REPUBLIC OF RWANDA
MINISTRY OF ENVIRONMENT

RWANDA WATER AND FORESTRY AUTHORITY

MUVUMBA MULTIPURPOSE DAM DEVELOPMENT PROJECT


ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR MUVUMBA MULTIPURPOSE DAM PROJECT

March, 2017

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CHAPTER 1 INTRODUCTION

1.1. Background

At national legislation level, the constitution of Republic of Rwanda adopted in 2003 ensures the protection and sustainable management of environment and encourages rational use of natural resources. The most applicable legislation of environment is the "Organic Law on Environmental Protection" that regulates the protection of environment in Rwanda and this organic law was introduced in 2005.

The principle of sustainability and sharing resources equitably between the present and future generation must be respected. To achieve this principle, EIA is needed for projects which can harm our environmental. Chapter IV of the Organic Law Article 67 clearly shows that EIA is needed and must be compulsory to these projects. Construction of dams is among projects that EIA is mandatory.

This report contains the findings of Environmental and Social Impact Assessment study for the **Nyagatare water resources development project in Muvumba river basin project. For this project,** Muvumba Dam will be constructed and this dam will be located in the Eastern Province, Nyagatare District, stretching across Karama and Rukomo Sectors, but the reservoir will extend to Rukomo, Karama nad Gatunda Sectors.

The proposed dam will comprise of the construction of mostly earth and concrete dam across the Muvumba River in a narrow section of the valley with a check dam to control sediment in the upstream of the main dam reservoir.

1.2.PROJECT DEVELOPER

The developer of this project is the Government of Rwanda through the Rwanda Natural Resources Authority (RWFA), later changed to Rwanda Water and |Forestry Authority. The Government of Rwanda through its Ministry of Natural Resources that changed to the Ministry of Environment (MoE) is investigating the feasibility of Nyagatare Water Resources Development Program. The scheme involves water harvesting, storage and distribution for servicing and generation of Hydro Electric Power generation. It is in this background that On October 31,
2013 the Korea International Cooperation Agency (KOICA) and Rwanda Natural Resources Authority signed a Record of Discussion for the project “Feasibility Study and Detailed Design of Nyagatare Water Resources Development”. The Rwanda Natural Resources Authority in partnership with the Korea International Cooperation Agency (KOICA) have initiated a project for the development of the Nyagatare Water Resources Development in Muvumba basin and K-Water have been engaged to conduct a feasibility study.

1.3. PURPOSE OF THE ESIA

Environmental and Social Impact Assessment (ESIA) is being used worldwide as a planning and management tool with the objective of minimizing the harmful consequences of development. It is a process in which a range of environmental, social and economic issues are taken into consideration to determine whether environmental constrains should be put on project or whether a project should not be allowed to proceed at all. EIA helps in better planning and it can be used as key support tool for sustainable development.

During this study, positive and negative impacts that will be caused by the construction of this dam will be assessed, mitigations measures will be proposed for negative impacts and environmental management plan will be proposed

1.4. SCOPE AND ESIA STUDY FRAMEWORK

A scoping study was undertaken at the beginning of the study process. This exercise involved consulting with the RWFA and K-WATER personnel; key stakeholders including District, Sectors, cells Officers and the community. The scoping study included also a short field/ site visit to have a general overview of the physical, biological, socio-economic environments and their interaction for the purpose of drawing main anticipated impacts of the project on general environment.

Through the scoping study, which entailed an initial and broad assessment of the project, policies, regulations and baseline data, a scope for the study was generated including geographical coverage, stakeholders (interested and affected parties), significant impacts (areas of study) and the levels of detail in each particular impact study.

The following scoping techniques were used to determine the scope study of the environmental impact assessment study including the public consultation: Site visits; Questionnaire; Checklists; Stakeholders identification and Literature review and documentation.

The terms of reference also helped in shaping the scope as well as the methodology to be applied in assessing the impacts and the scoping exercise resulted in the formulation of an initial Environmental Impact Identification.

1.5. APPROACH AND METHODOLOGY

To achieve the objectives for this study, literature review including published journals, papers, legal documents, reports and research papers were consulted. This consisted of using secondary data from books, articles report and other necessary documents and this was done through desk research.

To get responses of our questions, we conducted formal interview (Structured and semi-structured interviews) to different groups that this project will affect. Different stakeholders

were also consulted. Participatory approach with focused interviewers and observation were used.

a. Literature Review:

A literature review was conducted to determine the existing conditions within the study area and to identify habitats and species of potential importance that may be affected by the Project. The literature review included feasibility studies, reports undertaken in the area, academic studies, vegetation maps and land use maps, Nyagatare district development plans and integrated management of critical ecosystems (IMCE) reports.

b. Site visits and observations:

Following a literature review of available ecological data characterizing the project site, field survey including photographs taking was undertaken to subproject area to get direct knowledge of the area and keep informed and make a relationship with the information gathered from secondary data.

c. Habitat Survey:

During habitat survey in the study area, a special attention was paid to those areas, which will be directly impacted by the proposed project.

d. Global Flora & Fauna Survey:

The terrestrial floral and faunal survey recorded major plant and animal species and their relative abundance (Species richness, relative abundance, periodic and rare) in each habitat type within the study area. Efforts were also made to find the existence of protected species known to be threatened

Chapter 2. LEGAL, INSTITUTIONAL AND PLANNING FRAMEWORK

The purpose of this chapter is to describe the main regulatory texts and standards relating to the protection of the environment applicable to this project project, as well as to provide an overview of the main institutions concerned by the projects.

This chapter summarizes the applicable environmental legislative and regulatory context in Rwanda, and notes the international requirements including applicable World Bank Environmental and Social Safeguard Policies.

The project complies with Rwanda environmental laws and regulations. The Ministerial order 2008 classified the "Nyagatare water Resources development project" as a Full EIA category project. In addition to the requirements of national legislation, this project must also comply with applicable World Bank Safeguards requirements. The project triggered the following World Bank policies: Environmental Assessment; Natural Habitats; Indigenous Peoples; Involuntary Resettlement; Physical Cultural Resources; Safety of Dams; and International

Waterways. It also triggered all convention and treaties ratified by GoR. Full EIA was carried out following terms of reference (TOR) that were issued by the RDB.

2.1. International conventions and treaties

Rwanda has ratified and signed a number of international conventions and protocols on or related to environment (table 1) and has taken further steps to confirm his commitment in the area of environmental and natural resources management. Rwanda is an active participant in major international multilateral conventions relating to environmental governance, most notably the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention to Combat Desertification and Drought (UNCDD).

Table 1 ***Conventions and treaties ratified or signed by the GoR***

Conventions or Protocol , Date of signature and	**Approved by law and date signed/ratified by GoR**	**Overview**	**Relevance to Project**
International convention on biological diversity and its habitat signed in RIO DE JANEIRO in BRAZIL, June 5th ,1992	Ratified by Presidential Order No 017/01 of March 18th,1995	The Convention on Biological Diversity (CBD) is an international legally binding treaty with three principal goals: conservation of biological diversity (or biodiversity); sustainable use of its components; and fair and equitable sharing of benefits arising from genetic resources. Principle No. 10 of the declaration underscore that environmental issues are best handled with participation of all concerned citizens at all the relevant levels. At the national level, each individual shall have appropriate access to information that is concerning environment that is held by public	Issues pertaining to biodiversity conservation and sustainable natural resource management are fully applicable to Muvumba Dam Project and undergo assessment specifically within Chapters 4 and 5.
CARTAGENA protocol on biosafety to the convention of biological biodiversity signed in Nairobi and in New York , Nairobi from May 15, to 26, 2000 and in New York from June 5, 2000 to June 4, 2000	Law N°38/2003 of December 29th, 2003		

London (1990) and Copenhagen Amendments to the Montreal Protocol (1992),			
KYOTO protocol to the framework convention on climate change , March 06th, 1998 ,	Law N° 36/2003 of December 29th, 2003	Authorities. States shall encourage and facilitate public participation by making information widely available. The Kyoto Protocol (a Protocol to the UN Framework Convention on Climate Change (UNFCCC)) aims to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Project will comply with all national standards for GHG emissions in order to contribute to Rwanda targets set in line with the adoption of the Kyoto Protocol.	

BASEL convention on the control of transboundary movements of hazardous wastes and their disposal, May 22nd, 1989	Presidential Order No 29/01 of August 24th, 2003	The Basel Convention was designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries. It does not, however, address the movement of radioactive waste. The Convention is also intended to minimize the amount and toxicity of wastes generated, to ensure their environmentally sound management as closely as possible to the source of generation, and to assist LDCs in environmentally sound management of the hazardous and other wastes they generate The Project will comply with all national and international standards for hazardous waste generation and management.	The Project will comply with all National and international standards for hazardous waste generation and management. Issues pertaining to hazardous waste generation are applicable to the Project and are addressed in Chapter 10.
		Issues pertaining to hazardous waste generation are applicable to the Project and are addressed in Chapter 10.	

MONTREAL international convention on substances that deplete the ozone layer, 1987	Presidential Order N^{o} 30/01 of August 24th, 2003	The Montreal Protocol (a Protocol to the Vienna Convention on Ozone LayerProtection) is designed to protect the ozone layer by phasing out the production of numerous ozone depleting substances.	Through limitation of the release of CO_2 containing ozone depleting substances, the Project will support Rwanda's contribution toward the anticipated recovery of the ozone layer.
Convention Concerning The Protection of World Cultural and Natural Heritage (1972).....		The Convention Concerning the Protection of World Cultural and Natural Heritage is the precursor to the establishment of UNESCO World Heritage Sites as a place (i.e. natural or built environment) that is listed by the UNESCO as of special cultural or physical significance	Rwanda has UNESCO World Heritage Sites. However, the Project will have no interaction with these sites. As such, requirements under the convention will not be triggered.
RAMSAR international convention on wetlands of international importance, especially as waterfowl habitats, February 2nd,1971	Law N^{o} 37/2003 of December 29th, 2003	Formally known as the Convention on Wetlands of International Importance, especially as Waterfowl Habitat, the Ramsar Convention is an international treaty for the conservation and sustainable utilisation of wetlands.	Wetlands surrounding Muvumba River are wetland of importance for biodiversity and is one of the last wetlands remaining within the Nyagatare District. As such, potential Project interactions are discussed in Section

BONN Convention on conservation of migratory species of wild animals, June 23rd, 1979	Law Nº 35/2003 of December 29th, 2003	The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range.	Issues pertaining to Project interactions with migratory species undergo assessment within Chapter 5.
Washington agreement on international trade in endangered species of Wild Flora and Fauna, March 3rd,1973	Presidential Order Nº 211 of June 25th , 1980	The aim of Convention on International Trade of Endangered Species of Flora and Fauna ('CITES') is to ensure that international trade in specimens of wild animals and plants does not threaten their survival.	Issues pertaining to biodiversity conservation are fully applicable to the Project and undergo assessment within Chapter 4.

However, the ratification and implementation of the above convention and protocols were very limited up to 2003. The policy documents on environment were scattered and defined only the management sector of some fields where environment was taken into consideration. The environmental issues were in the portfolio of the Ministry of Agriculture (MINAGRI). Since 2003, most of the sectoral policies and legislation on environment and natural resources have been under review. Environmental policies and laws have been repealed and new ones enacted in line with the Constitution of 2003. The environmental issues were transferred to the Ministry of Environment (MoE) and the Rwanda Environment Management Authority (REMA) was established in 2005.

As part of the implementation of the Rio Conventions, the GoR developed national strategies and action plans for each convention: the National Biodiversity Strategy and Action Plan (NBSAP) 2003, the National Plan of Action (NAPA) for climate change adaptation (2006/7), and the National Action Plan (NAP) for combating desertification. These strategies and action plans reflect national priorities for the ENR sector that are in line with Rwanda's second phase Economic Development and Poverty Reduction Strategy (EDPRS II) as a medium-term framework for achieving the country's long-term development aspirations as embodied in Rwanda Vision 2020, the seven-year GoR programme, and the Millennium Development Goals (MDG) priorities.

In addition, Rwanda participates in regional initiatives related to environment protection and management such as the Nile Basin Initiative or the Lake Victoria Biodiversity Program.

2.2. National Regulatory Framework

The laws and regulations of Rwanda were reviewed to identify those relevant to the proposed development. These laws have been sorted to provide a timeline to the project proponent as to when they are most crucial during the project cycle.

In the Constitution of the Republic of Rwanda of June 4th, 2003 as amended to date, article 49 states that every citizen is entitled to a healthy and satisfying environment. The law determines the modalities for protecting, safeguarding and promoting the environment. Different policies and laws from the constitution, the Vision 2020, the PRSP and EDPRS and the National Decentralization Policy (the "Decentralization") take into account environmental aspects and are in accordance with international policy framework such as the MDG, the Convention on Biological Diversity (CBD), etc.

The Environmental organic Law, 2005 and the constitution 2003 are the main law and legislation respectively for ESIA studies. The law grants the REMA enforcement and standards-setting powers, and the power to ensure compliance with the Rwanda environmental assessment requirements/procedures. Additionally, the REMA is required to create environmental awareness and build environmental capacity among all sectors. The

REMA, including its District Offices, is also vested with the power to determine what constitutes an ‘adverse effect on the environment’ or an activity posing a serious threat to the environment or public health, to require environmental assessments and environmental management plans of an undertaking, and to regulate and serve enforcement notices for any offending or non-complying undertaking. The REMA is required to conduct monitoring to verify compliance with given approval/permit conditions, required environmental standards and mitigation commitments. Furthermore, different sector policies have been prepared and implemented including environmental policy, agriculture policy, water policy, energy policy, land policy, and forestry policy.

Table 2 Key environmental policies of Rwanda

Law/policy	Institution/date of adoption	Key areas
National environmental policy	MINIRENA, REMA, RDB November 2003	The overall objective is the improvement of people's wellbeing, the judicious utilisation of natural resources and the protection and rational management of ecosystems for sustainable and fair development Sets out specific objectives as well as fundamental principles for improved management of environment, both at the central and local level, in accordance with the country's current policy of decentralization and good governance Integrates environment aspects in all development policies, programmes and planning for all works, activities and projects at national, district and local levels with total participation of the population
National energy policy and strategy	MININFRA EWSA 2011	Creates conditions for the provision of sufficient, safe, reliable, efficient, cost-effective and environmentally appropriate energy services to households and to all economic sectors on a sustainable basis. The objectives are to support national development through: a) ensuring the availability of sufficient, reliable and affordable energy supplies for all Rwandans;
		b) promoting the rational and efficient use of energy; c) establishing environmentally sound and sustainable systems of energy production, procurement, transportation, distribution and end-use.
National land policy, February, 2004	MINIRENA, RWFA	Puts emphasis on appropriate land administration systems as a key element of land tenure security by providing the possibility of registering and transferring land and also the possibility of investment in land. Highlights key principles of appropriate land use and land management.

Land Organic Law n° 08/2005	MINIRENA RWFA	Determines the use and management of land in Rwanda
Law **N°49/2018 of 13/08/2018** determining the use and management of water resources in Rwanda	MoE,2018	This Law determines the use and management of water resources in Rwanda. Puts in place the use, conservation, protection and management of water resources regulations. Stipulates the modalities of protecting and appropriately using water resources, in respect of the natural balance, as they are of general interest and constitute an imperative duty for all, notably the state, the local communities, the private sector, the civil society and the citizens.
Law **N°48/2018 of 13/08/2018** on environment	MoE,20218	Determines the modalities of protecting, conserving and promoting the environment in Rwanda.
National water policy	MININFRA, EWSA	The mission is to create favourable conditions for fair and sustainable access for the population (men, women and children) to water and sanitation infrastructure and for the development of natural resources. The overall objective of the sector policy is to improve the living conditions of the population through optimal use of water resources and access to water and sanitation services.
National forest policy	MINIRENA 2004	Established Provincial Forest Commission to promote and oversee forestry activities which meet, on a sustainable basis, the population's needs for wood and other forest products and services. The main targets are forest cover to comprise at least 30 % of the national territory and to have at least 85 % of farmland under agro-forestry by 2020.
Law **N° 32/2015 of 11/06/2015** relating to expropriation in the public interest	April, 2007, MINALOC, RWFA	Determines the modalities and the procedures relating to expropriation in the public interest. States that only the Government shall carry out expropriation. Expropriation as provided for in this law shall be carried out only in the public interest and with prior and just compensation. Every project, at any level, which intends to carry out acts of expropriation in the public interest, shall provide funds for inventory of assets of the person to be expropriated and for just compensation on its budget.

Law No.17/2010	MINALOC	Establishing and organising the real property valuation profession in Rwanda.
National policy of decentralization	2006, MINALOC	Recreated Districts, sectors and cells to include environmental and land officers within the District organigram to help with planning and coordination of environmental and land management activities at District level.
Ministerial Order **N₀ 001/2019 OF 15/04/2019**	MoE,RDB	**Establishing The List Of Projects That Must Undergo Environmental Impact Assessment, Instructions, Requirements And Procedures To Conduct Environmental Impact Assessment**
Laws N° 005/2008 and **N° 007/2008** of August 15th, 2008	MINIRENA REMA 2008	Ministerial orders establishing modalities of inspecting companies or activities that pollute the environment and the list of protected animal and plant species
Law No. 001/2006 of 26/09/2006	MINIRENA RWFA September 2006	Ministerial order determining the structure of land registers as well as the responsibilities and the functioning of the District Land Bureau
Guidelines and procedure for EIA	REMA, 2006	Developed to operationalize the provisions of the Organic Law to make EIA mandatory for all development projects. Aim to serve agencies and individuals taking part in the EIA process.

a. National Environmental Policy

The national environmental policy adopted by the Cabinet in November 2003, has the overall objective to improve human well-being, the judicious utilization of natural resources and the protection and rational management of ecosystems for a sustainable development. The policy seeks to achieve this through improved health and quality of life for every citizen and promotion of sustainable socio-economic development through a rational management and utilization of resources and environment, integrating environmental aspects into all development policies and activities carried out at national, provincial and local level. These goals shall be achieved through full participation of the population, conservation, preservation and restoration of ecosystems and maintenance of ecological and systems. Hence, the policy requires that projects or policies, plans and programmes likely to have significant adverse ecological or social impacts undertake environmental studies before their implementation.

The overall goal of this policy is the promotion of sustainable economic and social development mindful of the needs of future generations. The EIA is one of the vital tools to ensure environmental quality and resource productivity on a long-term basis. This is also reaffirmed in the Rwanda environmental organic law, which makes EIA a requirement for eligible projects like the proposed micro hydropower projects (Chapter IV of the Rwandan Environment Organic Law, 2005).

b. Energy Policy

The aim of the energy sector policy is to efficiently contribute to the growth of the national economy and thereby improve the standard of living for the entire nation in a sustainable and environmentally sound manner.
The mission of the energy sector is to create conditions for the provision of safe, reliable, efficient, cost-effective and environmentally appropriate energy services to all sectors on a sustainable basis.

By fulfilling its vision and mission, the energy sector will contribute to socio-economic development, and in the long-term to poverty reduction.

The national energy policy objectives are to ensure availability of reliable and affordable energy supplies and their use in a rational and sustainable manner in order to support national development goals. The national energy policy therefore aims to establish

efficient energy production, procurement, transportation, distribution and end-use systems in an environmentally sound and sustainable manner.

The objective of the energy policy is to achieve the high rates of projected GDP growth of about 8.1% by 2013 using linear regression on the existing data from the Ministry of Finance and Economic Planning (MINECOFIN). At the same time, the policy aims at providing affordable energy access for mineral processing, agro industries, increased tourism and

electricity access for over 50% of the population by 2017. A key component of the energy policy is cross border electricity export to neighbouring countries after supplying the local demand. The least cost accelerated electricity generation mix of an additional 1,000 MW by 2017 shall be met from indigenous resources particularly hydropower, geothermal and methane gas. The basis of the strategy is to work towards an "energy transition" in which energy is more efficiently used and towards an energy mix that promotes the use of indigenous renewable energy resources to progressively displace biomass.

c. Natural Water Resources Management Policy

Water policy aims at fair and sustainable access to water, improvement of the management of water resources, etc. through reforestation of hillsides and water catchment areas. The policy also needs to adopt a holistic approach to the management of water resources and integrate other related policies including forest, wetlands, agricultural and land policies.

Water policy is relevant to this proposed project as some of the project activities will be undertaken in areas with water resources. Furthermore, one of the key project inputs is water, which is governed by the policy.

d. Vision 2020 and EDPRS II

The Energy Sector Policy has planning tools such as the second phase Economic Development and Poverty Reduction Strategy of Rwanda (EDPRS II 2012-2017), which is the medium-term programmatic framework for achieving the country's long-term development aspirations as embodied in Rwanda Vision 2020, as well as the intermediate targets in the 2015 MDGs.

In the Vision 2020, protection of the environment is amongst the priorities of Rwanda. According to the programme negative effects caused to the environment are to be mitigated by socio-economic activities. To this effect, every individual including the corporate world should make efforts in ventures that will bring sound development aimed at improving Rwanda's per capital GDP. Although national development is desired, any such development should be done in a sustainable manner as provided for in Rwanda's Environmental Policy.

In the EDPRS II, infrastructure and particularly energy development, plays a crucial role. The Government has planned to produce 1,000 MW and connect 50% of the population to electricity by 2017. The National Energy Policy supports each of the EDPRS flagships: Growth for Jobs and Exports, Vision 2020 Umurenge, and Governance. These flagships serve as a device to prioritise actions by the GoR, mobilise resources for development and improve policy implementation through coordinated interventions across different sectors.

However, the EDPRS II also highlights the environment priorities as major issues and has made efforts to focus on the environment and all key sectors that have at least one environmental indicator among their key performance indicators.

e. Provisions for Expropriation in the Public Interest

Law No. **N° 32/2015 of 11/06/2015** determines the procedures relating to expropriation of land in the interest of the public. Article 3 of the law stipulates that only the government has authority to carry out expropriation. Article 4 states that every project, which intends to carry out acts of expropriation in the public interest shall provide funds for inventory of assets of the person to be expropriated and for just compensation on its budget. Articles 8, 9 & 10 of this law clarify the institutions involved in the expropriation.

The following institutions are responsible to initiate expropriation: the Executive Committee at District level, in case the activities concern one District; the Executive Committee at the level of the City of Kigali, in case the activities concern more than one District in the boundaries of the City of Kigali; the relevant Ministry, in case the planned activities concern more than one District or are to be realised at national level.

Law No.17/2010 of 2010 establishes and organizes the Real Property Valuation Profession in Rwanda. It provides the registration of land valuers in Rwanda and conditions for registration. The law also allows the Government to conduct valuation when mandated by their government institutions. Articles 27, 29, 30 and 31 of the law deal with valuation methods and stipulate that the price for the real property shall be close or equal to the market value. Land values could also be compared country wide. Where comparable prices are not available to determine the value of improved land, the replacement cost approach shall be used to determine the value of improvements to land by taking real property as a reference. The law also allows the use of international methods not covered by the law after approval of the Institute of Valuers.

2. 3. World Bank requirements

a. Project Categorisation

The World Bank's Operational Policy 4.01 on Environmental Assessment (EA) requires environmental screening of projects to determine the appropriate extent and type of environmental assessment needed. The World Bank classifies proposed projects into categories depending on the type, location, sensitivity, and scale of the project, as well as the nature and magnitude of its potential environmental impacts.

Using World Bank criteria, this project is considered to be a Category A project because it has the potential to cause adverse impacts on the community and on the environment. The Project will permanently alter a considerable section of the Muvumba River. The Project will impact designated Muvumba offshore which is also registered as an important bird area. It will create diverse types of impacts. However, it is considered feasible to mitigate and manage the majority of impacts associated with the project through appropriate environmental and social management together with the monitoring to be specified in the ESMMP and related plans that will be the outcome of this ESIA process.

b. World Bank safeguard policies and requirements

International environmental and social safeguard standards are typically embodied by the World Bank environmental and social safeguards operational policies. A summary of the key objectives of relevant safeguards policies are provided in the table below.

Table 3 Environmental and social safeguard operational policies with Reference to the Planned Dam Projects

OP No.	Summary of Safeguard policy	Its implication to Muvumba Dam Project
OP 4.01	**Environmental Assessment:** Provides the framework for World Bank environmental safeguard policies and defines the project screening and categorization in order to determine the level of EA required. For category A projects, like this one, the policy requires public consultation and disclosure to be undertaken as part of the EA process. The Policy sets out requirements to comply and report on implementation of any environmental management plans. The planned works on the multi-purpose Muvumba dam will likely be major and trans-boundary hence, the EIA will be required to recommend measures that will be needed to prevent, minimize, mitigate, or compensate for such adverse impacts and improve environmental performance which qualifies the projects to be Category A type.	The planned Muvumba Dam Project fall under those projects that requires an EIA to be prepared and approved before their implementation. Muvumba Dam Project is triggered by this safeguard policy
OP 4.04	**Natural Habitat:** Outlines the World Bank policy on biodiversity conservation taking into account ecosystem services and natural resource management and use by project affected people. Projects must assess potential impacts on biodiversity. The policy	Natural habitats will be impacted by the planned project especially at the borrow pits and quarry sites.
	strictly limits circumstances under which conversion or degradation of natural habitats can occur and prohibits projects which are likely to result in significant loss of critical natural habitats.	

OP 4.09	**Pest Management:** In appraising a project that will involve pest management, the Bank assesses the capacity of the country's regulatory framework and institutions to promote and support safe, effective, and environmentally sound pest management. As necessary, the Bank and the borrower incorporate in the project components to strengthen such capacity.	At this stage is not known the kind of agro-chemicals shall be applied on the project, hence this study cannot commit to assess whether this safeguard will be triggered. This should be explored in the detailed before applying those agro- chemicals.
OP 4.11	**OP 4.11 Physical Cultural Properties:** Sets out the World Bank requirement to avoid or mitigate adverse impacts resulting from project developments on cultural resources.	This detailed study did not encounter any Information on physical cultural resources in the area of the project.
OP 4.12	**Involuntary Resettlement:** Provides the World Bank requirements for managing involuntary resettlement including avoidance where possible. Where the acquisition of land or other assets is necessary, the policy sets out requirements for participation in resettlement planning, mandates compensation for assets at replacement cost and expects to see that incomes restored to what they were prior to displacement. and standards of living of affected persons are improved or at least	The Project will involve land uptake for project infrastructure and associated facilities which makes the need for a RAP study apparent. Muvumba Dam Project is triggered by this safeguard policy.
OP 4.36	**Forests:** Describes the World Bank objective to reduce deforestation, enhance the environmental contribution of forested areas, promote afforestation, reduce poverty, and encourage economic development.	The project will impact on some forested areas hence; it triggers this safeguard policy instrument. The mitigation measures will be proposed and implemented to reduce or offset the impacts of deforestation

OP 4.37	**Safety of Dams:** Requires competent design and construction supervision to implement dam safety measures through the project cycle. This policy recommends any measures necessary to strengthen the institutional, legislative, and regulatory frameworks for dam safety programs. The Bank distinguishes between small and large dams where large dams are 15 m or more in height. Dams that are between 10 and 15 m in height are treated as large dams if they present special design complexities. Dams fewer than 10 m in height are treated as large dams if they are expected to become large dams during the operation of the facility. Such large dams require amongst others, that preparation and implementation of detailed plans ensure safety aspects. The EIA is one of the tools that can therefore formulate some of the safety aspects in large dams	Muvumba dam have heights above 15m and therefore qualify as large dam, as per OP 4.37. Therefore the proposed Muvumba dam project is triggered by this operation policy.
OP 7.50	**Projects on International Waterways:** Requires notification to other riparian's of planned projects that could affect water quality or quantity, sufficiently far in advance to allow them to review the plans and raise any concerns or objections.	Based on this Policy provisions above, the planned Muvumba Dam will be on Muvumba river systems that follow between Rwanda and Uganda, they also flow through more than two states. In addition, the river systems form part of the larger trans- boundary Nil River. This further justifies the need for an ESIA to be conducted on the proposed multipurpose dam projects.
OP 7.60	Projects in Disputed Areas: Projects in disputed areas may raise a number of delicate problems affecting relations not only between the Bank and its member countries, but also between the country in which the project is carried out and one or more neighboring countries.	The project areas for the planned dam site are not disputed, and therefore, this policy will not be triggered.

2.4. Institutional Arrangements

The proposed Muvumba Multipurpose Dam will be implemented by the Rwanda Water and Forestry authority (RWFA) with the involvement of Government Ministries, Departments and Agencies with major stakeholder interests and relevant responsibilities. As well private sector companies will play a role, especially with regards to construction. Many of the institutional arrangements for this Project will reflect existing relationships and responsibility that RWFA has with entities on other dams or water related projects. The roles and responsibilities are described below for RWFA, the Project Steering Committee and entities that are closely involved with environmental management and permitting, land acquisition and construction and operation.

a. Ministry Of Environment

Ministry of Natural Resources (MINIRENA) is responsible for formulating the policy related to environment and natural resource management including water resources, forests, mining, and land management. Its role is to provide policy guidance for these sectors, ensure the protection of the natural resources and environment, and provide oversight for the Rwanda Natural Resources Authority (RWFA) and REMA (Rwanda environmental Management Authority).

It ensures the follow up and evaluation of policies, strategies as well as environment protection. Furthermore, it drafts bills and establishes norms and practices for efficient land management and rational exploitation of the environment and water resources.

b. Rwanda Environmental Management Authority

Rwanda Environment Management Authority (REMA) created by law No. 16/2006 of 3rd April 2006, is the official organ in charge of implementing environmental policy. It coordinates and oversees all aspects of environmental management for sustainable development. Even though the agency is under the Ministry of Natural Resources, it has a legal status of financial and administrative autonomy.

REMA is responsible for regulating the environment and ensuring the implementation of government policies on the environment. Using its national and district based staff; REMA can monitor implementation of environmental management plans (EMP). As necessary, REMA Conducts monitoring to verify compliance with given approval or permit conditions, required environmental standard and mitigation commitments.

c. Rwanda Water and Forestry authority (RWFA)

RWFA is an Authority under the Ministry of Environment that heads the management, Protection of promotion of natural resources including land, water. The Authority supervises and ensures the implementation of all government policies related to the management, protection and regulations of Water and forestry resources.

RWFA attaches great importance to environmental issues and embraces principles of sustainable development in all its undertakings. Like any other development venture, construction of the proposed Muvumba Dam and operation can hardly be without any impacts on the environment whether positive or negative. However, RWFA believes that what is cardinal is to systematically identify all potential impacts and put measures in place aimed at either minimising to the required level or enhancing impacts through an elaborated Environmental Management and Monitoring Plan that covers all stages of project development.

d. Ministry of Agriculture and Animal Resources

The Mission of Minister of Agriculture and Animal Resources (MINAGRI) is to initiate, develop and manage suitable programs of transformation and modernization of agriculture and livestock to ensure food security and to contribute to the national economy. The Vision of Minister of Agriculture and Animal Resources is to modernize Agriculture and Livestock to achieve food security by using irrigation technologies.

e. Ministry of Infrastructure and Energy, Water and Sanitation Authority

The main institutions in electricity supply for Rwanda are the Ministry of Infrastructures (MININFRA) and the Electricity, Water and Sanitation Corporation (WASAC) and Rwanda Energy group Limited (REG) as a public institutions. MININFRA is responsible for policy development, advisory and monitoring. REG is the national company responsible for developing infrastructures at national level including the development of transmission lines and rural electrification programmes while as WASAC is in charge of production, transmission and distribution of water and in the country. It has as mission to create conditions for the provision of sufficient, safe, reliable, efficient, cost-effective and environmentally appropriate water and sanitation services to households and to all economic sectors on a sustainable basis.

f. Rwanda Development Board (RDB)

The RDB brings together all government agencies responsible for the entire investor experience. This includes key agencies responsible for business registration, investment promotion, environmental clearances, privatisation and specialist agencies, which support the priority sectors of ICT and tourism as well as SMEs and human capacity development in the private sector.
In order to facilitate investments in Rwanda and to ensure that the proposed development strives towards sustainable development. RDB's Investment Department in the

Division of Investment Promotion is responsible for ESIA permitting. The Department reviews ESIA documentation to ensure compliance with the Rwanda environmental assessment requirements and procedures.

g. Nyagatare District and Land acquisition

Various entities are involved in land acquisition. The Private Consultant will identify the lands and communities where the Muvumba Dam project may create physical and economic displacement in the Resettlement Action Plan (RAP). To produce the RAP, consultation with local community leaders, affected persons and government authorities is necessary. The ESIA team will aim to identify legitimate representatives for the acquisition of community lands. Surveys with the affected persons will be undertaken and their preferences will be reflected in the RAP, compensation for trees and crops to reflect the current market rates.

Alongside the RAP process there is the legal administration of land acquisition that must be undertaken. This entails the Project proponent communicating with the Ministry of Natural Resources and Nyagatare District to apply for land for a specific project.

The executive committee of the District is responsible to initiate the expropriation; the District Council implements the expropriation after having considered the decision of the Land Commission. With approval of the land and an interim valuation certificate to estimate compensation, the executive committee of the District will formally notify authorization to acquire the designated lands in the public interest.

Article 66 of the Environmental Organic Law specifies that at the levels of Province, City of Kigali, District, Town, Sector and Cell, Committees responsible for conservation and protection of the environment are established. Their organisation, functioning and responsibilities are determined by Prime Minister's Order. However, there is one staff at the district level who deals with conservation and protection of the environment.

h. Contract administration

The most common way of constructing a dam is for the project proponent to place a bid tender for an engineering contractor. RWFA did a competitive process for a contractor to carry out the feasibility study activities. The contractor will be responsible for feasibility study of the Muvumba dam and associated facilities. The selected contract will detail a full range of specific clauses the various national and international standards which construction must meet. The contractor will be expected to have "back-to-back" contracts, meaning they pass on their quality related obligations to any subcontractors or service providers.

In addition to the contractor, it is common for a proponent like RWFA to have an owner's engineer. RWFA will need to supervise the performance of the contractor through its various departments. The owner's engineer is a third party entity that helps with monitoring and supervision to protect the proponent's interest and ensure those contracted for construction are meeting their contractual requirements. For this Project, the owner's engineer would also be responsible for ensuring that good international industry practice is

being followed during construction. In addition to an owner's engineer, it is possible that a lender's engineer could be contracted to provide an additional monitoring role.

The operation of the dam is currently anticipated to be managed by the RWFA. The RWFA will provide more details on the management of the dam once the construction contract is completed.

5. ESIA Procedure in Rwanda

EIA studies have the direct benefit of assisting developers to incorporate environmental considerations at the planning phase and to minimise environmental risks and financial costs. Indirect benefits include beneficial circumstances created by the project. EIA is an invaluable tool for environmental management in a transboundary context. It provides a framework for promotion of efficient decision-making in project approval; enables implementation of environmental safeguards to mitigate significant negative impacts, avoid ecological damage and large-scale irreversible loss of natural resources; plays a role in information dissemination between Rwanda and neighbouring countries and widens the scope of understanding of impacts beyond national borders.

The ESIA process in Rwanda provides a justification and a basis for future international cooperation and also aids in conflict resolution concerning environmental impacts at a regional level. The World Bank has classified four categories of projects subjected to EIA depending on the type, location, sensitivity and scale of the project nature as well as the magnitude of potential environmental impacts.

Table 4 Categorization of projects subjected to EIA (World Bank, 1999)

Category A	Category B	Category C	Category FI
The project is likely to have significant adverse impacts that may be sensitive, irreversible, diverse, comprehensive, broad or precedent- setting. These impacts generally result from a major component of the project and affect the area as a whole or an entire sector. A full environmental assessment is required.	Although an EIA is not always required, some environmental analysis is necessary. The projects have impacts that are 'less significant, not as sensitive, numerous, major or diverse'. Few, if any of the impacts are irreversible and mitigation measures can easily be designed. Typical projects include rehabilitation, maintenance, or upgrades, rather than new construction.	No EIA or other analysis is required. The projects result in negligible or minimal direct disturbance of the physical environment. Typical projects include education, family planning, health and human resource development.	Involves investment of Bank funds through a financial intermediary.

An ESIA process in Rwanda includes 5 steps: (1) project application and registration, (2) screening, scoping and terms of reference, (3) SEIA study and report, (4) submission of an EIA report and (5) decision-making.

Screening enables categorisation of projects according to their Impact Level (IL)Category 1 (IL1): Full ESIA is not required. RDB advises on the appropriate environmental management measures (plan). The exercise may take 14 days from the day the project brief was received (time may be less or more depending on the nature of the project);

Category 2 (IL2): The proposed projects under this category are screened to determine whether or not a full EIA is needed. In this connection, RDB provides the developer with clear indication of the additional information required. Once this information is received, RDB will determine whether or not a full ESIA of the project is needed.
Category 3 (3): Full ESIA is required.

Ministerial order N°004/2008 of 15th August 2008 establishes the list of works, activities and projects that have to undertake an EIA. They are classified into infrastructure, agriculture and animal husbandry, works in parks and in their buffer zones and mine extraction. According to that law, dam construction falls in category 3 (IL3).

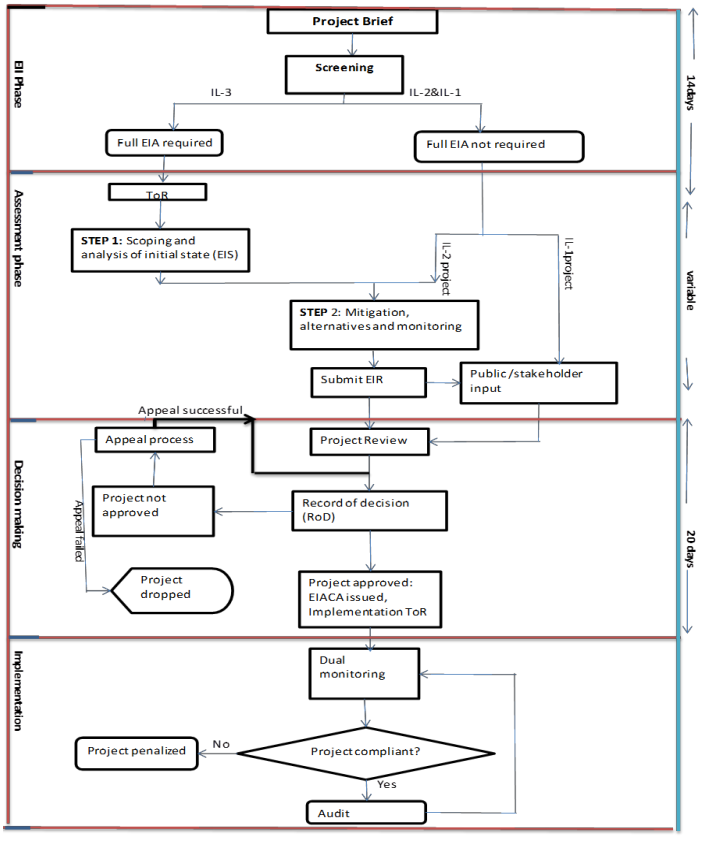

Figure 1 EIA procedure and timelines chart (adapted from REMA, 2006)

CHAPTER 3: PROJECT DESCRIPTION

3.1. Introduction

This project consists of constructing artificial lake on Muvumba River. The Name of the project is "**Nyagatare water resources development project in Muvumba river basin."**

Muvumba Dam will be located in the Eastern Province, Nyagatare District, stretching across Karama and Gatunda Sectors in Nyagatare district. The dam to be constructed at Muvumba Dam will have a maximum height 40 meters with a storage capacity of 191,000,000 m^3 spread over a considerable surface area.

It is also important to note that the filling up of the storage dam will only be completed after one year given the annual contribution of the watershed. This therefore, will be taken into account during the development of the perimeter. It is also important to note that results from the sensitivity tests indicate that in all scenarios the development option chosen remain very profitable and suitable with an internal rate of return exceeding 20% in all cases.

3.2. NATURE OF PROJECT

The government of Rwanda plans to improve the wellbeing of its society and sustainable development through the development of various man-made lakes amongst other water conservation measures within the Eastern Province. It is in this regard that the K-WATER (The Korea Water Resources Corporation), a corporation duly organized and existing under the laws of Republic of Korea, with head office at 200 Sintanjin-ro Daedeok-gu, Daejeon, 306-711, Korea was commissioned to carry out a technical study (Feasibility study) for the implementation of construction of artificial lake with storage capacity of 191,000,000 m^3 on Muvumba River.

The proposed dam on River Muvumba in Nyagatare District is the first such manmade lake for which this project has been structured. This is one of biggest dam proposed on Akagera River Basin. This dam will serve in six purposes which are: Water Conservation; Flood and Flow Regulation; Source of Water Supply; Aqua Culture; Tourism; Hydropower supply.

3.3. PROJECT RATIONALE AND JUSTIFICATION

This project is needed in this area based on water demand for different uses and energy demand in Nyagatare district. The maximum daily water consumption for human and livestock population is projected to grow from the current 24,000 m3/day to 37,700 m3 /day by the year 2022 for the whole district. Irrigation water usage, targeting some 6,200 Ha downstream of the proposed dam that can largely be irrigated by gravity is estimated as 5,000 cu.m/yr.per ha, which is equivalent to

3.59 m^3/sec at 100% irrigation. This project will contribute to solve this problem of water demand and energy demand for this district and this will contribute to its sustainable development particularly and the national development in general.

3.4. PROJECT RAW MATERIAL INPUTS

a. During Construction Phase

The raw materials that are expected to be used for the construction of the dam, irrigation networks, hydropower plant and their sources are summarized in the table below:

Raw Material	***Source***	***Mode of Delivery***
Aggregates for concrete and construction	Local approved suppliers	Road truck
Bricks	Local approved supplier	Road Truck
Cement	Local approved supplier	Road truck
Concrete blocks	To be manufactured on and offsite	Road truck
Machinery necessary in hydropower and water supply plants	International recognized and approved suppliers	Road trucks
Diesel for operation of plant and machinery	Local approved Service Station	Road truck
Equipment (e.g. Earth Moving Machinery & Equipment)	Local approved contractor	Road truck
General building materials (e.g. timber, polythene sheeting, brick force and mesh reinforcement, pipes, paint, etc.)	Local approved suppliers	Road truck
Lateritic soils (for construction e.g. access roads)	Approved borrow pits / quarries	Road truck
River and building sand for concrete and building mortar.	Local suppliers	Road truck
Water for construction, dust suppression and workers domestic use.	Onsite abstraction (rate < 2.5 l/s)	Pump

b. During Operational Phase

The main raw materials inputs required for the operational phase of the project will embrace the following:

- Water for irrigation, domestic and commercial use.
- Energy supply
- Provision of spare parts for different machines
-

3.5. By- and Waste Products

a. 3.5.1. By- and Waste Products during Construction Phase

The subsequent waste and by-products are predictable to be generated during the project construction cycle:

✓ **Runoff:** Storm water runoff from the site

✓ **Dust**: Dust will be generated on the site from delivery of material and various construction activities

✓ **Solid waste**: other solid construction waste will include material such as scrap timber and various off cuts and refuse such as discarded packaging (e.g. cement bags), workers garbage etc.

✓ **Building rubble**: This will include sub-soil removed and any rock rubble generated by blasting (or other rock breaking activities) during excavation of trenches for foundation strips and the laying of water reticulation pipes, excavations for water features, etc. and other spoil such as rejected concrete, broken blocks etc.

✓ **Used oil**: Used oil and lubricants will be generated from routine on-site maintenance of plant and equipments

✓ **Exhaust emissions**: from operation of vehicles and machinery on site.

Sewage: Sanitary waste generated by the construction workforce.

b. By- and Waste Products – Operational Phase

The following by- and waste products are anticipated to be generated during operational phase:

Solid waste: other solid waste will include material such as scrap timber and various off cuts and refuse such as discarded packaging (e.g. cement bags), workers garbage as a result of renovating and management of dam reservoirs and irrigation infrastructure etc

Sewage: Sanitary waste generated by the workforce during operational phase.

Storm Water: An increase in storm water runoff will result from the site due to the development of reservoirs, roofed and paved areas which do not allow infiltration of rain water. Storm water run-off from the fuel storage and dispensing area (service station) as well as parking areas may contain some hydrocarbons from minor oil or fuel leaks/spills. Storm water run-off typically also contains silt and suspended solids.

Hazardous Waste: Hazardous waste is not envisaged to be generated by the project:

Green waste: will include leaves and grass cuttings from maintenance of the areas around the reservoir, water canals and other landscaped areas of the project

3.6. PROJECT ACTIVITIES

a. Description of the project activities

Construction Phase

The construction phase will involve the following:

The development would involve the excavation of construction materials, the construction of the dam, the power station, access roads, and power lines.

The construction of a cofferdam to regulate flows during building;

Cut and fill in order to prepare the dam site

The construction of the dam

The construction of the power station

The erection of pylons and power lines

The construction of replacement access roads to the remaining communities in the valley

The Operational Phase will include

The generation of electricity

The regulation of river flows in the interests of flood control in the wet season and irrigation in the dry season

The maintenance of the dam, power station and power lines

Tourist activities around the lake

The possible development of fisheries

b. Project activities during the Construction Phase

Initial activities during this phase relating to construction management will engage the putting in place of the site inspection and construction professional teams, their offices, machinery and equipments handle site, sanitary facilities and site protection facilities.

As there will be no labour camp on the project site, the project will proceed for employing labour from the site proximity communities but for site security purposes, security personnel will be based and accommodated on the site. Various plant and equipment to be used during the execution of civil works will include: Graders, Vibrators /Rollers, Water Trucks, Bulldozers, Front End Loader, Vehicles, Containers, Concrete Mixers, Concrete Pokers, Excavators, Mechanical Tool Boxes, Civil Plate Compactors, Tipper Trucks, etc. The number of each article/ equipment or machinery is to be determined by the contractor for construction.

The project involves construction of one multipurpose dam, drinking water treatment plant, hydropower plant and irrigation and drainage channels/networks (hydraulic infrastructures). Muvumba dam development project will be composed and engaged the following main anticipated project construction activities that will have potential impacts on the physical, biological and socio-economic environment:

Site Preparation and Levelling

Initial site preparation will entail removal of the (small) amount of existing vegetation, scarifying of topsoil and earthworks to establish the required levels and falls. The project will be constructed by-and large on the existing level requiring minimal basic earthworks. Earthworks will for the most part involve the use of heavy machinery such as bull dozers and graders. This project will also need to move away population who are living in the site and buffer zone of this artificial Lake.

Excavation, foundations and Dam construction:

This will involve the excavation of trenches for foundation strips for buildings, drinking water and hydropower plants, canals for irrigation purposes and trenches. The geotechnical survey of the sites is indicative that the bearing capacities of soils are good and the foundation depth and design for the intended structures will be simple and straight forward, in accordance with local engineering standards. Construction of foundations will involve the compaction of underside of foundation trenches and the mixing, pouring and compaction of concrete.

The project civil works will engage the construction of reservoir/dam for water storage along canal system and a significant amount of earth moving will be required. This will enable farmers to take water as and when they need it especially during the dry season when water is low. The dam will hold the water so that it is available for irrigation when the farmer chooses to irrigate. There will be a construction of the upstream multipurpose storage dam/water reservoir on Muvumba River, Karama and Gatunda sectors in Nyagatare district catchment.

The topography of the area provides sufficient volume for water storage. The proposed reservoir will have maximum volume of storage of 191,000,000 m3 at an elevation of 1395 mAMSL, ie 40m high dam. The dam crest length is of the order of 1,200m. Below are the project indices:

Table 5 Project Indices

NO	ITEM	UNIT	DESCRIPTION
	River system	-	Muvumba River
	Catchment area	km²	948.6
	Mean annual inflow	10^6 m³/yr	196.8
	Reservoir Maximum water level (MWL)	EL. m	1,406.6
	Reservoir Flood water level (FWL)	EL. m	1405.8
	Reservoir High water level (HWL)	EL. m	1,405.0
	Reservoir Low water level (LWL)	EL. m	1,391.0
	Reservoir Total storage capacity	106m³	34.92
	Reservoir Effective storage capacity	106m³	30.20
	Dam Type	-	Earth fill dam (ED)
	Dam Crest elevation	m	1,408.5
	Dam Length	m	1,052

	Dam Height	m	30.5
	Spillway Type	-	Unregulated ogee
	Spillway Width	m	95
	Spillway Weir crest	EL. m	1,405.0
	Powerhouse Installed capacity	KW	740(370KW×2Units)
	Powerhouse Mean yearly energy production	GWh	5.719
	Check dam type	-	Concrete gravity dam
	Check dam length	m	233
	Check dam height	m	7
	Check dam Crest elevation	m	1430
	Check dam Crest width	m	2
	Check dam Upstream face slope	V:H	vertical
	Check dam Downstream face slope	V:H	1:0.7
	Check dam Normal high water level	El.m	1428.5 (overflow section crest elevation
	Check dam total storage	M^3	261472
	Check dam overflow section type		Non control type (nn gate type)
	Check dam overflow section length	m	45
	Check dam overflow section height	m	5.5
	Check dam overflow section design discharge	M3/sec	133.5 peak outflow under 200 year flood
	Check dam overflow section energy dissipater type		Type II stilling basin 20m length
	Hydropower plant		
	Rated water level	El.M	1,402.93m
	LWL for power generation	El.m	1,394.46m
	Tail water level	El.m	1,378.74m
	Rated Head	m	24.19m (rated water level - tailwater level)
	Head loss	m	1.81m
	Net head	m	22.38m (rated lead - head loss)
	Plant discharge	m^3/s	3.930 m^3/s
	Project benefits on Water supply	$106 m^3/yr$	Total water supply :

			125.9 - Domestic water : 8.9 - Irrigation water : 78.1 - Livestock water : 0.7 - Environmental flow : 38.2
	Reliability of water supply	%	84%
	Area of inundation	㎢	3.7

Construction of Access Roads and Drainage /Channel System

Roads accessing the project site are not well maintened and the contractors will need to rehabilitate these roads so that trucks and other vehicles may have access to the site easily.

This rehabilitation will involve earth moving and shaping of formation and shoulders, and stabilization of the base with the support, spreading and compaction of gravel and aggregate materials. It will need also water canalisation. Construction of drainage/channel system will involve excavation and shaping of drains and soil compaction. Lined drains/canals will require the preparing and pouring of concrete.

These roads and irrigation and drainage channels system to be constructed outside and within the site may cause considerable number of problems including drainage problems and disturbance of soil structure and texture (presences of clay soil in arable lands, dust pollution, erosion when in rain season).

Sub-structural works and floor slabs

This will involve block work, mixing, pouring and compaction of concrete, backfilling and compaction of material according to specifications. Construction of services will include the foundation, laying of water pipes if necessary.

Construction of Superstructures (Buildings)

This will involve: Preparing of mortar and concrete, laying of concrete block walls, landscaping.

Materials Mobilization, Handling and Storage

This refers to the acquisition, delivery and storage of materials required for construction works. Gravel, laterite and stone aggregates will be acquired and transported to the site from RWFA approved quarry sites within or outside Nyagatare District. Provision will be made for bulk storage of materials such as sand, aggregate and laterite.

Petroleum products for trucks (such as petrol/diesel) will require transportation although only limited amounts of these materials will be stored on site as reliable supply sources are within close proximity to the site (in Nyagatare Town). Other materials that will be transported and stored include sand, cement, blocks or bricks timber and iron sheets.

Maintenance of Machinery

A temporary machinery handling facility will be constructed on site for the maintenance of construction vehicles and machinery. This will be combined with the fuel storage facilities.

Movement of Construction Traffic and Heavy Machinery

Transportation of construction materials / waste to and from the sites will involve the movement of heavy vehicles on access roads to the project sites as well as within the sites. Construction activities such as clearing, excavation, earth moving and mixing of concrete will involve the movement and operation of heavy plant and equipment around the sites.

Construction Workers Activities

Although no labour camp is planned in the project area, social interaction activities will undoubtedly result between project workers and local communities. The project will as much as possible hire labour from within local communities. Local market transactions will take place between construction workers and local communities. Casual sexual relationships may also result from interactions between workers and the community.

A canteen will be encouraged and established on site to cater for construction workers in need. The presence of construction workers will require the provision of safe water for drinking, food preparation and domestic purposes as well as the provision of sanitation and health services.

Water Abstraction

Water will be required for construction, workers domestic purposes and dust suppression measures. Water will be abstracted from on site streams/streams; abstraction rate will consider the available water flow in the main river (Muvumba).

Waste Management

Waste management during the construction phase will include:

Provision of temporary workers sanitation in the form of portable chemical toilets or construction of ECOSAN toilet that maybe used also by local population or tourist after construction period.

Collection and disposal of domestic waste at REMA and RURA approved disposal sites.

Transportation and disposal of building waste and rubble.

Collection and disposal of used oils / lubricants according to REMA, RURA and RSB requirements and standards.

c. Activities during Operational Phase

Activities during operation that are likely to have an impact on the environment include:

Operation of the Dam/reservoir

The operation of Muvumba dam will result in changes of water flow hence might lead to flooding the natural habitats, high rates of evaporation, silting etc. Although less sediment may be deposited along the Muvumba river flow banks.

Access Roads maintenance and management

The access roads shall be cleaned routinely and monitored on a day to day basis for damage to the road surface. Any repairs necessary shall be carried out by an approved road contractor in conjunction, where necessary, with especially Nyagatare district. These roads will facilitate the tourism activity near and in this artificial Lake.

Vector/Pest Control (mosquitoes)

As the project area is susceptible to mosquitoes, the developer will carry out "larviciding" (killing with insecticides the mosquito larvae before they hatch), the removal of breeding grounds (ensuring that pools of standing water are dried up) and using biological controls such as fish and other aquatic species that consume mosquitoes'' larvae in the dam/reservoir and channels. The success of these controls depends highly on the type of vector and its breeding behaviour and the geographic descriptions of the eastern region of Rwanda.

3.7. PROJECT ALTERNATIVES

a. Alternative site

Muvumba dam was pre-selected based on an assessment of its potential for water- harvesting and irrigation needs, lack of drinking water and energy as well as incidence of drought, poverty, population pressure and levels of food insecurity. The site was selected also based on hydrologic and topographic data. Allocating the resources to the selected site is seen as a good and reasonable alternative. Changing the site would mean abandon this population and the whole project area that needed these interventions. The best option would be to expand the activities to other vulnerable areas that can profit from Muvumba dam project activities.

The project is proposed to be developed on land, which comprises existing houses and currently agricultural activities hence there is an environmentally sensitive area engaged. As such, no other sites of comparable size and location within more than 20km diameter of this site that would be suitable for the type of the intentional development have been identified, and therefore no alternative sites have been considered for the project. Numerous distinctive returns of the proposed sites take an account of:

The project is proposed in an area where agricultural is seriously hampered by water shortage and from eco climatic conditions of the area.

The site has good surface and ground water potential;

The project is well-suited with neighbouring activities and the trend of development in the area;

The terrain, the size, soil, topographic and hydrologic conditions of the site,

The site is selected and mandated for irrigation, drinking water, tourism and fisheries development activities;

The site has good surface and ground water potential according to its topography and altitude characteristics;

In close proximity communities offer a readily available pool of labour for employment during both the construction and operational phases of the project;
Location in the agricultural area of Nyagatare District means the project will have little direct impact on natural fauna or flora, big account of human settlements, etc.
The project is located in an area where there are several agricultural activities on-going in surrounding hillsides.
The site is located ideally in an expanding and emerging tangential joint of developmental/agricultural activity, in a sought after area away from, but within propinquity of the river and as such is perfectly situated for structured planning and the type of development propose

The following criteria were considered to select a feasible site for this project:

b. Socio-political Criteria

- ✓ Responsiveness/interest of beneficiaries
- ✓ District leadership and ownership
- ✓ Level of social impact:
- ✓ The number of beneficiaries on the site, relative to site size;
- ✓ The proportion of Households therein;
- ✓ The presence in a drought zone (also to be used as a food security indicator);
- ✓ The number of displaced households (using a ratio that measures displaced people relative to the site size);

Accessibility to markets (year-round access road to the command area exists or is planned)

c. Economic Criteria

Using the common economic and financial analysis (EFA), the site must have an economic rate of return greater than 12 percent (ERR > 12 %).

d. Technical and Environmental Criteria

- ✓ Topographic and hydrologic condition and altitude
- ✓ Sufficient water harvesting potential
- ✓ In a moisture regime where irrigation can make a difference
- ✓ Coincidence of excess rainfall and drought (using indicators for drought and rainfall in the socio-economic criteria);
- ✓ Level of environmental impact i.e. sites that would lead to high and significant adverse impacts were rejected
- ✓ Ecological functions were also important criteria in selecting the water bodies. This means that water bodies that provided sensitive ecological functions and contained species of rare significance were regarded as critical and if selected the need for stringent mitigation measures would be adopted.

e. Technology Alternative

Using one multipurpose dam is more sustainable than using one dam for each activity.Given the invocation of land consolidation for economies of scale in production, a uniform application of inputs (including water) made it desirable to have one collectively managed infrastructure rather than many small ones with ensuing variance. It was also clear that micro schemes could not have the same flood-control benefits as the reservoir model. Furthermore, such a highly decentralized approach and large number of schemes would limit the opportunities for environmental oversight.

f. No Project Alternative

The no Project activities option will entail leaving the population in the present situation. For a region facing with drought and a country emerging from fighting for poverty alleviation, this option is not desirable considering the need of the population to sustain their livelihood. The environmental effects of the proposed activities will be avoided, making the option desirable considering the state of the environment. The Project will result in a direct injection of millions of Rwanda Francs to the local economy and therefore a no project alternative will mean foregoing such investment.

g. Project activities development with mitigation measures

The most preferred alternative would be implementing the Project with mitigation measures in place. A pursuant of this alternative will entail going on with the activities but taking into account the potential impacts on the environment by incorporating mitigation measures. This alternative is more desirable as it will inject a significant amount of money into the economy thereby promoting sustainable development and providing better livelihood which is one of the government's goals. The potential impacts to the environment will also be improved by coming up with an Environmental Management Plan (EMP) that will incorporate mitigation measures.

CHAPTER 4: DESCRIPTION OF EXISTING ENVIRONMENT

4.1. PHYSICAL ENVIRONMENT

a. Location

Muvumba dam will be located in Nyagatare in Karama and Gatunda Sectors) of the Eastern Province of Rwanda. It is accessible by the National paved road Kigali– Kayonza- Nyagatare and unpaved road from Nyagatare town to Karama and Gatunda sectors (about 20 km of unpaved road.

The project location is shown in the following figure:

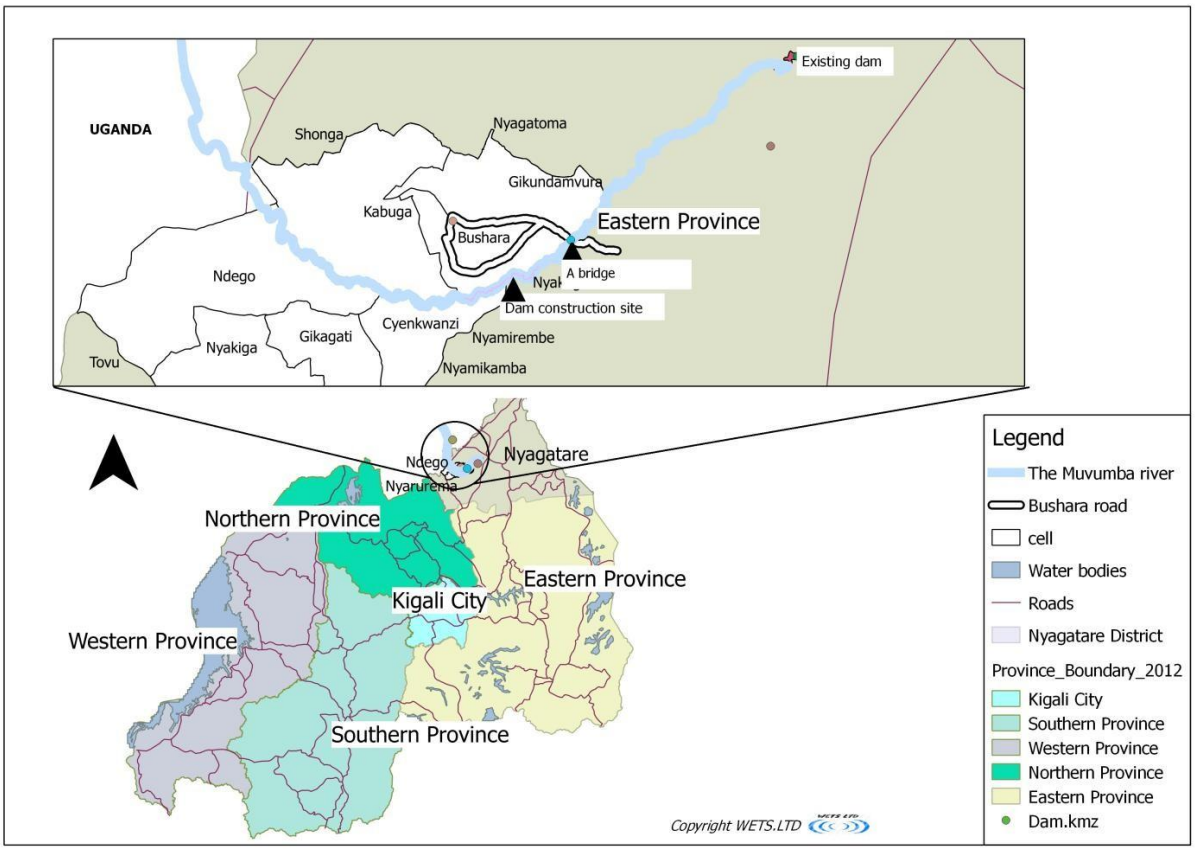

Figure 2 Location of project

Figure 3 Aerial view of Muvumba Dam Project location

b. Climate

The project area is characterized by two main seasons: the dry season with the annual average temperature varying between 20.3 °C and 21.7°C and the rainy season. The

rainy season is short and negatively influences the availability hydraulic for agro-pastoral activities.

The Muvumba dam construction project site falls in the Dry Low Land agro climatic zone, which covers 15.13% of the land of Rwanda, with a mean annual rainfall of about 863.5 mm (ranging between 827mm and 900mm) and these rain falls are bimodal. Main rainy season extends from February to mid-June; the maximum rainfall is in March, exceeding 120 mm/month. In November the project area receives the largest rainfall as part of the second rainy season (October to December). The driest month is August. In fact, rain falls are both very weak and very unpredictable to satisfy the needs in agriculture and livestock.

The most characteristics feature of the tropical climate is its uniformity with respect to temperature, solar radiation, humidity, wind speed and evaporation.

The major climatic parameter which varies in time and space is rainfall (Weert, 1994), indicating that rainfall data close to the project site are important as compared to other climatic variables. Climate data such as temperature, humidity, sunshine hours, wind speed and evaporation are required to estimate reservoir evaporation (Eo) and potential evapotranspiration (ETo). Critical missed data in and around the project area are wind speed and relative humidity. Project area wind speed and humidity data are derived from Kigali stations with the assumptions as indicated in FAO paper 56 that air masses are of the same origin and the general relief is similar (Low terrain for this case).

c. Topography

The steep slope of the project area including watershed is moderately covered with vegetation. The valley bottom and adjacent hillsides, especially the right bank side, are moderately cultivated with banana, maize and beans as the main crops. In the vicinity of the dam site the river has not formed a well defined course, and during the heavy rainy periods a large part of the valley is inundated.

d. Soil

Muvumba river especially its part localized in Nyagatare district, consist primarily of clays neoformed. These deposits have probably experienced during their evolution, a secondary enrichment in alkaline earth metals (especially Ca and Mg) from colluviums. The chemical point of view, because their high content of clay minerals of type 2: 1, they show high CEC and wealth in certain bases: Ca, Mg and K. The soils are rich in organic compounds.

They are low in kaolinite and montmorillonite-rich, which gives them a high natural fertility. The relief is flat and the slope is medium and does not exceed 3%. According to the previous Soil Surveys conducted and consultant's direct soil observations and analysis for this study, these soils have good structure in the surface horizon, but this structure is more or less stable and can change quickly, depending on agricultural practices.

e. Hydrology

The hydrographic network is very limited in Nyagatare district. Apart from the River Muvumba that cut across Nyagatare District, the Akagera and Umuyanja Rivers passing the District constituting its limits with Tanzania and Uganda, respectively, there is no other consistent river that can be exploited by the population in the area. There are other few of the rivers in Nyagatare district such as Nyiragahaya, Kayihenda, Karuruma, Nayagasharara and Kaborogota. The eastern part of this district is in Akagera National Park with the Akagera River forming the border with Tanzania. The weak river hydrographic network combined with the aforementioned relief offers timeliness of irrigation and constitutes a serious handicap to responding to the needs of water for people and animals.

f. Overview of Muvumba hydrological basin

The administrative catchment area is essentially administered by the districts of Gicumbi and Nyagatare. The Muvumba catchment consists from upstream to downstream of the relatively small catchment of the Mulindi River that is located in the mountainous and high rainfall central northern part of the country. The average annual rainfall is rated at 995 mm/annum, which equates to some 1,560 hm^3/annum from the total land surface area of 1,568 km^2.

The Mulindi River flows into Uganda onto a flat wetland zone near Kabale from where a complex flow pattern originates that ultimately joins the Muvumba River before it eventually flow back into Rwanda. Within Rwanda a number of relatively small tributaries join the Muvumba River which flows in a north easterly direction to follow the border between Rwanda and Uganda before it reaches the K-Water' Dam project location in Karama sector (See figure below). The river later flows downstream to join the Akagera River in the North East where the borders of Uganda, Rwanda and Tanzania meet.

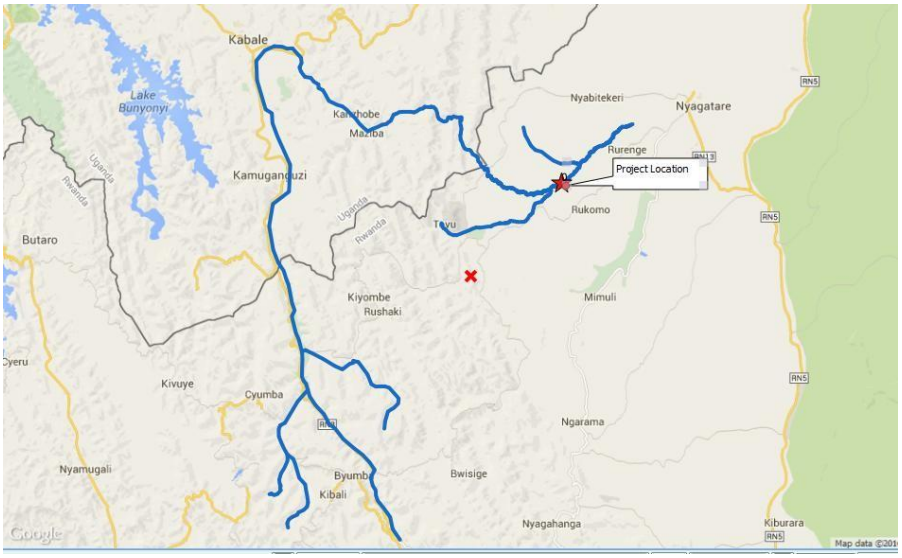

Figure 4 Muvumba Hydrological basin

g. Land use

The land use of Nyagatare area, especially in Karama and Gatunda sectors where the dam will be constructed is dominantly by agricultural land. There is no natural vegetation and natural tree

in this area. Apart from banana, which is the dominant crop in this area, planted trees are also found in these two sectors.

Figure 5 Muvumba Dam area and its land use

4.2. WATER QUALITY

The physico-Chemical and bacteriological results of Umuvumba River are summarized in the table below:

Table 6 Physico-Chemical and bacteriological results of Muvumba River

PARAMETERS		Unit	RBS limits	1st Sample
			14-21/8/2014	16-23/9/2014
Fecal Coliforms	CFU/100ml	4*10	$3*10^2$	$6*10^2$
E.	CFU/100ml	4*10	$3*10^0$	$5*10^0$
T°	°C	25	22	21.33
p		9	6.8	7
E	µS/c	1000	125	228.33
Turbidity	NTU	5	142	318
T	mg/l	100	90	93
Alkalinity	mg/l		26	32
NH	mg/l	5	0.122	0.1
NO	mg/l	10	0.003	0.007
NO	mg/l	25	0.072	0.063
PO4	mg/l	5	0.002	0.0018
SO4	mg/l	250	6.3	9.1
Ca^2	mg/l	200	80	87
Mg	mg/l	200	24	36
Cl	mg/l	250	18.7	9.5
M	mg/l	0.1	0.021	0.41
Fe	mg/l	0.3	0.038	1.25
F	mg/l	2	0.36	0.41
D	mg/l	5	8.4	6.1

CO	mg/l	50	9.6	8.3
BO	mg/l	30	5.4	4.9
T	mg/l	3	0.174	1.7
T	mg/l	5	0.073	0.14
C	mg/l	0.1	0.24	0.93
P	mg/l		Not detected	nd
A	mg/l	2	nd	nd
Z	mg/l	3	0.031	0.052
Aldri	mg/l		nd	nd
Chlordane	mg/l		nd	nd
Hexachlorobenze	mg/l		nd	nd

4.3. BIOLOGICAL ENVIRONMENT

a. Flora

The Vegetation of Nyagatare district is dominated by savanna grasslands represented by *Themeda triandra and Hyparrhenia filipendula,* in which the wetlands are dominated by Cyperus papyrus and Cyperus latifolius. The savanna is a mosaic of individual trees in a landscape open grassland and dense forest which is restricted to river banks and elevations. The predominant species are *Acacia Senegal, A.hockii, A.sieberana, Lannea stuhlmannii, Ozoroa reticulata, Entada abyssinica* and *Solanum species tree* (Fisher, 1992).

Species found in the marshlands surrounding Muvumba river and their vicinities have various uses, including the following:

- ✓ **Improvement of soil** (Acacia sieberana, A. albida, Albizzia gummifera, Erythrina abyssinica,etc.)
- ✓ **Stabilization of soil** (Albizziagummifera, Erythrina abyssinica, Vernoniaamygdalina, etc.).
- ✓ **Construction and carpentry** (Acacia sieberana, A.albida, Erythrina abyssinica, Vernonia amygdalina, etc.)
- ✓ **Fuelwood and charcoal** (all species and woody species)
- ✓ **Crafts** (Acacia sieberana, A.albida, Erythrina abyssinica, etc...)
- ✓ **Support hives** (Acacia sieberana, A.albida, Albizziagummifera, Erythrin*a abyssinica,* etc.*).*
- ✓ **Forage** *(Acacia sieberana, A. albida, Albizzia gummifera, etc...)*
- ✓ **Mulch** *(Acacia albida, Albizzia gummifera, Vernonia amygdalina,etc..)*
- ✓ **Limits fences and properties** *(Acacia albida, Erythrina abyssinica, Vernonia amygdalina, etc.)*
- ✓ **Gums and tannins**(Acacia sieberana, A. albida, etc…)
- ✓ **Pharmacopoeias** *(Acacia sieberana, A. albida, Erythrina abyssinica, Vernonia amygdalina, etc.)*
- ✓ **Shade for livestock farms and coffee plantations** *(Acacia albida, Albizzia gummifera, Erythrina abyssinica, etc.).*
- ✓ **Basketry, box, enclosures and ceilings** *(Cyperus papyrus)*
- ✓ **Mats** *(Cyperus latifolius).*

The main crops grown in the developed marshland and its hillsides are beans, maize, banana, sorghum, cassava, sunflower and sweet potatoes, vegetables including cabbages, tomatoes, eggplants, nightshade, and various onions.

Table 7 Main plant species observed in the study area

Family	Scientific name	Vernacular name (in Kinyarwanda)
Asteraceae	*Vernonia amygdalina*	Umubilizi
Cyperaceae	*Cyperus papyrus*	Urufunzo
	Cyperus latifolius	Umuberanya/Urufunzo
	Cyperus latiforialius	Urukangaga
	Fuirena pubescens	*Isovu*
Euphorbiaceae	*Euphorbia tirucalli*	Umuyenzi
	Euphorbia conderablum	Umuduha
Fabaceae	*Erythrina abyssinica*	Umurinzi/Umuko

Loganiaceae *Strychnos usambarensis* Umuhoko
Malvaceae *Hibiscus div. spp.* Umugusa
Mimosaceae *Acacia sieberana*
Umunyinya ***Loganiaceae*** *Strychnos usambarensis*
Umuhoko ***Malvaceae*** *Hibiscus div. spp.*
Umugusa ***Mimosaceae*** *Acacia sieberana*
Umunyinya
Acacia albida Muvumpa
Albizzia gummifera Umusebeya ***Rosaceae***
Rubus spp Umukeri ***Sapindaceae***
Dodonea viscose Umusasa

b. Fauna

Apart from domestic animals dominated by cows, goats, sheep, poultry, pigs etc, the area accommodates a huge diversified variety of birds such as birds of prey, guinea-fowl, partridges, heroes and so forth...
The project area includes many diverse habitats favoured by species that are favourable places for feeding, nesting, breeding, to take refuge, etc.

The marsh is also habitat for other species (mainly birds are a first group of animals to be affected or can affect rice plantations).

Scientific name	**Other name (French and English)**	**Vernacular name (Kinyarwanda name)**	**Particular Status (CITES & IUCN)**
Ardeacinerea	Héroncendré /Grey Heron	Uruyongoyongo	
Ciconiaciconia	Cigogne blanche/Black-White Stork	Inyamanza	
Balearicaregolosum	Gruecouronnée/ Grey crowned Crane	Umusambi	-
Bostrychia hagadash	Ibis hagedash/Ibis hadada	Nyirabaraza/ Nyirabaraz ana	-
Bubulcus ibis	Héron garde-boeuf/Cattle Egret	Inyange	-
Motacillaaguimp	Bergeronnette pie/African Pied Wagtail	Inyamanza	
	Anatidés(divers)/Anatidae		
-	Paridés (divers)/ Paridae		-
-	Plocéidés(divers)/ Ploceidae/Weavers	Isandi/ Isande	A Weaver species protected by CITES: *Ploceus cucullatus*
-	Columbidés (divers)/ Columbidae		-
Passer griseus)	Grey-headed sparrow	Igishwi	-
Colius striatus	Speckled mouse bird	Umusure	-
Apus caffer	white-rumped swift	Intashya	-
Streptopelia semitorquata	Red-eyed dove	Inuma	-
Meropsoreobates	Cinnamon-chested bee-eater	Umusamanzuki	-
Clarias liocephalus	*Clarias*	Inshonzi	-

The fish species surveyed in the swamp is a species of the family of Claridae which is *Clarias liocephalus* (Inshonzi). There are many termite mounds on the outskirts of the marshlands.

4.4. HUMAN ENVIRONMENT

a. Socio-economic Environment

Major economic activities are agriculture and livestock keeping. The Eastern Province is home to the nation's milk- producing cattle keepers. Other livestock kept include sheep, goats, poultry, pigs, bees and fish. Major crops grown in the project area include Maize, Beans, Sorghum, Banana, Cassava, Sun flour, Vegetables (cabbages, egg plants, onions, and carrots) and Potatoes. The province intends to promote the cultivation and processing of, Rice, Cassava and Banana- based products.

b. Population and Administrative Units

The project area is situated in Nyagatare and Gatsibo districts. Nyagatare district is composed by 14 Sectors such as Katabagemu, Mimuli, Matimba, Rwempasha, Karangazi, Gatunda, Karama, Kiyombe, Mukama, Musheli, Nyagatare, Rukomo, Rwimiyaga and Tabagwe.

According to the Fourth Rwanda Population and Housing Census (RPHC4) conducted in 2012, Nyagatare district is home of 465,855. About 47,480 (10.2) were living in urban area and 418,375 (89.8) were living in rural area. The density of population in Nyagatare district is242 population per km^2 while the national population density was 415 people per km^2. For Karama and Gatunda sectors which are the part of this project, they are covered respectively by 26,994 and 27,776 people.

c. Demography and Livelihoods

Based on the data from the Fourth Rwanda Population and Housing Census (RPHC4) conducted in 2012, Nyagatare is the second most populous district in Rwanda with 465,855 people after Gasabo district with 529,561 people. The increasing of population in this area is land. The main activities of the study area include agriculture and livestock farming

Chapter 5: PUBLIC CONSULTATION

5. 1. INTRODUCTION

The main objective of the public consultations with stakeholders is gathering information on their concerns, perceptions and fears of the livelihood changes to be brought about as a result/consequence of Muvumba dam construction project.

Public consultations were organized as a way to collect first-hand accounts of benefits and criticisms from interested/and affected parties by the implementation of this project. The public consultations involved organized group discussions with purposively selected individuals/stakeholders to gain information on their concerns, perceptions, reactions and experiences of livelihood changes brought as a result/consequence of construction of Muvumba dam project. Group discussions provided multiple views within a group context and were particularly useful in exploring the level of consensus on a given felt impact.

The exercise identified all the stakeholders within and in the surrounding area including local community, local authorities, government ministries and agencies, government projects and private sector among other stakeholders.

The public consultations on behalf of the Environmental Impact Assessment (EIA) study of this project which will take place in Nyagatare District of Eastern province was conducted and involved key various stakeholders that include among others the representatives of MINAGRI, MINIRENA, RWFA, REMA, RDB, local authorities including Nyagatare District staff, Karama and Gatunda sectors 'officers and local communities from all these 2 sectors surrounding and covering the watershed of the site.

At the sector level, consultants met with the Executive secretary or Agronomist/Veterinary or Social affairs Officer. The Consultation meetings were organized in Karama sector, Bushara cell, Meshero village with a group of farmers who will be affected by the project implementation. Another consultation meeting was also organized in Gatunda sector.

5.2. DATA COLLECTION TECHNIQUES

a. Semi-Structured Interviews

- ✓ Semi structured interviews were organized to gather information from focused groups participants in public consultation settings, by means of discussions guides. The guiding questions were prepared, and a feedback is composing the present section of the EIA report.
- ✓ The semi-structured interviews were conducted in order to know:
- ✓ The perceptions of the population regarding the Muvumba multipurpose dam construction project.
- ✓ What they think and observe as Benefits/Positive impacts of the proposed project
- ✓ What they think and observe as Constraints/ Negative impacts of the proposed project

- ✓ Suggestions to ensure both agriculture and animal husbandry combined system
- ✓ Problems relating to resettlement
- ✓ Problems relating to the land tenure and land ownership for knowing what a buffer zone of Muvumba river? Due to the fact that local project area farmers are confused about the limit of Muvumba river and valley.
- ✓ Informing the public different profits they have from the new coming project

Those questions were improved after a pilot test at the very first field visit in the project area. Their wording was again continuously readapted to different groups throughout the field research. Besides, sometimes guides were not rigidly followed, but served merely as guides, the team was adapting the interview process to the local setting in order to ensure a free flow of discussions and findings.

b. Focus Group Discussions

To undertake this stakeholders consultation, a worksheet questionnaire was used as a guide to collect needed and study related information concerning the status in which project is known, stakeholders perception and awareness, positive as well as negative effects of the proposed project on general development including social development through improved and increased income based agricultural production, drinking water supply, energy supply, fisheries, tourism and increased job opportunities, and on environmental protection and *suggestions of additional issues to be considered when implementing this project for ensuring* the project sustainability and more profitability and some methods to be applied to minimize and avoid negative effects and enhancing clear and long term considerable positive benefits of this project.

Prior to the actual public consultations, Consultants together with representatives farmers, cells and villages officials to discuss the way forward for their concerns about loss of agriculture land, associated problems and propositions of responses to be considered when decision making about this issues. For making local population to express their selves freely, the consultation with local population and local leaders were made on different appointment.

In focus group discussion with local farmers included those using the side where will be located the dam/reservoir site to discuss benefits and associated problems and their suggestions to handle negative effects and enhance profits and additional information about the proposed project.

The latter sympathetically made all arrangements necessary in connection with participants' invitation, the timing for the public consultation sessions. All discussions were conducted in Kinyarwanda.

c. Observations

Whenever possible, before and/or after the public consultations, the team made physical visits and observations of the proposed site of the project in order to verify and collaborate with respondents' perceptions and descriptions with the reality.

Figure 6 Consultation with affected public

d. KEY FINDINGS

Two meetings were arranged to have a general and same understanding on the benefits and negative effects of the proposed project. The first meeting and the second were respectively held Karama sector and Gatunda sector in close proximity of the Dam site. These meetings raised the flow discussions on the following:

- ✓ The need of the project,identification of different problems related to cattle farms and water dams to be affected by the project,
- ✓ Related socio-cultural and economic parameters to be considered in enhancing and mitigating associated positive and negative impacts respectively.
- ✓ Suggestions and propositions on what can be done to address raised problems due to the relocation and resettlement of local population and their lands.

The first meeting held in Karama highlighted different challenges and benefits associated to the development of this project through the above agenda, especially site based issues that include the following:

- Perception and awareness on expected project
- Increased agricultural production
- Solution to the lack of potable drinking water and electricity
- Increased income generated from this production and employment
- Reduced crop production varieties because the irrigation will more emphasize on rice production

- Reduced excessive soil erosion due to hillsides protection
- Resettlement issues
- Provision of beautification of the area due to the artificial lake,
- Provision of other related income generated business

The second meeting held in Gatunda sector. The main issues raised in this meeting focused on:

- Perception and awareness on anticipated project
- Enormous benefits from this project
- Negative effects of this project including loss of their plots for those whose the dam/reservoir will occupy their parts
- Resettlement issues
- Provision of beautification of the area due to rice plots,
- Provision of other related income generated businesses.

In general, during consultation local people were more concerned with the positive outcomes that the project will bring about and the major concern raised was the panic for loss of their land and how they will find another land. Members were concerned that that 15 meters surrounding Muvumba River belong to the government and saying that it is not clear that they will not be compensated for activities curried out on this surface. But fortunately during community works sector and cell executives explained that the buffer zone of wetlands are the property of the government of Rwanda but activities done on the ground belong to the people. About when they will be expropriated, local leaders explained that they will be informed on when they will be compensated and which season to stop cultivating their lands and conducting other activities. They will not be compensated for the new houses built; only perennial houses and trees will be considered for compensation.

Some people claimed that after the implementation of this project they will not have freedom on their lands because the land consolidation will be applied. So they were thinking that no one can grow varieties which are not needed by government. In one hand, some people suggested that during compensation they can prefer to take money and go away to look for another land. In another hand, other people especially women prefer not to get money but to be reimbursed in land because if they take money their husbands can use it inappropriately and at the end they can find that they lose both money and land.

Another issue raised by women concerning accident which may be caused by this artificial lake. In fact, children and other mature people may need to go to swim and this can

cause mortally accident. They said also this dam may be used as shortcut way for fragile people who need to commit suicide.

e. Consultations with other Stakeholders

Consultants held interviews and focus group discussions with stakeholders at the project site and at different stakeholder's offices. These include, MINIRENA, MINAGRI, REMA, RWFA, RDB, and NYAGATARE District, 2 Sectors surrounding the site, involved cells and villages and communities All respondents are aware of the project and its location and are devoted to contribute to the development of this project through their willing to accept, especially direct beneficiaries.

All public institutions consulted from districts to the villages will ensure their support in public/people mobilization and their participation in relocation or displacement and related compensation process. The project has many positive effects including the increase of agricultural, drinking water and electricity productions; beautification of the area, Environmental Safeguarding/protection, Job creation and promoting the wellbeing of the public. All negative impacts can be managed through sound design mitigation measures proposed in this report.

After noting positive and negative effects of the proposed project, consulted public indicated different suggestions to what can be addressed to minimize and avoid those negative impacts on the communities and the general physical environment to ensure sustainable development. Suggested measures include the establishment of a competent and designed structure with appropriate standards for farmers related trainings for farmers (including use of chemical fertilizers (to minimize the eutrophication in the dam), rice plots preparation, post harvest technology systems, adding value, maintenance of irrigation infrastructures, savings and other judged important). For this, the establishment of a formal participatory system of key stakeholders to enhance the efficiency operation of the project, a full implementation of regular monitoring system and implement measures for enhancing positive impacts, sensitize and build the technical capacity of the project beneficiaries as it is proposed in the EMMP section of this study report. Below is the table summarizing discussions held with consulted different stakeholders:

ISSUE RAISED	RESPONSE
Perceptions and awareness of stakeholders and the public in general, in relation to the proposed project	-Consulted Communities in the project area and all stakeholders involved including local authorities are aware of the project, its location, purpose and they agree and acknowledge the excellent/considerable importance of the project.
Expected risks and negative effects of the Project to the local community	-When there is no people mobilization, sensitization, capacity building, appropriate and professional construction and maintenance of project infrastructures, the project will become harm to different beneficiaries. -Risk of HIV/AIDS pandemic spreading form migration/incursion of people due employment opportunities and social interactions -Loss of agriculture land and issue of resettlement -Accident which may be caused by presence of this project -Loss of crops varieties and lack of freedom for their land because of land consolidation policy
Anticipated benefits likely to be occurred from the project for stakeholders.	-Increased income for different employed personnel that will contribute to the development of the project. -Augmented agriculture production which will enhance and promote food security. -Enforced technical capacity of farmers from different trainings offered. -Provided beautification of our area and this will attract the tourists -Improved wellbeing of our families -Increased number of business oriented in the project area.
The willing to accept and participate in resources mobilization for all involved stakeholders.	-Government related Ministries and institutions to advocate and enhance the technical capacity of stakeholders (especially beneficiaries) -Districts/Sectors to arrange and assist the land acquisition for the when -Local communities to accept obey and maintain project activities. -RWFA to collaborate and coordinate different stakeholders' activities relating to the implementation of the project.

Raised concerns/complaints from the proposed dam site owners.	-We need to be expropriated for our perennial crops and trees. -We need to be compensated for our private land where the dam/reservoir will affect. -During our displacement (if any), we need and suggest to be displaced and compensated for our destroyed properties and structures according to the national standards fixed by the related law. Remember to consider also our social and cultural aspects we will be unfastened. - We need to be provided water points as our former water sources will be affected by the project.

Chapter 6: POTENTIAL ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS

6.1. GENERAL CONSIDERATIONS

A number of project potential impacts (both positive and negative) in the area were identified during the scoping process of the study. The purpose of this chapter is to predict and make an assessment of the impacts on the environment that may potentially arise as a result of the implementation of the project. This chapter identifies analyses, classifies and discusses these impacts that could arise from the activities of the project, either during the construction phase or the operational phase.

Impacts that could occur are grouped and discussed below under the headings of the various environmental components or receptors (e.g. fauna, air quality, ground water, flora, etc) that it is anticipated are likely to be affected by implementation of the project. A certain amount of overlap between these components is unavoidable and therefore cross referencing is used where possible to avoid repetition.

An assessment of these impacts was made on the basis of information gathered during the scoping process, the detailed environmental baseline study of the project area which has included several field visits to the project site and its surrounds, as well as a desk study of relevant existing documents and information pertaining to the study and information describing the nature and design of the proposed project.

Potential positive and negative impacts are discussed below in separate sections as those that are expected to occur under construction of the project and those that may be anticipated during the operational phase. Mitigation measures to be incorporated into the design and implementation of the project so as to minimise, compensate for or avoid the occurrence of these impacts are discussed in detail also.

6.2. Impacts during Planning and Construction Phase

a. POSITIVE IMPACTS

Impacts on Local and National Economy

It is expected that works related to the multipurpose dam construction on Muvumba river will provide a positive boost to the local and national economy, which the project intends to maximize. The prefeasibility study estimated that 223,382,500 euro (about 210,044,250,000 RWF) would be spent on this project.

Table 9 Summary of Investment Cost

Item	Description	Amount (Euros)
1	Dam	107,500,000
2	Treatment Works	22,000,000
3	Pumping Main	19,800,000
4	Resevoirs	6,800,000
5	Distribution	29,975,000
6	Irrigation	15,000,000
7	Power Station	2,000,000
	Total	**203,075,000**
	Contingencies (10%)	20,307,500

Specialized equipments and construction materials will be procured. The developer is, however committed to ensuring that by using Rwandese companies, local raw materials 9if possible) and finished products will be utilized as much as possible for successful completion of the project.

It is expected that the demand for the supply and production of local building materials as well as provision of services will contribute to providing a boost to various sectors related to the construction industry. Manufacturers and suppliers of local materials will include manufacturers of protective ware, cement manufacturers, local manufacturers of blocks, quarries for the supply of sand and stone aggregate, metal fabricators as well as manufacturers of other local building materials such as timber. Other materials such as fuel, oil and motor/construction vehicle supplies will also be provided through local suppliers.

Rural employment and income generation

This multipurpose dam construction will be labour intensive activities and for that reason, the labour needed in the project area will create much needed employment opportunity to the rural population. The developer will commit to a policy that gives priority to the locals in the neighbourhood at the time of employing casual or skilled labor.

The project will require skilled technicians and crafts people as well as un-skilled labour and will offer many employment opportunities for persons from within local communities, including women. Women are generally regarded as reliable workers with a good eye, and there is an increasing trend to employ women in semi-skilled and skilled construction work. Contractors also generally hire women as casual workers for cleaning out operations in preparation for handover, who will undoubtedly come from the local communities surrounding the project site.

It is also anticipated that indirect employment opportunities will be created within local communities through the provision of services to the construction teams, such as the sale of food and beverages.

Truck and machine owners will earn money from renting out their vehicles for transportation of construction material and machines that will do various construction activities.

Increased public revenues

The implementation of the project will increase revenue and taxes for both the central (Rwanda Revenue Authority) and local authorities. Revenues will be collected by both the national and local authorities from the procurement of construction materials and finishes, employees' salaries, VAT on materials and services, among others.

Health insurance and education

From their pay, Employees shall afford medical insurance (Mutuelle de santé) and even pay school fees for their children.

Impacts on Local Capacity

The scale of the construction project with the logistics involved and speeds of construction that will be required, while maintaining construction, health and safety standards will involve considerable management and planning skills and will contribute to capacity building within the Rwandese engineering and construction sector. Co-operation between international suppliers of specialised equipment and contractors (who have the expertise in the technology to be introduced) and local contractors and sub-contractors and companies will result in the transfer of skills and will build additional local capacity.

b. NEGATIVE IMPACTS

Impacts during the Design and Planning Phase

The design and planning phase of this subproject involved identification of a suitable site for the infrastructure and undertaking of a detailed feasibility study. There are no adverse impacts expected during this stage, however, best practices were incorporated at this stage to ensure that the design takes into account the environmental issues to consider.

Impact during the Construction Phase

As the construction goes on, there will be a number of excavations, soil disturbance and increased traffic around the site as a result of heavy trucks delivering various construction materials and taking away the generated waste including construction debris. All these are likely to pollute and degrade the environment, through mudslides, noise, and dust and air pollution.

Physical Impacts

<u>Loss of cultivable land</u>

Due to the construction of water dam, irrigation channels, drinking water and electricity plants and networks, a part of the cultivable land will be used and therefore lost for agricultural activities.

This impact will be considered to be high significance in term of magnitude and duration. This multipurpose dam will cover a high surface which is normally used in agriculture. The impact durations is also expected to high significant. However, one of the main objectives of this project is to improve the agriculture practice by using irrigation technologies.

One of suggested mitigation measures is to reimburse the local population who will loss the cultivable land during implementation of this project. They may be reimbursed in term of money so that they can go to look for another land where they can continue to use in agriculture sector. They can also use money in creating another job which may be more profitable than agriculture. However, for some families, considering ideas from their women, considering also the consensus of all family members (husband, wife and children), it may be

necessary to reimburse them in term of another cultivable land because wives are fearing that their husbands can use money in inappropriate manner and this can creates dip poverty to their families. Another proposed mitigation measures for the families that will prefer to stay near this artificial dam, is to introduce fish-farming in this dam and organize the affected community members into a fish-farming cooperative.

Impacts on Soils and Geology

The topography of the dam site shows that the dam site is flat and localised between two small hills. The construction of the project will consist of building blocks from mother rocks up to required level of the dam. The mass of soil collected during digging up to the mother rock will be compacted. Implementation of this project component will involve considerable earthworks. Preparation of construction site will need also the clearing and compacting the topsoil.

Scarifying the site of topsoil (and clearing of the limited amount of existing vegetation) combined with soil compaction during site preparation and levelling will result in reduced capacity of the ground to retain water and increase surface water run-off during periods of rainfall. Meanwhile, the ground's ability to resist erosion will be reduced in areas especially where sub-soils have been destabilized by construction activities.

Some negative impacts are anticipated to arise and these include: Soil contamination from drilling muds, vehicle tracks, oil and diesel spills; loss of soil fertility due to improperly planned re -settlement of people from the site; borrow pits and quarries; soil compaction due to heavy equipment and bulk earthworks; disturbance/loss of pedagogical features of sensitivity importance e.g. hydro orphic (wetland) soils; loss of soil under overburden and waste rock dumps. On land degradation, although raw materials for aggregates are abundantly available in Karama and Gatunda sector , a potential area of concern will be the encouragement of illegal sources of materials due to the large demand which will be created by this project.

Erosion

During the execution of all works relating to implementation of this multipurpose dam some activities may result in the increased erosion in areas where vegetation has been stripped and stockpile. This could lead to increased sediments deposited into the valleys and turbidity in the river downstream. It is expected that all major earthworks will be carried out during the dry season under the various phases of the project and that the permanent storm

water road and site drainage system will be in place before the rain season and this will control potential erosion. The significance of soil erosion impact will be low significance based on magnitude and duration. The erosion that will occur during the construction will be minimal and localized in the areas where excavation will take place only. The impact duration is only expected to be felt during the construction phase. Soil erosion occurring during the construction phase of the project can be avoided through: Planting vegetation on the cleared sites immediately after construction, only clear areas earmarked for construction and compacting the piled soil.

Borrow Pit Impacts

Borrow pits are generally associated with scarring of the general environment and landscape due to the excavation related works. If not backfilled immediately and replanted, the borrow pits end up becoming a health hazard and a source of spread of water borne related diseases like bilharzias, malaria, etc. This is because the pits end up collecting water that stagnate and hence becoming a rich breeding ground for the disease vectors. Borrow pits are also known to be potential sources of hazards especially accidental drowning of livestock and human beings.

This impact is going to be low in significance in terms of magnitude and scope and scale will be localized. The duration of the impact will be short term and only experienced during the construction phase. It is possible to reverse the impacts through rehabilitation. For mitigating this negative impact, the borrow pits are immediately backfilled after excavation related works and replanted with vegetation.

Impacts on Surface Water Resources

Creation of a reservoir

The damming of a river creates a reservoir upstream from the dam. The reservoir waters spill out into the surrounding environments, flooding the natural habitats that existed before the dam's construction. The newly created dam will have more water holding capacity than the river would have had, and therefore more evaporation occurs than previously. Through evaporation, a significant amount of water can be lost. However, on a positive note, this reservoir will significantly indirectly serve as a flood control point for this area and the evaporated water will come back to the earth by cycle of water.

Impacts on Surface Water Quality

Siltation and pollution of streams/rivers due to poorly constructed access tracks, topsoil removal and stockpiles, spoils created by bulk earthworks, borrow pits and quarries, water pollution from fuel spillage and waste disposal will be anticipated during the construction phase by erosion control.

Impacts on Ground Water Resources

Normally, construction of dam by the lowering of water table levels in the dam site can impact on ground stability and rural water supply. Fortunately, this is not likely to occur and this project is going to solve the problem of water supply.

Impacts on Ground Water Quality

Due to the increased availability of water at the ground surface, there is increased evaporation which may then results in fractionation and deposition of salts. This subsequently degrades the quality of the soils. In the marshland where damming and irrigation is to be done, this effect may not be as much pronounced. The groundwater quality deterioration is mainly resulted of increased use of fertilizers and pesticides. Much as the increased availability of water will result into increased crop production, great care should be taken to avoid excessive use of fertilizers and pesticides. Other potential sources of groundwater pollution as a result of construction activities are pit latrines and incorrect waste disposal practices. However, these are anticipated to be on a very minimal scale.

Impact on water availability for domestic uses

Muvumba River is the main source of drinking water and for other domestic uses. Although they use this water without any treatment they do not have other sources of water because they will be limited to use Muvumba dam during construction because the point for water collection is in dam site. The developer shall put in place water tanks will serve the local population during construction phase.

c. Biological Impacts

During dam construction on Muvumba River, there will be areas to be flooded that will lead to vegetation / food crop loss. Some crops and trees established in the project area will have to be destroyed. This is because they are either in areas where dam and channels will be constructed, in areas where drinking water and electricity networks will be implemented. The affected population would lose benefits which they were already reaping from activities carried out on this site including getting food for home consumption and for livestock. There

is no plant species of special conservation purpose surveyed that will be affected by dam construction except some planted cultural species known as "umuko" and "umuvumu" which are located in this site. This impact is going to be fairly significant in terms of magnitude because local population in Rwanda depend a lot on agriculture as a means of livelihood. The scope will be localized and felt in the reservoir area. The impact will also be long term in terms of duration on reservoir sites because the crops and land will be lost for as long as the project is implemented.

This impact is unavoidable and will be mitigated through compensation measures which will include compensation of land, crops and trees on reservoir sites. However, it is advisable to plants aquatic plants like Cyperus papyrus in dam buffer zone and other plant which play role in water regulation and water purification to avoid the eutrophication in this dam. The zone around the buffer zone and along will be established and stabilized with vegetation in three layers, including grass layer, shrub layer and tree layer. For tree layer, it is better to plant the same cultural tree (Umuvumu and

umuko) as local population mentioned that these trees are very meaningful to their culture. The borrow pits will also be backfilled and rehabilitated with vegetation.

For fauna, domestic livestock will be affected and this will be mitigated by compensation. We however, anticipate minimal pollution Muvumba river from organic, hydrocarbon, silt or microbiological sources. Interference with fish called *claria liocephalus* (Inshonzi) and siltation of Muvumba river, will not arise.

d. Impacts on Air Quality

During site clearing, foundation excavation and other site preparation activities, large masses of soil are likely to be displaced. Heavy machines will be used for this purpose. The expected adverse impacts include the likelihood of air pollution and respiratory diseases as a result of dust from the site especially in the early stages of construction, noise pollution and gases from exhaust fume, possibility of oil spillage from machines such as; excavators, trucks, wheel loaders, etc.

In order to reduce the quantities of exhaust fumes, all plant and construction vehicles will be operated according to manufacturer's recommendations and shall be properly supervised, managed and maintained in good condition and adjusted to limit the emission of black smoke. Designated access routes will be set and complied by the Contractor to confine the areas likely to be affected by air pollution due to construction traffic. There shall be no burning of waste materials on site.

e. Impacts on Noise and Vibrations

Noise will be caused by construction traffic transporting construction materials/workers to and from the site and from the operation of machinery on site. However, additional noise from construction traffic and machinery will be relatively insignificant. Some areas of Gatunda and Karama sectors which are located close to the sites may experience some noise nuisance from the site. The noise nuisance experienced will be for short periods and intermittent**.**

In order to minimize the noise from construction activities, the Contractor shall restrict any of his operations, which result in undue noise disturbance to nearby communities and dwellings (e.g. blasting activities and operation of heavy machinery and construction traffic) between hours of 6:00 and 18:00. Blasting shall be conducted safely in accordance with Rwanda explosives regulations and the guidelines. Badly maintained construction equipment will not be allowed to operate on the site to ensure quiet operation. Designated access routes will be set and complied by the Contractor to confine the areas likely to be affected by noise pollution due to construction traffic.

f. Impacts on Cultural Heritage

No known archaeological or historical sites exist on the project site and no impacts on any features of importance to national heritage are expected. Any such features that may be found (e.g. during excavation works) that were not apparent on surface investigation or that did not come to light during

the years that the area was cultivated will be reported by the project and appropriate procedures will be followed.

g. Impacts on Rural Livelihoods

Impact on the availability of natural resources traditionally used by local communities like plants used for medicinal and nutritional purposes, fuel wood, water resources etc are envisaged to be very minimal. Other anticipated impacts on land use such as loss of grazing land, agricultural land, access to resources etc

h. Impacts on Local Infrastructure Services

The project will many times experience a high volume of heavy construction traffic delivering materials and / or equipment to the site. This has the potential to cause damage to access roads approaching the site. The impact is compounded by the fact that maintenance of public roads in the area by the relevant authorities is generally inadequate or, in some cases, non-existent. However, they are no major anticipated loss/disruption of important communal pathways, public services and utilities e.g. sewerage, electricity, water supply, health care; and there will not be a burden on existing local infrastructure and services like roads, hospitals.

i. Socio-economic Impacts

Resource Use Conflict

A good part of the marshland is mainly used for the production of non irrigable crops, such as bean, maize, sorghum, potato, and for livestock production. The river is also a source of water for domestic purpose. The construction of this dam therefore might trigger resource use conflict over agro pastoral land and domestic water uses. For water use conflict, this might be a problem in areas during construction phase because there is no other alternative source of water in this area.

This impact is going to be short in terms of magnitude because this project aims at improving water supply in this area. In addition, the promotion of irrigation practices in this area will increase their harvest and will make them to grow their crops even during dry sea.

To prevent conflict over agricultural and domestic water uses, the developer should compensate for parcels affected by water reservoir. The developer shall also put in place water tanks which will be used by local population for water domestic uses.

Population Migration and Settlements

The construction of this multipurpose dam infrastructure as well as installation of other activities planned on this dam will cause people to emigrate from the dam site to other areas. It will also attract many people in search for employment and settlements.

The effect of this impact will be felt in the health sector through increased rates of AIDS infection and other diseases that are spread through demographic changes. The population migration in the area may also be a potential source of contamination of water resources which can have significant implications for public health risks. Water contamination, sewage leaks or inadequate treatment of sewage may increase the risk of diseases such as hookworm and other water borne diseases such as cholera and dysentery. Also waterlogged areas could provide favorable breeding grounds for mosquitoes and the prevalence of diseases such as malaria is likely to increase.

This impact will put pressure on social facilities including heath care, water, energy, sanitation and land. Water resources will also be degraded through contamination with fecal matter as the sewer system is lacking in the area.

The Project will prepare a Resettlement Action Plan, which will guide the resettlement of affected households, lands, and crops on the site.

Managing Population Influx

There are no measures for preventing population migration in the subproject areas. However the project and the local government in that site should control settlement in fragile areas including marshlands and steep hills. Another measure to manage influx is through provision of social infrastructure including water and sewer. During construction phase of the project, the contractors should have employment policy which gives preference to the local people. By employing the locals, this would discourage population influx to the area.

This impact is going to be significant in terms of magnitude because local population in Rwanda depend a lot on agriculture as a means of livelihood.

This migration impact is unavoidable. It will be mitigated through compensation for crop and vegetation loss, land and housing through the preparation of Resettlement Action Plans (RAPs) and guided by the Resettlement Policy Framework (RPF) document. In case of displacement of the local community members, a resettlement action plan has to be drawn and be implemented. Also as previously described, most of the area has been in recent years used for seasonal cultivation by local residents. This is a common phenomenon of public marshland, plots and natural ecosystems around Rwanda. If prior notice is not given of the intended project and construction activities commence before produce can be harvested, the fruits of the season's hard worked labour will be lost and the impact could be hard felt by

most of the households of these people. However, during our field visits we share this information with the interested and affected parties and prior to the commencement of the project activities the cooperative leaders operating in this marshland will be informed and given enough time to harvest the cultivated crops.

Households owning houses and lands within the proposed dam site a will lose their land permanently but this shall affect many people. Land parcels affected by irrigation canals/channels development,

water supply and hydropower plants shall also be compensated. Fishes will also be introduced in the reservoir. The community affected by the proposed reservoir area and the silt trap zones may also be grouped in fish farming cooperative.

6.3. Impacts during Operational phase

a. POSITIVE IMPACTS

Impacts on Local and National Economy

The construction of this multipurpose will provide a range of economic, environmental, and social benefits, including; flood control, water storage and drinking water supply, energy, tourism and other uses, and fish-farming. This dam will create also jobs for local population and for other skilled staff. Operation of the project will provide increased revenue in terms of rates payable to Nyagatare District. Increased employment opportunities and other multiplier effects downstream in the economy will provide opportunities for increased revenue for RRA due to increased payments in the form of PAYE, VAT and corporate income tax from retailers and suppliers. The businesses operating on the site will also make substantial contributions on the form of corporate income tax. There will also be increased revenue to utility providers such as EWSA. This dam will increase the opportunity for touristic area and this will be very beneficial to the country and local area.

Flood control

On flood control, in addition to helping farmers to cultivate the marshland through the entire year, the dam will help prevent the loss of life and property caused by flooding. Flood control dams impound floodwaters and then either release them under control to the river below the dam or store or divert the water for other uses. In some instances, dams provide

enhanced environmental protection, such as the retention of hazardous materials and detrimental sedimentation.

Water supply

As government of Rwanda plans to increase the accessibility and affordability of drinking water, this dam will increase the amount of drinking water and this will help to achieve different targets set by central government and local government. This will improve also the public health by reducing water borne disease.

The maximum daily water consumption for human and livestock population is projected to grow from the current 24,000 m3/day to 37,700 m3/day by the year 2022 for the whole district. Irrigation water usage, targeting some 6,200 Ha downstream of the proposed dam that can largely be irrigated by gravity is estimated at 5,000 cu.m/yr.per ha, which is equivalent to 3.59 m^3/sec at 100% irrigation.

Water Supply for Human and Livestock Population

This multipurpose dam will help to meet the human and livestock water demand is as follows:

- Water treatment works of capacity 40,000 m3/day,
- Treated water Pumping station, total capacity 1.5 megawatts,
- Pumping lines to reservoirs, of diameter DN400, and total length 90km,
- Storage reservoirs, 4No each of capacity 10,000 m3
- Distribution system covering all of Nyagatare, total human and livestock population of 655,000 Number

Irrigation

This dam will help to improve agriculture practices by using irrigation technology in this area. As planned in prefeasibility study, the total length of the primary irrigation canal will be 45 km. Two major branches will serve the valleys of Rwikubo and Rwentuha from the main canal. These branches will cross the Muvumba River by inverted siphons preferably. The canal will be terminated at Rugarama, the northern point near the Uganda- Rwanda Boarder. The canal capacity of 2,7cms will allow delivering sufficient water for supplementary irrigation in the valley by gravity

Energy supply

The government of Rwanda set a target of producing 563MW in 2017. Actually the estimation of energy production is about 120 MW. As the hydropower which is planned to be built on this dam will produce 1 MW, this will contribute to the target set. Local population will have also access to electricity and this will help to improve their socio-economic situation.

b. **NEGATIVE IMPACTS**

Physical impacts

Impacts on Soils / cultivated land

Due to continuous use of the irrigated land, there is a potential problem of saltination, alkalination, water logging and acidification of soils. Below we present main reasons for an increase in soil salinity on an irrigation scheme:

Salts carried in the irrigation water are liable to build up in the soil profile, as water is removed by plants and the atmosphere at a much faster rate than salts. The salt concentration of incoming flows may increase in time with development activities upstream and if rising demand leads to drain water reuse;

Salts which occur naturally in soil may move into solution or may already be in solution in the form of saline groundwater. Where the groundwater level is both high and saline, water will rise by capillary action and then evaporate, leaving salts on the surface and in the upper layers of the soil;

The transfer from rain fed to irrigation of a single crop, or the transfer from single to double irrigation may create a "humidity/salinity bridge" in the soil, between a deep saline groundwater and the (so far) salt-free surface layers of the soil. Careful soil monitoring is highly recommended whenever the irrigated regime is intensified, even

though the saline layers might be far below the soil surface and the irrigation water applied is of high quality.

The accumulation of salts in soils can lead to irreversible damage to soil structure essential for irrigation and crop production. Effects are most extreme in clay soils where the presence of sodium can bring about soil structural collapse. This makes growing conditions very poor, makes soils very difficult to work and prevents reclamation by leaching using

standard techniques. Gypsum in the irrigation water or mixed into the soil before irrigation is a practice that is used to reduce the sodium content of sodic soils.

The danger of potential soil acidification needs to be considered. The transfer from rainfed to irrigated crop production, or intensification of existing crop production requires a higher level of nutrient availability in the soil profile. If this aspect is not given adequate attention, the irrigation efficiency remains low. High water losses through the profile will result and useful cations may be washed out from the soil -complex. A general lowering of pH may result in a decrease of the plants capability to take up nutrients. The decrease of pH may also result in an increased availability/release of heavy metals in the soil profile. Rectifying soil acidification problems can be very costly. For similar reasons the content of organic material in the soil may decrease. Such decrease leads to a degradation of soil structure and to a general decrease of soil fertility. The loss/modification of geological sites of scientific importance due to development of borrow pits and quarries, and dams is not anticipated. Soil contamination from oil and diesel spills from vehicles and disturbance/loss of pedagogical features of sensitivity importance like hydro orphic (wetland) soils will also be minimal.

Reduced Water Flow/Downstream Flooding

Reservoir construction for irrigation involves deviation of the flow of water to the dam filling and irrigation channels. Due to this, the downstream water users might experience temporary shortfall (until the reservoir fills up) in the amount of water available therefore disrupting activities and sources of livelihood that depend on the water. This is a short-term impact that only happens when the water will be diverted to the reservoir.

This impact will be minimum in terms of magnitude, severity and scale. The diversion of a portion of stream water to fill up the reservoir will reduce the river flow downstream. This impact is short term and only expected to occur during the reservoir fill up during rainy season and over the night.

Water wastage

The retention of water in the reservoir would lead to increased evaporation leading to surface water loss, ground seepage and spills. Due to semi- arid climatic conditions of the area, much loss of water through evaporation is anticipated.

The water loss will be through percolation, spills and leaks, evaporation among other factors. As the area regularly faced with drought, loss of water through evaporation is going to be of significant impact.

For losses through ground seepage, the transfer canals should be lined. This will prevent ground seepage of water in loose soil. This measure will only apply in areas where the soils are loose or sandy. The irrigation farmers can adopt water saving irrigation approach.

Silting/Sedimentation of the Reservoirs

Rivers/Streams carry sediments down their riverbeds, allowing for the formation of riverbanks, river deltas, alluvial fans, braided rivers, oxbow lakes, levees and coastal shores. The construction of a dam blocks the flow of sediment downstream, leading to downstream erosion of these Sedimentary depositional environment, and increased sediment build-up in the reservoir. While the rate of sedimentation varies for each dam and each river, eventually all reservoirs develop a reduced water-storage capacity due to the exchange of storage space for sediment. Diminished storage capacity eventually results in reduced availability of water for irrigation, and if left unaddressed, may ultimately result in the expiration of the dam and stream. Because of the large, wide 'U'-shaped nature of the catchment and the subsequent distance the runoff follows, silting (sediment deposition) in this reservoir is only going to be at minimal levels. The rate of silt accumulation is attenuated by the drop in the stream velocity downstream towards the retaining wall. As the stream velocity drops, the carrying capacity of the stream also drops thus the rate of silting (sediment deposition) at the dam site. Downstream of the dam, there will be reduction in the soil deposition however it is not bound to be significant.

As all dams result in reduced sediment load downstream, a dammed river/stream turns out to be "hungry" for sediment. Because the rate of deposition of sediment is greatly reduced since there is less to deposit but the rate of erosion remains nearly constant, the water flow eats away at the river shores and riverbed putting a lot at risk including the farms nearby, ecosystems and sometimes deepening the riverbed. The resulting water tables and the stream flow are thus affected.

Reservoir and Canal siltation is an adverse impact that clogs the reservoir and canals leading to less flow of water into the command area and this can reduce the crop yields. Increased soil erosion and siltation is generally impacting the hydrology of the command area

and streams negatively. Furthermore, clogged canals could soon become possible breeding site for mosquitoes if not maintained and unclogged. These mitigations measures can be suggested:

Establishment of silt trap zones

Silt trap zones around the reservoir and along main drainage and irrigation canal have been included in the general design of the project. The silt trap zone around the reservoir comprises of grass layer, shrub layer and tree zone for the protection against siltation This buffer zone must be 50 m along the dam. A 5 m distance along the irrigation and drainage canals, protected with vegetation is recommended to minimize siltation impact.

Care should be taken not to introduce invasive species during re-vegetation of the area. The water hyacinth (*Eichornia crassipes*), responsible for much disruption of aquatic systems, must not be introduced in Muvumba dam.

Erosion control in the water catchment and command area catchment

In order to control erosion and protect reservoir and canals against siltation, the water catchment and command area catchment will be treated with land husbandry technologies.

Soil fertility deterioration

Regular monitoring of soil fertility status and application of appropriate fertilizer in the right amount at the right time and application of IPM techniques should be done.

Impacts on Ground Water Quality

Due to the increased availability of water at the ground surface or near the ground surface, there is increased evaporation which then results in fractionation and deposition of salts. This subsequently degrades the quality of the soils. Much as the increased availability of water will result into increased crop production, great care should be taken to avoid excessive use of fertilisers and pesticides.

Infiltration of irrigation water in excess of available root zone storage will penetrate beyond the reach of roots and eventually recharge groundwater. Nitrates, salts, and other chemicals used in rice cultivation that dissolves in the soil water will move with the water. Crops with high water and N requirements, like rice and vegetables, will increase the potential risk of nitrate pollution to groundwater. The nitrates/nitrites are likely to remain in water until consumed by plants or other organisms.

This impact will be felt more in areas with light-textured soils and intensive production of shallow-rooted crops that will contribute to considerable nitrate losses by leaching.

Mitigating ground water contamination will require measures as used in preventing surface water pollution. Preventive measures will include practicing IPM and rational application of fertilizer and pesticides only as a last results while use of organic manure.

Surface Water Resource Pollution

The use of fertilizers and pesticides in the marshland is going to be a potential source of introducing nutrients into the water resource of the Muvumba river and Akagera River. These chemicals, if applied in large amounts and at inappropriate time, will pollute water resources in the local water courses and have cumulative effects in the basin and groundwater. Pesticides applied will bio-accumulate in the soaked soils of the command area, upset the natural ecological balance and biodiversity of the wetlands downstream.

The impact can be high in terms of magnitude and depending on the quantities of chemicals used. The scope of the impact will be felt throughout the drainage system and beyond hence cumulative impact

will be long term for as long as the chemical runoff continue ending up in the drainage network causing nutrient load effect. However, taking into consideration the national consumption of fertilizers per hectare (less than 4 kg/ha/year) (MINAGRI, 2007) and pesticides (0.1 kg/ha/year), the impact of fertilizer and pesticide is not going to be severe.

Farmers will also be trained in techniques of agrochemical applications (handling, labeing and application of agro-chemicals under field conditions). The training should be incorporated in a farmer's field school curriculum. Extension workers should also be able to deliver awareness program on the amounts and conditions for applying fertilizers and pesticides to prevent water pollution.

Putting in place techniques aiming at filtering pollutants introduced into the water system through farm runoff such as creation of buffer zones in the marshland downstream and along streams, stabilizing drainage canals with grasses, etc. should be encouraged.

Impacts on Air Quality

It is not envisaged that any activities of the proposed development during operation will result in significant impacts on air quality. However, some potential sources of reduced air quality include the following:

Increased traffic exhaust emissions

A significant volume of additional vehicular traffic is expected in the area once the development is fully realised. This will result in increased emission of exhaust fumes, especially around the more heavily trafficked nodes entering / exiting the dam site area. However the road layout will be designed in such a way as to ensure free flowing traffic which will reduce potential congestion and therefore traffic fumes (very slow moving vehicles or vehicles that are stationary with their engine running increase the discharge of exhaust fumes to the atmosphere).

Impacts on Noise Environment

Generally speaking, it is not envisaged that any activities will be undertaken on the project sites during operation which will result in noise nuisance. Potential source of noise might be due to increase road traffic and waterway traffic. The increased volume of traffic to the area will not result in an increased background noise level, especially during peak times. However, given that the dam site is located quite far from existing busily trafficked roads which include fast moving small and heavy duty vehicles, it is not considered that the impact of noise from the additional traffic will be significant.

Biological environment

Water weeds and Eutrophication

There is a potential of water weeds infesting the reservoir especially with increased use of fertilizers in water catchment. Improper and increased application of fertilizers in these areas will lead to increase of nutrients into the dam through, providing a good environment for weeds to grow in the reservoirs. If

nutrient will contain excess of N/P ratio, this will lead to Lake Eutrophication and this will affect the lake productivity and aesthetical value.

The existence of vegetation in the reservoir also contributes to the emissions of methane, a potential Greenhouse Gas, and it is preferable that weeds and vegetation be cleared prior to filling of reservoir.

Mitigation

Water weeds survive in water bodies due to supply of nutrients. To prevent infestation of weeds in the reservoir, nutrients should not be allowed to enter the reservoir. This should be achieved through practicing protection of the catchments and rational application of fertilizer in farms. Vegetation in the dam area should also be cleared before filling the reservoir. **T**he use of compost/organic farming instead of inorganic fertilizers should be encouraged to reduce the amount of chemicals that end up in the water.

Ecological disturbances

The ecological disturbance is likely to affect the plant species recorded in dam site in catchment areas. Damming of river tend to affect biodiversity through reduced water quality and quantity especially in downstream areas. For instance, the physic-chemical parameters of the water, including turbidity and pH, could be affected by the reduced or regulated water flow regimes affecting macro-invertebrates and flora that increased under particular water flow regimes. After construction of this dam and during operation phase, it is better to restore the previous ecological habitat downstream the dam.

Impacts on Terrestrial and aquatic Fauna

A small number of species and individuals of granivorous birds and bird of prey were recorded in the study areas. The use of pesticides in the agriculture fields is likely to negatively affect the top predators (the birds of prey). Regardless of the fore going observations, a number of impacts that will likely result from the implementation of the projects, have been identified:

The areas of inundation where the dam will be installed will result into loss of habitats for the avifauna.

The water retention dams will likely create new habitats for biota (such as groups of invertebrates, fish, amphibians and water birds). This could have both positive and negative impacts on the flora individuals.

The application of excessive pesticides in the fields might result in the loss of top predators. Loss of top predators would result in increased depredation on rice and other crops by granivorous birds and rodents.

Mitigation measures

i. Avoidance of introduction of invasive/Exotic species and degradation of habitat

Care should be taken not to introduce invasive species during re-vegetation of the area. The water hyacinth *Eichornia crassipes*, responsible for much disruption of aquatic systems, must not be introduced in Muvumba dam.

ii. To avoid ecosystem demolish

The avoidance of ecosystem destruction from the use of agrochemicals will be taken into account to minimize chemical usage as described in different above sections of this report.

Social-economic environment

Loss on crop diversity

Some of the affected communities are concerned that the project is going to bring about reduced farming flexibility. Irrigation is only intended to improve rice growing and therefore the areas will lose out on crop diversity as the areas that are being used to grow other crops will be converted to rice growing. This they say will bring about food insecurity in future and reduced activities such as grazing animals, operating woodlots etc. Lack of crop diversity can pose nutrition problems due to unbalanced diets. As was observed, the hill slopes do not favour farming activities due to poor soils, much of the cropping other than rice is being done in the marshlands and their peripheries. Once the project is completed, rice will be grown throughout the year and therefore these other crops that have been growing will be neglected and this is likely to create food shortages in future and lead to increases in the price of food.

However, this behaviour of local society is not true; this project aims to increase the agriculture production by using irrigation technology for all crops.

Increased Spread of Water Borne Diseases

Households feared that there would be an increase in the incidences of malaria because the water reservoir would serve as a breeding ground for mosquitoes. They also feared that there would be a "cool breeze" prevailing as a result of the water mass that would result in respiratory related problems due to continuous exposure of residents.

Impact Significance

The impact of disease spread will be long term for as long as the reservoir is existing and drainage canals which are habitats for disease vectors and the scale and severity is also moderately high and can be severe especially for children under 5 years and pregnant mothers who are vulnerable to malaria.

The scope of the impact will initially be localized but transmission of the disease is likely to extend the scope beyond the project area.

Sensitization of local population about water borne diseases and use of anti-malaria net is advisable for mitigation of this negative impact. Awareness meetings on hygiene of potable water will be encouraged.

Accident in this artificial Lake

During the public consultation process respondents expressed fears in drowning incidents of people (particularly children). They fear also that this dam should increase the case of suicide in this area. Also some local people and tourism may have accident in this lake when they are swimming.

The impact is not significant in terms of magnitude. In terms of scope, it is expected that the impacts will be localized but long term in nature for as long as the reservoir area is existing. It is better that the project developer will show the area where it is allowed to swim, and safe jacket must be in this area.

The developer must also before the construction of the reservoir, undertake education and awareness of the local communities and make them aware of the hazards related to unrestricted entry into the reservoir. Much more efforts should be put on teaching local people proper safety behaviour and swimming.

Chapter 7. MITIGATION AND ENHANCEMENT MEASURES

7.1. Introduction

Measures to mitigate the potential negative impacts of the project can be divided into three categories:

- Measures to be incorporated in the detailed design of the project by the Consultant;
- Measures to be taken by the Contractor during the construction phase;
- Measures to be taken by developer as well as various other relevant stakeholders and authorities during the project's operational phase

This section is divided into two parts comprising mitigation measures that will be implemented during the construction phase and measures that will be implemented or come into effect during the operational phase of the project. The discussion in these sections includes environmental design and engineering features of the project. For other impacts, mitigations measures are discussed under the environmental component headings in the section concerning environmental impacts identified.

During the construction phase, measures to be implemented by the Contractor will be incorporated with the various construction activities that have potential impacts. The Contractor has prime responsibility for the implementation of these measures which includes undertaking the necessary planning and actions to ensure that all persons on the site can work in a safe and healthy environment. This applies from the beginning of site take-over to practical completion of works for each project phase and will be regulated by the Project Management Team. The Project Manager will have the ultimate responsibility for ensuring the project's and the Contractor's compliance with the necessary regulations and standards.

During construction phase, an external hired expert will be appointed to monitor if mitigation measures are being implemented. An external expert has to visit the site at least once a week and has to report to developer at least once a month.

A public consultative (scoping) meeting has already been held in which a presentation was given to inform members of local communities, various stakeholders and other interested and affected parties as to the nature of the project and anticipated impacts. During construction, a formal environmental liaison person / Safety, Health and Environmental (SHE) officer will be appointed as part of the Project Management Team, on site, to act as a link between the project, members of local communities and other identified stakeholders regarding environmental issues.

The Safety, Health and Environmental (SHE) officer will be appointed by developer. Responsibilities of the SHE officer will include, and not be limited to:

- Ensuring compliance with REMA / RDB regulations;
- Ensuring compliance with the requirements of the Ministry of Environment and Lands and other lead agencies;
- Ensuring adherence to the environmental management and monitoring plan

(EMMP).

- Ensuring Occupational Health and Safety of various workplaces in the development;
- Monitoring of environmental issues like water quality, water flow, sediments deposition, waste management, vector control etc
-

7. 2. Mitigation and Enhancement Measures during the Construction Phase

a. Enhancement of Positive Impacts

To promote local employment

During construction period, this project is expected to create enormous jobs.It is recommended that, as far as is possible, priority should especially be given by the Contractor to the employment of labour from local communities around the project area like Gatunda and Karama sectors. This will increase economic benefits accrued to local communities during construction in terms of income as well as be an advantage to the Contractor due to reduced transport time and costs for workers.

Mitigation of Negative Impacts

Impacts on Land and Soil

To prevent soil erosion: Under each project phase, it is expected that all earthworks for site preparation and levelling will be carried out during the dry season if possible. Construction of the access roads and site drainage systems will occur simultaneously with preparation of the site for sub- structural works and the construction of the road formations such that the permanent storm waters road and other site works will be in place before the onset of the following rains. This will minimize the risk of problems due to runoff and erosion.

In the event that this work will not be completed before the start of the rain season, construction of temporary drains will precede the permanent drainage system such that storm water is controlled and directed appropriately as phased construction proceeds.

To prevent land degradation

The Contractor shall procure all raw materials and construction inputs from approved sources. This includes REMA or RWFA authorized quarries and existing approved gravel pits. In such a case as it may be deemed necessary to open up an alternative new source of material (e.g. for gravel or laterite), Rwanda environmental legislation requires that a separate environmental project brief be elaborated for each separate material extraction site and the Contractor is required to obtain permits from RDB for the operation of borrow pits (and / or quarry sites).
The Contractor should be held liable in case he opens unauthorised pits or dumps waste and spoils indiscriminately or fails to rehabilitate any of the sites according to the approved plan. Materials should only be taken from quarries and borrow pits with an environmental permit.

Impacts on Air Quality

To minimise dust releases and nuisance

As mentioned, dust nuisance to workers is likely to be localized and higher at certain strategic locations on the site where construction activities are on-going and impacts on neighbor communities are expected to be intermittent. All work areas and access roads on site will be regularly watered by water browser in order to reduce dust levels. Large stockpiles of materials such as sand and gravel will also be watered regularly.

To minimise exhaust pollution and nuisance

In order to reduce the quantities of exhaust fumes, all plant and construction vehicles will be operated according to manufacturer's recommendations and shall be properly supervised, managed and maintained in good condition and adjusted to limit the emission of black smoke. Designated access routes will be set and complied by the Contractor to confine the areas likely to be affected by air pollution due to construction traffic. There shall be no burning of waste materials on site.

Impacts on Noise Environment

To minimise noise from construction activities: The Contractor shall restrict any of his operations, which result in undue noise disturbance to nearby communities and dwellings (e.g. blasting activities and operation of heavy machinery and construction traffic) between hours of 18:00 and 06:00. Blasting shall be conducted safely in accordance with Rwanda explosives regulations and the guidelines. Badly maintained construction equipment will not be allowed to operate on the site to ensure quiet operation. Designated access routes will be set and complied by the Contractor to confine the areas likely to be affected by noise pollution due to construction traffic.

Impacts on Water Flow

To minimise disruption to surface drainage: The permanent road and site drainage system, have to be preceded by temporary drains as necessary, this will ensure that the site is at all times drained adequately and surface run off is directed appropriately to avoid water logging, siltation or erosion of the site or adjacent areas.

Impacts on Water Quality

To prevent contamination of surface and ground water: To prevent or avoid potential sources of pollution, the following waste management protocols shall be observed by the Contractor(s):

Maintenance of Vehicles and Machinery: Poorly maintained machinery will not be allowed to operate on site. All routine maintenance of construction machinery and vehicles, if carried out on site, shall be carried out in a designated workshop / maintenance area with concrete hard standing surface and drainage to an oil interceptor.

The oil interceptor will be inspected every six months and cleaned / emptied as required by a REMA registered and licensed company in accordance with organic laws on hazardous waste management.

The outflow from the oil interceptor will be tested quarterly to ensure compliance with environmental standards for the discharge of effluent and waste water to the aquatic environment.

Drip pans will be available on hand for the capture of any substance leaking from machinery.

Fuel Storage: Liquid fuel storage and dispensing on site shall be provided in accordance with relevant standards set by REMA and Rwanda Standards Board.

This will include the installation of an above ground steel tank not exceeding 1500 litres mounted on either metal or concrete skids. The tanks and pipe work will be constructed within a concrete containment bund with a reinforced concrete slab and solid concrete block walls of volume of liquid fuel equal to the total fuel capacity of the tank in the enclosure. The pump bay will also be within its own containment bund in order to prevent any fuel or lubricant leaks to ground due to pipe leaks or pump seal failure.

All bunds will have a drainage sump with a valve fitted to the outside of the bund and a piped drain to a common oil interceptor (shared with the workshop / maintenance area), constructed in accordance with the calculated flows of storm water anticipated.

Used Oil: Used oil and lubricants will be stored in approved containers on a concrete hard standing surface with retention bund as per Rwanda standards and disposed of in accordance with the hazardous waste management regulation.

Concrete Batching Plant Washout: The concrete batching plant / mixing area will be surrounded by a retention bund and all excess and wash water will be retained and recycled.

Sanitation: During initial phases, workers shall be provided with adequate sanitary facilities in the form of chemical toilets or mobile toilet in order to prevent contamination of the aquifer. In case the contractor decide to construct toilet, AQUASAN toilet type is advisable so this may be even used during operation phase by tourists or other staff.

Solid Waste: A skip shall be provided on site for the disposal of construction waste and refuse such as rejected off-cuts and packaging, workers garbage, waste from workers canteen etc. Waste from the skip shall be collected on a regular basis by an approved Solid Waste Collection Company and disposed of at approved dumping sites in accordance with REMA and RURA waste management regulations. Materials such as scrap timber and cement bags should be recycled as far as possible on the site.

- Contaminated soil: Immediate soil remediation will be carried out for any major oil or fuel spillages that may occur by mopping up with an appropriate material and disposal off site by a registered contractor in an approved manner.
- All hazardous wastes, material soiled with hazardous wastes and empty containers of hazardous materials shall not be disposed of on site. All such waste shall be stored on site in an approved manner, and be removed at regular intervals to offsite waste disposal facilities designed to handle such hazardous waste as required by law.
- Rubble such as concrete spoil or broken blocks and excess sub-soil from trench excavations will be stockpiled in a designated area on site and utilised on site as backfill and hardcore for the new slabs and substructures, and will not require removal from the site for disposal. Any limestone rock rubble generated from blasting will be used on site for backfill.
- Topsoil removed will be stockpiled in a designated area and will be re-used on the site for landscaping and other green areas.

Stockpile Areas: Stockpile areas for materials such as sand, gravel, stone, laterite, and topsoil, should be surrounded by perimeter drains with sediment and other pollutant traps located at drain exits.

Impacts on Local Ecosystem

To conserve vegetation/habitat: Mature trees that exist in proximity to the dam sites will be retained. The landscaping and re-vegetation of the site, which will contribute to habitat conservation, as well as the promotion of bio -diversity in the area is mandatory.

Impacts on Road and Traffic Safety

To ensure safety on public access roads: The Contractor must implement measures for ensuring safe passage of traffic on public access roads and around the construction site at all times.

Designated access routes shall be set and complied with by the Contractor.

The Contractor must establish traffic and safety barriers and signs wherever needed or required by the police and local authorities. This includes warning signs at egress / ingress points to the site.

When high levels of construction traffic are expected, the project management team will arrange with local police authorities to position traffic officers at the junctions to the site to control traffic flow and reduce the likelihood of accidents.

When high levels of traffic are expected, it is recommended that advance warning of expected traffic is given to neighbouring communities e.g. through the Cell leaders and/or schools/churches.

To ensure traffic safety on construction site: The Contractor shall on a regular basis water all gravel access roads and exposed work areas on site to minimise dust emissions. The Contractor shall ensure that personnel shall, at all times, wear high visibility fluorescent garments where work is carried out on or adjacent to trafficked roads. Clear markings directing traffic should be in place at all relevant places on site and a maximum speed limit of 20 km/h should be enforced.

Impacts on Occupational Health and Safety

To ensure occupational health and safety on the construction site: The Contractor shall be obliged to comply with the health and safety standards. The Contractor has prime responsibility to take the well planned and necessary actions to ensure healthy and safe working conditions are maintained on site. The occupational health and safety of the Contractor's employees as well as all authorised or non-authorised persons present at the work site is the sole responsibility of the Contractor.

The Contractor shall arrange for, and is fully responsible for, ensuring that all employees, subcontractors, suppliers and visitors are made aware of and comply with safety rules and measures that will apply on site, and is responsible for conducting the necessary trainings of personnel. The Contractor must inform all employees that repeated violation of safety regulations or unsafe/disruptive behaviour

will result in disciplinary action, which can include termination. The Contractor must execute his obligations with due diligence and in accordance with Rwanda environmental laws and international rules for labour protection.

Other specific safety rules and practices that shall apply on site include the following:

The contractor shall ensure that all equipment, tools, temporary facilities and other items used to carry out the works are in a safe sound and good condition.

The contractor shall conduct risk assessment in the planning of potentially hazardous tasks to be done.

A system of permits/procedures shall be required depending on the type of works and risk levels (e.g. for working in confined spaces, work in deep excavations, work at heights, etc.)

Good housekeeping shall be strictly enforced to maintain a safe working environment. The Contractor is fully responsible for keeping the Site and the Works free from waste materials or garbage resulting from the Works or caused by any of the Contractors' employees. (This and other waste management protocols are outlined in Section 7.1.2.5)

Personal Protective Equipment (PPE) shall be issued as required to the various categories of the workforce. This includes items such as hard hats, gloves, overalls, boots, respiratory protection, hearing and eye protection, high visibility waist coats, fall protection harnesses and individual padlocks for LOTO procedure.)

LOTO (Lock out/tag out Procedure) shall be mandatory for working on live equipment that could cause injury due to contact with energised parts, mechanically moving parts, etc.

All personnel performing welding and cutting or operating mobile equipment shall be trained and qualified.

Burning of any kinds of wastes or construction materials is forbidden.

Key personnel shall receive training in basic Fist Aid. The Contractor shall provide a First Aid post on site, which is appropriately equipped and staffed by fully trained First Aid personnel. In case of serious injuries on site, e.g. accidents with heavy machinery, etc., the Contractor shallformulate a plan to deal with such emergencies, prior to possession of the site.

Use of Explosives: If blasting is required, the Contractor shall use explosives only in circumstances where it is safe to do so, having due regard for the safety of persons, third party property and the safety of works. The following guidelines for the safe use of explosives shall be observed:

1. The Contractor shall only operate with all necessary licences and shall provide and maintain a secure explosives store in accordance with the relevant Explosives Regulations.

2. Blasting shall be carried out carefully to avoid loosening or shattering of rock beyond the required line of excavation, and all loose or shattered rock shall be removed by scaling down or other means before personnel will be permitted to restart operations after blasting.
3. Notices of blasting operations will be posted on site. Before each firing, the Contractor shall give audible warning, clear the area, and shall take positive measures to prevent personnel entering the area. Audible warning shall be adequate to give warning to neighbouring residential areas, schools etc., or by flyers, of the type of warning signal that will be given (e.g. Siren).
4. The Contractor shall strictly comply with the provisions of the Rwandan laws and regulations.

It is expected that the permanent property boundary fence will be erected at an early stage during construction. If not a temporary hording will be erected by the Contractor to control the access of persons as well as vehicles, equipment and materials to the site. All site safety rules must be strictly and permanently adhered to within the fence areas. The Contractor will also install temporary lighting for roads, pathways and work areas according to applicable local standards.

These rules and procedures apply for the full period of each construction phase from inception of the works to practical completion and acceptance.

Impacts on Public Health and Safety

To avoid accidents involving members of the public: Safety measures on public access roads were discussed above. A hording fence will be erected by the Contractor as a preliminary action to ensure that there is no unauthorised access to the site. In addition, all visitors will be required to sign a visitors log at the entrance to the site.

To reduce risk of malarial infection: In order to reduce the possibility of malarial infection, the Contractor will ensure adequate drainage on site to prevent stagnant water that can provide a breeding habitat for mosquitoes.

Construction workers should also be made aware of preventative measures that can be taken to reduce the risk of malaria such as proper drainage to eliminate stagnant water as potential mosquito bleeding point.

To reduce risk of HIV and communicable diseases transmission: The Contractor will conduct HIV/AIDS awareness and prevention campaigns amongst all members of the workforce in conjunction with the local Health Centre under which the catchment area of the development falls. Such programmes are conducted under the auspices of the Ministry of Health as part of the Government's overall HIV/AIDS awareness and prevention policy. In addition:

HIV/AIDS awareness and prevention posters and information leaflets will be displayed prominently at the construction site e.g. at the Site Office notice board. Free condoms will be made available to all members of the workforce.

Where practicable, and without prejudice to the Contractor's other contractual obligations, preferential employment should be given to members of local communities in the project area. This will reduce the risk of communicable diseases transmission associated with labour that originates from outside the community.

Impacts on Public Infrastructure

All public and private roads used by the Contractor, sub-contractors or suppliers for the construction of the project shall be kept trafficable and free of excessive dirt and mud arising from the work.
If damage arises to public access roads, which is directly attributable to construction activities or to the Contractors negligence, the Contractor shall be liable for its repair to the original specifications or the cost of repair.

Impacts on Socio-economic

To avoid disruption/displacement of communities: As described, there exists some lands which is being used by local population while is considered as marshlands. However, the site has been used for informal subsistence cultivation by local residents for a number of years, and loss of crops can cause undue hardship. If possession of the site and construction activities is to commence before harvest time, it is recommended that prior notice is given of this intention such that crops are harvested early or the cultivation of areas is prevented in order to avoid conflict with local residents / communities.
For people who will be expropriated, it is also mandatory to inform them before demolition and damage of their houses and lands.

To avoid loss of livelihoods: As their properties are already evaluated, It is advisable to compensate the affected people immediately to an already identified area or to compensate them in money so that they can go to look for other land themselves and so that their social wellbeing is not affected.

*Conflicts:*Awareness creation will be put in place to educate the local communities on the benefits that will be realized not only at individual level but benefits be seen from the community and national level.

Loss of crop diversity:
A plan will be put in place on how these irrigated areas will be exploited to meet other food requirement other than rice. Provision of alternative plots to displaced people will improve on alternative food crop production hence will not be impaired by the project.

Health and Disease:
Creation of awareness on Malaria and provision of mosquito nets (to neighbouring households) is the most appropriate mitigation measure.

7. 3. Mitigation and Enhancement Measures during the Operational Phase

a. Enhancement of Positive Impacts

Impacts on tourism and aesthetics

Tourism is one of main purpose of this dam. RDB should prepare the strategic plan of tourism for this dam, which is not far of Akagera National park.

In order to maximise the benefit of this, and to mitigate what might be seen as the elitist image of this high profile project, 50 meters of buffer zone can be served as secondary function as botanic garden for some aquatic plants which play an important role in water purification and other indigenous species. Planting with a wide variety of appropriate indigenous trees and shrubs on the perimeter of this buffer zone could help also to conserve species whose natural habitats are being lost.

Other socio-economic impacts

For other socio-economic impacts like drinking water supply, electricity supply, agriculture services, and fisheries, strategic plan for their enhancement have to be prepared by concernedauthorities

b. Mitigation of Negative Impacts

Impacts on Air Quality

To reduce or avoid gaseous emission: Traffic Exhaust Fumes: The road network will be designed to maximise the free flow of traffic within the development as well as on the adjacent main roads to avoid congestion and the concentration of exhaust fumes.

To prevent odour from solid waste: Proper house cleaning and management of solid waste (waste from tourists and other workers) will ensure the risk of odour due to the accumulation of refuse is minimal. Respect of RURA and REMA regulations on solid waste management will be enhanced. The burning of plastic and other solid waste will be strictly prohibited.

Impacts on Surface Water Flow

To prevent flash flooding or siltation, the site and road drainage system will be designed to carry storm water to artificial lake created. The lake will act as a retention / buffer pond to allow controlled further discharge of storm water to the downstream of dam. The artificial lake will also function as a sedimentation/collection pond to ensure sufficient separation of suspended solids before further discharge of storm water to the drainage system.

Impacts on Water Quality

In order to minimise potential risk of contamination of surface or ground water resources from point or diffused sources of pollution, different measures have to be taken. Proper soil management will be the one mitigation measures to protect water quality. Although the 50 meters buffer zone will act as lake protection purification area, soil management in catchment area will be also enhanced.

For Fuel Storage and Dispensing (Service Station), all petroleum products to this site will be transported, stored and dispensed in accordance with the applicable Acts and Statutory Instruments and other local laws, Rwanda Standards Board. The operation of the service station and the design of the mechanical equipment, namely tanks, pumps and dispensers and plastic pipes with secondary containment will ensure no leaks and spills, if any, from the station. These leaks, if they do occur, will be detected instantaneously and before petroleum has been discharged into the ground. The Oil Interceptor will be inspected weekly during the dry season and daily during the rainy season to ensure that discharge of

Petroleum to the storm water drainage system does not occur. The outflow from the Oil Interceptor will be tested quarterly to ensure compliance with REMA standards for the discharge of effluent to the aquatic environment.

To protect the quality of water, waste management regulations have to be respected.

Solid Waste Management:The following Solid Waste Management protocols will be followed:

Proper housekeeping ensuring that all parts of the project area are clean all times.
Designated covered areas will be provided for the storage of normal solid waste arising within the project areas in enclosed (caged) skips to prevent material from being blown around (or off) the site.
Facility will be provided for the segregation of recyclable materials. Recyclable materials (such as paper/cardboard and plastic) will be collected by a registered recycling company.
An approved waste removal company will be contracted by the management to collect un-recyclable solid waste for disposal at an approved refuse dumping site in accordance with REMA waste management standards.
The Oil Interceptor will be emptied at least once every six months or more frequently as required. Emptying of the Petroleum separation chamber will be contracted out to a REMA approved company for disposal in accordance with REMA guidelines.
Medical waste will be stored, collected and disposed of by a registered contractor in accordance with REMA hazardous waste management standards.

Agrochemicals Management is also mandatory within objective of water quality management.
Use of fertilizer will be minimised by use of organic waste. Green waste will be composted to produce organic fertilizer and reduce dependence on synthetic products. Only approved chemicals shall be used under the application standards set by MINAGRI for farmers. Other management measures to minimise use of agrochemicals will include

The use of chemicals in response to problems rather than as routine preventative treatment.
Adequate application of organic manure and mineral fertilizers should be adopted.

Impacts on Ecosystem

Ecological degradation: This multipurpose dam will change the natural landscape to artificial aquatic ecosystem. This will affect the loose of natural vegetation but will create another ecological habitat which is very favourable to aquatic life. For fisheries services, it is advisable to make study before introduction of new fish species. The new fishes must be species which do not disturb the aquatic food chain.

These measures have to be taken to against the ecological degradation:

Operate dam to suit downstream requirements and encourage plant species diversity around reservoir.

Designate land for flood plains; wetlands; watersheds; drainage water disposal; river corridors.

The vegetation in areas will need to be enhanced by encouraging regeneration and re-vegetation with less water demanding trees. It would be a good thing if these buffer zone areas were acquired by government and managed in ways that would protect the lake.

There might be a need to restore pockets of marshland around the ecosystem to act a sieve to capture and retain some of the excess nutrients in the water

The use of compost instead of inorganic fertilizers should be encouraged to reduce the amount of chemicals that end up in the water.

Erosion and Sedimentation

Providing good vegetative cover will disperse the energy of rain drops. This should be done by doing reforestation and constructing erosion control ditches in the entire catchment area and to be planted with using tree species such as Alnus, Fruit trees such as mangoes, avocadoes and agro forestry tree species such as calliandra and other fodder plants and planting grass on the immediate marshland fringes.

<u>To avoid introduction of invasive species and degradation of habitat</u>

Care should be taken not to introduce invasive species during re-vegetation of the area. Lantana camara is especially invasive and is a declared noxious weed. The water hyacinth Eichornia crassipes, responsible for much disruption of aquatic systems, must not be introduced to the new lake.

Impacts on Health and Safety

To minimise risks to occupational health and safety: Good housekeeping of the dam and other related infrastructures will be given high priority and all procedures and practices involved in their operation will comply with the health, safety and environmental rules and regulations.

7.4. ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

This plan is made as part of the whole environmental management and monitoring plan for this project at various phases. It is intended to ensure that all the mitigation measures proposed are addressed and monitored.

The purpose of an environmental management plan is to:

Define the mitigation, monitoring, and execution requirements associated with the construction and operation phase of the project.

Define the indicators and processes used to identify and execute mitigation actions related to the project.

Ensure that any other impacts that may arise out of the project during implementation can be identified from indicators set and appropriate mitigation measures are taken.

Establishing roles and responsibilities and implementing procedures for effective execution of the mitigation process.

A brief description of other stakeholders that will have monitoring roles during the construction and operational phases of the project and Water Quality Parameters to be considered for irrigation and drinking water supply purposes are also prearranged in this plan. This plan describes the mitigation, monitoring and execution approach, responsibilities, and procedures associated with the project.

The environmental monitoring plans for the different project phases (construction and operation) are given according to the proposed mitigation measures in the preceding chapters.

1. **Environmental Management Plan for Planning and Construction Phase**

Table 10 Environmental Management Plan for Planning & Construction Phase

COMPONENT	Activity	Adverse Impacts	Proposed Mitigation measures	Implementation Schedule	Responsible	Incidence/ Occurrence	Budget($ US)
SOCIAL & ECONOMIC ENVIRONMENT	Site Selection	Disagreement and misunderstanding over project beneficiaries	Involve all the stakeholders in Site Selection	Planning phase	RWFA	Done	Part of project preparation costs
	Land Acquisition	People displacement Resettlement Loss of cultivable land	Calculation and giving value to all things which will be damaged Compensation of damaged properties	Planning phase	RWFA and contractor	As needed	Cost of damaged properties
		Livelihood disturbance (Especially agricultural	Compensation for land, crop and properties	Planning stage	RWFA and contractor	As needed	Cost of crops and other farm investment
B I O P	**Access road constructio n**	Destruction of structures, crops and vegetation.	Compensation/ Expropriation of damaged properties	Planning stages	RWFA & Contractor	To be ended in the first month starting construction	Part of project preparation costs

H Y S I C A L		Potential accidents during construction, erosion among other factors	The Contractor in collaboration with the Project Managers and relevant authorities shall arrange that all supervisory employees of the Contractor and his sub contractors are trained to ensure the following:	Construction stage	RWFAA	Every Month in the construction phase	To be determined by contractor

E N V I R O N M E N T			i. A basic understanding of the key environmental features of the site and its environs. This will include sharing of information on bio-physical and socioeconomic aspects of the environment to prevent misunderstanding. ii. Thorough familiarity with the environmental protection requirements as they apply to the works. ii. Awareness of archaeological artifacts. v. Awareness of any other environmental matters which are deemed necessary by the Team of Project administration (e.g. appropriate behavior / community relations, public health issues). v. Basic First Aid.				

	Site clearing	Soil erosion and contamination of water in the adjacent streams	All earthworks for site preparation and leveling will be carried out during the dry season of each implementation phase and the permanent storm water, road and site drainage	Construction phase	RWFA and contractor	continuous	To be determined by contractor
			system will be in place before the onset of the following rains.				
	Construction of building site and dam	Potential soil erosion during construction	-Only clear areas Earmarked for construction -Planting of vegetation on cleared site immediately after construction	Construction phase	RWFA	Continuous	To be determined by contractor
B I O P H Y S	Purchase of materials during construction such as stones, gravel, laterite and sand	Potential Water and Land degradation	Procurement of all raw materials and construction inputs from approved sources and quarries and gravel pits approved by RWFA.	Construction phase	RWFA and contractor	Continuous	To be determined by contractor

I C A L E N E N T	Extraction of materials for construction	Land degradation	Backfilling borrow pits after excavation and rehabilitating with vegetation	Construction phase	RWFA and Contractor	Continuous	To be determined by contractor
	Construction of reservoir and irrigation channels	Fugitive dust generated during excavation works could cause respiratory diseases	Wetting the surface during construction	during construction	Contractor	Twice daily during the dry periods of the road construction	Contracted Company budget
		exhaust pollution	Maintenance of Equipment engine, fuel and emission systems of construction machinery and vehicles in accordance with manufacturers' recommendation to minimize exhaust smoke, fuel and oil leaks.	During Construction &implementation phase	Contractor	Continuous	To be determined by contractor
			Designated access routes will be set and complied with by the Contractor.	During Construction & implementation phase	Contractor	Continuous	To be determined by contractor

		Air pollution	Avoiding burning of any kinds of waste or construction materials	During all construction activities	RWFA, Contractor	Monthly follow-up by the RWFA Environmental Officer	None
B I O		High nuisance from construction	The Contractor shall restrict any of his operations, which	Construction period	RWFA, Contractor	Daily follow up	None
P H Y S I C A L E N V I R O		activities	result in undue noise disturbance to nearby communities and dwellings (e.g. blasting activities and operation of heavy machinery and construction traffic) between 18:00 and 06:00 hours.			by field officers	
		Loss of cultivable land	Compensation of PAPs Integration of PAPs into fish cooperative	Before construction During operation phase	RWFA		

N M E N T		Contamination of surface and groundwater	All routine maintenance of construction machinery and vehicles, if carried out on site, shall be carried out in a designated workshop (maintenance area) with concrete hard standing surface.	Construction & implementation phase	Contractor	- RWFA Environmental Officer and Contractor	None
			Drip pans will be available on hand for the capture of any substance leaking from machinery	Construction & implementation phase	Contractor	Continuous	Contractor
			Liquid fuel storage and Dispensing on site shall be provided in accordance with relevant standards set by the energy regulations and RSB.	Construction& implementation phase	contractor	Monthly	None
			All bunds of the fuel storage facility will have a drainage pump with a piped drain to a common oil interceptor (shared with the workshop /maintenance area)	Construction & implementation phase	contractor	Monthly	None

BIOPHYSICAL			The oil interceptor shall be cleaned / emptied as required by an REMA/RDB/RURA registered and licensed company in accordance with the Hazardous Waste Management Regulations.	Construction & implementation phase	Contractor	As required	none
			Used oil and lubricants will be stored in approved containers	Construction & implementation phase	RWFA and contractor	As required	Contractor budget
ENVIRONMENT			on a concrete hard standing surface with retention bund as per standards and disposed of in accordance with REMA/RURA regulations.				
			The concrete batching plant / mixing area will be surrounded by a retention bund and all excess and wash water will be retained and recycled.	Construction & implementation phase	RWFA and the contractor	Ongoing	Part of construction contract value
			Adequate sanitary facilities shall be provided for workers in the form of portable chemical toilets.	Construction & implementation phase	RWFA and the contractor	monthly	Part of construction contract value

			A skip shall be provided on site for the disposal of construction waste and refuse such as rejected off-cuts and packaging, workers garbage, waste from workers canteen etc. Waste from the skip shall be collected on a regular basis by approved Solid Waste	Construction & implementation phase	contractor	weekly	4000

			Collection Company and disposed of at approved dumping sites in accordance with REMA and RURA Waste Management Regulations.				
		Contamination of surface and ground water	Stockpile areas for materials such as sand, gravel, stone, laterite, and topsoil, should be surrounded by perimeter drains with sediment and other pollutant traps located at drain exits.	Construction & implementation phase	contractor	continuous	none
S O C I A	Construction of public access Roads	Accidents on Public access roads	Designated access routes shall be set and complied with by the Contractor.	Construction& implementation phase	contractor	continuous	none

L & E C O N O M I C V I R O N M E N T		Accidents on public access roads	The Contractor must establish traffic and safety barriers and signs wherever needed or required by the local police authorities.	Construction phase	contractor	continuous	none
		Damage to public access roads due to heavy traffic	Damage arising to public access roads due to heavy traffic	Construction phase	Contractor	As required	Part of construction contract budget
			Employees are made aware of and comply with safety rules and measures that will apply on site	Construction phase	RWFA and the contractor	continuous	Part of construction contract budget
			Key personnel shall receive training in basic First Aid. The Contractor shall provide a First Aid post on site, which is appropriately equipped and staffed by fully trained First Aid personnel.	Construction phase	contractor	continuous	Part of construction contract budget

			Personal Protective Equipment (e.g. hard hats, gloves, overalls, boots, respiratory protection, hearing and eye protection, high visibility waist coats, fall protection harnesses, garments) shall be issued as required to the various categories of the	Construction phase	RWFA and The contractor	continuous	Part of construction contract value
			workforce and replaced when Necessary.				
N T			The Contractor will install temporary lighting for roads, pathways and work areas according to applicable local standards	Construction phase	RWFA and the contractor	continuous	Part of construction contract value
			A boundary fence shall be erected at site takeover by the Contractor. All site safety rules must be strictly and permanently adhered to within the areas of the site.	Construction phase	contractor	As required	Part of construction contract value

	Construction of the dam and other related activities	Conflict between land tillers & cattle keepers with rice growers	Compensation for properties affected by reservoir, silt trap zone & canals Developing domestic water sources and troughs for domestic animals		RWFA		To be determined by the contractor
	Employment of workers and	Risk of HIV and communicable disease	Conducting HIV/AIDS awareness and prevention campaigns amongst all	Construction phase	contractor	Bi-annually	Part of construction contract budget
	technicians	transmission	members of the workforce in conjunction with the local Health Centre Make condoms Free available to all				
			Employment should be given to members of local communities to reduce the risk of communicable diseases associated with migrant labor.	Construction phase	contractor	continuous	none

7.4.1.Environmental Management Plan for Operational Phase

Table 11 Environmental Management Plan for the Operation Phase

Activity	Adverse Impacts	Mitigation Measures	Implementation Schedule	Responsibility	Budget (US$)
Reservoir filling	Reduced water flow downstream during the time that the reservoir fills up	Control water abstraction rates to half the stream flow to replicate natural flooding regime. Install master meter Proper design and operation of dam spillways and gates (timing and volume of discharges).	Design and operation phases	contactor	Construction budget/ To be determined by contractor
	Water wastage	Transfer canals should be ined, especially in areas with loose and sandy soils. Irrigation farmers should adopt water saving irrigation approach	Design and operation phases	Contractor,	Construction budget/ To be determined by contractor

	Changes in Hydrology	During the filling up the dam by water, the part of Muvumba river will be deviated so that downstream will continue to have access to the water	During design and operation phase	RWFA and contractor	Construction budget/ To be determined by contractor	
	Reduced Water Flow	Regulate water abstraction through practices and design of the intake structures;	During construction and operation Should be done before project commissioning	RWFA	None	
	Water wastage	Adopt water saving irrigation approach	During operation phase	RWFA	Part of capacity building	
Irrigation	Soil erosion and Reservoir and Canal Siltation	Silt trap zones have been included in the general design of the project and the canals will be flushed as frequent as possible to minimize this impact.	During construction phase	RWFA and other stakeholders like MINAGRI	RWFA	

		Water catchment protection with land husbandry technologies;	During construction	RWFA	RWFA budget	
	Water Weeds	To prevent infestation of weeds in the reservoir, nutrients should not be allowed to enter the reservoir. This should be achieved through practicing protection of the catchments and rational application of	During construction and operation phase	RWFA	RWFA budget	
		fertilizer in farms.				
	Change in hydrology	Control water abstraction through management practices	During irrigation	RWFA	None	
	Soil salinization or acidification	Control irrigation water quality	During irrigation	RWFA Cooperative members	RWFA budget	

	Water borne diseases	Prevent or remove aquatic vegetation from canals and reservoir Regularly fluctuate water levels Periodic rapid drying of irrigation canals; Prevent contamination of waterbodies with feces; Supply safe and clean drinking water	Operation phase	RWFA and local authorities	None	
		Control measures including: (i) Providing for biological vector control (eg. Suitable fish species) in reservoir; (ii) Preventative measures (provision and promotion of insecticide treated mosquito nets) (iii) curative measures (provision for medications at the health center/ Hospital)	Operation phase	RWFA and Ministry of Health	None	

	Water accidents and suicide	Sensitization of local population; Training on swimming Availability of safety coat	Operation phase	RWFA, local authorities	RWFA budget	
	Population migration	Control settlement in fragile areas (marshlands & steep hills) Provision of social infrastructure including water sewer	Construction & operational phase	RWFA and Local authorities	None	
	Loss of livelihoods	Compensate for properties, land and crops loss Integrate the people into the project beneficiaries	Planning stages	RWFA, contractor and Local authorities	Dependant on the outcome of Compensation survey	
	Emergence of pests and crop diseases	IPM approaches are proposed	Operation phase	RWFA & MINAGRI	Capacity buildin g budget	

Application of agrochemicals (compost, fertilizer and pesticides)	Water Pollution	Adoption Integrated Pest Management (IPM) approach. A training program on application of agro-chemicals under field conditions Create buffer zones/ silt trap zone around the reservoir and command area Identification and protection of domestic sources of water	Design and planning stages During construction and operation phase	RWFA RWFA	RWFA budget RWFA budget RWFA and Contractor's budget RWFA Budget	
	Displacement of staple food	Promote importance or diversifying crop production and good farming practices like improved inputs, rotation, etc. on hillsides Good land use planning that incorporates rice and staple food crops	Planning and operation phases	RWFA, MINAGRI and Local authorities	RWFA budget	

Failure of the Reservoir	Excessive seepage	Lowering the water to a safe level; Determining the source of seepage and do repairing	During operation phases	Reservoir operator, Supervising RSSP Engineer,	Cost can only be determined at the time of Reservoir failure	
	Failure of Appurtenant Structures such as Outlets or Spillways	Implement temporary measures to protect the damaged structure like closing an outlet or providing temporary protection for a damaged spillway	During operation phases	Reservoir operator Supervising by RWFA	Cost can only be determined at the time of reservoir failure	
	Cracks in the reservoir	Lowering water level through the low level outlet until a safe elevation is reached Doing repairing after determining the source of cracks	During operation phases	Reservoir operator Supervising RWFA	Cost can only be determined at the time of reservoir failure	

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7.4.2.. Environmental Management Plan for decommissioning Phase

Table 12 Environmental Management Plan for decommissioning Phase

COMPONENT	Phase and Activity	Adverse Impacts	Proposed Mitigation measures	Implementation Schedule	Responsible	Incidence/ Occurrence	Budget ($ US)
BIOPHYSICAL , SOCIAL &ECONOMIC ENVIRONMENT	Civil works	Burrow pits that could provide habitats for vectors	Rehabilitate Through levelling and re-vegetation	During decommissioning phase	Contractor	End of all civil works	Part of the contract budget
	Dam Operation	Soil erosion on the dam and stream banks	Creation of 50 m silt trap zone (buffer zone) around the Reservoir and protect them with vegetation;	Decommissioning of the civil works	RWFA and contractor	End of all civil works	To be determine d by contractor

		Breeding of mosquitoes that spread Malaria and drownin g hazards	Rehabilitate pits created after dam/ reservoir construction through filling	Decommissioning stages	Local authority and community	After all infrastructures establishment	Contractor budget
		Emptying the reservoir resulting in flood downstream	Emptying the dam gradually to ensure that volumes are safely Maintained. this should be done during dry season to avoid high water volumes during this activity	Decommissioning phase	Dam operation manager, RWFA	As required	None
	Demoliti on of Installed structures	Dust noise and rubble	Controlled demolition coupled with installation of dust screens (e.g. Canvas cloth), and respect working hours where structures are near human presence and activities or structures	Decommissioning of civil works	Contractor		Part of the contract budget

4. ENVIRONMENTAL MONITORING PLAN

Environmental Monitoring Plan for Planning and Construction Phase

a. Environmental Monitoring Plan for the Construction Phase

Table 13 Environmental Monitoring Plan for the Construction Phase

Activity	Adverse Impacts	Proposed Mitigation measures	Responsibility	Implementation schedule	Frequency	Budget ($ US)
Compliance	Potential absence of compliance to the EMP and REMA licenses and regulations	Routine inspections of the site, routine environmental record(water, sanitation and waste management), Construction materials, audits and incident Reports as and when required (e.g. for pollution, accidents, etc.)	RWFA, Environmental officers and hired consultant	During construction	At least once a week	To be determined by contractor

Reservoir design and construction of reservoir and canals	Fugitive dust generated during excavation works could cause respiratory diseases	Wetting the surface during Construction	Contractor	During construction	As required	Part of the contractor's budget
	Contamination of surface and ground water	Records will be kept on site of inspection and approval of fuel and oil storage and dispensing facilities. Routine inspections will be made of such facilities for leaks and discharges to ground.	RWFA Engineers, contractor and EO	During construction	Daily	None

		Regular inspections will be carried out for works to audit safety of the site including actual construction operations, workshops and storage facilities, documents required to certify conformity of equipment, tools and materials used by the Contractor.	RWFA, hired consultant and EO	During construction		At any time	None
	Soil erosion	Create contour drains during Construction; Efforts should be made to contain earth movement	Contractor	Construction phase	Before the supply of construction materials		Part of The contractors budget

Monitoring site activities	Exhaust pollution	Maintenance records will be kept for all construction vehicles and plant equipment engines.	RWFA	During construction	Continuous	None
Occupational Health and Safety	Potential accidents	An inventory shall be kept of all explosives brought to site and used on site	RWFA, EO and Contractor	At any time during construction	continuous	None
Sanitary	Risks to Health and Safety on the construction site	Sanitation, waste management and pollution control protocols will be monitored	RWFA and EO	Every 2 months	continuous	None
Compliance	Risks to Health and Safety on the construction site	Documents to certify conformity of tools, equipment and materials used by the Contractor shall be kept on site and be available for inspection.	Contractor	During the construction phase	None	

Reservoir maintenance	Loss of livelihood downstream Unnecessary repair work	Prepare a maintenance schedule for 6 month period (routine maintenance & repair) Regular removal of floating debris in the reservoir	RWFA and EO	During operation phase	Cost can only be determined at the time of Reservoir maintenance

b. **Environmental Monitoring Plan during Operational Phase**

Throughout the operation phase, monitoring is proposed for water quality, disease transmission, and seepage/leakage.

Water Quality Monitoring

This mainly focused on determining the intensity/level and concentration of pesticides and fertilizer content in the command area water networks. As this dam will serve to drinking water supply, drinking water quality must be respected. Raw water must be also analyzed. Water sampling points should be at the upstream, middle and at the mouth of the command area. These samples should be taken by the RWFA and Environmental officer for laboratoryanalysis. The results should be used to design appropriate water quality mitigation programs. The same will apply to analysis of water quantities in relation to the abstraction impacts.

Monitoring of diseases spreading

In order to monitor the possible impacts of the marshlands development to malaria and bilharzia transmission in the area, the RWFA EO together with the Nyagatare districts staff in charge of social affairs/Public health should undertake periodic surveys of the health records around the marshlands to ascertain prevalence of disease spread. The surveys should be done every trimester in a year. Even though it cannot be proven that the RWFA project could be directly contributing to the spread of these diseases, the results can be used to assist RWFA increase its interventions on malaria and bilharzia prevention.

Monitoring Seepage and leakage

Measurement of seepage through the dam body, foundations & abutments of the dam may indicate erosion or blocking of downstream drains and relief wells by increase or decrease of seepage respectively at constant reservoir level. Seepage and erosion may take place along the lines of poor compaction and through the cracks in formation and fills. This may be indicated by such measurement. Measurement of seepage water at interface of dam and its foundation will provide direct indication of the efficiency of cutoff and indicate about the necessary remedial measures. The chemical analysis of water will provide the information of seepage of water through the foundation drainage arrangement and any foundation material being washed out

Table 14 Environmental Monitoring Plan for Operation Phase

Adverse Impact	Factor/ Parameter	Indicator	Method/Technique	Frequency of Measurement	Responsible	Costs Estimates (USD)
Physical environment						
Reduced Water flow Downstream	Quantity	Flow rates per second	stream gauging	Seasonally	RWFA Environmental Officer Cooperative, WUA	RWFA budget
Water pollution	Quality	Nutrient Load (Nitrates, phosphates, potassium, pesticide residue) Turbidity etc	Bi-Annually during wet and dry season	Seasonally	RWFA	RWFA budget
Water wastage	Water quantity	Water availability for irrigation	Amount of water used for irrigation	Continuous	RWFA	None

Soil erosion	Sediment yield	Water turbidity & landslides	Observation	Continuous, mainly in rain season periods	RWFA, REMA & Community Beneficiaries	RWFA budget
Flooding	Flooded area	Floods downstream of project area	Observation and Reported cases of flooding.	Continuously, Especially rain season period.	RWFA Community Beneficiaries(Farmers, etc)	RWFA M&E budget

Biological Environment						
Adverse Impact	**Parameter**	**Indicator**	**Method**	**Frequency of Measurement**	**Responsible**	**Costs Estimates (USD)**
Loss biodiversity		Species and taxa diversity	Quadrant survey	Yearly	REMA and RWFA	RWFA budget
Loss of crop diversity	Agro biodiversity	Number of species cultivated by local farmers	Observation and crop production reports	Seasonally	RAB, RWFA	RWFA budget

Socio-economic Environment						
Adverse Impact	**Parameter**	**Indicator**	**Method**	**Frequency of Measurement**	**Responsible**	**Costs Estimates (USD)**
Population influx	Population	Change in total human population within 5km radius from dam	Census	Seasonally	Local authority, EO, RWFA	RWFA budget
Safety Hazard	Safety of live stock and humans	Reported cases of incidences and accidents , Seepages and leakages reported or observed on the dam; Color, turbidity and change in seepage chemical content.	Review and evaluation of incidents and accidents register Direct observation of seepage water.	Continuous monitoring of leakages, seepages, movements through instrumentation	RWFA & MoH	RWFA budget

Water-borne Diseases	Disease prevalence	Increased cases of malaria and bilharzias among other waterborne diseases	Review of health records at near health centre in the project area	Each trimester	RWFA Environmental Officer, and Ministry of Health	RWFA M&E budget
Water resource use conflict	Persons	Complaints and reported cases of conflicts	Conflict reports	continuous	RWFA	None
Displacement	persons	Number of people displaced	RAP	continuous	RWFA	RAP budget
Food insecurity		Food crop production	Crop assessment report	Seasonally	RAB/MINAGRI	Part of food security monitoring budget

Water Quality Parameters to be considered for Irrigation in this Project

Table 15 Water Quality Parameters to be considered for irrigation purpose

Probable irrigation problems	Associated Parameters	Recommended Frequency	Estimate costs (in USD)
Specific Ion Toxicity *(affects sensitive crops)*	Sodium, Chloride, Boron, Trace Elements	Each trimester	
Infiltration (*affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)*	Sodium Adsorption Ratio (SAR) and EC	Each trimester	
Salinity (*affects crop water availability)*	EC_W or TDS	Each trimester	
Miscellaneous Effects *(affects susceptible crops)*	pH, Nitrogen (NO3 - N), Bicarbonate (HCO3)	Each trimester	

Note that, the allocated cost/Budget for each activity includes the transport for sampling technicians, car hiring and calculated based on time frequency will be calculated depending on laboratory cost.

Table 16 Water Quality Parameters to be considered for drinking water supply purpose (Source WHO)

Parameter	Unit	Guideline value
Microbiological quality Fecal coliforms Coliforms organisms	Number/100ml Number/100ml	0 0

Inorganic Constituents		
A r s e n i c C a d m i u	M g / l M g / l M g /	0.01 0.003 0.05 0.07 1.5 0.01 0.001
Aesthetic Quality		
Aluminum	Mg/l	0.2

Chloride	Mg/l	250
Color	True color unit (TCU)	15
Copper	Mg/l	1.0
Hardness	Mg/l (as $CaCO_3$)	500
Iron	Mg/l	0.3
Manganese	Mg/l	0.1
pH	Mg/l	6.5 to 8.5
sodium	Mg/l	200
solids (total dissolved)	Mg/l	1000
Sulphate	Mg/l	350
Taste and odor		Inoffensive to most consumers
Turbidity	NTU	5
Zinc	Mg/l	3

Safety Management Plan: The majority accidents and other safety breakdowns that are likely to occur at construction and quarries sites can be prevented if precautions are taken during the planning phase. With a risk management (safety action) plan, it is recommended that the contractor takes a proactive approach to managing accidents and safety precautions. To ensure the general safety of workers on site during the construction phase, the following measures need to be put in place.

General safety measures

- A safety officer in charge of overseeing that workers are complying with the safety code at the site is recommended;
- Safety office (and safety officer) with a first aid kit needs to be in place on site;
- In the event of the need for evacuation to hospital of any worker(s) for whatever reason, an ambulance shall be called to transport the injured to the nearest hospital;
- Sensitization of the workers on the safety precautions on site to ensure that all workers adhere to the rules and dress code of the safety gear while on site.

Below is a safety management plan that shall be applied during the construction and operation phases. The compiled safety management planning is summarized in the table below:

Risk	Origin/Cause	Safety action in place	Responsible
Physical injuries	Falling debris Sharp objects Hard objects and surfaces	Safety gear that includes boots, helmets, overalls, leather gloves etc, will be given to workers on site.	Contractor
Respiratory tract effects	Inhalation of dust and other particles	Gas masks and eye goggles will be provided to protect worker against cement and other particles	Contractor
Fire outbreak and waste burning	Inflammable fuels Welding and other Gases. Burned waste	-Proper storage of fuels and gas cylinders in restricted authorization and designated areas. -Security alarm system and elementary firefighter equipment such as fire extinguishers will be installed on site at the offices. -Properly designated escape roots with directions. -Frequent fire out break management drills as precaution and awareness to the employees and students.	Contractor
Welfare on sit/	Toilet/sanitation facilities	Preferably mobile ECOSAN toilets shall be installed on site	Contractor

public health	Drinking water	-The site will be provided with clean Drinking water. -Water storage containers will be properly marked and protected. -Water storage containers will be properly marked and protected from potential contamination and these tanks shall be labeled either "Boiled drinking water" or "washing water".	Contractor

During construction phase

Establishment of temporary storm water collection pool made o f impervious material, positioned at probably the lowest point of the site based on the area contours. This will hold water which after pre-treatment may be used for construction Excavation of the plots shall be done in phases to avoid opening big chunks of land at once fast tracking of the project works to avoid keeping plots open for long, Compacting of excavated area to minimize erosion effect from storm water.

During Operation phase

Natural area conservation- Green areas and other vegetation cover are provided for the dam/reservoir surroundings and other quarries pits to reduce run-off, through re-vegetation and forestation (planting of grass and trees);

Structural storm water management measures-Structural storm water measures are physically constructed controls that may remove pollutants from runoff, limit the rate of runoff, prevent contact between runoff and pollutants and stabilize pollutants. The following structural storm water management practices shall be designed to satisfy an applicable minimum control at both the construction and operation phases.

Surface drainage open channels for storm water collection, shall be built at the site boundaries/limitations and along the access roads for accessing different areas to be developed.

Water drains shall be built to channel surface water off the site into a planned storm water collection pond at the construction stage to avoid its stagnation when unnecessary (this can result flooding, stagnated water, soil compactation, loss vegetation and small animals, etc).

Physical buffering through well planned landscaping of the project site is planned for, to reduce the run-off velocity thereby reducing soil erosion, sedimentation or any other adverse effects of storm water.

Vegetative buffers (such as grass growing), to allow for storm water infiltration, shall assist in ground infiltration of the likely storm run-off and thereby improving the ground water re-charge.

Storm water monitoring plan

This storm water-monitoring plan is intended to ensure that all the mitigation measures proposed about storm water are addressed in the management plan.

Table 18 Storm water management and monitoring plan

A. DURING CONSTRUCTION PHASE				
Activity	**Requirements**	**Procedure**	**Implementation schedule**	**Responsible**
Storm water management	Site plans indicating the area to be excavated	Phased excavation of the plots to avoid opening big chunks of land at once	Site clearing time	Contractor
	Work implementation schedules	Fast tracking of the project works to avoid keeping plots open for long	Excavation for foundation base	Contractor
	Ground compacting equipment	Compacting of excavated Area to minimize erosion Effect	Foundation backfilling time. Leveling of site after construction	Contractor
	Work implementation schedules	Surface irrigation/drainage open channels built at the site boundaries	- Excavation for foundation base	Contractor
	Work implementation schedules	Physical Buffering through well planned landscaping of the project site	- Foundation backfilling time - Leveling of site after	Contractor
B. DURING OPERATIONAL PHASE				
Activity	**Requirements**	**Procedure**	**Implementation schedule**	**Responsible**
Storm water management	Provision of green areas	Damaged green areas(quarries sites, bellow pits, etc) and other Dam/reservoir surroundings have to be re-vegetated to	At the end of the construction, when preparing the site for commissioning	Contractor

7.5. ENVIRONMENTAL MANAGEMENT PLAN IMPLEMENTATION

The environmental management plan (EMP) will be implemented by several institutions mentioned below which are directly or indirectly involved in this subproject.

a. **The sponsor**

The main role of the financial sponsor of this project including EMP is to ensure that compliance is achieved as per the requirements of the EMP.

b. Rwanda Natural Resource Authority (RWFA)

RWFA is the lead agency in the implementation of this EMP and the project. The role of the RWFA is to implement mitigation measures, coordination of monitoring activities maintenance of monitoring information, building the capacity of other actors, environmental management and in collection and analysis of monitoring data.

The RWFA will also supervise infrastructure design and construction including reservoirs and drainage/ irrigation channels. RWFA will ensure that the dam is constructed according to the specifications, international technical, and safety standards.

The RWFA Environmental Officer will be the focal point for training in EMP and agrochemical application. He will also liaise with other stakeholders to execute the plan. In collaboration with MINAGRI, this focal point will be responsible for capacity building of local population.

The training for capacity building of cooperatives will include among others:
Pesticide/Fertilizer/compost Application Training

The training objective is to ensure beneficiary farmers in the project area do not pollute water resources through unsustainable application of inorganic and organic fertilizers. This capacity building activity can be undertaken by MINAGRI and RWFA with the technical support from Rwanda Agriculture Board (RAB) and research institutions such as National University of Rwanda, ISAE.

The RWFA staff and the district level field agronomist will conduct training to the local farmers on the safe application of pesticides and fertilizers. This is practices that can immensely contributing to the reduction of possible chemical pollution water body. The training on pesticide application touches on the quantities to apply, timing (when), and

protective gears to wear among others and should be incorporated in the Pest Management Plan.

Maintenance of land husbandry infrastructures

The maintenance of improved bench terraces, soil bunds, constructed waterways, terraces' embankments, planted trees/ shrubs and grasses as well as canal buffer zone is needed to control erosion on hills and protect the reservoir from siltation. Land husbandry

infrastructures in the command area also need to be well maintained. The farmers will be trained on the maintenance of those infrastructures.

Efficient water use

Inefficient use of water in the farmland could cause water logging, health impacts and loss of water downstream as well as destruction of land husbandry infrastructures in the command area. The project irrigation engineer will coordinate training in irrigation water use.

c. Rwanda Environment Management Authority

Rwanda Environment Management Authority (REMA) is the oversight authority over the environment in Rwanda. Its role will be of monitoring environment indicators as identified in this EMP. The role of Rwanda Environment Management Authority (REMA) includes:

Oversight Monitoring

As the lead agency responsible for the protection of environment in Rwanda, REMA will play the leading oversight role of monitoring the activities of the project according to the Organic Law establishing REMA and its functions.

Site Inspection Visits

REMA will undertake regular site visits to inspect and verify for themselves the nature and extent of the impacts. REMA will also undertake regular site visits to inspect and verify for themselves the extent to which the mitigation measures proposed in this EMP are being complied with or vice versa. They will then be expected to make viable recommendations based on their findings to the RWFA.

Periodic Reports

In collaboration with RWFA, REMA will prepare periodic environmental consolidated reports on the monitoring progress of the water catchment and command area development. These reports should be forwarded to the financial sponsor for information.

d. Community Group/Project Beneficiaries

The project beneficiaries being the people on the ground will have the role of execute some of the mitigation measures, collecting and monitoring the identified indicators and practicing sustainable farming as well as catchment rehabilitation and management. The project beneficiaries are organized in cooperatives, which have management committees for water, production, and maintenance.

e. Contractors

The contractor will be in charge of designing and constructing the infrastructure according to the World Bank operation policy on dam safety, restoring the burrow pits and degraded areas, ensuring the safety of the users and others.

f. Ministry of Health

Due to possible health impacts especially malaria and bilharzias in the subproject areas, the ministry of heath comes into the picture of this project. The role of the ministry of health will be to promote environmental health, health prevention methods including sleeping in treated nets and monitoring incidences of malaria and bilharzias.

g. Local Authorities

The RWFA subprojects are being implemented in several districts which are administered by the respective district authorities. These local authorities have jurisdiction over the subproject areas and control the marshlands including use and conservation. The department of land and natural resource would be the focal point in Nyagatare District and concerned Sectors.

The role of the local authorities will be to monitor and ensure sustainable utilization of the command area after the project period. They will be the agency close to the project and will ensure the EMP is implemented by the different stakeholders as indicated

Chapter 8. SEDIMENT YIELD ESTIMATION

8.1. Background

Rwanda suffers from limited water resources and an increasing demand for water due to the increase in population growth rate, so the water authorities in the last two decades started water-harvesting projects, especially dam projects in many regions.

As part of its policy and its fight against poverty, the government of Rwanda through the Rwanda Natural Resources Authority in paternership with the Korea International Cooperation Agency (KOICA) have initiated a project for the development of the Nyagatare Water Resources Development in Muvumba basin and K-Water have been engaged to conduct a feasibility study.

In the framework of this project, of the implementation there is plan to construct a multipurpose dam in Karama sector, Nyagatare District. Because, the useful life of dams and future planning for water resources depend on sedimentation in reservoirs, K-Water engaged WETS. Ltd, to estimate the sediments yield at the project location on Muvumba River, where the Multipurpose Dam is planned to be constructed. Sediment yield is a critical factor in identifying non-point source pollution as well as in the design of the construction such as dams and reservoirs.

The estimation of soil loss in the river basin from upstream has been made and this approximation could lead designers in predicting the river sedimentation during a year. We estimate the maximum soil loss in the basin during the storm event.

Sediment deposition in reservoirs is a reflection of catchment erosion and deposition processes, which are controlled by terrain form, soil, surface cover, drainage networks, and rainfall-related environmental attributes. It is generally assumed that if soil erosion is controlled, then sediment will also be controlled. This is true since erosion must occur to produce sediment. WETS.Ltd has practically processed on sediment load assessment at the project location by both physical sample collection analysis and basin system survey by using computer-based modelling systems.

8.2. Problem

For dam's projects with purpose of water resource development, any loss of storage increases the risk of failure to meet the design objectives in extreme dry periods.
Sedimentation in a reservoir is a natural consequence from the construction of a dam, which slows down the stream flow and thus causes sediment deposition in the impoundment because of the increased sediment loads carried by the upstream rivers feeding into the Dam reservoir.
To tackle the on- and off-site threats of erosion, there is an urgent need for improved catchment-based erosion control and sediment management strategies. To implement such strategies, it is necessary to understand the magnitude of the problem and factors responsible for it. Knowledge of cause–effect relationships and their spatial patterns are also essential to plan water-harvesting schemes and to de-sign necessary management precautions.

Figure 1. Suspended sediment in Muvumba River at the Project location

Although catchment erosion is believed to be responsible for the rapid loss of storage capacity of the reservoirs, there are no detailed studies done in Muvumba catchment at this

time, on the quantification of erosion rates or on the spatial dynamics of erosion/siltation processes on a catchment scale.

However, current developments in geographic information systems (GIS) make it possible to model complex spatial information. A GIS is used in this study to determine how soil erosion potential varies throughout a watershed.

8.3. Methodology

The spatial discretization of the catchment and the derivation of the physical parameters related to erosion in the cells are performed through USLE. The method involves spatial disaggregation of the catchment into cells having uniform soil erosion characteristics. The computations have been implemented in the Python programming language using the PCRaster library in combination with the spatial analysis capabilities of GIS packages.

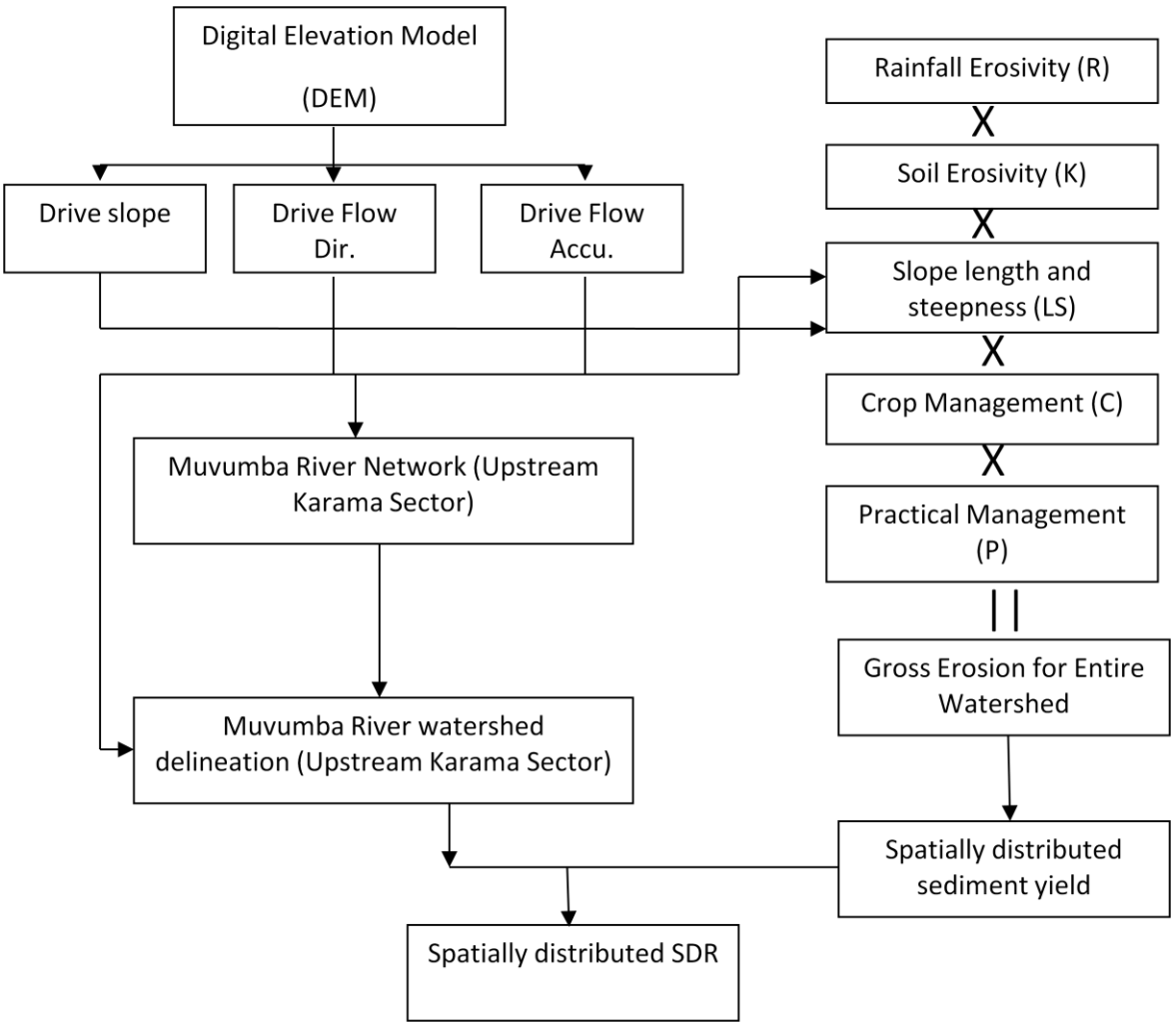


Figure 2 Overview of the methodology followed

The advantage of using the USLE model is that it has been widely used and tested over many years; subsequently the validity and limitations of this model are already known. The surface erosion from each of the discretized cells is routed to the catchment outlet and the sediment yield of the catchment is defined as the sum of the sediments delivered

by each of the cells. The amount of eroded soil that actually reaches a stream is difficult to determine. Many factors affect when and where sediments will be deposited.

Because some portion of the eroded soil may be deposited while travelling to the downstream towards the project location, the Sediment Delivery Ratio (SDR) for a given watershed have been used to estimate the total sediment transported to the place of Dam construction.

a. Using the Universal Soil Loss Equation (USLE)

The USLE computes average annual soil loss from sheet and rill erosion. Major erosion factors such as rainfall, soil erodibility, slope length, slope steepness, soil and crop management, and supporting conservation practices are assigned numerical values. The USLE combines these major erosion factors to predict average annual soil losses (Figure 2). The equation is:

A = R K L S C P (1)

In this equation A = R K L S C P (1), soil erosion, A, is described as a function of: R = rainfall and runoff (rain erosivity)

K = soil erodibility

L = slope length

S = slope steepness

C = soil and crop management

P = conservation practices

To estimate average annual erosion potential of any given field, simply multiply the appropriate numerical values developed for each factor.

b. Using the Sediment Delivery Ratio

The amount of eroded soil that actually reaches a stream is difficult to determine. The sediment delivery ratio (SDR) have been used to adjust the gross sediment estimate to compensate for deposition along the path travelled by the runoff water as it moves from fields in the watershed to a continuous stream system. Thus, The Sediment Delivery Ratio (SDR) for a given watershed have been be used to estimate the total sediment transported to the watershed that contains the place where will be constructed the Dam.

The SDR is expressed as follows:

Where

SDR = Sediment Delivery Ratio,

SY = Sediment Yield,

SDR = SY/E (2)

E = Gross Erosion for Entire Watershed.

8.4. Overview of Muvumba hydrological basin

The administrative catchment area is essentially administered by the districts of Gicumbi and Nyagatare. The Muvumba catchment consists from upstream to downstream of the relatively small catchment of the Mulindi River that is located in the mountainous and high rainfall central northern part of the country. The average annual rainfall is rated at 995 mm/annum, which equates to some 1,560 hm^3/annum from the total land surface area of 1,568 km^2.

The Mulindi River flows into Uganda onto a flat wetland zone near Kabale from where a complex flow pattern originates that ultimately joins the Muvumba River before it eventually flow back into Rwanda. Within Rwanda a number of relatively small tributaries join the Muvumba River which flows in a north easterly direction to follow the border between Rwanda and Uganda before it reaches the K-Water' Dam project location in Karama sector (See Figure 3). The river later flows downstream to join the Akagera River in the North East where the borders of Uganda, Rwanda and Tanzania meet.

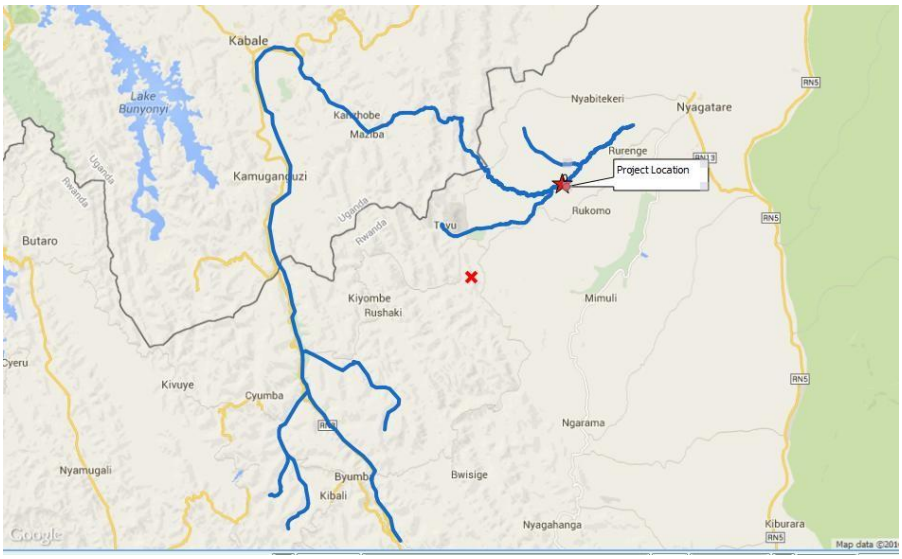


Figure 3 Muvumba River Network route from source to project location

The land cover of the catchment largely dominated by rainfed agriculture with natural open land and limited forest plantation on the hill sides completed with limited irrigated or agricultural wetland in valley bottoms of the Mulindi and Muvumba Rivers. Built-up area is limited in size and mostly restricted to the, not very dense, urban centers of Nyagatare and Gicumbi as well as dispersed centres throughout Nyagatare district area.

8.5. Project Site description

The project area is located on River Muvumba approximately about 8km from the

Ugandan boarder and is centered at approximate coordinates $01^{o}21.845^{I}S$, $030^{o}12.912^{I}E$.
The project area is basically the district of Nyagatare, which forms part of the current Eastern Province. The Dam will be located in Bushara Cell, Karama Sector of Nyagatare District(Figure4).

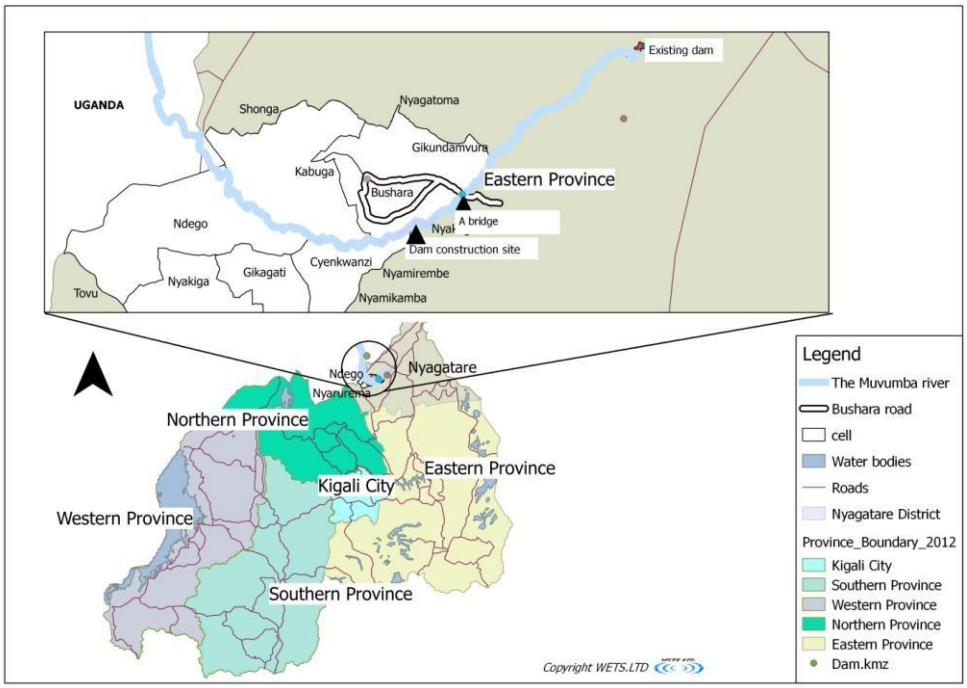


Figure 4 Project Location

The District of Nyagatare is characterized, in general, by lowly inclined hills separated by dry vallies for a long period of the year (June–October). The District is located in the granite low valley whose altitude is 1513,5m (Source: *UNEP/UNDP/ GOR Poverty and Environment Initiative Project (PEI)*). This kind of topographical layout constitutes an important potentiality for modern and mechanized agriculture.

8.6. LITERATURE REVIEW

8.6.1. Soil erosion and sediment yield.

The ultimate source of the sediment that is measured as sediment yield is the rock underlying the drainage basins. Until the rock is broken or weathered into fragments of a size that can be transported from the basin, the sediment yield will be low.
These rocks, if exposed on a hill slope, move slowly down the slope to the stream channel the rate of movement depending on slope inclination; density of vegetation; etc

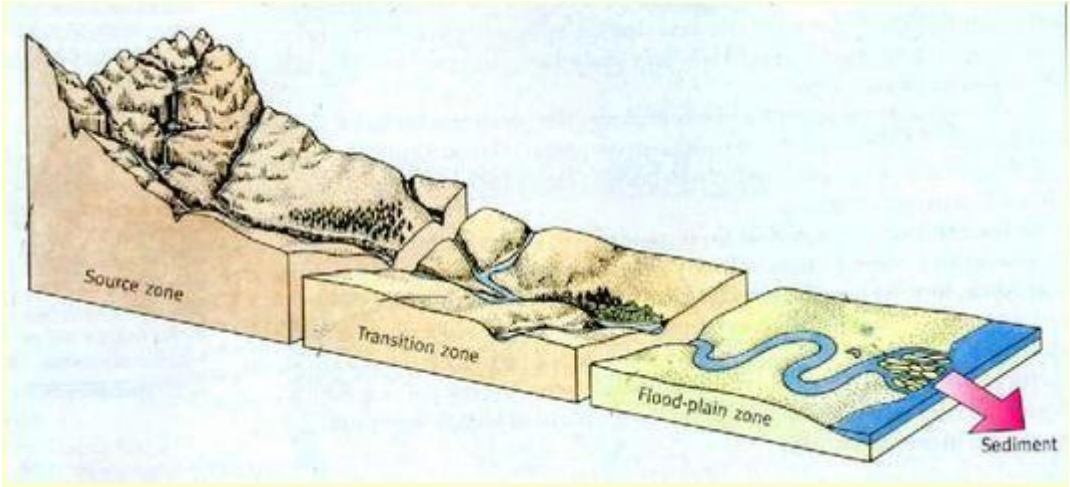


Figure 5 Soil erosion sequences (Source: *http://www.mrstevennewman.com/geo)*

Water and wind are the main agents responsible for soil erosion. Sedimentation and soil erosion includes the processes of detachment, transportation, and deposition of solid particles also known as sediments.

The forms of water responsible for soil erosion are raindrop impact, runoff, and flowing water. Erosion from mountainous areas and agricultural lands are the major source of sediment transported by streams and deposited in reservoirs, flood plains and deltas.

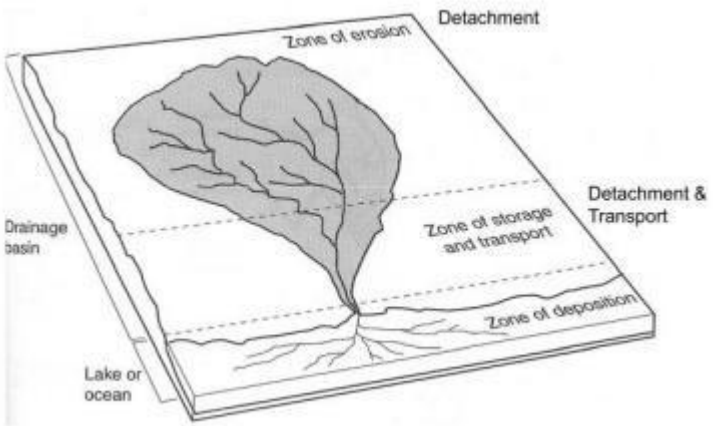


Figure 6 Soil Erosion (Iowa Stormwater Runoff Control, n.d.)

Rill erosion occurs when water from sheet erosion combines to form small concentrated channels. Erosion rates increase due to higher velocity flows as rill erosion starts. When
water in rills concentrates to form larger channels, it results in gully erosion. Finally, stream channel erosion takes place when water flows cut into the bottom of the channel and makes it deeper.

Sediment load is also generated by erosion of beds and banks of streams, by the mass movements of sediment such as landslides, rockslides and mud flows, and by construction activity of roads, buildings and dams.

8.6.2. Measurement of sediments load

When a dam is constructed, the sediment transported by a stream is deposited in the still waters of the reservoir. In this case, both bed load and suspended load are deposited, but the dissolved load eventually moves out with the water released from the reservoir.

The many dams that have been constructed for flood control, recreation, and power generation hold much of the sediment load of rivers in reservoirs.

The sediment load can be measured in different ways:

Collection of water samples from a river and measurement of the sediment contained in each unit of water

Because sediment in a stream channel is transported in suspension, in solution, and as material rolling or moving very near the bed, the water samples will contain suspended and

dissolved load and perhaps some bed load. Much of the bed load, however, cannot be sampled by existing techniques, as it moves too near the bed of a stream. It is fortunate, therefore, when the greatest part of the total sediment load is in the form of suspended load.

surveys of the drainage systems:

Estimation of sediment yields from measurements of hill slope and channel erosion within the basin or by the evaluation of erosion conditions. This can be achieved mainly by using computer-based models, built based on natural conditions expressed in terms of mathematical equations.

8.6.3. Soil Erosion Models

Models available in the literature for sediment yield estimation can be grouped into two categories:

(I) Physically-based models; and(ii)lumped models

In the physically-based models the ground surface is generally separated into inter-rill and Rill erosion areas. Detachment over inter-rill areas is considered to be by the impact of rain drops because flow depths are shallow, while runoff is considered to be the dominant factor in rill detachment and sediment transport over both rill and inter-rill areas.

The physically-based models include AGNPS, ANSWERS , WEPP (Hearing et al.,1989)and SHE (Abbott et al., 1986; Wicks & Bathurst, 1996). And SWAT
Physically-based models are expected to provide reliable estimates for the sediment yield. However, these models require the coordinated use of various sub-models related to meteorology, hydrology, hydraulics and soil. In our analysis, we did not use such models due to that constraint of acquiring very expensive data and modelling systems.

Alternatively, lumped models such as the universal soil loss equation USLE (Wischmeier & Smith, 1978), modified universal soil loss equation MUSLE (Williams, 1978) or revised universal soil loss equation RUSLE (Renard et al., 1991), combine the erosion from all processes over a

catchment into one equation. Rainfall characteristics, soil properties, and ground surface conditions are represented by empirical constants in these methods.

8.6.4. Universal soil loss equation and it's field application

The Universal Soil Loss Equation (USLE) predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind, or tillage erosion.

Five major factors are used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages.

The units of average annual soil loss (A) are carried by the Rand Kfactors. These two factors represent the cause and effect of soil erosion. The Rfactor represents rainfall erosivity, or the erosive power of rainfall on the soil regardless of what type of soil it is. The K factor represents the soil erodibility, or the extent that the specific soil type resists erosive forces. The remaining USLE factors (L, S, C, P) may be thought of as adjustment factors.

The goal of this project is to model the soil erosion potential on a watershed scale. The methods developed in this report will integrate the USLE within a GIS software environment called PCRaster, which was used as a library as a programming language called Python.

A general introduction to GIS, PCRaster and their capabilities will be given in the next section.

8.6.5. Geographic Information System and Soil Erosion Modeling

A Geographic Information System (GIS) is a system that captures, stores, integrates, analyzes, manages and visualizes data that are linked to coordinates or locations. GIS is a combination of statistical analysis, database, and cartography that allows the user to identify geographic information, relationships, patterns, and trends.

GIS is a very helpful program for soil erosion modeling. GIS application in soil erosion analysis is increasing because of the advantages of combining GIS and soil erosion models.

Firstly, interfacing GIS capabilities with the USLE provides a relatively fast analysis and visualization of likely sheet and rill soil erosion potential (Blaszczynski, 2001).

PCRaster is a GIS (Geographical Information System) which consists of a set of computer tools for storing, manipulating, analyzing and retrieving geographic information. PCRaster library incorporated in Python language forms architecture that permits the integration of environmental modelling functions with classical GIS functions such as database maintenance, screen display, and hard copy output.

PCRaster offers the building blocks, which allow for high-level expression of (physical, environmental, societal) processes (Figure 7). It uses map algebra functionality and deals with raster files .

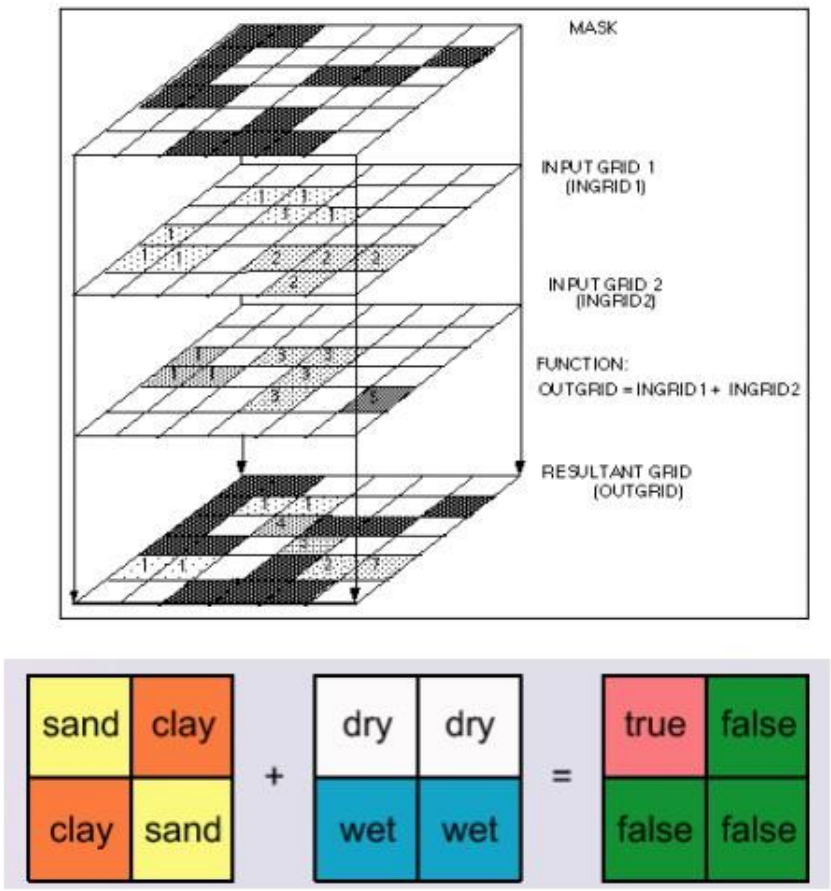


Figure 7 Map algebra local Function

The USLE is combined with the PCRaster to calculate the estimated average annual soil loss (A) that is occurring within the Muvumba Watershed. Raster layers corresponding to each of the six USLE factors are created, stored, and analyzed with the ArcGIS. This combination computes the estimated soil erosion potential for the entire watershed and areas of high soil erosion potential are identified. The grid cells in each layer overlap and the USLE computation can be done by multiplying all the USLE factors together (Figure 8).

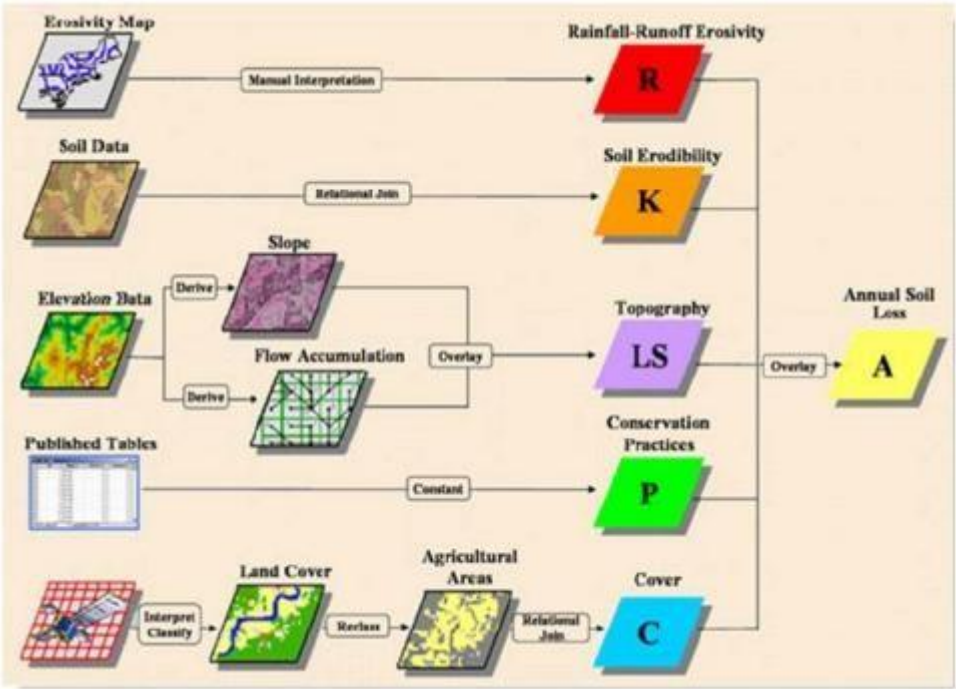


Figure 8 Procedures of USLE integrated in GIS

ANALYSIS

1. Rainfall Erosivity Factor (R)

a. Literature Review

The rainfall factor, R, accounts for the potential of falling rain drops and flowing water in a particular area to produce erosion. Cumulative effects of all yearly storms above a certain intensity and duration make up this numerical value. As the energy of a storm increases, the potential for more soil particles to detach increases. Runoff also increases with intensity and duration of storms, thereby increasing erosion potential. At present, little can be done to change the amount, distribution, and intensity of rainfall, but measures can be adopted to limit its effect on erosion. For example, vegetative soil cover can reduce the effect of raindrop impact on the soil and the velocity of runoff.

The equation used to calculate the R factor is shown below in

$$R = 0.0483 * P^{1.610} \quad (3)$$

Where P =annual precipitation (mm)

$$R = 0.0483 * P^{1.610}$$

Where P =annual precipitation (mm)

(3)

The annual rainfall for the each catchment of interest was acquired from data for the closest rainfall station.

b. Data

In order to compute the R facto, we have used rainfall data obtained from METEO Rwanda. Unfortunately, the Muvumba Basin doesn't have main rainfall Gauge Station. For this reason, we have utilised only data available from Nyagatare Station. Of course, this hve an impact on the accuracy since the whole catchment is quite wide.

In Figure 9, we present the storm events recorded on Nyagatre Rain Gauge station from 1970.

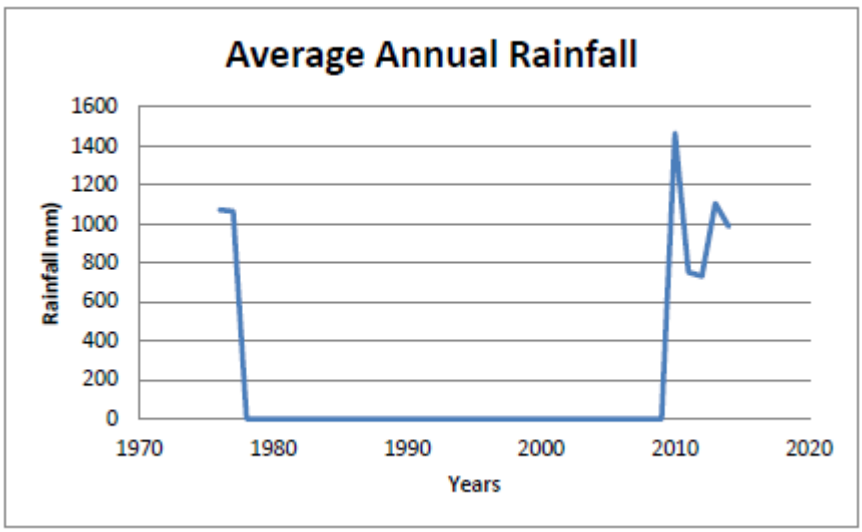


Figure 9 Annual Rainfalls

The peak rainfall event recorded in last 34 years (until August 2014 the last recorded obtained) was observed in the year 2010. It is 1465 mm. They were no records available between 1978 and 2010.

c. Method

After data collection, R factor was determined for each the maximum rainfall event ever recorded on the selected rainfall gauge station using the equations

and R Factor maps.

$$R = 0.0483 * P^{1.610}$$

Where P =annual precipitation (mm)

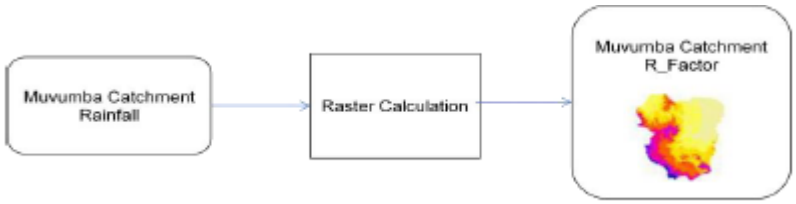


Figure 10 Summary of R Factor calculation in PCRaster

Rainfall erosivity map for the R factor was developed using the method described above. Because only one rain gauge station was considered, the rain map was identical for the catchment.

There was not enough spatial coverage of pluviographic data from the rain gauge station to obtain an accurate R factor using equation because data for one rainfall station is not enough for interpolation of R factor for the area of the upper catchment of Muvumba river, upstream the project location. The R factor obtain was 4950 MJ.mm/(ha.hr.year).

$$R = 0.0483 * P^{1.610} \quad (3)$$

Where P =annual precipitation (mm)

2. Soil Erodibility Factor (K)

a. Literature Review

The soil erodibility factor, K, considers soil properties that influence both detachment and transport of soil materials. These include soil organic matter con-tent, texture, structure, size, shape, and stability of aggregates, and the permeability of the soil to water. Soil erodibility tends to increase with greater silt content and decrease with greater sand and clay contents.

Organic matter binds individual particles together thus increasing aggregate strength, hence the resistance to detachment. Soil structure, in terms of its size, shape, and aggregate stability, influences the infiltration rate. Erosion will not occur if the infiltration rate is greater than the rainfall rate. Permeability of the soil to water affects erosion because rainfall must enter and move through the soil if runoff is to be minimal.

The equations used to calculate K factor is here below:

$$K = 0.0293(.65 - Dg + .24Dg^2)\exp\left[\begin{array}{l} -.0021\left(\frac{OM}{f_{clay}}\right) - .00037 f_{clay} * \\ \left(\frac{OM}{f_{clay}}\right)^2 - 4.02 f_{clay} + 1.72 f_{clay}^2 \end{array}\right] \quad (4)$$

Where;

$$Dg = -3.5 f_{clay} - 2.0 f_{silt} - 0.5 f_{sand} \quad (5)$$

OM : percent organic matter

fClay : clay fraction

fSilt : silt fraction

fSand : sand fraction

Dg: The geometric mean of particle size

c. **Data**

The soil map was available from RWFA for the whole country. However, the OM was not that easy to determine, as it did not figure in the soil spatial database. For the part of the Muvumba upper catchment that belongs to Uganda, we have estimate that the soil properties are the same and we did a comparison with the Uganda Soil Atlas available on the FAO website. The soil series shape file shows three soil categories: mined land, steep land and urban land.

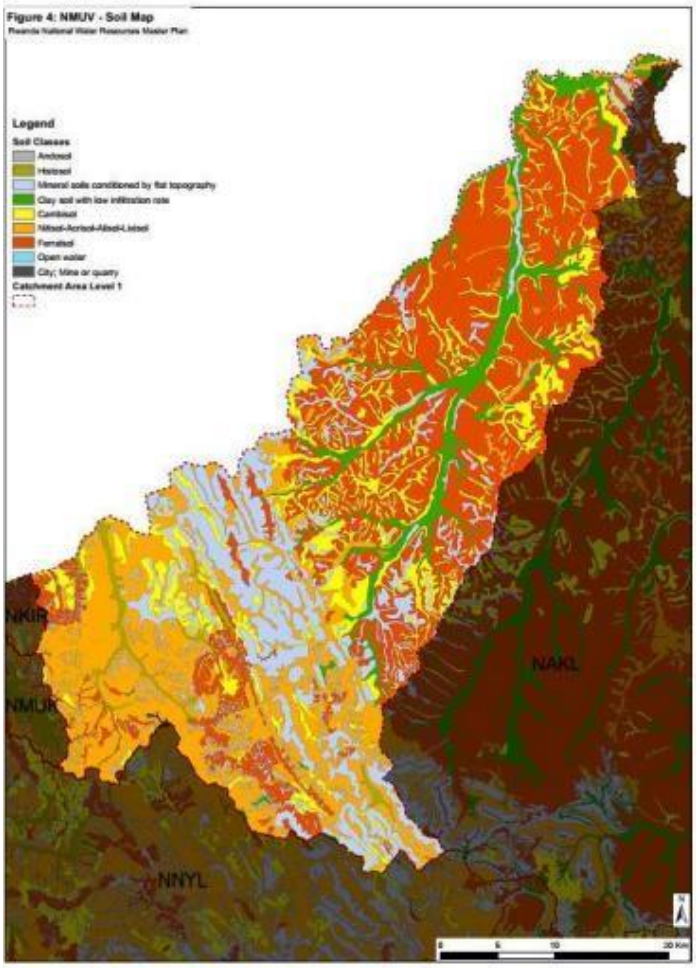


Figure 11 Soil map of the catchment area

c. Method

Figure 12 shows the procedures to determine the K factor. After the shape file of soil map was added as a layer into ArcGIS, the attribute table of the soil map was edited with adding a new field of sand, silt and clay fractions values under the Edit menu at attribute view before K factor was produced.

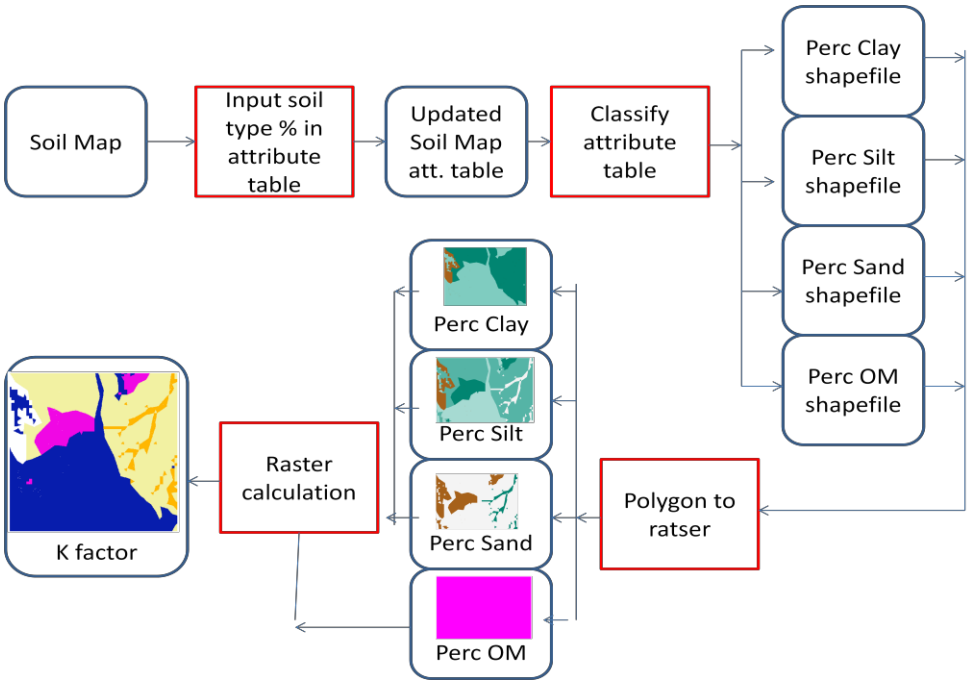


Figure 12 Schematic diagram for determination of K factor

The fractions were calculated according to estimation from literature and on the basis, that clay occupies more than 35 %. This is a poor estimation of K factor because detailed soil map of Muvumba basin is not available yet. Soil map of Muvumba basin can be obtained only after rigorous soil survey study for multiple years at the site.

d. Results

Soil erodibility map for K factor was developed using the method described above. The theme produced is shown in Map 6.

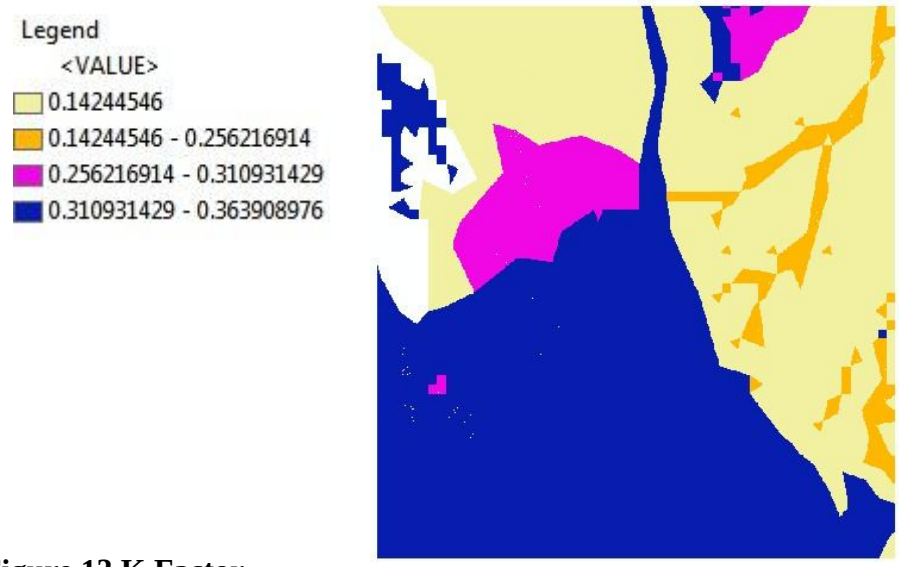


Figure 13 K Factor

3. Slope Length and Slope Steepness Factor (LS)

a. Literature Review

Soil erosion by water is affected by slope length, L, and slope steepness, S, which jointly determine the amount and velocity of runoff. Doubling the length of slope increases the erosion hazard one and one-half times. Doubling the steepness of slope increases the hazard two and one-half times.

The effect of topography on soil erosion is accounted for by the LS factor in USLE, which combines the effects of a slope length factor (L) and a slope steepness factor (S). The slope length is defined as the distance from the point of origin of overland flow to the point where the slope decreases enough that deposition begins or the point where runoff becomes concentrated in a defined channel. Slope steepness reflects the influence of slope gradient on soil erosion.

b. Data

LS factor is based on topography map. For this study, boundary and contour themes were used to generate triangulated irregular network (TIN) and digital elevation model (DEM). The boundary and contour shape files of Cameron Highlands were obtained from the RWFA, These shape files were added as data into ArcGIS. The DEM was obtained from
NASA's Earth Observing System Data and Information System, pre-processed by clipping to match the Muvumba Catchment.

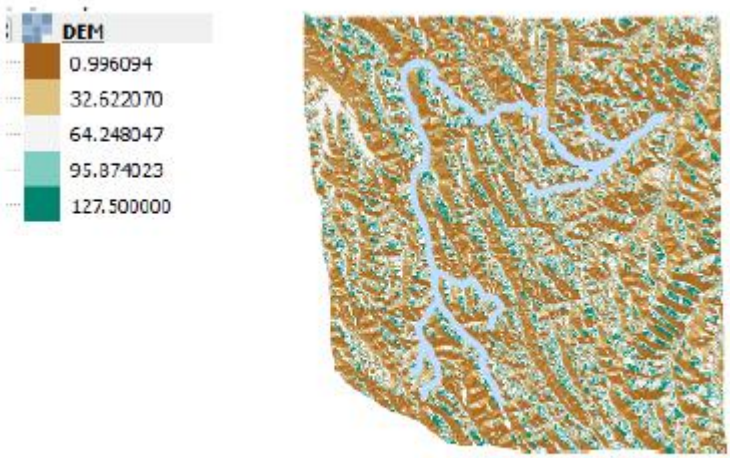


Figure 14 DEM of the basin

c. Method

Following is a description of LS factor calculations for the USLE and RUSLE. Then we introduce the method we used to calculate the LS factor in ArcMap, called the Unit Stream Power Erosion and Deposition (USPED) method. Finally, we provide instructions on the generation of a depressionless DEM, and then give the step-by-step instructions on
performing the calculations in ArcMAP. We used ArcMap 10.1 when performing the steps ourselves.

The LS calculation from the original USLE is provided in Equation (6).

Where λ is the horizontally measured plot length, θ is the slope angle, and m is a variable plot exponent adjustable to match terrain and soil variants. m varies between 0.5 (slopes of 5% or more) and 0.2 (slopes of $< 1\%$)

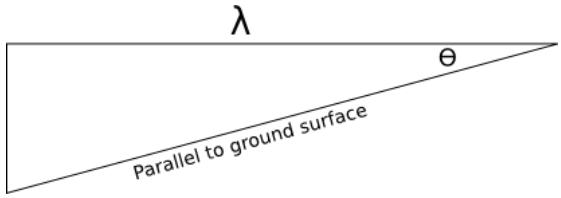
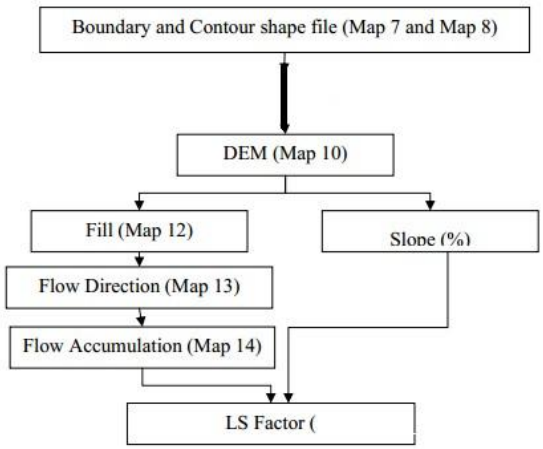


Figure 15 Illustration of the values used in the calculations of LS

In arcGIS, LS factor was calculated after pre-processing maps by sinking the DEM, slope calculation, generation of flow direction and flow accumulation maps. Here below is the followed procedure.



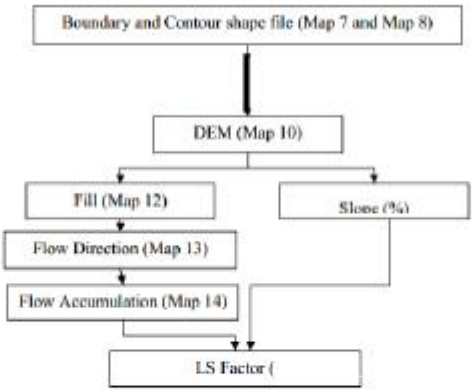


Figure 16 LS factor methodology using ArcGIS

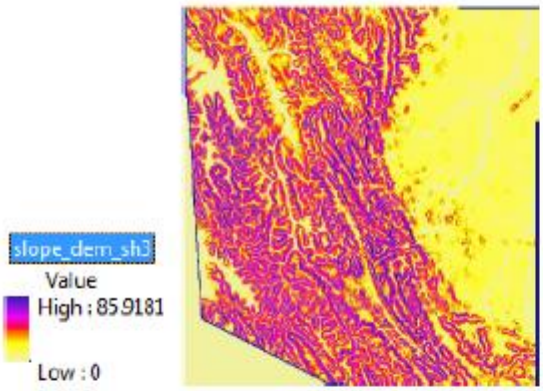
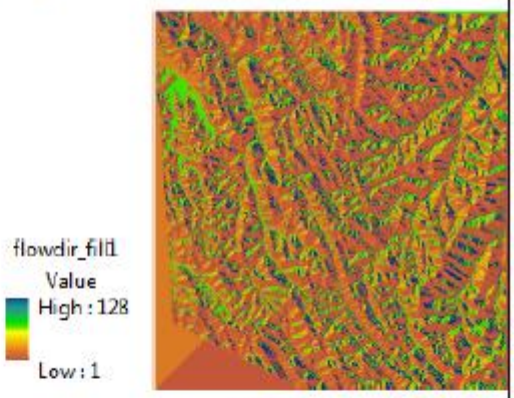
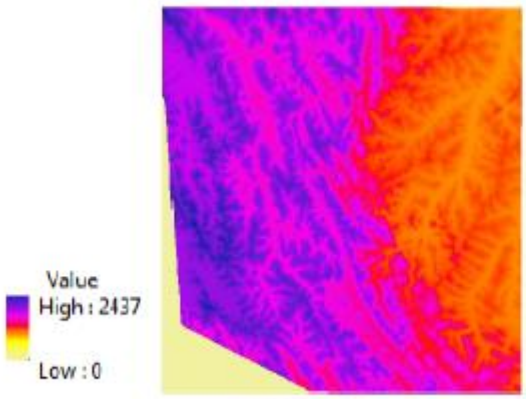


Figure 17 Slope (%)



Flow dir



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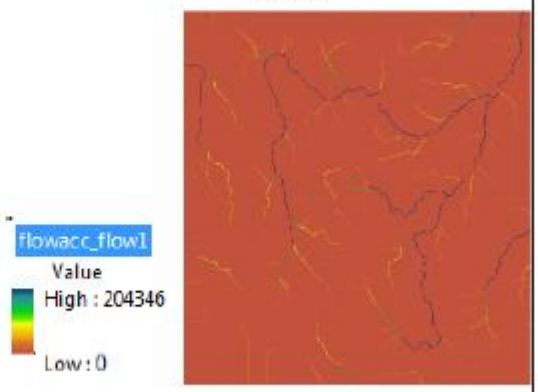

Flow accumulation

Figure 18 DEM processing maps

d. Results
e.

Slope length and steepness for LS factor was developed using the method described above. The theme produced is shown in

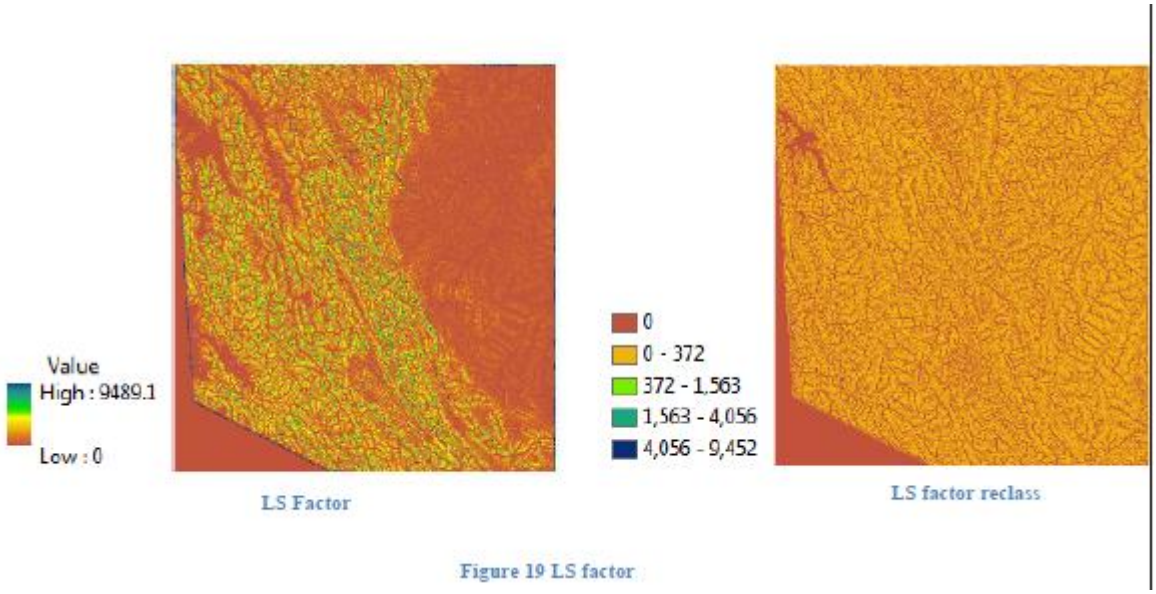

Figure 19 LS factor

4. Cover Management Factor (C) and Support Practice Factor (P)

a. Literature Review

The soil and crop management factor, C, includes crop sequences, residue management, soil fertility management, time of tillage, intensity of tillage, and row spacing of row crops. Factor P represents soil conservation practices that essentially slow the runoff water and thus reduce the amount of soil it can carry. The most important of these supporting practices are contour tillage, strip cropping, and terracing.

Cover Management Factor (C) and Support Practice Factor (P) are two management factors that can be used to control soil loss at a specific site. The Cover Management Factor (C) represents the effect of vegetation and management on the soil erosion rates. The Support Practice factor (P) represents the impact of support practices on the soil erosion rates.

Cover Management Factor (C) is the ratio of soil loss of a specific crop to the soil loss under the condition of continuous bare fallow. The amount of protective coverage of a crop for the surface of the soil influences the soil erosion rate. C value is equal to 1 when the land has continuous bare fallow and have no coverage. C value is lower when there is more coverage of a crop for the soil surface resulting in less soil erosion.

Support Practice factor (P) is the soil loss of a specific practice relative to the soil loss incurred when plowing up and down the slope. P value is equal to 1 when the land is plowed on the slope directly. This is also known as the worst practice. P value is lower and less than1 when the adopted conservation practice reduces soil erosion. P values are chosen based on land use or soil management.

b. Data

The land use map was available for Rwanda, obtained from RWFA. As we could not find Uganda part land-use map, we use approximation and filled the missing values.

c. Method

To produce C and P factor maps, the land use shape file was added to ArcGIS. C and P factors were generated the same way as K factor by auditing the attribute table. The land-use attribute table was edited with adding a new field of C and P values under the Edit menu at attribute view before the C and P factor was produced (Table 1). The values of C and P were adopted from other African located projects.

Table 1 C and P factors for Muvumba Project catchment

Land Use	C	P
Open agriculture	0.3	0.12
Closed agriculture	0.3	0.12
Built up areas	0	0
Grassland	0.04	0.12
Closed agriculture	0.3	0.12
Shrubland	0.036	0.12
Open agriculture	0.3	0.12
Water bodies	0	1
Wood land	0.006	0.8

d. Results

Cover Management factor (C) and Support Practice factor (P) were developed using the method described above.

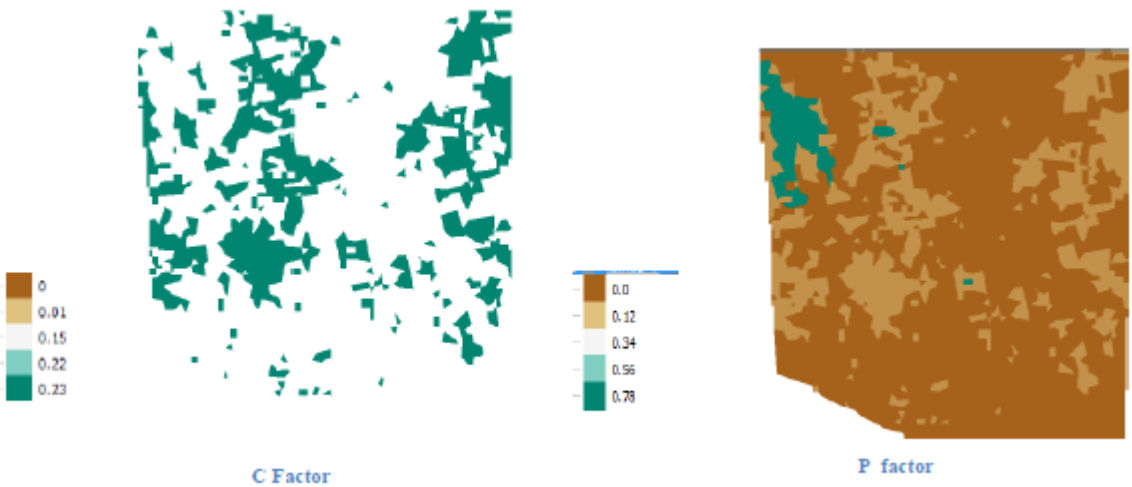

Figure 20 C and P factors

RESULTS

1. Estimation of sediment yield

The USLE equation (1) was used to calculate the annual average soil loss rate (A) in ton/ha/year. In order to predict the annual sediment yield in the upper catchment of Muvumba River that contribute to the project location area, the R, K, LS, C and P factors from the earlier chapters were multiplied using PCRaster function as shown in Figure Figure 8. The Gross Erosion for Entire Watershed was calculated by summing the sediment yield of all the sub-basins. The project location is situated in the sub-basin in yellow, which total area is 17,300 ha (Figure Figure 21).

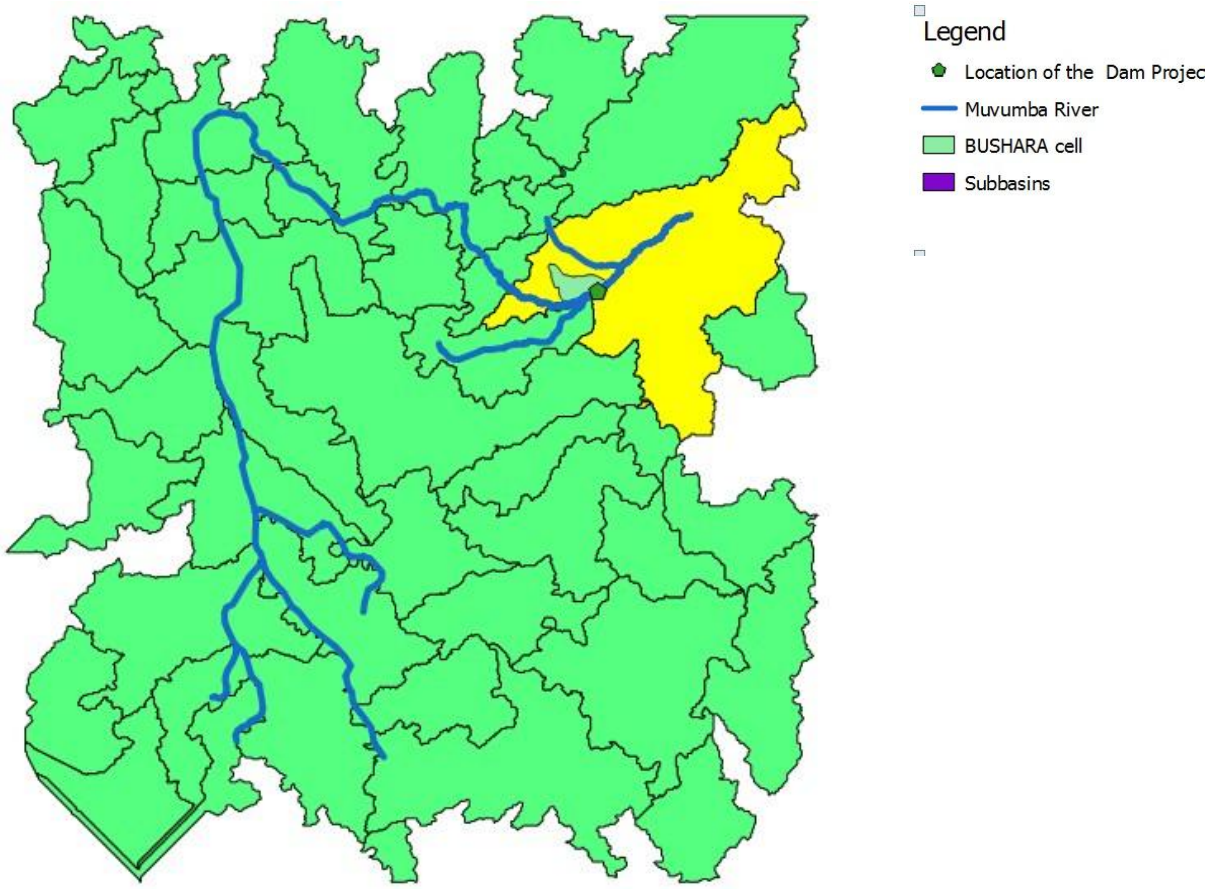

Figure 21 Sub-basins for Muvumba Upper catchment

The Gross Erosion for Entire Watershed (E) obtained was 295,329 m3/ year by estimating using the maximum rainfall event recorded in past years. It is the total amount of eroded soil particles from all sources.

Then the annual soil loss map for each sub-catchment in Muvumba project catchment were produced by clipping each R, K, LS, C and P values of the selected catchment area from the original factor which includes the whole area of Muvumba project catchment. Finally, the sediment yield is determined by multiplying the annual average soil loss rate and the area of the sub catchment.

The sediment yield map indicates the potential for erosion in different segments of the catchment (Figure 22).

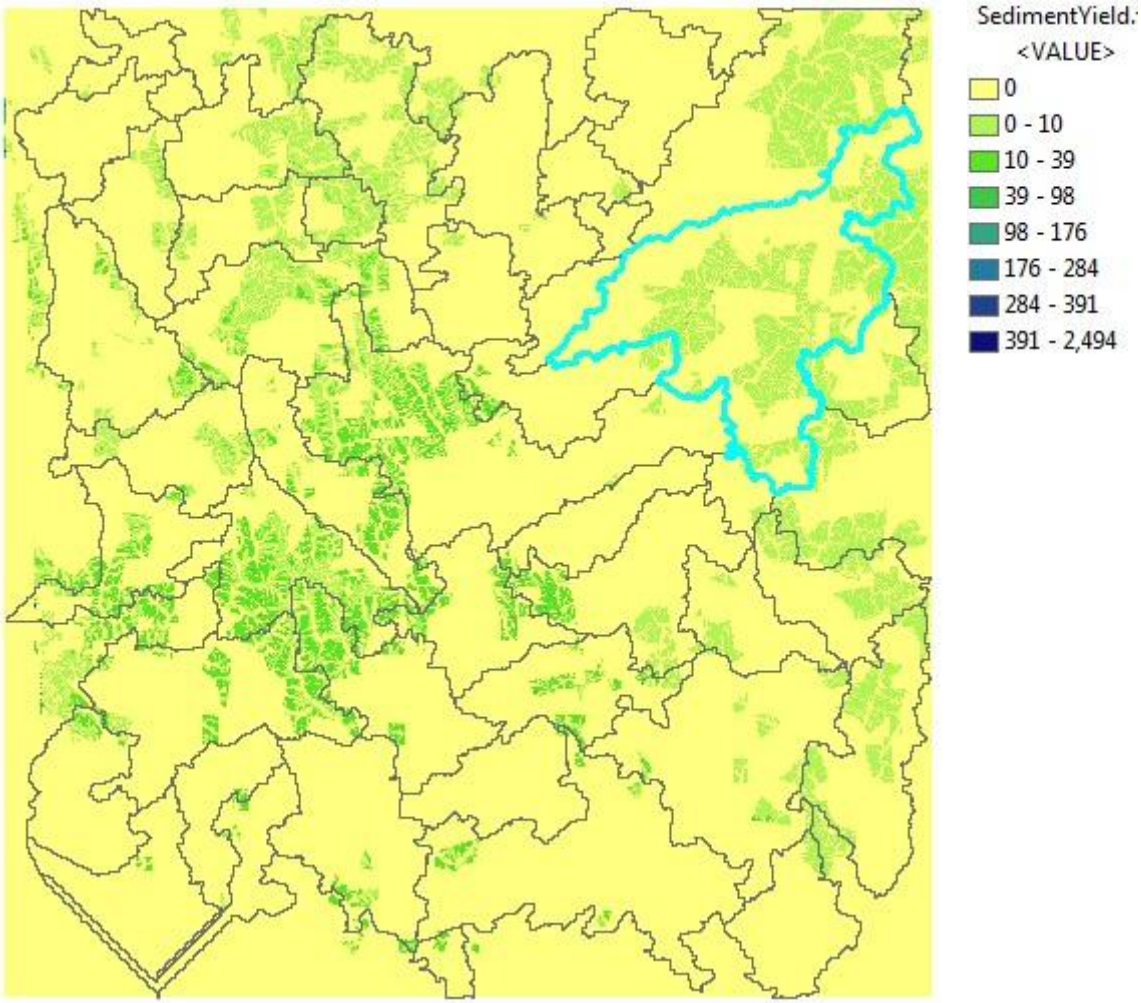

Figure 22 Sediment Yied Map

The sediment yield obtained for the catchment that contains the Dam project location, is equal to 295,329 m3/ year. The sediment yield map is shown here below in Figure 23.

2. Estimation of the sediment yield Ratio from a single storm event

Sediment delivery ratio may range from near 100 percent to less than 1 percent, depending on field slope and what is between the eroded site and stream that can slow down the flow and trap eroded sediment prior to its reaching a flowing stream.

Sediment delivery ratios vary widely for any given size drainage area, but limited data have shown that they generally vary inversely with the size of the drainage area.

The sediment yield that actually reach the Muvumba river from the sub-basin where the dam project is supposed to be implemented equals 4,640 m^3 / year, thus **4.6 Tons of sediment per year**.

Here below is the sediment yield map of the sub basin in case of return fall event similar to the peak observed in 2010.

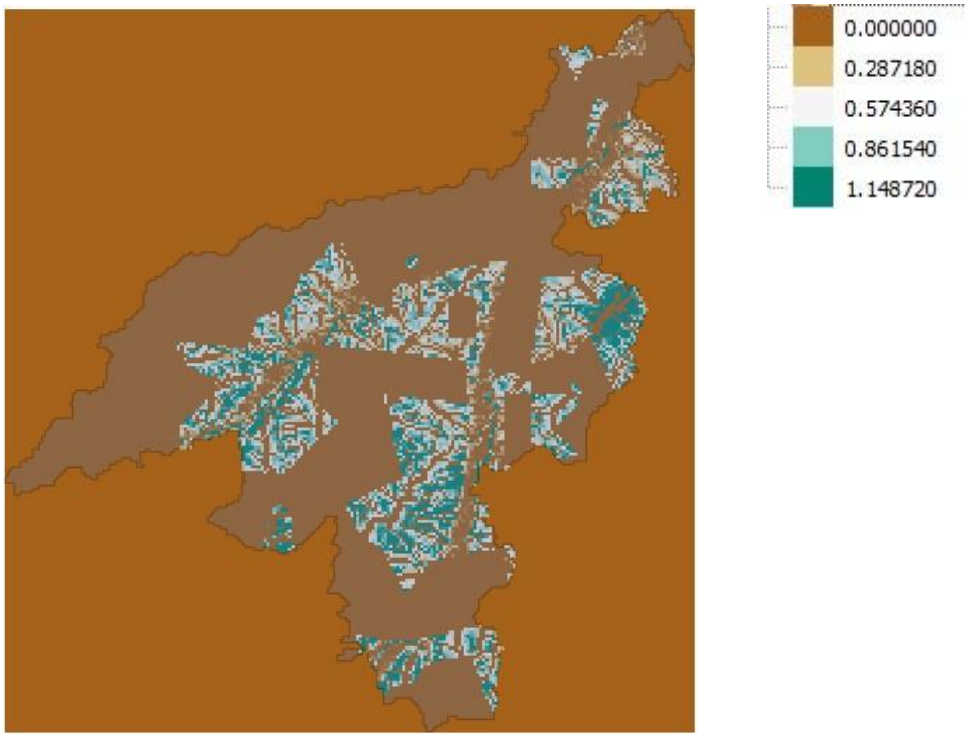

Figure 23 Sediment Yield map at the project sub basin

Following the equation, the value of the SDR will be of 4,640 m^3 / 295,329 m^3

SDR = 1.6%

CONCLUSION AND RECOMMENDATION

Based on the sediment yield map, decision makers can prioritize the most vulnerable upstream areas for effective erosion control management. To mitigate this phenomenon, trapezoidal sand trap should be designed and built, to be used as a sediment decanter.

The sedimentary records from depositional environments such as downstream dams and reservoirs can be used to provide information on the past long-term behaviour of a river basin. In future work, more detailed, quantitative assessments of gullies need to be performed.

In brief, as the erosion problem have been assessed, there are various conservation practices and structures to choose from. All of these are designed to help manage soil to minimize erosion and sedimentation. Proper soil and crop management practices will increase infiltration rates, thus increasing groundwater supply, while reducing runoff and improving surface water quality.
A field measurement program of sediment yield at the dam site is recommended to gain more confidence in the validity of the proposed model in predicting future sediment accumulation

Chapter 9. Water Quality

9.1. Introduction

Demand for water is steadily increasing throughout the world. There is no life on earth without water, our most important resource apart from air and land. During the past three centuries, the amount of water withdrawn from freshwater resources has increased by a factor of 35, world population by a factor of 8. With the present world population of ~8 billion still growing at a rate of about 90 million per year, and with their legitimate expectations of higher standards of living, global water demand is expected to rise by a further 2-3 percent annually in the decades ahead (http://www.icold-cigb.org/GB/Dams/role_of_dams.asp).

Nowadays freshwater resources are limited and unevenly distributed. In the high-consumption countries with rich resources and a highly developed technical infrastructure, the many ways of conserving, recycling and re-using water may more or less suffice to put a stop to a further growth in water demand. In many other regions, on the other hand, water availability is critical to any further development above the present unsatisfactorily low level, and even to the mere survival of existing communities or to meet the continuously growing demand originating from the rapid increase of their population.

In these regions man cannot forego the contribution to be made by dams and reservoirs to the harnessing of water resources. Most of the dams are single-purpose dams, but there is now a growing number of multipurpose dams. Using the most recent publication of the World Register of Dams, irrigation is by far the most common purpose of dams. Among the single purpose dams, 48 % are for irrigation, 17% for hydropower (production of electricity),
13% for water supply, 10% for flood control, 5% for recreation and less than 1% for navigation and fish farming (http://www.icold-cigb.org/GB/Dams/role_of_dams.asp).

9.2. SCOPE OF INVESTIGATION

In the process of identifying possible water quality impacts associated with multipurpose dam development, this study should identify the possible water contaminants that exist in the area and to document the baseline chemical composition of the water of the study area.
The purpose of this reporting effort is to assess current and water quality status as concerns the potential development of multipurpose dam as a solution of many issues such as water supply, flood control, irrigation, navigation, sedimentation control, and hydropower development. A systematic investigation of water quality information relating to multipurpose dam development activity has been made. This report represents the results of a baseline water quality assessment at the proposed site as requested by K-Water.

The assessment comprised water quality sampling and testing to establish a pre- development baseline data. The sampling and laboratory analysis were taken on 14 August and 24 September 2014 (1^{st} campaign), and on 15 October and 05 November 2014 (2^{nd} campaign).

9.3. MATERIALS AND METHODS

To monitor and understand the background of water quality for the chosen site, different activities and approaches were carried out to meet the study objectives. Firstly a series of water samples collection has been done, and then the second series of laboratory water analysis has been performed. In the following section study area description, sampling methods and analytical methods applied are briefly described.

9.3.1. Study areas description: Muvumba River

Muvumba River is located in Eastern Province, Nyagatare District; in both Tabagwe and Rwempasha sectors. It has an extension of cultivable area of 1750 ha alongside Muvumba River. The section of our investigation starts from Gitengure Cell, Tabagwe Sector to Kazaza Cell, Rwempasha Sector near the border with the Republic of Uganda.

The river cuts across Nyagatare District and it is a result of the reunion of two rivers: Ngoma and Karungeli. The river is the main water reserve for the people and the cattle in the large dry land. Few other rivers found in that area such as Nyiragahaya, Kayihenda, Karuruma, Nayagasharara and Kaborogota are erratic and intermittent. A part Muvumba, there is no other consistent river that can be exploited by the population in Nyagatare. The weak river network constitutes a serious handicap to responding to the needs of water for people and animals. The marshland alongside the river has been developed since 2011 in order to increase the agricultural productivity; and the rice has been selected as crop to be grown in the developed marshland for the first time.

Muvumba is drained in the soil characterized by the tightness of the hemisphere layer brought about by the grassy savanna and by the verti-soils that are rich in nutrients mineral elements but lacking organic substances. According to Water quality monitoring in Rwanda: Report I (October – November 2011); Muvumba River takes its source in schistose areas and
travels granitic ground. Abundant culture and vegetation is Acacia, rice and banana.

Figure 1 Muvumba River

Figure 2 Muvumba watershed activities

Polyethylene and glass bottles with 1000 ml volume were used for sampling of different parameters to be analyzed in the laboratory. One milliliter of ultra pure concentrated nitric acid was filled in the bottles to prevent precipitation of iron and related metals.

Glass bottles (500 ml) with screw caps and PTFE inserts were used for tightly sealed stable heavy metal samples. The bottles were filled completely leaving no headspace. Samples were filtered only in case of visible suspended load to remove particulate matter.

As mentioned above, Muvumba River Basin is covered by agricultural lands where the use of fertilizers and pesticides are very common in the area. That was the main factor that influenced in the monitoring frequency. In this study, seasonally monitoring was performed (two samples in wet season and also two samples in rainy season).

Figure 3 Sample collection and onsite measurement

9.3.3. Water analysis

Various batch experiments were performed with the aim of assessing the water quality for samples collected from different water bodies.

a. Physical analysis

During sample collection, in-situ measurement of some parameters, such as pH; conductivity; turbidity and temperature have been recorded. Afterwards, all samples have been transported and analyzed in KIST and EWSA laboratories for further analysis.

For measurement of above mentioned in-situ parameters a battery operated multi parameter instrument was used (WTW, Temp/Cond 340i SET, as shown in the figure above) for temperature and conductivity, while a universal indicator for pH levels was used and turbid-meter for turbidity.

b. Chemical analysis

TP and TN analysis

For total phosphorus, samples of well-mixed unfiltered water were digested in an autoclave or pressure cooker for 1 hour at 121°C with potassium per sulphate to convert all phosphorus to orthophosphate. Afterwards the digest was cooled down at room temperature and settled for at least 24 hours before analysis. The orthophosphate (PO_4^{3-}) was then analyzed using the acid ascorbic method. In the same way TN was measured. Firstly pH had to be neutralized with 15 µl NaOH 30%, before adding Na-salicylate.

The total nitrogen was measured as nitrogen ammonia (NH_4-N) with the UV/VIS Spectrophotometer at 655nm whereas the total phosphorus was measured as orthophosphate (PO_4^{3-}) with the ascorbic acid spectro-photometric method at 880nm.

Arsenic, copper, zinc, and lead analysis

The analysis described in this method involves multi-elemental determinations ICPE using sequential. Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element specific emission spectra are produced by radio-frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and the intensities of the line spectra are monitored at specific wavelengths by a photosensitive device. Photocurrents from the photosensitive device are processed and controlled by a computer system. A background correction technique is required to compensate for variable background contribution to the determination of the analytes. Background must be measured adjacent to the analyte wavelength during analysis.

Calcium and magnesium, total hardness and alkalinity analysis

For the determination of Ca^{2+} and Mg^{2+} titration was used.
In this experiment, a solution of EDTA has been standardized by titration against a standard solution made from calcium carbonate, $CaCO_3$.

The EDTA solution was used to determine the hardness of water sample. Since both EDTA and Ca^{2+} are both colorless, it was necessary to use a rather special indicator to detect the end point of the titration.

Eriochrome Black T indicator was used, which forms a rather stable wine-red complex, MgIn- with the magnesium ion. A tiny amount of this complex will be present in the solution during the titration. The titration was carried in an NH_3-NH_4^+ buffer, which keeps the EDTA mainly in the half -neutralized form, where it complexes the Group IIA ions very well.

BOD

The BOD test is an empirical bioassay-type test which measures the dissolved oxygen consumed by microbial life while assimilating and oxidizing organic matter in a sample. A

water sample was incubated for five days at 20^oC in the dark. Dissolved oxygen was measured before and after incubation using a modified Winkler or oxygen probe method (e.g., EPA Method 360.2 and 360.1). The reduction in dissolved oxygen during the incubation period yields a measure of BOD.

COD

The most popular current testing method for COD involves using sealed and heated (i.e., closed reflux) low-range (3 - 150 ppm) or high-range (20 - 1500 ppm) pre-prepared vials that change color from orange to green based on the amount of oxidation and that are read using a laboratory colorimeter.

Spectrophotometer (DR 5000), Atomic Absorption Spectrometer (AAS) and titration methodology were applied in order to determine the concentration of different ions and metals in water samples. Concentration of different elements (DO, TDS, Fe, Mn, NO_2^-, NO_3^-, NH_4-N, SO_4^{2-}, PO_4^{3-}, F^- and Cl^-) was analyzed with spectrophotometer DR 5000.

c.Bacteriological analysis

Fecal coliforms, total coliforms and E. coli

Bacteria are single-celled organisms that can only be seen with the aid of a very powerful microscope. However, coliform bacteria form colonies as they multiply, which may grow large enough to be seen. By growing and counting colonies of coliform bacteria from a sample of water, it is possible to determine approximately how many bacteria were originally present. Methods used in this study were the most probable number (MPN) method and the membrane filter (MF) methods were all used.

9.4. RESULTS AND DISCUSSION

9.4.1. Results

Table 1 is showing results for physico-chemical and bacteriological of selected parameters (Temperature, pH, Conductivity, Total Suspended Solids, Turbidity, total hardness, Alkalinity, Total Nitrogen, Total Phosphorus, Chemical Oxygen Demand, Biological Oxygen Demand, DO, Total dissolved solids, Fe, Mn, As, Cu, Zn, Pb, NO_2^-, NO_3^-,

NH_4-N, SO_4^{2-}, PO_4^{3-}, F^- and Cl^-), fecal Coliforms and Escherichia Coli.) monitored at Muvumba River

The results are shown in a comparative table for dry and wet seasons, and they are referred to RBS (Rwanda Bureau of Standard) limits for water quality standards.

Table 1 Physico-Chemical and bacteriological results of Muvumba River

PARAMETERS	Unit	RBS	1st Sample	2nd Sample	Average dry season	3rd Sample	4th Sample	Average rainy season
			14-	**16-**		**23-**	**12-**	
Fecal Coliforms	CFU/100 ml	$4*10^2$	$3*10^2$	**$6*10^2$**	**$5*10^2$**	**$8*10^2$**	**$7*10^2$**	**$8*10^2$**
E. Coli	CFU/100	$4*10^0$	$3*10^0$	**$5*10^0$**	**$4*10^0$**	**$5*10^0$**	**$6*10^0$**	**$6*10^0$**
T°	°C	25	22	21.33	21.75	21.5	21.1	21.3
p		8.5	6.8	7	6.95	7.1	7	7.05
E	µS/cm	1500	125	228.33	159.9	194.8	175.7	185.25
Turbidity	NTU	5	**142**	**318**	**182.5**	**223**	**336**	**279.5**
T	mg/l	Absenc	223	570	342	386	546	531
T	mg/l	300	90	93	89.5	89	54	71.5
Alk	mg/l	100	26	32	33.5	41	45	43
N	mg/l	0.5	0.122	0.1	0.121	0.12	0.21	0.165
N	mg/l	0.003	0.003	0.007	0.007	0.011	0.009	0.01
N	mg/l	45	0.072	0.063	0.598	1.124	1.076	1.1
P	mg/l	2.2	0.002	0.0018	0.0195	0.037	0.051	0.044
S	mg/l	300	6.3	9.1	7.35	8.4	18	13.2
C	mg/l	150	80	87	85.5	91	114	102.5
M	mg/l	100	24	36	34.5	45	40	42.5
C	mg/l	250	18.7	9.5	29.05	39.4	72.3	55.85
M	mg/l	0.1	0.021	**0.41**	**0.5755**	**1.13**	**1.159**	**1.1445**
F	mg/l	0.3	0.038	**1.25**	**3.144**	**6.25**	**5.9**	**6.075**
F	mg/l	1	0.36	0.41	0.53	0.7	0.6	0.65
D	mg/l	5	**8.4**	**6.1**	**7.8**	**7.2**	**8.3**	**7.75**
C	mg/l	50	9.6	8.3	28.6	47.6	55.4	51.5
B	mg/l	30	5.4	4.9	10.3	15.2	22.16	18.68
T	mg/l	3	0.174	1.7	1.237	2.3	2.14	2.22
T	mg/l	5	0.073	0.14	0.7715	1.47	1.73	1.6
C	mg/l	1	0.24	0.93	0.79	**1.34**	**1.21**	**1.275**
P	mg/l		nd	nd		nd	nd	
A	mg/l	2	nd	nd		nd	nd	
Z	mg/l	3	0.031	0.052	0.0645	0.098	0.14	0.119
Aldrin	mg/l	0.03	nd	nd		<0.02	<0.02	
Chlordane	mg/l	0.3	nd	nd		<0.02	<0.02	
Hexachlo	mg/l	1	nd	nd		<0.02	<0.02	

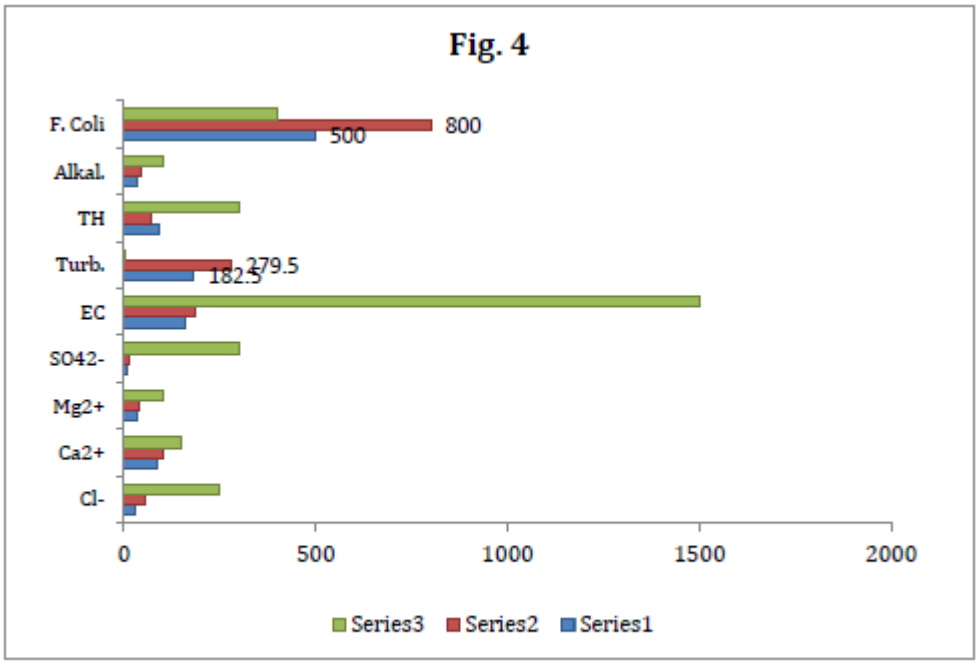

Figure 4 Results (1)

Figure 4 shows test results of faecal coliforms alkalinity, TH, turbidity, conductivity (EC), Cl^-, Mg^{2+}, Ca^{2+}, and SO_4. All parameters were within the RBS limits except faecal coliforms and turbidity.

Figure 5 Results (2)

Figure 5 shows test results of TP, TN, DO, F^- and faecal coliforms. All parameters were within the RBS limits except DO and E. Coli.

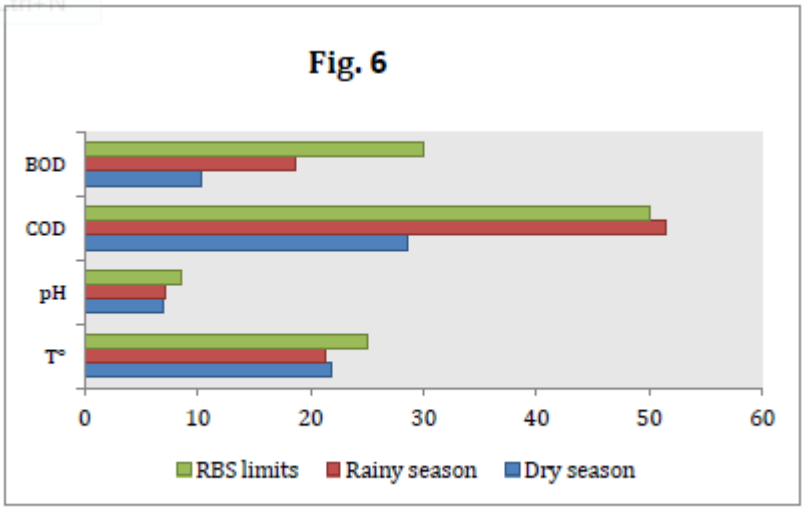

Figure 6 Results (3)

Figure 6 shows test results of BOD, COD, pH and temperature. All parameters were within the RBS limits.

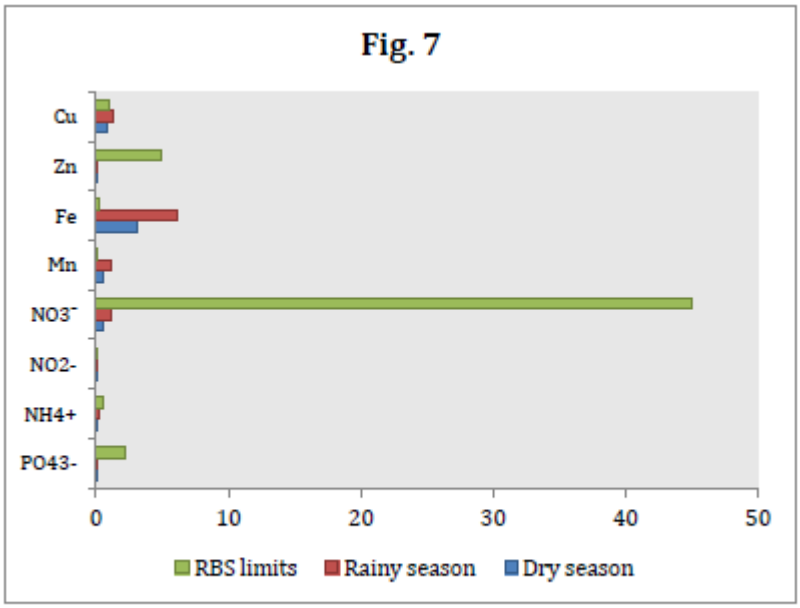

Figure 7 Results (4)

Figure 7 shows test results of Cu, Zn, Fe, Mn, NO_3^-, NO_2^-, NH_4^+ and PO_4. Most of the parameters were within the range (RBS limits) except Fe content especially during the rainy season.

9.4.2. Discussion

a. Physico-chemical Characteristics

The results revealed a difference between wet and dry seasons values for most of parameters especially turbidity, EC, TSS, chlorides, TN, TP, BOD, COD, Cu, Fe, Mn, faecal coliforms and E. Coli.

Mean turbidity values measured in the water samples were higher than the guideline value of 5.0 NTU for all seasons. High turbidity values measured during the wet season compared to the dry season's data can be attributed to runoff into water bodies with high entrained suspended articles. As a consequence, the suspended particles (high turbidity) absorb heat from the sunlight, making turbid waters become warmer, and so reducing the concentration of oxygen in the water (oxygen dissolves better in colder water). Those suspended particles scatter the light, thus

decreasing the photosynthetic activity of plants and algae, which contributes to lowering the oxygen concentration even more (http://www.lenntech.com/turbidity.htm).

The main impact is merely esthetic; nobody likes the look of dirty water. But also, it is essential to eliminate the turbidity of water in order to effectively disinfect it for drinking purposes. This adds some extra cost to the treatment of surface water supplies. The suspended particles also help the attachment or adsorption of heavy metals and many other toxic organic compounds such as nutrients and pesticides (Kasine, Y.C. 2013. The role of sediments for Phosphorus adsorption in Migina Catchment, Rwanda. MSc Thesis, UNESCO-IHE).

In present study, DO values were out of range. During dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases. During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls. More sunlight and warmer temperatures also bring increased activity levels in plant and animal life; depending on what organisms are present, this may increase or decrease the DO concentration.

A high DO level in a community water supply is good because it makes drinking water taste better. However, high DO levels speed up corrosion in water pipes. Dissolved oxygen is an important environmental parameter for the survival of aquatic life.

Numerous scientific studies suggest that 4 - 5 mg/L of DO is the optimum amount that will support a large, diverse fish population. The DO level in good fishing waters generally averages about 9.0 mg/L, but when it drops below about 3.0 mg/L, even the rough fish dies, while high DO concentrations (>20 mg/L) are toxic to fish and cause physiological dysfunctions and developmental abnormalities in fertilized eggs and larvae.

The Chemical Oxygen Demand (COD) values measured in the water samples were slightly high (55.4 mg/L) with the wet season's data higher than that of the dry season. No direct health implications for COD, but also an important indicator of overall water quality.

Heavy metals content were also analyzed in the Muvumba River for both wet and dry seasons. Data analysis showed pronounced significant variation in the mean values between the wet and dry season for Cu, Mn, Fe whereas Zn showed a similar trend for both seasons.

Their presence in natural waters is a combination of contribution from weathering of rocks and minerals, dumpsite leachates, sewage effluents and farming activities. Most importantly, the high level of iron content in the water has no identifiable point source though, it has been reported that iron occurs at high levels in Rwandan soils and could manifest in surface waters that flow over them (Kasine, Y.C. 2013. The role of sediments for Phosphorus adsorption in Migina Catchment, Rwanda. MSc Thesis, UNESCO-IHE).

The aesthetic objective for manganese in drinking water is 0.05 mg/L and its in drinking water supplies may be objectionable for a number of reasons. At concentrations above 0.15 mg/L, manganese stains plumbing fixtures and laundry and produces undesirable tastes in beverages. As with iron, the presence of manganese in water may lead to the accumulation of microbial growths in the distribution system. Even at concentrations below 0.05 mg/L, manganese may form coatings on water distribution pipes that may slough off as black precipitates. Manganese at the recommended limit of 0.05 mg/L is not considered to represent a threat to health, and drinking water with much higher concentrations has been safely consumed [17].

b. Water Microbiology

The presence of both E. Coli and fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease producing bacteria or viruses which can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A (http://bcn.boulder.co.us/basin/data/FECAL/info/FColi.html).

The presence of those bacteria is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste (UNEP, 2006).

Higher values were recorded during the wet season than in the dry season, attributable to influx through runoff of microorganisms originating from vegetation decay, municipal sewage, garbage, and domestic and feacal waste into the Muvumba River body. This condition constitutes a threat to end users, thus suggesting adequate disinfection process before distribution for domestic and industrial uses. On the other hand, most aquatic bacteria are free-living and perform beneficial functions such as the decomposition of organic matter.

9.5. Conclusion

The physicochemical characteristics of the dam water samples revealed a fresh water environment with low chemical pollutants risk. However, high turbidity and TSS values compared with drinking water standards were recorded. Seasonal variation in most of the measured water quality parameters was significant. Microbial burden of the river water was high compared to the recommended standards for drinking water, thus constituting a serious hazard to public health, as their presence is indicative of a possible presence of micro organism associated with water-borne diseases, suggesting the need for adequate disinfection process before distribution for domestic and industrial uses. The distribution pattern of heavy metals levels in the water column suggests more of lithological origin with possible contribution from anthropogenic influences through runoff into the water body.

Although, the levels of the metals in the water body were low not to cause trepidation to both the aquatic lives and human health, the cumulative effect through bioaccumulation could be of concern in the future, hence calling for regular monitoring of the river and control of anthropogenic input into the water body.