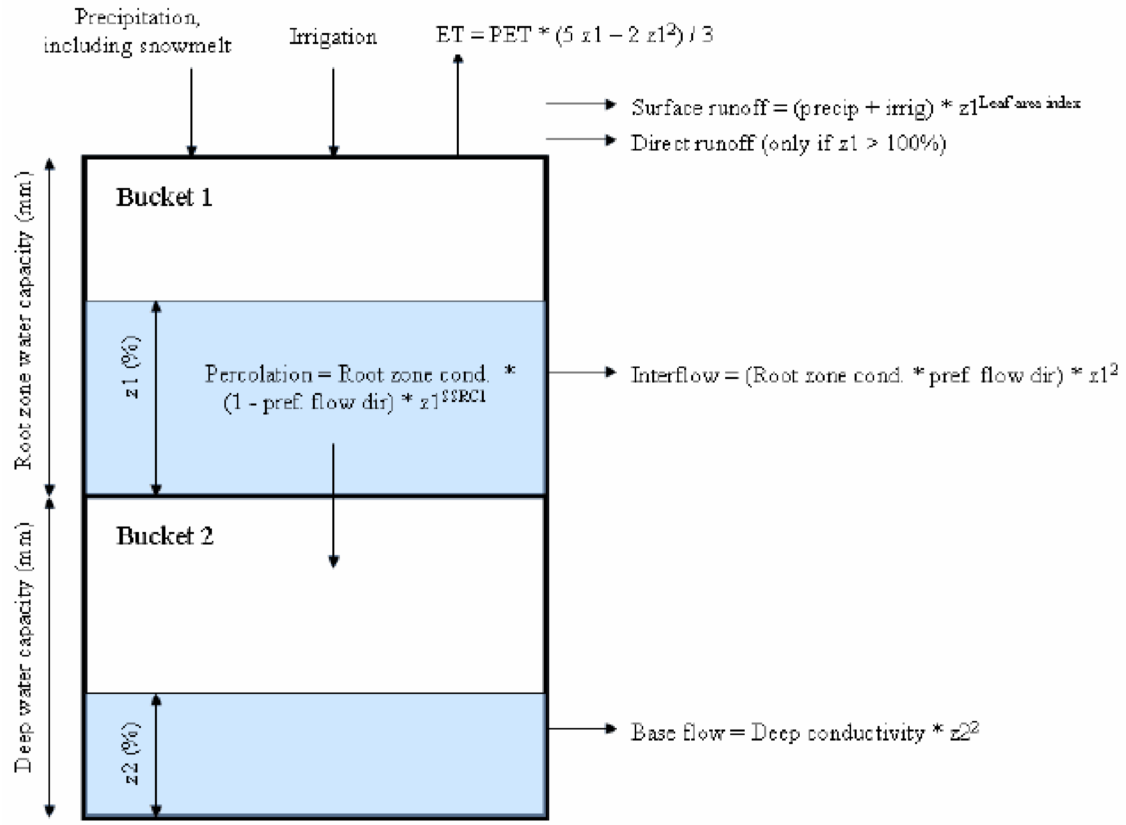


FIGURE C-0 1 SOIL MOISTURE METHOD MODEL (SOURCE: SIEBER, 2005)

Using the Soil Moisture Method to more accurately describe the hydrologic response of the basin has the implication that more detailed hydrologic and climatic parameters are required for the model. Consequently, the parameters and data are often difficult to define with certainty. The basic input parameters are listed in Figure C-0-1 along with the sensitivities identified for each parameter which are a result of the work of Jantzen et al. (2006).

TABLE C-0 1 INPUT PARAMETERS AND SENSITIVITY

Parameter	Units	Resolution	Sensitivity
Land Use			
Area	sq km	Catchment	High
Deep Water Capacity	mm	Catchment	High
Deep Conductivity	mm/day	Catchment	Moderate
Initial Z2	no unit	Catchment	No Influence
Soil Water Capacity	mm	Soil	Moderate
Root Zone Conductivity	mm/day	Soil	Moderate
Preferred Flow Direction	no unit	Soil	Moderate
Initial Z1	no unit	Soil	No Influence
Crop Coefficient, Kc	no unit	Land Use	High
Leaf Area Index	no unit	Land Use	High
Climate			
Precipitation	mm/day	Catchment	High
Temperature	C	Catchment	Moderate
Wind	m/s	Catchment	Low
Humidity	%	Catchment	Low
Melting Point	C	Catchment	Not evaluated
Freezing Point	C	Catchment	Not evaluated
Latitude	degree	Catchment	Not evaluated
Initial Snow	mm	Catchment	Not evaluated

In order to define soil and land-use characteristics, the following features were defined.

- *C.1.1 DEEP WATER CAPACITY*

Deep Water Capacity is the effective water holding capacity, in millimetres, of the deep soil layer, or the second bucket in the Soil Moisture Method. WEAP applies this parameter to an entire catchment so that the parameter cannot be characterized by land use or soil area. These conditions were represented by 1000 mm for the respective sub-catchments to account for the storage capacity and percolation rate for each sub-basin for a three-soil layer, or three-bucket model.

- *C.1.2 DEEP CONDUCTIVITY*

The Deep Conductivity parameter represents the conductivity rate of the second bucket. It was represented as 20 millimetres per month. As Figure 1 shows, Deep Conductivity controls the transmission of base flow. WEAP applies a single value of Deep Conductivity to the entire catchment.

- *C.1.3 INITIAL Z2*

The “Initial Z2” parameter is the relative storage given as a percentage of the total effective storage of the Deep-Water Capacity at the beginning of a simulation. WEAP, like Deep Water Capacity, forces Initial Z2 to be constant for each basin. A value of 30 percent was assigned to each sub-catchment.

- *C.1.4 SOIL WATER (ROOT ZONE) CAPACITY*

Soil Water or Root Zone Capacity is the effective water holding capacity, in millimetres, of the first bucket in the Soil Moisture Method. The WEAP model structure allows this parameter to characterize the soils groups within a sub-catchment. Typically, in WEAP, values of Soil Water Capacity are applied to the land use groups delineated within each sub-catchment.

WEAP employs a method known as “Key Assumption”, which allows parameter values that will be applied frequently to be coded in once as a Key Assumption and then referenced throughout the model. The Soil Water Capacity values were coded using the Key Assumption function to assign the sub-catchment value to each land use within each soil group. The Root Zone Capacity Key Assumption setup and associated values for respective land use classes are shown in Figure C-0-2.

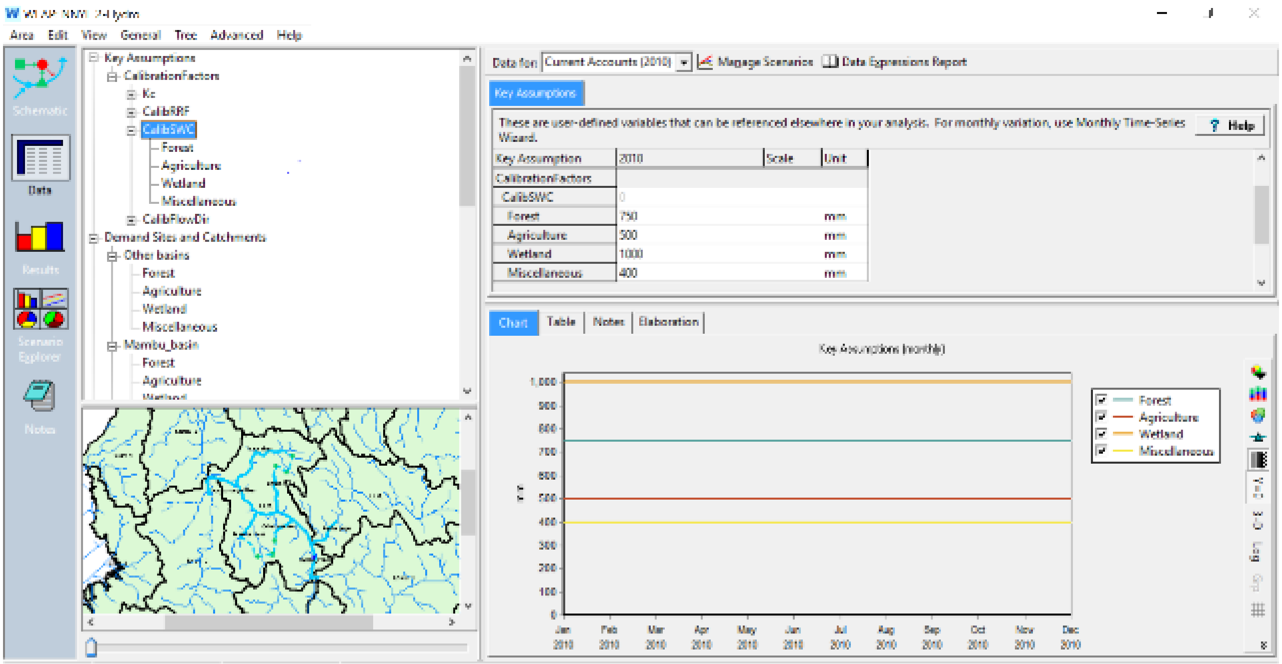


FIGURE C-0 2 ROOT ZONE CAPACITY KEY ASSUMPTIONS SETUP

- ### *C.1.5 ROOT ZONE CONDUCTIVITY*

Root Zone Conductivity or soil conductivity is the conductivity in the first bucket. Conductivity rate was described as 20 mm/day.

- ### *C.1.6 PREFERRED FLOW DIRECTION*

The Preferred Flow Direction parameter is used to partition flow out of the root zone layer to the lower soil layer or groundwater. Preferred flow direction can vary by land use classification and ranges from 0 to 1. A preferred flow direction of 1 indicates 100% horizontal flow direction while 0 indicates 100% vertical flow direction. The Key Assumption for the Preferred Flow Direction of each land use category was defined as shown in Figure C-0-3.

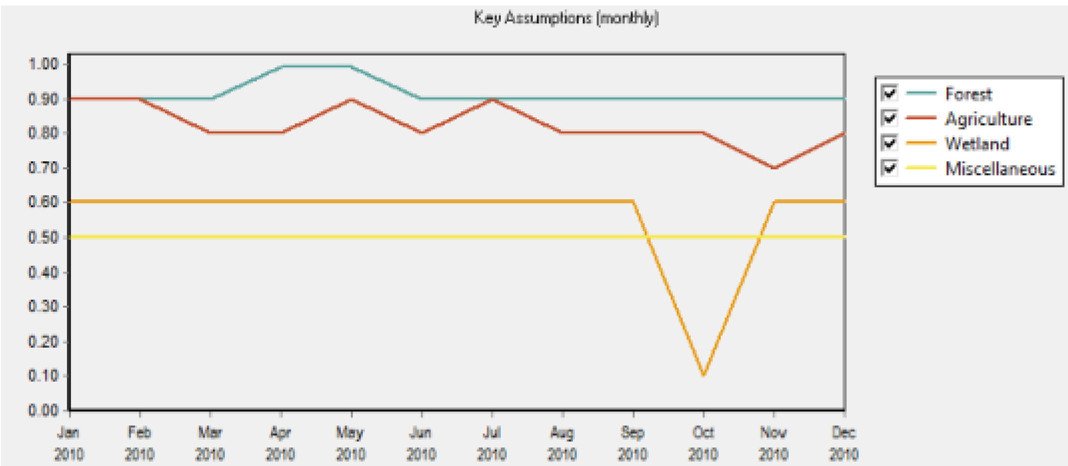


FIGURE C-0 3 PREFERRED FLOW DIRECTION VALUES

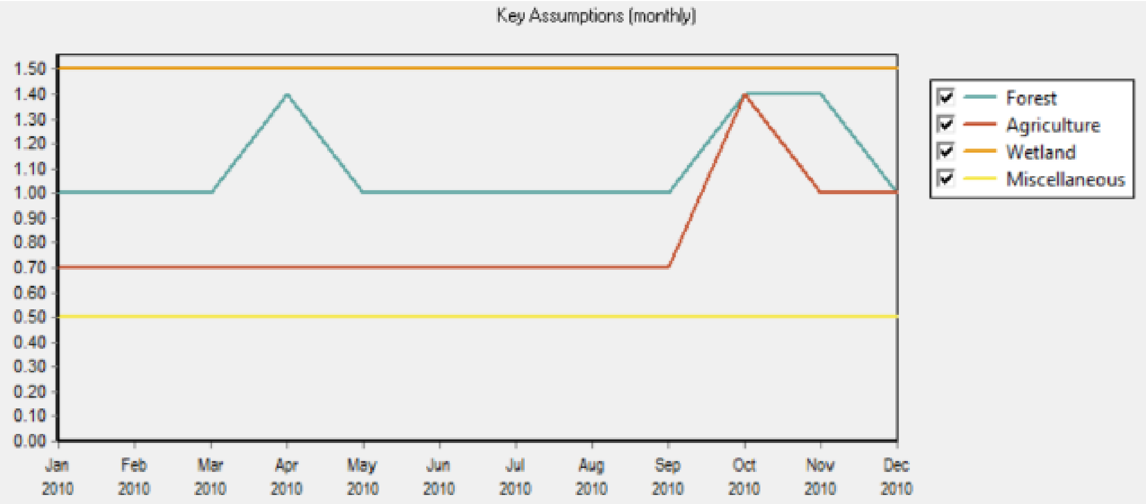
▪ *C.1.7 INITIAL Z1*

The Initial Z1 parameter is the relative storage given as a percentage of the total effective storage of the Root Zone Water Capacity at the beginning of a simulation. Therefore, like Root Zone Water Capacity this parameter typically varies with the land use. Initial Z1 value of each sub-catchment was defined with a value equal to 40 percent.

▪ *C.1.8 CROP COEFFICIENT, KC*

The crop coefficient, Kc, parameter represents the effects of vegetative evapotranspiration and soil evaporation, for this reason the parameter varies by land class type. The parameter was created to study the required soil moisture to maximize crop biomass production; hence, Kc is typically used to calculate the required evapotranspiration using the equation:

(Evapotranspiration) required = Kc * (Evapotranspiration)reference



A Key Assumption for the Kc value of each land use category was created and defined in **Figure C-0-4**.

FIGURE C-0 4 CROP COEFFICIENT VALUES

▪ *C.1.9 PRECIPITATION*

Precipitation data was obtained from the Meteo Rwanda file as spatially weighted grid values. This data sets the basis of precipitation values within respective sub-catchments, Figure C-0-5.

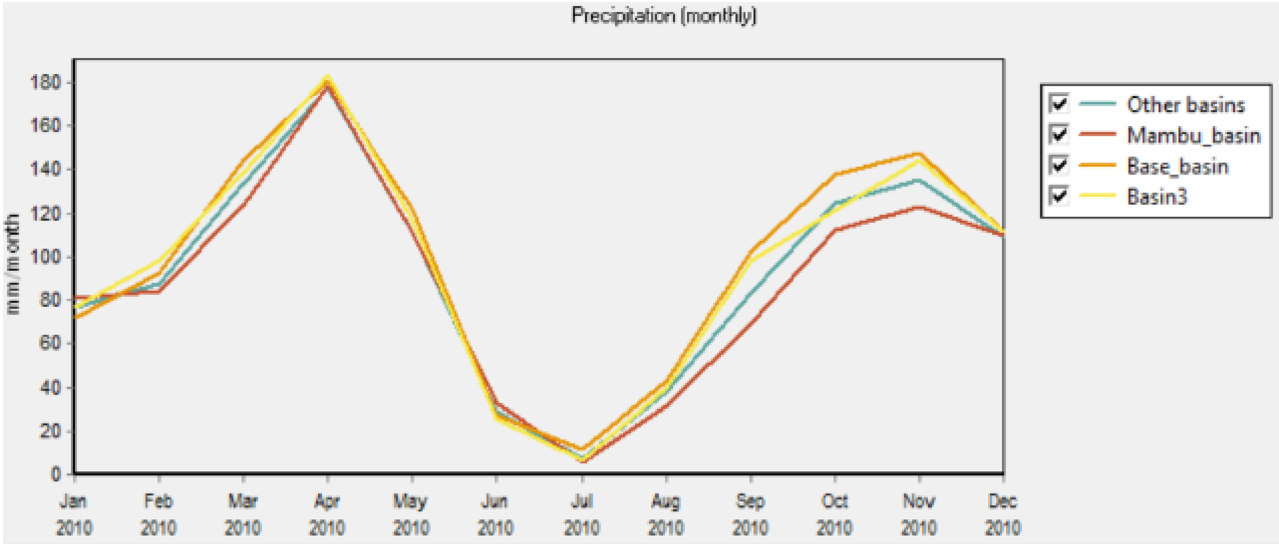


FIGURE C-0 5 AVERAGE PRECIPITATION OVER SUB-CATCHMENTS

The precipitation data extracted from the grid file was formatted in Excel and saved as a CSV file, which can be read by WEAP as a monthly time series expression. Figure C-0-6 shows the structure time series is entered for each sub-catchment in WEAP.

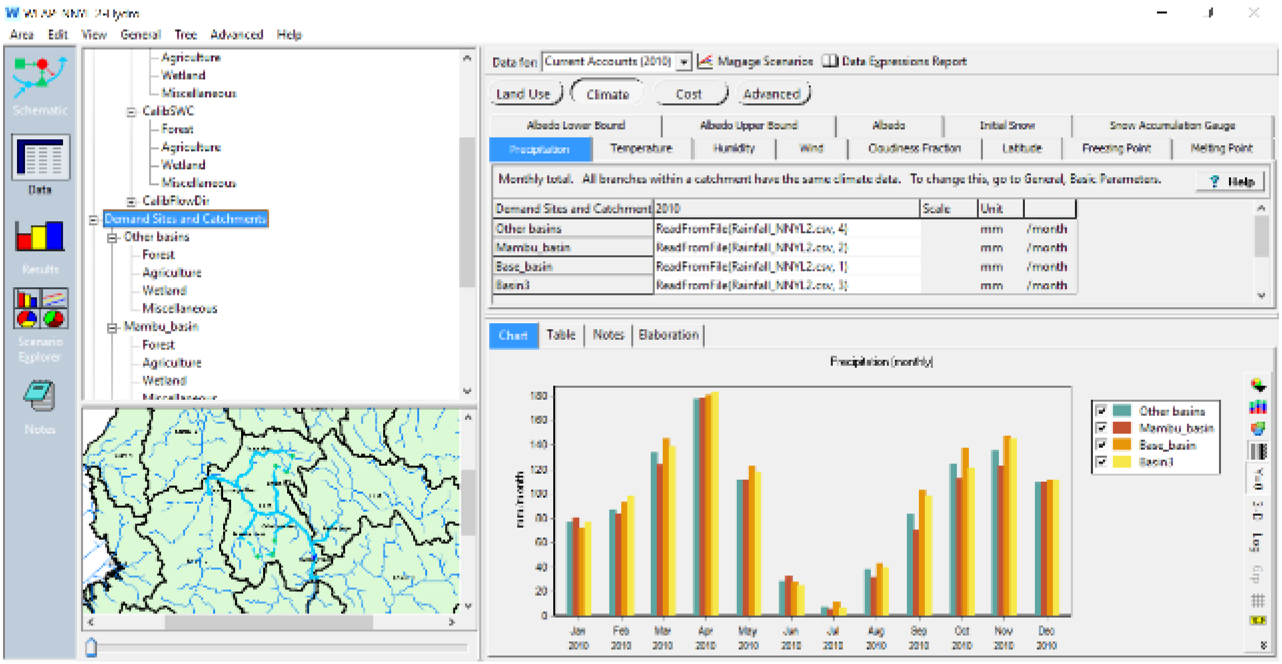


FIGURE C-0 6 WEAP PRECIPITATION TIME SERIES

- *C.1.10 TEMPERATURE, WIND AND HUMIDITY*

Temperature data is entered in degrees Celsius. Humidity is the relative humidity entered as a percentage and Wind values are entered in meters per second. Ideally, each of the parameters should be entered as time series data following the chosen time step of the model, days. However, only averaged monthly data in raster format was available for the Nile Akagera Upper catchment. The monthly values were read into WEAP as a time series expression from a CSV file, **FIGURE C-0-7**.

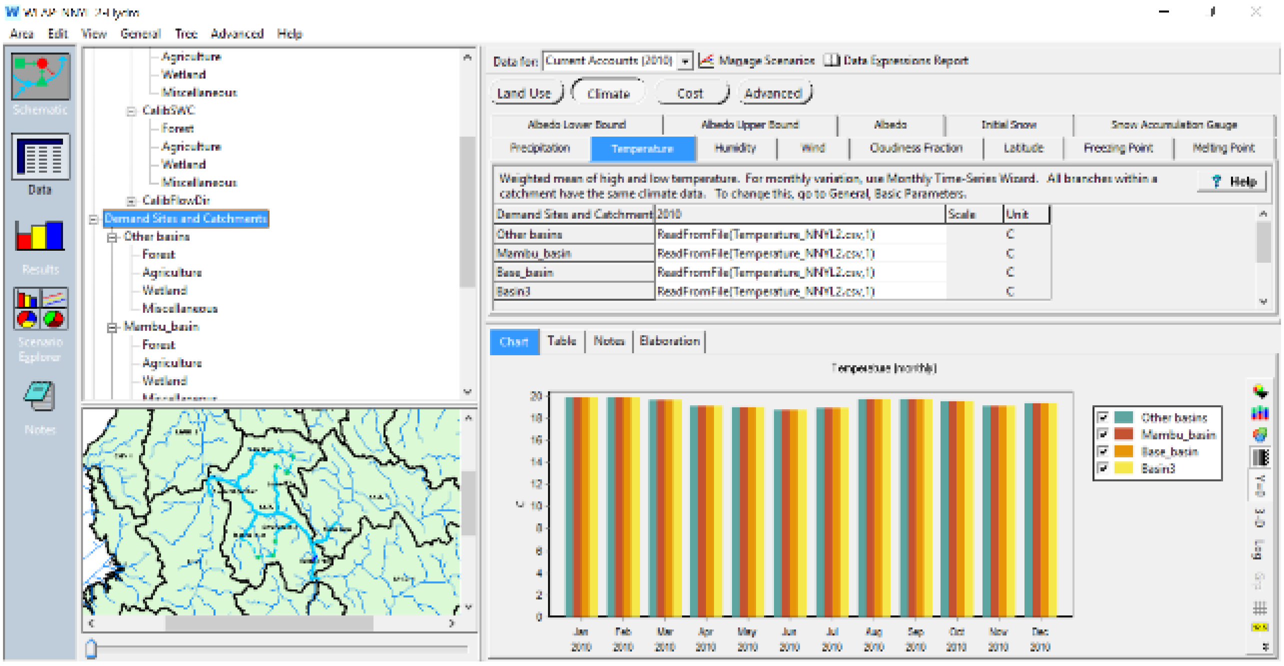


FIGURE C-0 7 WEAP TEMPERATURE DATA TIME SERIES

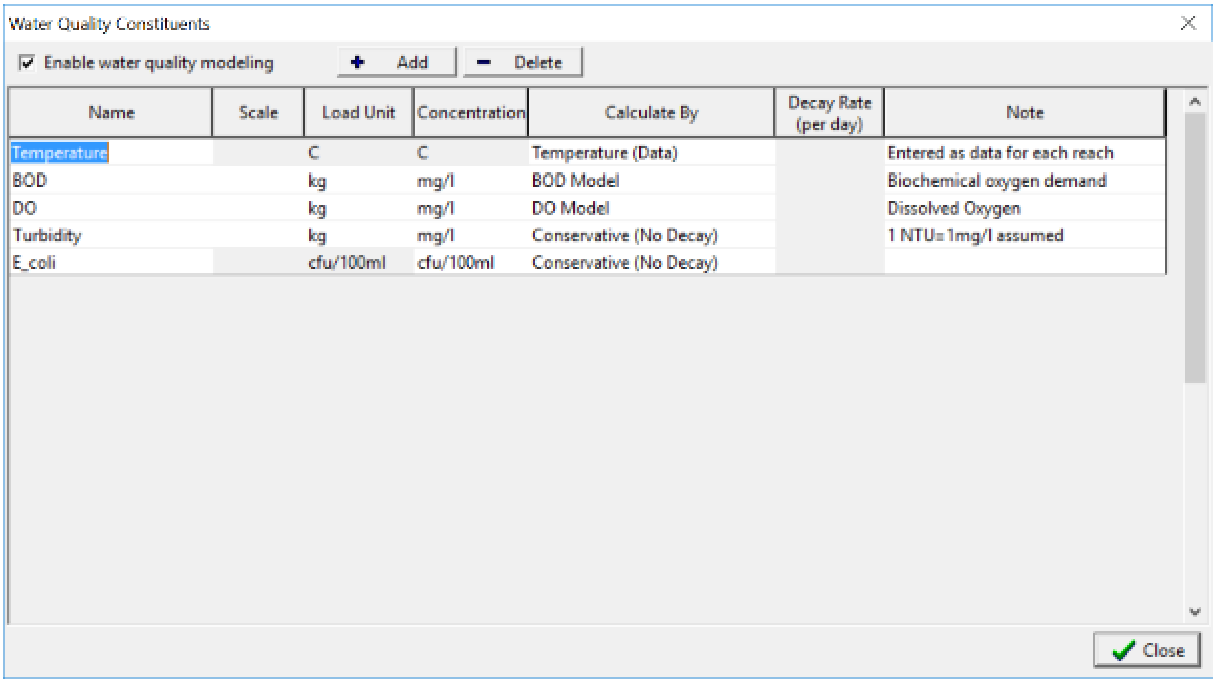
▪ *C.1.11 WATER QUALITY*

WEAP can model the concentration of water quality constituents in a river using simple mixing and assuming conservative behaviour, or with first-order decay and built-in BOD (biochemical oxygen demand), temperature, and DO (dissolved oxygen) models, or by linking to QUAL2K. QUAL2K was developed by a team of experts at Tufts University, which provides detailed water quality modelling of nitrogen, phosphorous, sedimentation, algae, pH and pathogens at a finer spatial scale than WEAP.

To indicate whether simulation of water quality parameters is desired, the User needs to choose *Data View* and click on *River* under *Supply and Resources*. Clicking on the *Water Quality* Category will access a window where the User can select rivers for which the User wants to simulate water quality parameters.

For instance, the User can choose to model water quality only on the main river but not on its tributaries. Here, the User can also enter data for BOD, Temperature, and other water quality constituents determined by the User. It is important to note that these data sets pertain to the head flow for a river. If the User chooses not to model water quality in a river, a concentration or temperature input can be used as a value representing the conditions at the outflow of the river.

WEAP tracks water quality, including pollution generation at demand sites, waste removal at wastewater treatment plants, effluent flows to surface and groundwater sources, and water quality modeling in rivers. On the water quality constituents setup screen, the User needs to turn on water quality modeling by checking the **Enable water quality modeling** checkbox, as shown below.



Name	Scale	Load Unit	Concentration	Calculate By	Decay Rate (per day)	Note
Temperature		C	C	Temperature (Data)		Entered as data for each reach
BOD		kg	mg/l	BOD Model		Biochemical oxygen demand
DO		kg	mg/l	DO Model		Dissolved Oxygen
Turbidity		kg	mg/l	Conservative (No Decay)		1 NTU= 1mg/l assumed
E_coli		cfu/100ml	cfu/100ml	Conservative (No Decay)		

The User can then define up to 20 constituents to track in the specific water quality conditions along the river system. In this context, it is important to set the **scale** and **load unit** as appropriate for entering the annual production of the pollutant by the demand site, per unit of activity. Can you elaborate on what is meant by Scale since it is not indicated in the example above.

Method of Calculation

For each constituent, it is important to specify which method WEAP should use to calculate surface water quality concentrations, in the **Calculate By** column:

Conservative: There is no decay of this constituent--the instream concentration will be computed using simple mixing and weighted average of the concentration from all inflows.

First-Order Decay: This constituent decays following an exponential decay function. Enter the daily **decay rate** here.

BOD: WEAP will use its built-in BOD model to simulate the changes in the biochemical oxygen demand (BOD) in the river. In order to model BOD, you will need to include water temperature as one of your water quality constituents (with unit = Celsius), and either enter as data the temperature of water in the river for each reach, or model it in WEAP.

DO: WEAP will use its built-in DO model to simulate the changes in dissolved oxygen (DO) in the river. Because the DO model uses BOD as an input, you will also need to simulate BOD.

For temperature values (required by WEAP to implement the BOD and DO modeling), the User can choose from either of two methods:

Temperature (Modeled in WEAP): WEAP will calculate water temperature for each river reach based on climate data (air temperature, humidity, wind, and latitude) entered as input in the Data view (under the Climate tab for the reach).

Temperature (Data): the user specifies the water temperature for each reach. If this option is selected and temperature for a particular reach is left blank, WEAP will assign to that reach the temperature of the immediate upstream reach. Water temperature is needed by the BOD model.

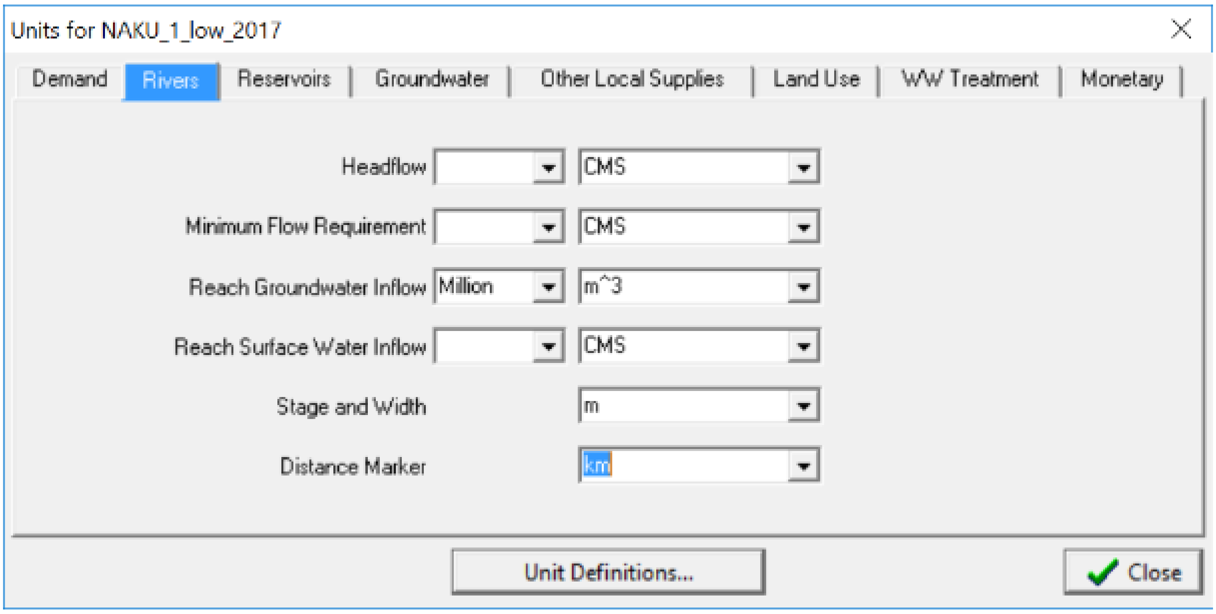
Minimum Data Requirements

In order to model water quality in a river, the User must enter the following data:

Distance Marker

In order to model decay within a reach, WEAP must know how long that reach is. The User must enter the distance marker for the top of each reach. The distance markers should increase in a downstream direction. The first reach does not need to start with 0. Finally, the distance marker is entered for the bottom of the river (the bottom of the last reach).

If any reach is left blank, WEAP will use the relative lengths from the schematic to estimate the reach lengths. At a minimum, the User must enter the distance for the top of the first reach and the bottom of the last reach. To change the distance marker unit, the User needs to use the "Rivers" tab of the "General, Units" screen. It is important to note that this data is entered only for Current Accounts.



Flow Stage Width

WEAP uses a flow-stage-width function to derive the velocity (e.g., m/s) of a stream from its flow rate (e.g., m^3/s). Using the Flow Stage Width Curve function, the User can enter data points relating flow to stage (depth) and width. The "Flow-Stage-Width wizard" will facilitate data entry. The wizard will calculate the corresponding velocity at each data point, which is useful as an error check, since the velocity should increase as the flow rate increases.

WEAP will use a linear extrapolation to calculate stage (depth) for flows greater than the highest flow data point entered. If the characteristics of a reach are similar to the upstream reach, you can leave it blank and it will use the FlowStageWidthCurve from the upstream reach. To change the stage and width unit, go to the "Rivers" tab of the “General, Units” screen. This data is entered only for Current Accounts.

Water Temperature

If the User choses to model BOD and DO but have chosen not to model river water temperature (the method for the temperature water quality constituent is "Temperature (Data)"), the User will need to enter the water temperature for each reach. WEAP will use values from the immediate upstream reach if this value is left blank. If the User is modeling BOD, the water temperature of each reach must be entered.

Level 2 Catchment

It is important to note that in order to evaluate water quality conditions along the riverine segments of NAKU-1, the following actions were taken:

a. Parameters selected

The two water quality parameters selected for detailed analyses included:

- Electrical Conductivity to evaluate fitness for irrigation water use and
- E. coli to evaluate fitness for domestic water use, but
- BOD and DO were also integrated to the WEAP model presented as part of the current project.

Electrical Conductivity (EC) estimates the amount of total dissolved salts, or the total amount of dissolved ions in the water. EC is controlled by:

1. *geology* (rock types) - The rock composition determines the chemistry of the watershed soil. For example, limestone leads to higher EC because of the dissolution of carbonate minerals in the catchment.
2. The *size of the watershed* relative to the surface area of the river system - A bigger watershed to river surface area means relatively more water draining into the river system, because of a bigger catchment area, and more contact with soil before reaching the river system.
3. *"other" sources of ions* to the river system - There are a number of sources of pollutants which may be signaled by increased EC:
   - wastewater from sewage treatment plants (point source pollutants)
   - wastewater from septic systems and drainfield on-site wastewater treatment and disposal systems (non-point source pollutants)
   - agricultural runoff of water draining agricultural fields typically has high levels of dissolved salts (another major nonpoint source of pollutants). Although only a minor fraction of the total dissolved solids, nutrients (ammonium-nitrogen, nitrate-nitrogen and phosphate from fertilizers) and pesticides (insecticides and herbicides mostly) typically have significant negative impacts on streams and lakes receiving agricultural drainage water. If soils are also

washed into receiving waters, the organic matter in the soil is decomposed by natural aquatic bacteria which can severely deplete dissolved oxygen concentrations.

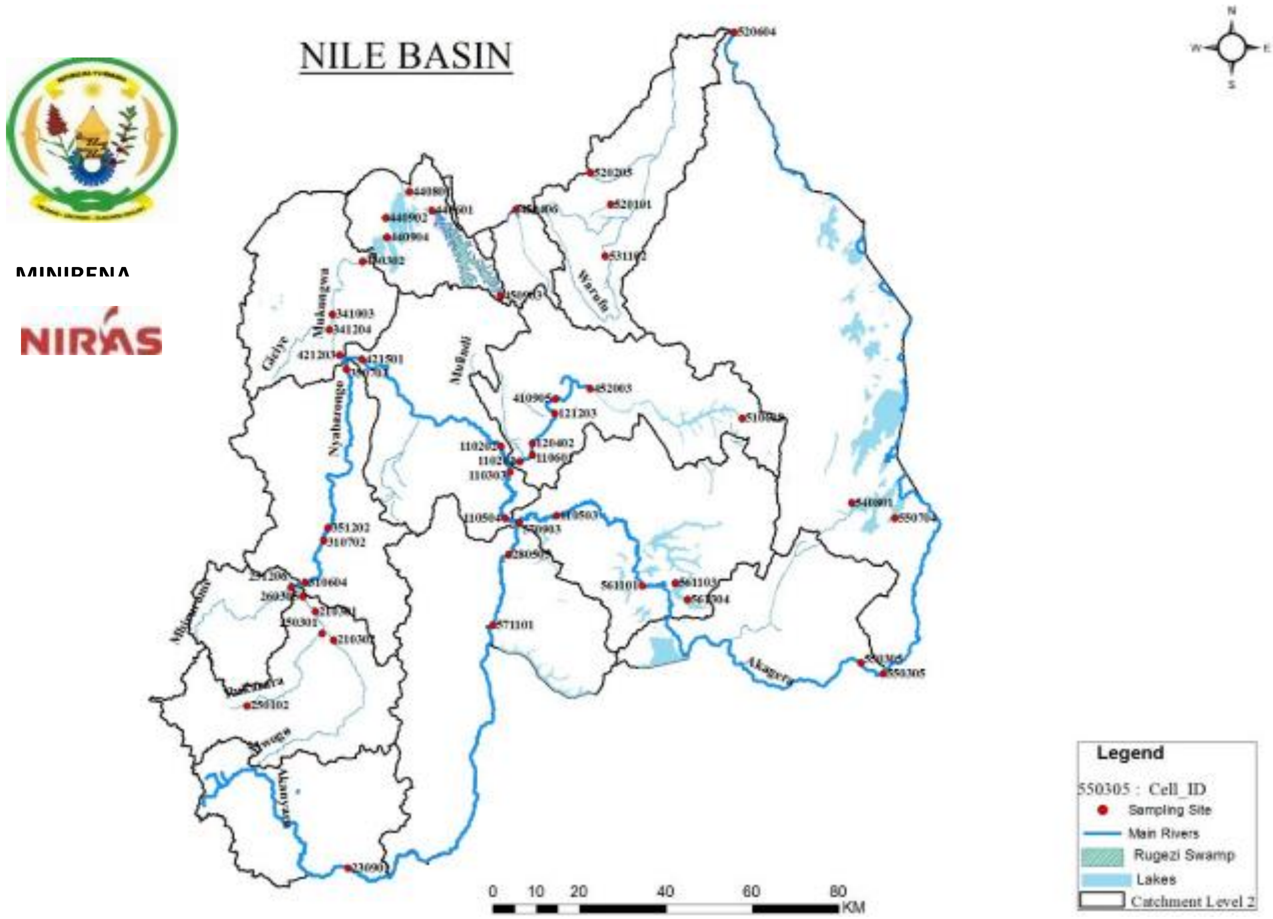
- E. coli is a subgroup of the faecal coliform group. Most E. coli bacteria are harmless and exist in the intestines of people and warm-blooded animals. However, some strains can cause illness. The presence of E. coli in a drinking water sample usually indicates recent fecal contamination. That means there is a greater risk that pathogens are present. In such conditions, it is recommended to use boiled or bottled water for drinking, preparing food, and brushing teeth.

b. Processes considered

Due to the fact that WEAP has a **decay-function** oriented process, the potential for a User defined decay functions for both EC and E-Coli was evaluated.

c. Site-specific measurements evaluated

The site-specific measurements as presented in the recently completed NIRAS report (shown below) (Water Pollution Baseline Study, 2017) were evaluated. Standards for EC and E. coli were also noted. Detailed monitoring and assessment of various parameters along the river systems were presented in the NIRAS report. Data sets evaluated included two reference years of 2012 and 2016.



Water quality monitoring sites and their distribution in different level 2 catchments of the Nile basin

- STANDARD OF THE PARAMETERS MONITORED

Parameter Name	Parameter Short name	Target Value	Unit	Target Type
Electrical conductivity	EC*	1000	□S/cm	Higher
E-coli	-	4	cfu/100 ml	Higher

* Core parameters for open water bodies proposed by SDGs

TABLE C-0 2 WATER QUALITY MONITORING RESULTS BY KEY WATER BODY AND THEIR COMPLIANCE WITH THE TARGET VALUE (WATER POLLUTION BASELINE STUDY: RWB, 2017) (NOTE: HIGHLIGHTED CELLS IN GREEN INDICATE THAT THE TARGET IS MET AND CELLS IN ORANGE INDICATE THAT THE TARGET IS

ID	L2 Catchment	Name of the water Body	EC	DO	TDS	TSS	Turbidity	pH	T	DIP	DIN	E-Coli	Complian target v paramete
													% Compliance per site
1	NNYL_2_110202	Nyabarongo river	88.9	87.3	45.7	865.5	1740.0	7.2	21.9	2.2	5.2	455.0	60
2	NNYL_2_421501	Nyabarongo river	93.1	94.2	49.5	1240.0	5615.0	7.4	19.4	0.6	0.8	14.0	70
3	NNYL_2_110303	Nyabarongo river	105.7	81.1	53.3	1226.7	2628.3	8.1	19.2	1.5	3.9	92.7	60
4	NNYL_2_110504	Nyabarongo river	99.7	71.4	51.0	639.3	1523.3	6.8	21.8	1.4	4.8	82.3	60
44	NNYU_3_350703	Nyabarongo river	31.1	92.1	16.0	2631.7	5935.0	6.7	20.3	0.6	1.3	1200.0	70
5	NNYL_1_110202	Nyabugogo river	216.8	56.3	110.9	1204.7	3690.0	7.4	21.8	0.7	3.8	2200.0	50
14	NAKU_1_570903	Akagera river	110.0	43.9	55.9	557.7	1260.0	6.7	21.8	1.8	4.6	230.0	50
15	NAKU_1_110503	Akagera river	101.8	62.7	51.9	796.0	2058.3	7.3	21.3	2.0	5.2	153.3	50

16	NAKU_1_561101	Akagera river	112.3	53.2	56.3	466.7	1036.7	6.9	22.3	1.3	5.5	35.7	50
25	NMUK_2_421203	Mukungwa river	216.5	98.8	114.4	582.3	1560.0	8.2	20.2	0.5	2.1	160.0	80
46	NAKN_3_280505	akanyaru river	135.4	5.1	66.4	46.0	172.0	7.5	22.5	0.4	1.5	750.0	60

d. Outcomes

These detailed results were evaluated in the context of inlet, outlet and internal conditions within the two Level 2 catchments. Due to the fact that site-specific measurements did not convey consistent set of outcomes, and decay driven properties, it was not possible to express water quality processes using WEAP decay functions. In this context, it is important to structure a consistent set of measurements to reflect site-specific properties and pressures driven by point (mainly industrial facilities) and distributed (mainly agricultural activities) sources of pollution. The observed data sets representing year 2012 were more consistent than the ones in year 2016, in terms of defining decay processes along the river reaches. Therefore, observed data sets for the year 2012 were integrated to the WEAP model.

In the context of NNYL_2

- EC (conservative) remained without decay in 2012 data set, but showed a minor increase in 2016 data set.

- E-Coli does not decay in 2016 and quite the contrary increases significantly between the inlet and outlet points of NNYL_2. This is driven by agricultural activities. On the other hand, E coli loads from the Nyabogogo, which brings pollution from Kigali into the Nyaborongo, were not evident from the measurements of 2016. Year 2012 was characterized by extremely high value at the inlet, which could not be confirmed against the outlet of upstream catchments.

In the context of NAKU_1

- EC (conservative) showed a minor decrease in 2012 data set, but showed a minor increase in 2016 data set.

- E-Coli showed significant levels of decay between the inlet and outlet points of NAKU_1 in both 2012 and 2016. This is driven by wetland areas within the catchment

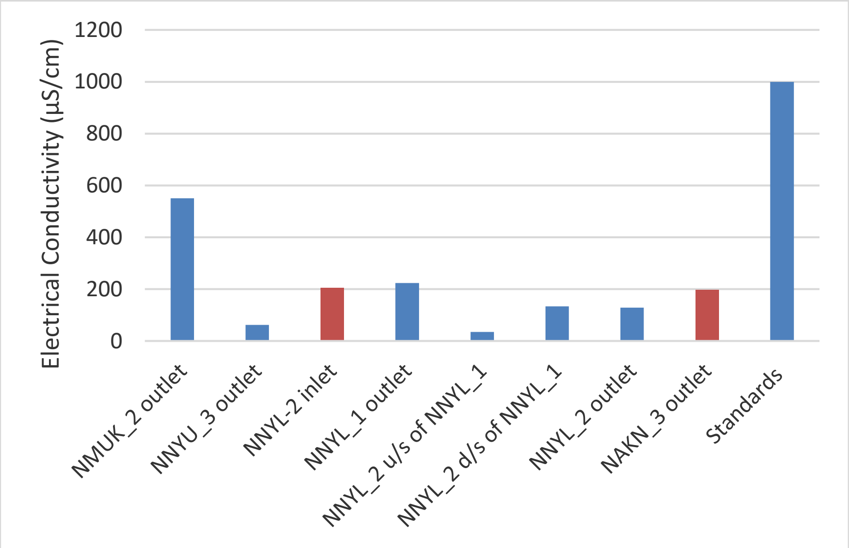


FIGURE 0- 1 EC WITHIN NNYL-2 (REFLECTING 2012 DATA SETS)

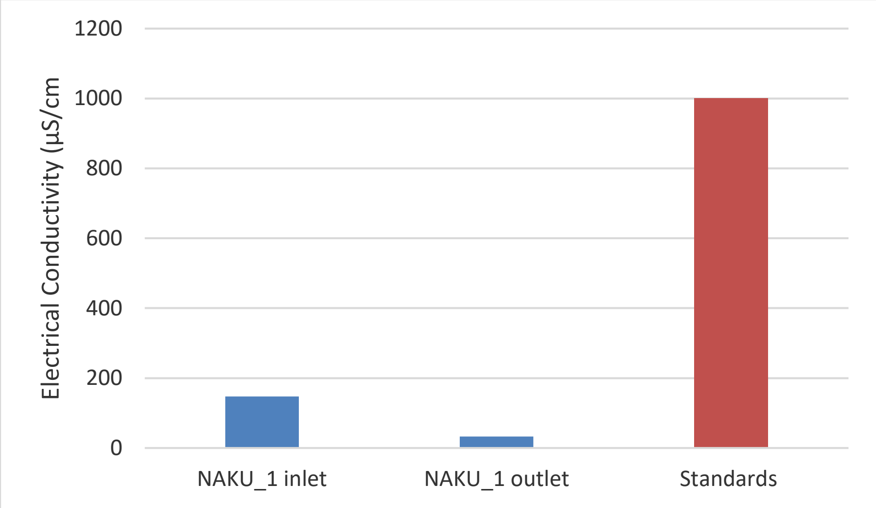


FIGURE 0- 2 EC WITHIN NAKU-1 (REFLECTING 2012 DATA SETS)

TABLE C-0 3 EVALUATION OF EC (REFLECTING 2016 DATA SETS)

Monitoring No	Level 2 Catchment	Water Body	EC	Notes
44	NNYU_3_350703	Nyabarongo river	**31.1**	Inflow Nyabarongo upper
25	NMUK_2_421203	Mukungwa river	**216.5**	Inflow Mukungwa
2	NNYL_2_421501	Nyabarongo river	**93.1**	**Inlet of NNYL-2**
1	NNYL_2_110202	Nyabarongo river	**88.9**	
5	NNYL_1_110202	Nyabugogo river	**216.8**	Inflow Nyabugogo
3	NNYL_2_110303	Nyabarongo river	**105.7**	
4	NNYL_2_110504	Nyabarongo river	**99.7**	**Outlet of NNYL-2**
46	NAKN_3_280505	Akanyaru river	**135.4**	Inflow Akanyaru
14	NAKU_1_570903	Akagera river	**110**	**Inlet of NAKU-1**
15	NAKU_1_110503	Akagera river	**101.8**	
16	NAKU_1_561101	Akagera river	**112.3**	**Vicinity of the outlet of NAKU-1**

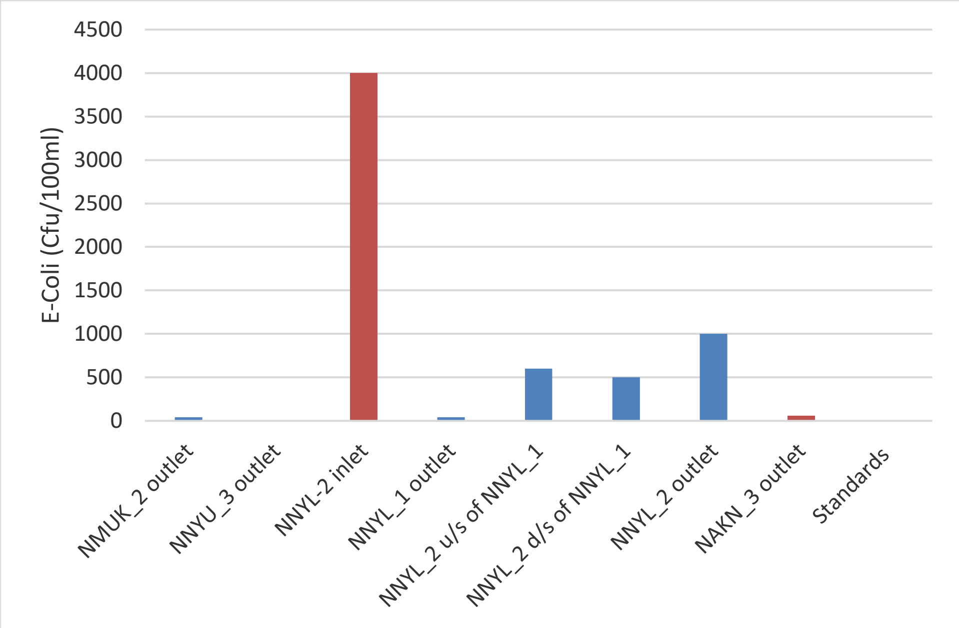


FIGURE 0- 3 E-COLI WITHIN NNYL-2 (REFLECTING 2012 DATA SETS)

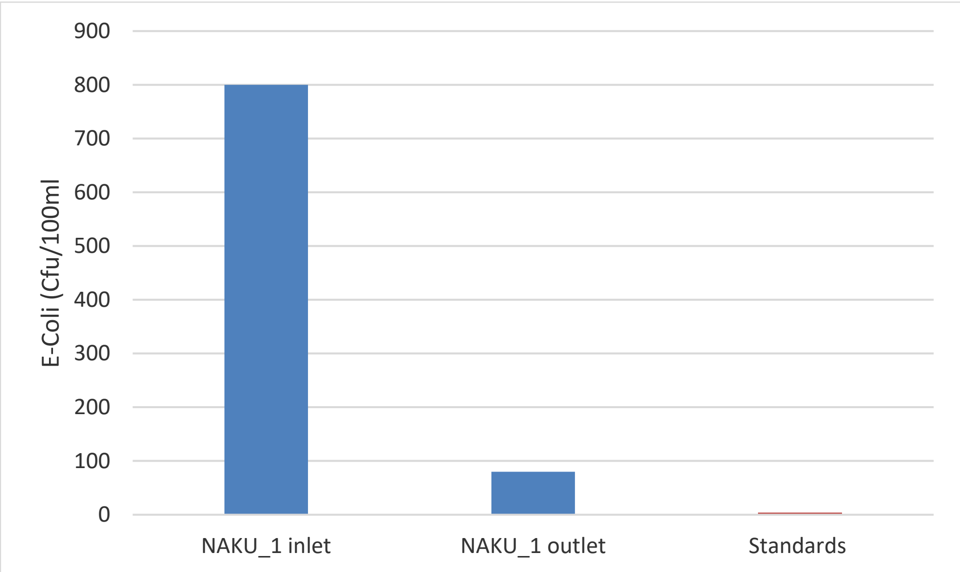


FIGURE 0- 4 E. COLI WITHIN NAKU-1 (REFLECTING 2012 DATA SETS)

TABLE C-0 4 EVALUATION OF E. COLI (REFLECTING 2016 DATA SETS)

Monitoring No	Level 2 Catchment	Water Body	E-Coli	Notes
44	NNYU_3_350703	Nyabarongo river	**1200**	Inflow Nyabarongo upper
25	NMUK_2_421203	Mukungwa river	**160**	Inflow Mukungwa
2	NNYL_2_421501	Nyabarongo river	**14**	**Inlet of NNYL-2**

1	NNYL_2_110202	Nyabarongo river	**55**	
5	NNYL_1_110202	Nyabugogo river	**2200**	Inflow Nyabugogo
3	NNYL_2_110303	Nyabarongo river	**92.7**	
4	NNYL_2_110504	Nyabarongo river	**82.3**	**Outlet of NNYL-2**
46	NAKN_3_280505	Akanyaru river	**750**	Inflow Akanyaru
14	NAKU_1_570903	Akagera river	**230**	**Inlet of NAKU-1**
15	NAKU_1_110503	Akagera river	**153**	
16	NAKU_1_561101	Akagera river	**35.7**	**Vicinity of the outlet of NAKU-1**

(12) ANNEXURE D: SECTORAL WATER CONSUMPTION

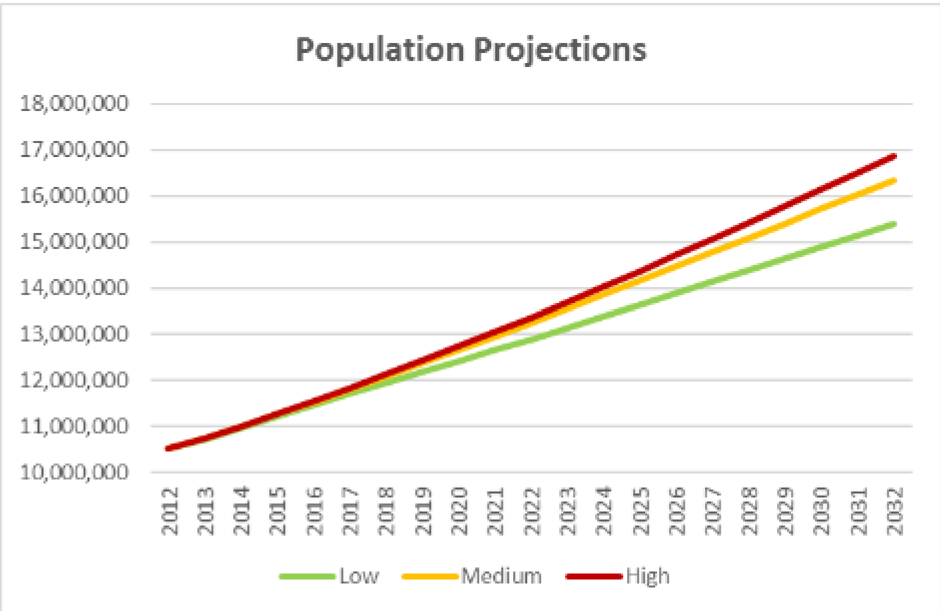
○ D.1 DOMESTIC WATER CONSUMPTION

- Step 1: Existing Rural and Urban population (as of 2012) were collected from NISR data sets at the Sector scale.

Sample data set is presented below:

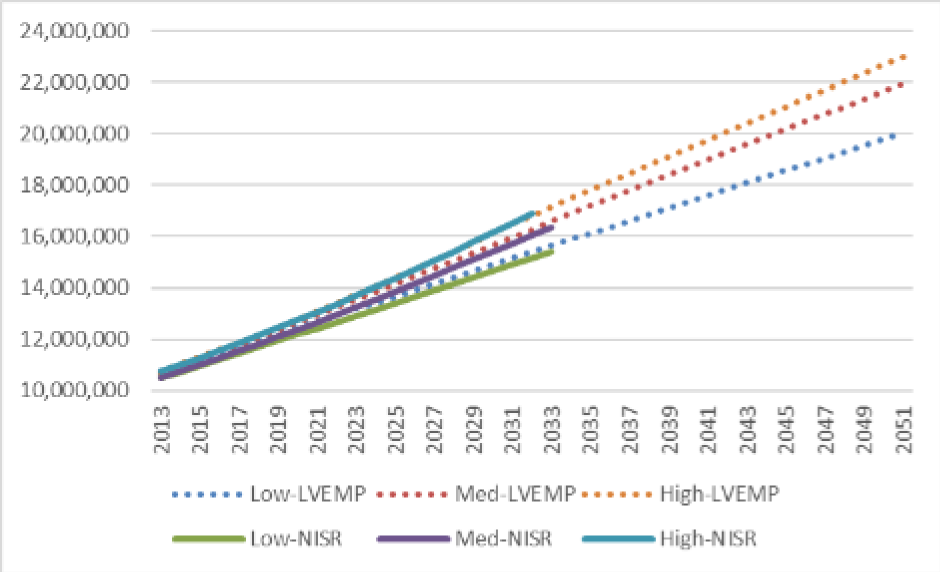
			Rwanda			Urban			Rural		
			Both Sex	Male	Female	Both Sex	Male	Female	Both Sex	Male	Female
Kigali City			1,132,686	586,123	546,563	859,332	451,673	407,659	273,354	134,450	138,904
	Nyarugenge District		284,561	148,132	136,429	214,020	113,092	100,928	70,541	35,040	35,501
		1. Gitega Sector	28,728	14,989	13,739	28,728	14,989	13,739	-	-	-
		2. Kanyinya Sector . . .	21,859	10,777	11,082	-	-	-	21,859	10,777	11,082
		3. Kigali Sector	30,023	15,375	14,648	4,748	2,594	2,154	25,275	12,781	12,494
		4. Kimisagara Sector	46,753	24,451	22,302	46,753	24,451	22,302	-	-	-
		5. Mageragere Sector	23,407	11,482	11,925	-	-	-	23,407	11,482	11,925
		6. Muhima Sector	29,768	17,222	12,546	29,768	17,222	12,546	-	-	-
		7. Nyakabanda Sector	25,666	13,351	12,315	25,666	13,351	12,315	-	-	-
		8. Nyamirambo Sector	40,292	20,290	20,002	40,292	20,290	20,002	-	-	-
		9. Nyarugenge Sector	21,302	11,477	9,825	21,302	11,477	9,825	-	-	-
		10. Rwezamenyo Sector	16,763	8,718	8,045	16,763	8,718	8,045	-	-	-
	Gasabo District		529,561	274,546	255,015	365,371	194,128	171,243	164,190	80,418	83,772
		1. Bumbogo Sector. .	35,381	17,722	17,659	4,246	2,213	2,033	31,135	15,509	15,626
		2. Gatsata Sector. .	37,110	19,445	17,665	37,110	19,445	17,665	-	-	-
		3. Gikomero Sector .	16,625	8,082	8,543	-	-	-	16,625	8,082	8,543
		4. Gisozi Sector . .	44,003	23,209	20,794	44,003	23,209	20,794	-	-	-
		5. Jabana Sector . .	33,577	16,718	16,859	9,271	4,651	4,620	24,306	12,067	12,239
		6. Jali Sector . . .	25,057	12,121	12,936	3,808	1,913	1,895	21,249	10,208	11,041
		7. Kacyiru Sector. .	37,088	19,816	17,272	37,088	19,816	17,272	-	-	-
		8. Kimihurura Sector	21,672	12,170	9,502	21,672	12,170	9,502	-	-	-
		9. Kimironko Sector.	57,430	31,881	25,549	57,430	31,881	25,549	-	-	-
		10. Kinyinya Sector .	57,846	30,320	27,526	53,162	27,686	25,476	4,684	2,634	2,050

Step 2: Future population forecasts (up to 2032) were collected from NISR data sets at the Country

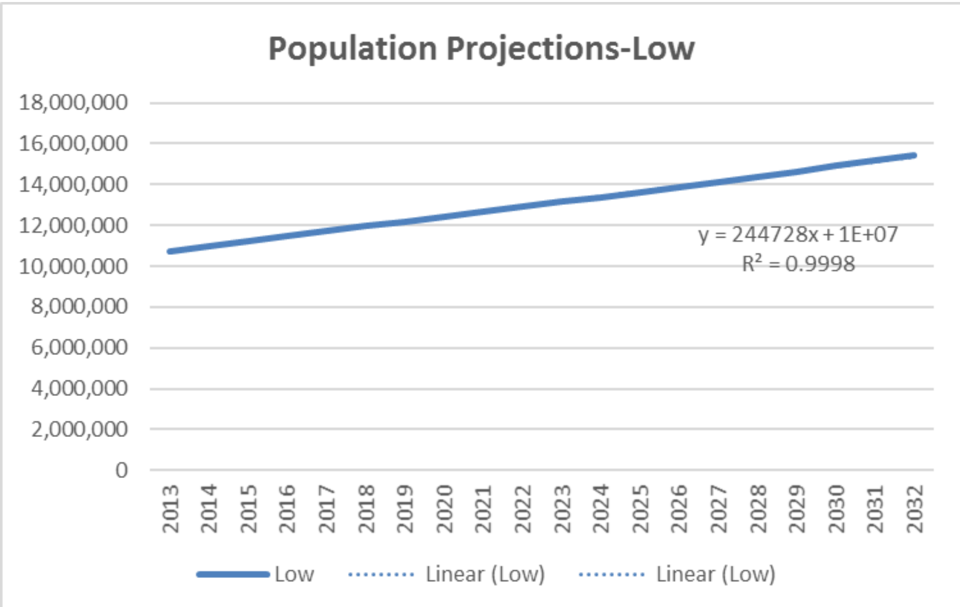


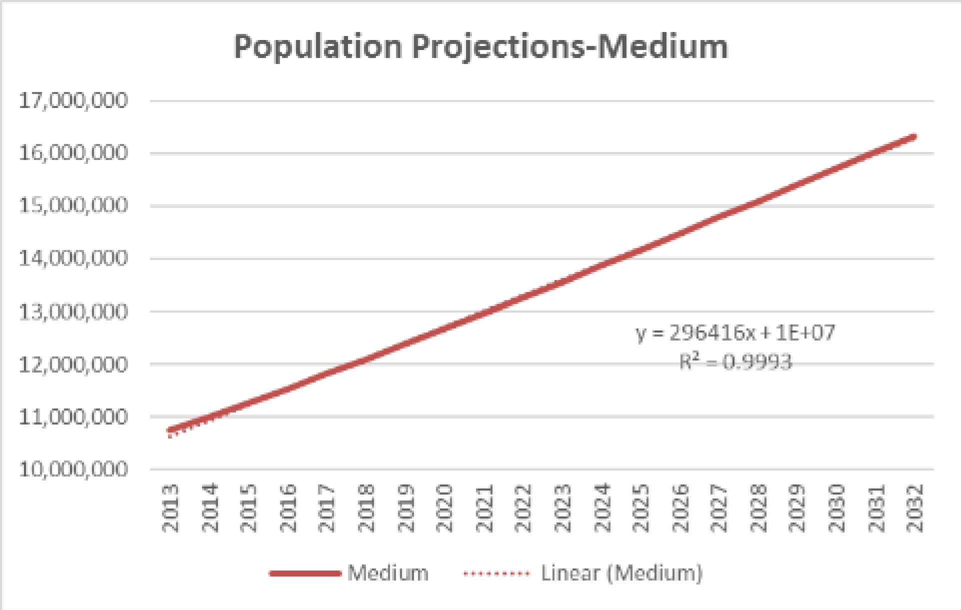
scale

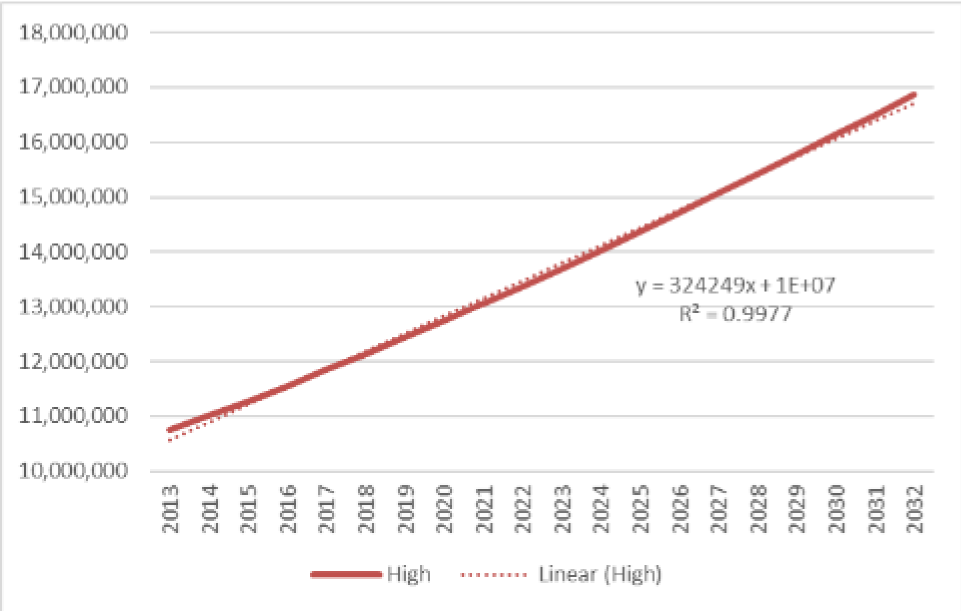
- Step 3: Low, Medium and High population scenarios were collected from NISR data sets



- Step 4: Statistical tools (regression analysis) were used to extrapolate the population forecasts of NISR up to 2050 for all population scenarios of Low, Medium and High. The population trends at the Country scale was assumed to represent the population trends at the Sector scale.



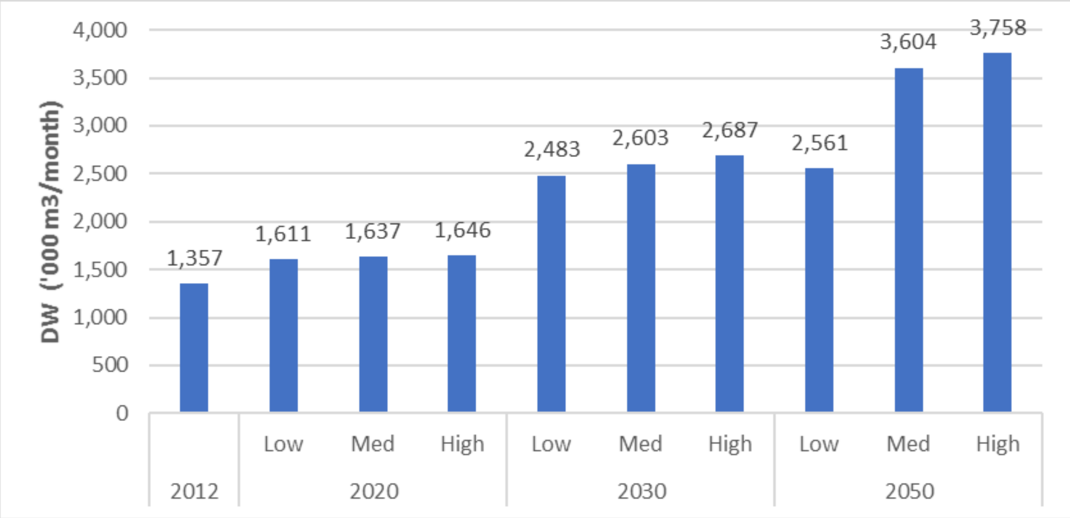




- Step 5: Water consumption by Urban and Rural populations for existing and future conditions (2020, 2030 and 2050) were collected from WASAC.

Existing		**2020**		**2030**		**2050**	
Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
l/person/day			**l/person/day**	**l/person/day**		**l/person/day**	
100	30	100	30	120	40	150	40

- Step 6: Existing and Future conditions DWC values were calculated at the Sector scale



- Step 7: These data sets were transferred to GIS to calculate DWC values at the sub-catchment scale within the Nile Akagera Upper catchment.

D.2 IRRIGATION WATER CONSUMPTION

- Step 1: Existing and Planned Irrigation Command areas were collected from MINAGRI, RAB and JICA
- Step 2: Existing and year 2020 reflect the same Command areas. Year 2030 reflect the irrigation areas under "development" and year 2050 reflect irrigation areas under "planned"

Level 2	Subcatchments	Existing/2020		2030		2050	
		Facility Name	Area (ha)	Facility Name	Area (ha)	Facility Name	Area (ha)
NAKU-1	1		267	Rwamagana 34	267	Rwamagana 34	267
	2		510	Rugende complex	510	Rugende complex	510
	3	Gitinga	225	Gitinga	225	Gitinga	225
	3	Mwambu	210	Mwambu	210	Mwambu	210
	3	Ngoma22	240	Ngoma22	240	Ngoma22	240
	3		338		338		338
	3		200		200	Ntovi	200
	3		1000		1000	IMP- Gatare site	1000
	Subtotal 3		**2213**		**2213**		**2213**
	4	Gashora sit	750	Gashora site A	750	Gashora site A	750
	4		750		750	Gashora site B	750
	4		1000		1000	Hillside sites around Rweru, Gaharwa and Kirimbi lakes	1000
	4	Rurambi	850	Rurambi	850	Rurambi	850
	4		500		500	IMP- Rusheshe site	500
	4					LWH	8886.82
	Subtotal 4		**3850**		**3850**		**12736.8**

- Step 3: The corresponding crop water requirements (m3/ha) were collected from the feasibility reports documented by MINAGRI, RAB and JICA

Vicinity of Gitinga and Mwambu

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gross CWR (m3/ha/month)	149	-	510	74	325	901	643	765	639	1,006	458	436

Vicinity of Gashora and Rurambi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gross CWR (m3/ha/month)	287.2	280.4	389.2	213.1	196.6	914	1775.4	1750.5	546.2	394.9	281.1	531.1

- Step 4: Irrigation requirements were calculated by considering three main factors: Effective precipitation, Crop water requirement and Irrigation command areas.

D.3 COFFEE WASHING STATION

- Step 1: Locations of Coffee Washing Station were collected from MINAGRI

District	Sector	Name of Coffee washing station	Owners/Partners/Renter
Kamonyi	Mugina	Mugina CWS	CBC Ltd (ex.COFII)
	Mugina	Amayaga Highland Coffee	Amayaga Highland Coffee Ltd/Mrs.Musayidire Jacqueline
Rwamagana	Karenge	RWACOF Karenge	RWACOF Ltd
	Karenge	GMC (ex.KOPAKABI)	GMC Ltd (former KOPAKABI Coop)
	Karenge	Gutanga Farms CWS (ex. Nyamatete CWS)	Rwanda Trading Company Ltd
	Muyumbu	Muyumbu Shema CWS	Mr.SHEMA Charles
	Muyumbu	MCAC Muyumbu (rented by new Investor)	MCAC Coop.
	Muyumbu	Bujyujyu CWS	Mr.NTEZIRIZAZA Theogene
	Nyakariro/Karenge	Bihembe CWS (ex.Coffee Vision)	IMPEXCOR Ltd
	Gahengeri	Gahengeri CWS	Mr.HABUMUGISHA J.Paul
	Nzige	Nzige CWS	ENAS/NKUBIRI Alfred
	Musha	Habumugisha JP CWS (ex Musha coop)	Mr.HABUMUGISHA J.Paul
	Nyakariro	Nyametete CWS	Mr.Faustin NIYIBIZI/Dorman Ltd
	Fumbwe	Mununu/Aburwagasabo	Aburwagasabo Coop.
Kayonza	Nyamirama	RTC Nyamirama CWS (ex.KCC)	RTC Ltd
Ngoma	Sake	SAKE Farm Ltd/Leatitia	Mrs.KAYITESIRE Leatitia
	Kazo	Ngoma Trading Company	NTC Ltd/KAKS
	Kibungo	Cyiza CWS (New CWS)	Butara Mountain Coffee /Mrs.UWICYUSA Martine
	Gashanda/Remera	Abakangukiyekawa CWS	Abakangukiyekawa Coop.
	Rurenge	Ishema CWS (Women in coffee initiative Ltd)	Women in coffee initiative Ltd / Mrs. TUSHABE Joy
Bugesera	Ntarama	Ntarama CWS	Dr. NDAHIRO Alfred
Gasabo	Gikomero	Gikomero CWS (ex. Dallas Invest)	Rwanda Trading Company Ltd

- Step 2: Water requirements of cherries were collected from MINAGRI

Theorical capacity in cherries (T) in 2015	Cherries received Up in 2015 (T)	Water consumption in 2015(L)
500	286	572,000
250	130	130,000
1500	1874	3,748,000
500	186	372,000
0	0	0
500	333	666,000
500	13	26,000
500	13	26,000
500	691	1,382,000

- Step 3: Watering technology (conventional vs. eco-flex) were collected from MINAGRI

❖ Conversion

❖ 5kg cherries=5l of water with ecoflex and 10l of water of conventional machines

- ❖ Ecoflex= (received cherries in tons/ 0.005T)*5l
- ❖ Conventional=(received cherries in tons/0.005T)*10l

- Step 4: Future development plans were collected from MINAGRI

Theoritical cherries_2020	Water consumption_2020 (L)	2020_ Projected water consumption (L) /per month	(m3/month)	Theoritical cherries_2030	Water consumption_2030 (L)	2030_ Projected water consumption (L) /per month	(m3/month)	Theoritical cherries_2050	Water consumption_2050 (L)	2050_ Projected water consumption (L) /per month	(m3/month)
750	1,500,000	375,000	375	1000	1,000,000	250,000	250	1000	1,000,000	250,000	250
500	500,000	125,000	125	750	750,000	187,500	188	1000	1,000,000	250,000	250

○ D.4 FISH PONDS

- Step 1: Locations of Fish ponds were collected from MINAGRI

Sample data sets

No	Cooperative	District	Sector
1	MUHIRE Emmanuel	GASABO	RUSORORO
2	MUNYANGEYO Themistocle	GASABO	RUSORORO
3	NKURIKIYIMFURA Janvier	GASABO	GIKOMERO
4	ABUNZUBUMWE	GASABO	RUSORORO
5	INYANJA-NGARI	GASABO	REMERA

- Step 2: Surface area and depth requirements (to maintain fishery services) were collected from MINAGRI

Sample data sets

Number of ponds	Surface (Ares)	Surface Area (m2)	Height (m)	Volume (m3/year)
2	13	1,300	1	1,300
8	72	7,200	1	7,200
10	120	12,000	1	12,000
6	45	4,500	1	4,500

- Step 3: Water requirements were customized to reflect wet and dry periods

Normal dry (Dec-Feb)	Wet (Mar-May)	Dry (June-Aug)	Normal Wet (Sep-Nov)
30%	**10%**	**40%**	**20%**
390	130	520	260
2,160	720	2,880	1,440
3,600	1,200	4,800	2,400
1,350	450	1,800	900

- Step 4: It was assumed that existing conditions are valid for future conditions water consumption.

○ D.5 INDUSTRY

- Step 1: Locations of Existing and Future Industrial facilities were collected from MINEACOM

INDUSTRIAL PARK	District	Sector
BUGESERA	BUGESERA	GASHORA
RWAMAGANA	RWAMAGANA	MWURIRE
KICUKIRO SME PARK	KICUKIRO	GAHANGA
MUHANGA	MUHANAGA	NYAMABUYE

- Step 2: Existing and Future development plans for these facilities were collected from MINEACOM

Planned facilities	AREA (Ha)	Location (Sector, District)	Planned (m^3/month)	Existing Consumption (m^3/month)
150	330	GASHORA, BUGESERA	100,000	0
80	80	MWURIRE, RWAMAGANA	97,000	0
30	43	GAHANGA, KICUKIRO	43,200	288
60	63	NYAMABUYE, MUHANAGA	30,000	200

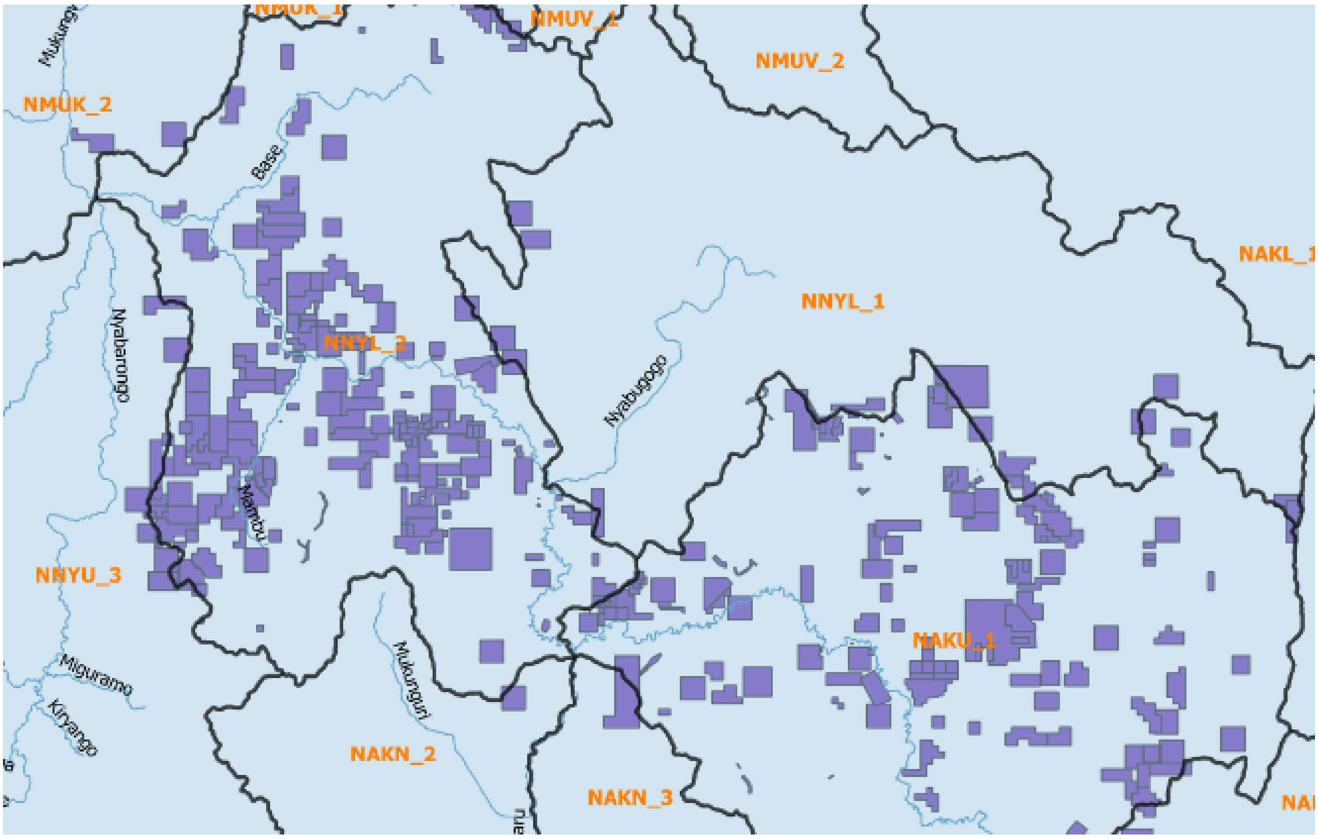
- Step 3: Planned water consumption values for these facilities were collected from MINEACOM

- Step 4: Statistical process (linear regression) was used to calculate corresponding water consumption in existing and future conditions

2020	2030	2050	Existing Consumption	2020	2030	2050
(m^3/month)	(m^3/month)	(m^3/month)	(TCM/year)	(TCM/year)	(TCM/year)	(TCM/year)
0	1,333	2,000	0	0	16	24
0	1,293	1,940	0	0	16	23
576	576	864	3	7	7	10
1,000	4,000	6,000	2	12	48	72

D.6 MINING

- Step 1: Locations of Mining Concessions were collected from RMPGB



- Step 2: Existing water consumption within level 2 catchments were collected from NIRAS report.

	Water Consumption: 6-Month period
NNYL_2	**89,297**
NAKU_1	**102,755**

- Step 3: Production capacity of these facilities were collected from the Ministry of Environment web-site.

District	**Sector**	**Monthly production capacity (t)**	**Monthly production capacity (t)**
Gakenke	Nemba	1.5-5.5	5.5
Muhanga	Kabacuzi	0.7 - 1.7	1.7
Gakenke	Ruli	3-5	5.0
Kamonyi	Rukoma	0.5	0.5
Rulindo	Shyorongi	30KG	0.5

- Step 4: Statistical process (linear regression) was used to calculate corresponding water consumption in existing and future conditions

Existing Monthly water consumption (m3/month)	**Subcatchment**	**2020**	**2030**	**2050**
6,201	1	6,821	7,503	8,254
1,917	2	2,108	2,319	2,551
5,637	4	6,201	6,821	7,503
564	4	620	682	750
564	4	620	682	750

(13) ANNEXURE E: HOUSEHOLD SURVEY

A household survey was conducted according to an approved methodology with permission by the National Institute of Statics in Rwanda (NISR). The survey was conducted of a representative ample of households within each catchment and according to the objectives as set out in the terms of reference of this assignment. This section set outs briefly the methodology for the survey. The findings of the survey are included in various chapters in this report, as well as the consolidated findings in the Household Survey Report.

This section describes methodology used under a scientific approach from the sampling method and techniques to the analysis and report publication. The different phases are as follows:

Sampling techniques

It was not possible to collect and analyse all data from every possible case or group member in all catchments. It was therefore imperative to select a sample that provided a representative selection of the catchment areas especially beneficiaries of LVEMP II project.

Target Population

The target population for this study was all people who have activities and beneficiaries of LVEMP project

Sample size

The simple size for this survey is 400 households in each catchment. This means that 800 Households have been visited during filed data collection combined from both catchments. The sample size has been discussed and agreed during the inception report stage.

Sample selection and distribution

Based on the nature of the study, purposive sampling was used to select 400 respondents because it provides a range of alternative techniques to select samples that will help to meet the objectives of the study. The techniques also were used to select the Districts to be covered by the study. Sampling techniques (stratified random sampling) was applied and based on total number of population for each district and district is considered as a stratum. Our study area was concentrated mostly in sensitive area where LVEMP II project established interventions and rehabilitation projects such as cells crossing or located in the vicinities of main rivers, wetlands, swamps, lakes and other areas like where the project created terraces etc. To identify people to interview, LVEMP field technicians directed our surveyors where they have beneficiaries.

Therefore, there exist some bias in the selection of respondents because all respondents were beneficiaries of the LVEMP II project, but this bias was mitigated by the triangulation of methods, where in addition to questionnaire distributed to beneficiaries of the LVEMP II project, we have also used the key in-depth interview with key informants as well as the observation technique by observing the realities on the ground.

Training of survey team

The purpose of the training was to familiarize and make familiar with surveyors of the field tools with the Computer Assisted Personal Interview (CAPI) questionnaires in tablets and allow the data programming team to develop and finalize the necessary data entry programs and templates using the CSPro software. The training sessions also gave them an opportunity to assess the quality of questionnaires.

The training session covered the following activities:

1. Familiarize all surveyors with all questions in questionnaire, including their purpose, range of potential answers, how to prompt if needed, sensitiveness of the questions if any, and so on;
2. Accustom all surveyors with the use of tablets and CSPro software along data collection;
3. Test the surveyors for their learning ability, knowledge, interviewing skills, and so on;
4. Decide how to resolve confusing issues related to interviewing, when and how to prompt.

Data collection

Data collection activity was conducted in period from 14th -25th August 2017 by 20 surveyors and 4 supervisors. Before collecting data, team of surveyors presented to the sector the following documents: (1) introduction letter given by REMA and (2) survey VISA given by NISR.

Data Cleaning and Processing

CAPI data collection was done simultaneously with data quality checks using CsPro collect, thus involving checking the accuracy and consistency of the collected data and preparing the data sets for analysis. The first step was focused on data verification entailing a set of pre-specified checks, including range, outliers and invalid values for categorical variables. The list of invalid entries was examined for correction. At the second step, the checks for logical consistency skip patterns, missing values and inapplicable answers was done.

Data analysis

For data analysis, the survey datasets were transferred from CsPro collect application to SPSS. The analysis was based on producing frequencies and cross tabulations based on the final datasets.

Livelihoods

The livelihoods information gathered during the household survey link up with catchment management in the sense that the characteristics described during household survey as well as the problems stated by the respondents helps to identify the appropriate strategies to be used in the catchment management. For example, a certain number of households ascertained that there is malaria in the catchment, this information can form the basis to know which kind of strategies that can be undertaken to face that problem. The information on lack of mechanism to manage solid waste will help to take appropriate measures in line with waste management.